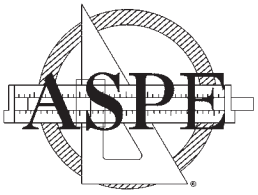
American Society of Plumbing Engineers

Plumbing Engineering Design Handbook

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Plumbing Engineering Design Handbook

Volume 1

Fundamentals of Plumbing Engineering

Plumbing Engineering Design Handbook

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About ASPE

The American Society of Plumbing Engineers (ASPE) is the international organization for professionals skilled in the design and specification of plumbing systems. ASPE is dedicated to the advancement of the science of plumbing engineering, to the professional growth and advancement of its members, and to the health, welfare, and safety of the public.

The Society disseminates technical data and information, sponsors activities that facilitate interaction with fellow professionals, and, through research and education programs, expands the base of knowledge of the plumbing engineering industry. ASPE members are leaders in innovative plumbing design, effective materials and energy use, and the application of advanced techniques from around the world.

Worldwide Membership — ASPE was founded in 1964 and currently has 7,500 members. Spanning the globe, members are located in the United States, Canada, Asia, Mexico, South America, the South Pacific, Australia, and Europe. They represent an extensive network of experienced engineers, designers, contractors, educators, code officials, and manufacturers interested in furthering their careers, their profession, and the industry. ASPE is at the forefront of technology. In addition, ASPE represents members and promotes the profession among all segments of the construction industry.

ASPE Membership Communication — All members belong to ASPE worldwide and have the opportunity to belong and participate in one of the 62 state, provincial or local chapters throughout the U.S. and Canada. ASPE chapters provide the major communication links and the first line of services and programs for the individual member. Communications with the membership is enhanced through the Society's bimonthly magazine, *Plumbing Systems and Design,* and the bimonthly newsletter ASPE *Report* which is incorporated as part of the magazine.

Technical Publications — The Society maintains a comprehensive publishing program, spearheaded by the profession's basic reference text, the ASPE *Plumbing Engineering Design Handbook.* The *Plumbing Engineering Design Handbook,* encompassing 47 chapters in four volumes, provides comprehensive details of the accepted practices and design criteria used in the field of plumbing engineering. New additions that will shortly join ASPE's published library of professional technical manuals and handbooks include: *Pharmaceutical Facilities Design Manual, Electronic Facilities Design Manual, Health Care Facilities and Hospitals Design Manual,* and *Water Reuse Design Manual.*

Convention and Technical Symposium — The Society hosts biennial Conventions in even-numbered years and Technical Symposia in odd-numbered years to allow professional plumbing engineers and designers to improve their skills, learn original concepts, and make important networking contacts to help them stay abreast of current trends and technologies. In conjunction with each Convention there is an Engineered Plumbing Exposition, the greatest, largest gathering of plumbing engineering and design products, equipment, and services. Everything from pipes to pumps to fixtures, from compressors to computers to consulting services is on display, giving engineers and specifiers the opportunity to view the newest and most innovative materials and equipment available to them.

Certified in Plumbing Design — ASPE sponsors a national certification program for engineers and designers of plumbing systems, which carries the designation "Certified in Plumbing Design" or CPD. The certification program provides the profession, the plumbing industry, and the general public with a single, comprehensive qualification of professional competence for engineers and designers of plumbing systems. The CPD, designed exclusively by and for plumbing engineers, tests hundreds of engineers and designers at centers throughout the United States biennially. Created to provide a single, uniform national credential in the field of engineered plumbing systems, the CPD program is not in any way connected to state-regulated Professional Engineer (P.E.) registration.

ASPE Research Foundation — The ASPE Research Foundation, established in 1976, is the only independent, impartial organization involved in plumbing engineering and design research. The science of plumbing engineering affects everything… from the quality of our drinking water to the conservation of our water resources to the building codes for plumbing systems. Our lives are impacted daily by the advances made in plumbing engineering technology through the Foundation's research and development.

American Society of Plumbing Engineers

Plumbing Engineering Design Handbook

(4 Volumes — 47 Chapters)

Volume 2 Plumbing Systems (Estimated date: Fall 2005)

Chapter 1	Sanitary Drainage Systems
2	Gray-Water Systems
3	Vents and Venting Systems
4	Storm-Drainage Systems
5	Cold-Water Systems
6	Domestic Water-Heating System
7	Fuel-Gas Piping Systems
8	Private Sewage-Disposal Systems
9	Private Water Systems
10	Vacuum Systems
11	Pure Water, Systems
12	Lab-Waste Systems

Volume 3 Special Plumbing Systems (Estimated date: Fall 2006)

Chapter 1	Fire Protection Systems
2	Plumbing Design for Health-Care Facilities
3	Industrial Waste-Water Treatment
4	Irrigation Systems
5	Reflecting Pools and Fountains
6	Public Swimming Pools
7	Gasoline and Diesel-Oil Systems
8	Steam and Condensate Systems
9	Compressed Air Systems
10	Site Utility Systems

Volume 4 Plumbing Components and Equipment (Estimated revision date: Fall 2007)

Chapter 1	Plumbing Fixtures
2	Piping Systems
3	Valves
4	Pumps
5	Piping Insulation
6	Hangers and Supports
7	Vibration Isolation
8	Grease Interceptors
9	Cross Connection Control
10	Water Treatment
11	Thermal Expansion
12	Potable Water Coolers and Central Water Systems
13	Bioremediation Pretreatment Systems

(The chapters and subjects listed for these volume are subject to modification, adjustment and change. The contents shown for each volume are proposed and may not represent the final contents of the volume. A final listing of included chapters for each volume will appear in the actual publication.)

Chapter 1, Formulas, Symbols and Terminology . . . . . .

Division 5 Metals 74
Division 6 Wood and Plastics 74
Division 7 Thermal and Moisture Protection 74
Division 8 Doors and Windows 74
Division 9 Finishes 74
Division 10 Specialties 74
Division 11 Equipment 74
Division 12 Furnishings 75
Division 13 Special Construction 75
Division 14 Conveying Systems 75
Division 15 Mechanical 75
Division 16 Electrical 75
Appendix 3-A4 76
Appendix 3-A5 76
Appendix 3-B1 77
CSI Masterformat Divisions (2004 Edition) Procurement and Contracting Documents Group 77
Specifications Group 77
General Requirements Subgroup 77
Facility Construction Subgroup 77
Facility Services Subgroup 77
Site and Infrastructure Subgroup 78
Process Equipment Subgroup 78
Appendix 3-B2 79
Appendix 3-B3 79
Appendix 3-B4 81
Appendix 3-B5 84
Appendix 3-C Section Shell Outline 88
Part 1—General 88
1.1 Summary 88
1.2 References 88
1.3 Definitions 88
1.4 System Description 88
1.5 System Performance Requirements 88
1.6 Submittals 88
1.7 Quality Assurance 89
1.8 Delivery, Storage, and Handling 89
1.9 Project Conditions 90
1.10 Sequencing and Scheduling . . . . .

2.3 Materials, General [Products, General] 90
2.4 Equipment [Name of Manufactured Unit] 91
2.5 Components 91
2.6 Accessories 91
2.7 Mixes 91
2.8 Fabrication 91
2.9 Source of Quality Control 91
PART 3—Execution 91
3.1 Examination 91
3.2 Preparation 91
3.3 Installation, General [Application, General] 91
3.4 Installation {Of [Name]} {Application of [Name]} 91
3.5 Connections (Not A CSI Article—but Useful for Division 15) 91
3.6 Field Quality Control 91
3.7 Adjusting [Cleaning] [Adjusting and Cleaning] 92
3.8 Commissioning (Not A CSI Article — But Useful for Division 15 [Demonstration]) 92
3.9 Protection 92
3.10 Schedules 92

Chapter 4, Plumbing Cost Estimation 93
Labor Costs 94
Take-off Estimating Method 94
Productivity Rates 95
Other Estimating Methods 97
Other Cost Factors 98

Chapter 5, Job Preparation, Drawings, and Field Reports 99
Job-preparation Guidelines 99
Plumbing Drawing Guidelines 100
Plumbing-Drawings Checklist 101
Plans 101
Risers and Details 102
Schedules and Specifications 102
Field Checklist 102
Building Drains 102
Water and Gas Services 103
Above Grade Rough-in 103
Final 103

Chapter 6, Plumbing for People (Or Persons) with Disabilities 105
Introduction 105
Background

Anthropometrics . . . 109
Plumbing Elements and Facilities . . . 109
References . . . 123

Chapter 7, Energy and Resource Conservation in Plumbing Systems 125
Introduction . . . 125
Domestic Hot Water System Energy Conservation . . . 125
Design Techniques . . . 125
Domestic Hot Water Heating Equipment . . . 129
Water Management . . . 134
Design Techniques . . . 134
Water-management Equipment . . . 135
Glossary . . . 136

Chapter 8, Corrosion . . . 139
Introduction . . . 139
Fundamental Corrosion Cell . . . 139
Basic Relations . . . 139
Electrochemical Equivalents . . . 139
Common Forms of Corrosion . . . 141
The Galvanic Series . . . 141
Electromotive Force Series . . . 144
Factors Affecting the Rate of Corrosion . . . 144
General . . . 144
Acidity . . . 145
Oxygen Content . . . 145
Film Formation . . . 145
Temperature . . . 145
Velocity . . . 145
Homogeneity . . . 145
Corrosion Control . . . 145
Materials Selection . . . 146
Design to Reduce Corrosion . . . 146
Passivation . . . 146
Coating . . . 147
Cathodic Protection . . . 147
Inhibitors (Water Treatment) . . . 151
Glossary . . . 151
References . . . 154

Chapter 9, Seismic Protection of Plumbing Equipment . . . 155
Introduction . . . 155
Causes and Effects of Earthquakes . . . 156
Plate Tectonics and Faults . . . 156
Damage From Earthquakes . . . 158
Earthquake Measurement and Seismic Design . . . 158

Ground Shaking and Dynamic Response 158
The Response Spectrum 160
Learning From Past Earthquakes 161
Damage to Plumbing Equipment 161
The 1964 Alaska Earthquake 161
Damage Summary 161
The 1971 San Fernando Earthquake 162
Seismic Protection Techniques 163
General 163
Equipment 163
Piping Systems 166
Codes 171
Design Philosophy 171
Code Requirements 183
Analysis Techniques 184
Determination of Seismic Forces 184
Determination of Anchorage Forces 186
Computer Analysis of Piping Systems 186
Design Considerations 186
Loads in Structures 186
Potential Problems 188
Additional Considerations 190
Glossary 191
References 191

Chapter 10, Acoustics in Plumbing Systems 193
Introduction 193
Acceptable Acoustical Levels in Buildings 193
Acoustical Performance of Building Materials 193
Insulation Against Airborne Sound 193
Acoustical Ratings of Plumbing Fixtures and Appliances 194
General Acoustical Design 195
Water Pipes 195
Occupied Domestic Spaces 196
Pumps 196
Flow Velocity and Water Hammer 198
Design Procedures 198
Noise and Vibration Control 199
System Design 200
Glossary 206

Chapter 11, Basics of Value Engineering 211
The Intent of Value Engineering . . . . .

Phase Two: Analysis/function Analysis 224
Rules of Function Analysis 225
Function Definitions 225
Fast 227
Purpose of the Model 231
Creativity 231
Creative Thinking Personified 231
Divergent Thinking 232
Evaluation 235
In Concert With 235
Refining, Combining, Evaluating By Comparison 235
Cost Analysis and Evaluation 235
Incorporating the Functional Definitions 243
The Pencil: Another Look 243
Development/ Investigation 243
Consultation and Evaluation 243
Second Creativity, Evaluation, Cost Anaylsis 254
Final Alternatives 254
The Gut Feel Index 254
Cost Analysis, More 254
Are We there Yet? 254
Recommendation/Presentation 257
Present Costs 257
Present Recommendation 258
Making the Presentation 258
Is It Value Engineering? 258
Cost Fitting . . . . .

Figures

Figure 1-1 Square . . . 3
Figure 1-2 Rectangle . . . 3
Figure 1-3 Rhombus . . . 4
Figure 1-4 Rhomboid . . . 4
Figure 1-5 Trapezoid . . . 4
Figure 1-6 Trapezium . . . 4
Figure 1-7 Right-Angle Triangle . . . 4
Figure 1-8 Isosceles Triangle . . . 4
Figure 1-9 Ellipse . . . 4
Figure 1-10 Cylinder . . . 4
Figure 1-11 Cube or Rectangular Solid . . . 4
Figure 1-12 Pyramid . . . 4
Figure 1-13 Cone . . . 4
Figure 1-14 Circle . . . 5
Figure 1-15 Triangle . . . 5
Figure 6-1 Dimensions of Adult-Sized Wheelchairs . . . 108
Figure 6-2 Clear Floor Space for Wheelchairs . . . 109
Figure 6-3 Wheelchair Approaches . . . 110
Figure 6-4 Clear Floor Space in Alcoves . . . 110
Figure 6-5 Unobstructed Forward Reach Limit . . . 111
Figure 6-6 Forward Reach Over an Obstruction . . . 111
Figure 6-7 Unobstructed Side Reach Limit . . . 112
Figure 6-8 Obstructed Side Reach Limit . . . 112
Figure 6-9 Cantilevered Drinking Fountains and Water Coolers . . . 112
Figure 6-10 Horizontal Angle of Water Stream — Plan View . . . 113
Figure 6-11 Leg Clearances . . . 113
Figure 6-12 Ambulatory Accessible Stall . . . 114
Figure 6-13 Wheelchair Accessible Toilet Stalls — Door Swing Out . . . 114
Figure 6-14 Clear Floor Space at Water Closets . . . 115
Figure 6-15 Water Closet — Side View . . . 115
Figure 6-16 Water Closet — Front View . . . 115
Figure 6-17 Wheelchair Accessible Toilet Stalls — Door Swing In . . . 116
Figure 6-18 Clear Floor Space atLavatories and Sinks . . . 117
Figure 6-19 Clear Floor Space at Bathtubs . . . 118

Figure 6-20 Bathtub Accessories 119
Figure 6-21 Transfer Type Shower Stall 120
Figure 6-22 Roll-in Type Shower Stall 120
Figure 6-23 Grab Bars at Shower Stalls 121
Figure 6-24 Size and Spacing of Grab Bars 122
Figure 6-25 Shower Seat Design 123
Figure 7-1 Energy Savings fromReduced Faucet Flow Rates 127
Figure 7-2 Refrigeration Waste-Heat Recovery 132
Figure 7-3 Condenser Water Heat Recovery 132
Figure 7-4 Condenser Water Heat Recovery with Storage Tank 133
Figure 7-5 Waste Water Heat Recovery 133
Figure 8-1 Basic Corrosion Cell 140
Figure 8-2 Basic Cell Applied to an Underground Structure 140
Figure 8-3 Uniform Attack 142
Figure 8-4 Pitting Corrosion 142
Figure 8-5 Galvanic Corrosion 142
Figure 8-6 Concentration Cells 142
Figure 8-7 Impingement Attack 142
Figure 8-8 Stress Corrosion 142
Figure 8-9 (A) Plug-Type Dezincification(B) Layer-Type Dezincification 142
Figure 8-10 Stray Current Corrosion 143
Figure 8-11 Corrosion by Differential Environmental Conditions 143
Figure 8-12 Cathodic Protection by the Sacrificial Anode Method 148
Figure 8-13 Typical Sacrificial Anode Installation 149
Figure 8-14 Cathodic Protection by the Impressed Current Method 149
Figure 9-1 Significant Earthquakes in the United States 155
Figure 9-2 (A) Seismic Zone Map of the United States; (B) Map of Seismic Zones and Effective, Peak-Velocity-Related Acceleration (Av) for Contiguous 48 States 157
Figure 9-3 World Map Showing Relation Between the Major Tectonic Plates and Recent Earthquakes and Volcanoes 156
Figure 9-4 Elastic Rebound Theory of Earthquake Movement 158
Figure 9-5 Earthquake Ground Accelerations in Epicentral Regions 159
Figure 9-6 Undamped Mechanical Systems: (A) Single-Degree-of-Freedom Systems; (B) Multiple-Degree-of-Freedom Systems 160
Figure 9-7 Response Spectrum 161
Figure 9-8 Snubbing Devices: (A) Three-Dimensional Cylinder Snubber 164
Figure 9-9 Isolators with Built-In Seismic Restraint 164
Figure 9-8 Snubbing Devices: (B) Three-Directional Angle Snubbers 165
Figure 9-10 Parameters to Be Considered for Pipe Bracing 167
Figure 9-11 Pipe Bracing Systems: (A) Typical Pipe Bracing 168
Figure 9-11 Pipe Bracing Systems: (B) Tension 360 169
Figure 9-11 Pipe Bracing Systems: (C) Superstrut 170
Figure 9-12 Construction Details of Seismic Protection for Pipes: (A) Transverse Bracing for Pipes 171
Figure 9-12 Construction Details of Seismic Protection for Pipes: (B) Longitudinal Bracing for Pipes 172

Figure 9-12 Construction Details of Seismic Protection for Pipes: (C) Strut Bracing for Pipes 173
Figure 9-12 Construction Details of Seismic Protection for Pipes: (D) Alternate Attachment to Hanger for Pipe Bracing 174
Figure 9-12 Construction Details of Seismic Protection for Pipes: (E) Alternate Bracing for Pipes 174
Figure 9-12 Construction Details of Seismic Protection for Pipes: (F) Strut Bracing for Pipe Trapeze. 175
Figure 9-12 Construction Details of Seismic Protection for Pipes: (G) Connections to Steel Beams 175
Figure 9-12 Construction Details of Seismic Protection for Pipes: (H) Connections to Open-Web Steel Joists 176
Figure 9-12 Construction Details of Seismic Protection for Pipes: (I) Connections to Steel 176
Figure 9-12 Construction Details of Seismic Protection for Pipes: (J) Hanger Rod Connections 177
Figure 9-12 Construction Details of Seismic Protection for Pipes: (K) Hubless Cast-Iron Pipe 177
Figure 9-12 Construction Details of Seismic Protection for Pipes: (L) Riser Bracing for Hubless Pipes 178
Figure 9-12 Construction Details of Seismic Protection for Pipes: (M) Connections for Pipes on Trapeze. 178
Figure 9-13 Sway Bracing, 0.5 G Force 179
Figure 9-14 A Seismic Bracing Method: (A) Lateral Sway Bracing . . . . . .

Figure 11-4A General Project Information Collection 215
Figure 11-4B Detailed Basic Project Information Collection 216
Figure 11-5 Project Description 219
Figure 11-6 Information and Data Sources 221
Figure 11-7 Cost Structure of Product/Service/Material. 222
Figure 11-8 Generalized Total Cost to Each User 223
Figure 11-9 Cost Breakdown Checklist 223
Figure 11-10 Function Definition Verbs and Nouns 224
Figure 11-11 Function Analysis/Definition Form 226
Figure 11-12 Function Analysis Systems Technique (FAST) Model 229
Figure 11-13 HOW and WHY Relationship with Example 230
Figure 11-14 Creativity Worksheet. 233
Figure 11-15A Creativity Checklist 234
Figure 11-15B Creativity Checklist 234
Figure 11-16 Creativity Worksheet. 236
Figure 11-17A Basic Idea Evaluation Worksheet 237
Figure 11-17B Initial Example — Idea Evaluation Worksheet. 238
Figure 11-18A Functional Development Sketch Worksheet — Blank 239
Figure 11-18A Functional Development Sketch Worksheet — Example. 240
Figure 11-18B Functional Idea Development and Estimated Cost Worksheet — Blank 241
Figure 11-18B Functional Idea Development and Estimated Cost Worksheet — Example 242
Figure 11-19 Functional Evaluation Worksheet — Part 1, Blank 244
Figure 11-19 Functional Evaluation Worksheet — Part 2, Blank 245
Figure 11-20A Functional Evaluation Worksheet — Part 1, Example. 246
Figure 11-20B Functional Evaluation Worksheet — Part 2, Example. 247
Figure 11-20C Functional Evaluation Worksheet — Part 1, Example. 248
Figure 11-21 Completion of Functional Definition and Analysis Worksheet. 249
Figure 11-22A Functional Evaluation, Part 1, Step 1 250
Figure 11-22B Functional Evaluation, Part 2 251
Figure 11-22C Functional Evaluation, Part 1, Step 2 252
Figure 11-23 Completed Idea Evaluation Form. 253
Figure 11-24A In-progress Alternative Sketch 255
Figure 11-24B In-progress Alternative Idea Development and Cost Estimates 256
Figure 11-25 Risk Guide 257
Figure 11-26 Value Engineering Team Recommendation. 259
Figure 11-27 Example of Value Engineering Change Proposal Contract Clause . . . 260

Table 1-1 Standard Plumbing and Piping Symbols 8
Table 1-2 Standard Fire-Protection Piping Symbols 12
Table 1-3 Abbreviations for Text, Drawings, and Computer Programs 14
Table 1-4 Temperature Conversion Chart, °F – °C 38
Table 1-5 Conversion to SI Units 39
Table 2-1 Codes and Standards Listed by Category 42
Table 2-2 Complete List of Standards By Standard-Writing Organization 46
Table 2-3 Organization Abbreviation, Address, and Phone Number Listing . . . . . .

1 Formulas, Symbols and Terminology

RFF = Hydraulic radius, full-flow condition, ft (m)

Equation 1-4, Water flow in pipes Two types of water flow exist: Laminar and turbulent. Each type is characterized by the Reynolds number, a dimensionless quantity. The physical characteristics of the water, the velocity of the flow, and the internal diameter of the pipe are factors for consideration, and the Reynolds number is represented as:

Equation 1-4

$$Re = \frac{VD\rho}{\mu g_c}$$

W = Weight of body, lbf (kg)
g = Gravitational acceleration, 32.2 ft/s^2 (9.8 /s^2)
g_c

Equation 1-13c, Rhombus (See Figure 1-3.)

$A = bh$

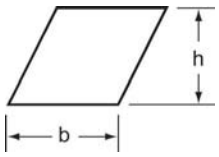


Figure 1-3 Rhombus

Equation 1-13d, Rhomboid (See Figure 1-4.)

$A = bh$

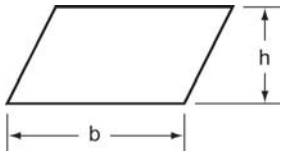


Figure 1-4 Rhomboid

Equation 1-13e, Trapezoid (See Figure 1-5.)

$A = \frac{\qquad}{\qquad}$

Equation 1-13o, Circle (See Figure 1-14.)

$A = \pi R^2$

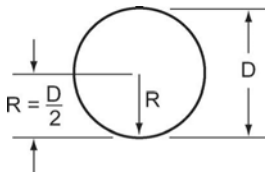


Figure 1-14 Circle

Equation 1-13p, Triangle[3] (See Figure 1-15.)

Known: 2 angles
Required: Third angle
Solution: $A = 180° - (B + C)$

Equation 1-13q, Triangle[3] (See Figure 1-15.)

Known: 3 sides
Required: Any angle
Solution: $\cos A = \frac{b^2 + c^2 - a^2}{2bc}$

Equation 1-13r, Triangle[3] (See Figure 1-15.)

Known: 2 sides and included angle
Required: Third side
Solution: $c = (a^2 + b^2 - 2ab \cos C)^{1/2}$

Equation 1-13s, Triangle[3] (See Figure 1-15.)

Known: 2 sides and included angle
Required: Third angle
Solution: $\tan A = \frac{a \sin C}{b - a \cos C}$

Equation 1-13t, Triangle[3] (See Figure 1-15.)

Known: 2 sides and excluded angle
Required: Third side
Solution: $c = b \cos A \pm (a^2 - b^2 \sin^2 A)^{1/2}$

Equation 1-13u, Triangle[3] (See Figure 1-15.)

Known: 1 side and adjacent angles
Required: Adjacent side
Solution: $c = \frac{a \sin C}{\sin A}$

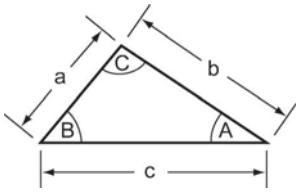


Figure 1-15 Triangle

Equation 1-14, Flow rate in outlet With Equation 1-11, we determined that the flow rate (Q) in the outlet should be equal to the flow rate in the fixture drain. The maximum discharge rate is expressed as:

Equation 1-14

$$Q_D = c_D Q_I$$

where

Q_D = Actual discharge quantity, gpm (L/s)
c_D = Discharge coefficient
Q_I = Ideal discharge quantity, gpm (L/s)

The discharge coefficients (c_D) may be obtained from Baumeister and Marks's "Handbook for Mechanical Engineers."

Equation 1-15, Gravity circulation This principle is used to keep the sanitary system free of foul odors and the growth of slime and fungi. The circulation is induced by the pressure difference between the outdoor air and the air in the vent piping. This pressure difference is due to the difference in temperature (T) and density (ρ) between the two and the height (h) of the air column in the vent piping. The gravity circulation is determined by using the following formula:

Equation 1-15

$$P = 0.1925 (\gamma_O$$

g = Gravitational acceleration, 32.2 ft/s^2 (9.8 m/s^2)

g_c

Equation 1-22

$$Ep = \frac{WH}{BHP}$$

where

Ep = Pump efficiency as a decimal equivalent

WHP = Water horsepower derived from:

$$WHP = \text{ft Hd} \times \frac{\text{gal}}{\text{min}} \times \frac{8.33 \text{ lb}}{\text{gal}} \times \frac{HP}{33{,}000 \text{ ft-lb/min}}$$

BHP = Brake horsepower input to pump

From Equation 1-22, the brake horsepower can be represented as:

Equation 1-22a

$$BHP = \frac{WHP}{Ep} \text{ or } \frac{\text{ft Hd} \times \text{gpm}}{3960 \times Ep}$$

Equation 1-23, Rational method of storm design Calculates the peak storm-water runoff.

Equation 1-23

$$Q = CIA$$

where

Q = Runoff, ft^3/s (m^3/s)

C = Runoff coefficient (surface roughness in drained area)

I = Rainfall intensity, in/h (mm/h)

A = Drainage area, acres (m^2)

Equation 1-24, Spitzglass Formula Used to size gas piping in systems operating at a pressure of less than 1 psi.

Equation 1-24

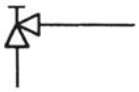
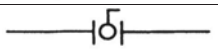
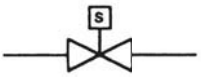
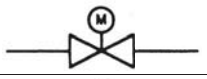
$$Q = 3550 \left(\frac{d^5}{1 + \frac{3.6}{}} \right)^{1/2} \left(\frac{h}{} \right)^{1/2}$$

Table 1-1 Standard Plumbing and Piping Symbols

Symbol	Description	Abbreviation
——— SD ———	Storm drain, rainwater drain	SD, ST
——— ——— SSD ———	Subsoil drain, footing drain	SSD
——— SS ———	Soil, waste, or sanitary sewer	S, W, SAN, SS
— — — — — — — — — —	Vent	V
——— AW ———	Acid waste	AW
— — — — AV — — — — —	Acid vent	AV
——— D ———	Indirect drain	D
——— PD ———	Pump discharge line	PD
——— – ———	Cold water	CW
——— – – ———	Hot water supply (140°F)[a]	HW
——— – – – ———	Hot water recirculating (140°F)[a]	HWR
——— TW ———	Tempered water (temp. °F)[b]	TEMP. HW, TW
——— TWR ———	Tempered water recirculating (temp. °F)[b]	TEMP. HWR, TWR
——— DWS ———	(Chilled) drinking water supply	DWS
——— DWR ———	(Chilled) drinking water recirculating	DWR
——— SCW ———	Soft cold water	SCW
——— CD ———	Condensate drain	CD
——— DI ———	Distilled water	DI
——— DE ———	Deionized water	DE
——— RO ———	Reverse osmosis water	RO
——— CWS ———	Chilled water supply	CWS
——— CWR ———	Chilled water return	CWR
——— LS ———	Lawn sprinkler supply	LS
——— F ———	Fire protection water supply	F
——— G ———	Gas–low-pressure	G
——— MG ———	Gas–medium-pressure	MG
——— HG ———	Gas–high-pressure	HG
— — — — GV — — — — —	Gas vent	GV
——— FOS ———	Fuel oil supply	FOS
——— FOR ———	Fuel oil return	FOR
— — — — FOV — — — — —	Fuel oil vent	FOV
——— LO ———	Lubricating oil	LO
— — — — LOV — — — — —	Lubricating oil vent	LOV
——— WO ———	Waste oil	WO
— — — — WOV — — — —	Waste oil vent	WOV
——— O_2 ———	Oxygen	O_2
——— LO_2 ———	Liquid oxygen	LO_2
——— A ———	Compressed air[c]	A
——— X#A ———	Compressed air–X#[c]	X#A
——— MA ———	Medical compressed air	MA
——— LA ———	Laboratory compressed air	LA
——— HPCA ———	High pressure compressed air	HPCA

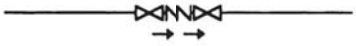
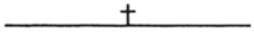
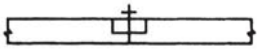
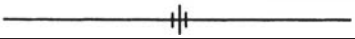
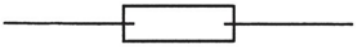
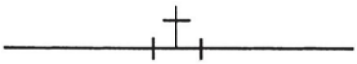
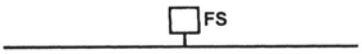
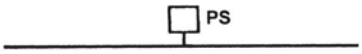
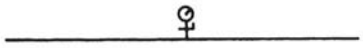
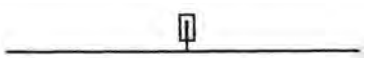
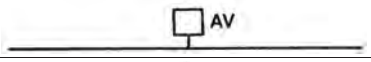
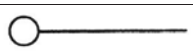
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Table 1-1 Standard Plumbing and Piping Symbols (continued)

Symbol	Description	Abbreviation
HHWS	(Heating) hot water supply	HHWS
HHWR	(Heating) hot water return	HHWR
V	Vacuum	VAC
NPCW	Non-potable cold water	NPCW
NPHW	Non-potable hot water	NPHW
NPHWR	Non-potable hot water return	NPHWR
MV	Medical vacuum	MV
SV	Surgical vacuum	SV
LV	Laboratory vacuum	LV
N_2	Nitrogen	N_2
N_2O	Nitrous oxide	N_2O
CO_2	Carbon dioxide	CO_2
WVC	Wet vacuum cleaning	WVC
DVC	Dry vacuum cleaning	DVC
LPS	Low-pressure steam supply	LPS
LPC	Low-pressure condensate	LPC
MPS	Medium-pressure steam supply	MPS
MPC	Medium-pressure condensate	MPC
HPS	High-pressure steam supply	HPS
HPC	High-pressure condensate	HPC
ATV	Atmospheric vent (steam or hot vapor)	ATV
	Gate valve	GV
	Globe valve	GLV
	Angle valve	AV
	Ball valve	BV
	Butterfly valve	BFV
	Gas cock, gas stop	
	Balancing valve (specify type)	BLV
	Check valve	CV
	Plug valve	PV
	Solenoid valve	
	Motor-operated valve (specify type)	
	Pressure-reducing valve	PRV

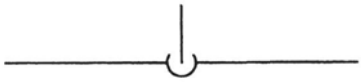
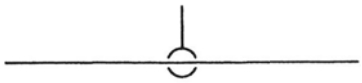
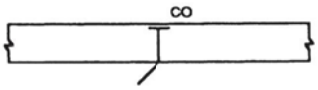
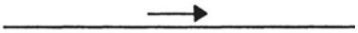
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Table 1-1 Standard Plumbing and Piping Symbols (continued)

Symbol	Description	Abbreviation
	Pressure-relief valve	RV
	Temperature-pressure-relief valve	TPV
	Backflow preventer	RZBP
	Hose bibb	HB
	Recessed-box hose bibb or wall hydrant	WH
	Valve in yard box (valve type symbol as required for valve use)	YB
	Union (screwed)	
	Union (flanged)	
	Strainer (specify type)	
	Pipe anchor	PA
	Pipe guide	
	Expansion joint	EJ
	Flexible connector	FC
	Tee	
	Concentric reducer	
	Eccentric reducer	
	Aquastat	
	Flow switch	FS
	Pressure switch	PS
	Water hammer arrester	WHA
	Pressure gauge with gauge cock	PG
	Thermometer (specify type)	
	Automatic air vent	AAV
	Valve in riser (type as specified or noted)	
	Riser down (elbow)	
	Riser up (elbow)	
	Air chamber	AC

(CONTINUED)

Table 1-1 Standard Plumbing and Piping Symbols (continued)

Symbol	Description	Abbreviation
	Rise or drop	
	Branch–top connection	
	Branch–bottom connection	
	Branch–side connection	
	Cap on end of pipe	
	Cleanout plug	CO
	Floor cleanout	FCO
	Wall cleanout	WCO
	Yard cleanout or cleanout to grade	CO
	Drain (all types) (specify)	D
	Pitch down or up–in direction of arrow	
	Flow–in direction of arrow	
	Point of connection	POC
	Outlet (specify type)	
	Steam trap (all types)	
	Floor drain with p-trap	FD

a Hot water (140°F) and hot water return (140°F). Use for normal hot water distribution system, usually but not necessarily (140°F). Change temperature designation if required.

b Hot water (temp. °F) and hot water return (temp. °F). Use for any domestic hot water system (e.g., tempered or sanitizing) required in addition to the normal system (see note "a" above). Insert system supply temperature where "temp." is indicated.

c Compressed air and compressed air X#. Use pressure designations (X#) when compressed air is to be distributed at more than one pressure.

Table 1-2 Standard Fire-Protection Piping Symbols

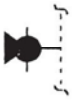
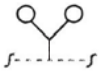
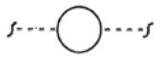
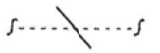
Referent (Synonym)	Symbol	Comments
Water supply and distribution symbols		
Mains, pipe		
Riser		
Hydrants		
Public hydrant, two hose outlets		Indicate size,[a] type of thread, or connection.
Public hydrant, two hose outlets, and pumper connection		Indicate size,[a] type of thread, or connection.
Wall hydrant, two hose outlets		Indicate size,[a] type of thread, or connection.
Fire department connections		
Siamese fire department connection		Specify type, size, and angle.
Free-standing siamese ire department connection		Sidewalk or pit type, specify size.
Fire pumps		
Fire pump		Free-standing. Specify number and sizes of outlets.
Test header		Wall
Symbols for control panels		
Control panel		Basic shape
(a)		Fire alarm control panel
Symbols for fire extinguishing system		
Symbols for various types of extinguishing systems[b]		
Supplementary symbols		
Fully sprinklered space		
Partially sprinklered space		
Nonsprinklered space		

Table 1-2 Standard Fire-Protection Piping Symbols (continued)

Referent (Synonym)	Symbol	Comments
Symbols for fire sprinkler heads		
Upright sprinkler[c]		
Pendent sprinkler[c, d]		
Upright sprinkler, nippled up		
Pendent sprinkler, on drop nipple[c, d]		
Sidewall sprinkler[c]		
Symbols for piping, valves, control devices, and hangers[e]		
Pipe hanger		This symbol is a diagonal stroke imposed on the pipe that it supports.
Alarm check valve		Specify size, direction of flow.
Dry pipe valve		Specify size.
Deluge valve		Specify size and type.
Preaction valve		Specify size and type.
Symbols for portable fire extinguishers		
Portable fire extinguisher		Portable fire extinguisher
Symbols for firefighting equipment		
Hose station, dry standpipe		
Hose station, changed standpipe		

Source: National Fire Protection Association (NFPA), Standard 170.

[a] Symbol element can be utilized in any combination to fit the type of hydrant.

[b] These symbols are intended for use in identifying the type of system installed to protect an area within a building.

[c] Temperature rating of sprinkler and other characteristics can be shown via legends where a limited number of an individual type of sprinkler is called for by the design.

[d] Can notate "DP" on drawing and/or in specifications where dry pendent sprinklers are employed.

[e] See also NFPA Standard 170, Section 5-4, for related symbols.

Table 1-3 Abbreviations for Text, Drawings, and Computer Programs

Term	Text	Drawings	Program
Above finished floor	–	AFF	–
Absolute	abs	ABS	ABS
Accumulat(-e, -or)	acc	ACCUM	ACCUM
Air condition(-ing, -ed)	–	AIR COND	–
Air-conditioning unit(s)	–	ACU	ACU
Air-handling unit	–	AHU	AHU
Air horsepower	ahp	AHP	AHP
Alteration	altrn	ALTRN	–
Alternating current	ac	AC	AC
Altitude	alt	ALT	ALT
Ambient	amb	AMB	AMB
American National Standards Institute[a]	ANSI	ANSI	–
American wire gage	AWG	AWG	–
Ampere (amp, amps)	amp	AMP	AMP, AMPS
Angle	–	–	ANG
Angle of incidence	–	–	ANGI
Apparatus dew point	adp	ADP	ADP
Approximate	approx.	APPROX	–
Area	–	–	A
Atmosphere	atm	ATM	–
Average	avg	AVG	AVG
Azimuth	az	AZ	AZ
Azimuth, solar	–	–	SAZ
Azimuth, wall	–	–	WAZ
Baromet(-er, -ric)	baro	BARO	–
Bill of material	b/m	BOM	–
Boiling point	bp	BP	BP
Brake horsepower	bhp	BHP	BHP
Brown & Sharpe wire gage	B&S	B&S	–
British thermal unit	Btu	BTU	BTU
Celsius	°C	°C	°C
Center to center	c to c	C TO C	–
Circuit	ckt	CKT	CKT
Clockwise	cw	CW	–
Coefficient	coeff.	COEF	COEF
Coefficient, valve flow	C_v	C_v	CV
Coil	–	–	COIL
Compressor	cprsr	CMPR	CMPR
Condens(-er, -ing, -ation)	cond	COND	COND
Conductance	–	–	C
Conductivity	cndct	CNDCT	K
Conductors, number of (3)	3/c	3/c	–
Contact factor	–	–	CF
Cooling load	clg load	CLG LOAD	CLOAD
Counterclockwise	ccw	CCW	–
Cubic feet	ft^3	CU FT	CUFT, CFT
Cubic inch	in^3	CU IN	CUIN, CIN
Cubic feet per minute	cfm	CFM	CFM
cfm, standard conditions	scfm	SCFM	SCFM
Cubic ft per sec, standard	scfs	SCFS	SCFS
Decibel	dB	DB	DB
Degree	deg. or °	DEG or °	DEG
Density	dens	DENS	RHO
Depth or deep	dp	DP	DPTH
Dew-point temperature	dpt	DPT	DPT
Diameter	dia.	DIA	DIA
Diameter, inside	ID	ID	ID
Diameter, outside	OD	OD	OD
Difference or delta	diff., Δ	DIFF	D, DELTA
Diffuse radiation	–	–	DFRAD
Direct current	dc	DC	DC
Direct radiation	dir radn	DIR RADN	DIRAD
Dry	–	–	DRY
Dry-bulb temperature	dbt	DBT	DB, DBT
Effectiveness	–	–	EFT
Effective temperature[b]	ET*	ET*	ET
Efficiency	eff	EFF	EFF
Efficiency, fin	–	–	FEFF
Efficiency, surface	–	–	SEFF
Electromotive force	emf	EMF	–
Elevation	elev.	EL	ELEV
Entering	entr	ENT	ENT
Entering air temperature	EAT	EAT	EAT
Entering water temperature	EWT	EWT	EWT
Enthalpy	–	–	H
Entropy	–	–	S
Equivalent direct radiation	edr	EDR	–
Equivalent feet	eqiv ft	EQIV FT	EQFT
Equivalent inches	eqiv in	EQIV IN	EQIN
Evaporat(-e, -ing, -ed, -or)	evap	EVAP	EVAP
Expansion	exp	EXP	XPAN
Face area	fa	FA	FA
Face to face	f to f	F to F	–
Face velocity	fvel	FVEL	FV
Factor, correction	–	–	CFAC, CFACT
Factor, friction	–	–	FFACT, FF
Fahrenheit	°F	°F	F
Fan	–	–	FAN
Feet per minute	fpm	FPM	FPM
Feet per second	fps	FPS	FPS
Film coefficient, inside[c]	–	–	FI, HI
Film coefficient, outside[c]	–	–	FO, HO
Flow rate, air	–	–	QAR, QAIR
Flow rate, fluid	–	–	QFL
Flow rate, gas	–	–	QGA, QGAS
Foot or feet	ft	FT	FT
Foot-pound	ft-lb	FT LB	–
Freezing point	fp	FP	FP

(CONTINUED)

Table 1-3 Abbreviations for Text, Drawings, and Computer Programs (con't)

Term	Text	Drawings	Program
Frequency	Hz	HZ	–
Gage or gauge	ga	GA	GA, GAGE
Gallons	gal	GAL	GAL
Gallons per hour	gph	GPH	GPH
gph, standard	std gph	SGPH	SGPH
Gallons per day	gpd	GPD	GPD
Grains	gr	GR	GR
Gravitational constant	*g*	G	G
Greatest temperature difference	GTD	GTD	GTD
Head	hd	HD	HD
Heat	–	–	HT
Heater	–	–	HTR
Heat gain	HG	HG	HG, HEATG
Heat gain, latent	LHG	LHG	HGL
Heat gain, sensible	SHG	SHG	HGS
Heat loss	–	–	HL, HEATL
Heat transfer	–	–	Q
Heat transfer coefficient	*U*	U	U
Height	hgt	HGT	HGT, HT
High-pressure steam	hps	HPS	HPS
High-temperature hot water	hthw	HTHW	HTHW
Horsepower	hp	HP	HP
Hour(s)	h	HR	HR
Humidity ratio	W	W	W
Humidity, relative	rh	RH	RH
Incident angle	–	–	INANG
Indicated horsepower	ihp	IHP	–
International Pipe Std.	IPS	IPS	–
Iron pipe size	ips	IPS	–
Kelvin	K	K	K
Kilowatt	kW	kW	KW
Kilowatt hour	kWh	KWH	KWH
Latent heat	LH	LH	LH, LHEAT
Least mean temp. difference[d]	LMTD	LMTD	LMTD
Least temperature difference[d]	LTD	LTD	LTD
Leaving air temperature	lat	LAT	LAT
Leaving water temperature	lwt	LWT	LWT
Length	lg	LG	LG, L
Linear feet	lin ft	LF	LF
Liquid	liq	LIQ	LIQ
Logarithm (natural)	ln	LN	LN
Logarithm to base 10	log	LOG	LOG
Low-pressure steam	lps	LPS	LPS
Low-temperature hot water	lthw	LTHW	LTHW
Mach number	Mach	MACH	–
Mass flow rate	mfr	MFR	MFR
Maximum	max.	MAX	MAX
Mean effective temperature	MET	MET	MET
Mean temp. difference	MTD	MTD	MTD

(CONTINUED)

Term	Text	Drawings	Program
Medium-pressure steam	mps	MPS	MPS
Medium-temperature hot water	mthw	MTHW	MTHW
Mercury	Hg	HG	HG
Miles per hour	mph	MPH	MPH
Minimum	min.	MIN	MIN
Noise criteria	NC	NC	–
Normally closed	n c	N C	–
Normally open	n o	N O	–
Not applicable	na	N/A	–
Not in contract	n i c	N I C	–
Not to scale	–	NTS	–
Number	no.	NO	N, NO
Number of circuits	–	–	NC
Number of tubes	–	–	NT
Ounce	oz	OZ	OZ
Outside air	oa	OA	OA
Parts per million	ppm	PPM	PPM
Percent	%	%	PCT
Phase (electrical)	ph	PH	–
Pipe	–	–	PIPE
Pounds	lb	LBS	LBS
Pounds per square foot	psf	PSF	PSF
psf absolute	psfa	PSFA	PSFA
psf gage	psfg	PSFG	PSFG
Pounds per square inch	psi	PSI	PSI
psi absolute	psia	PSIA	PSIA
psi gage	psig	PSIG	PSIG
Pressure	–	PRESS	PRES, P
Pressure, barometric	baro pr	BARO PR	BP
Pressure, critical	–	–	CRIP
Pressure drop or difference	PD	PD	PD, DELTP
Pressure, dynamic (velocity)	vp	VP	VP
Pressure, static	sp	SP	SP
Pressure, vapor	vap pr	VAP PR	VAP
Primary	pri	PRI	PRIM
Quart	qt	QT	QT
Radian	–	–	RAD
Radiat(-e, -or)	–	RAD	–
Radiation	–	RADN	RAD
Radius	–	–	R
Rankine	°R	°R	R
Receiver	rcvr	RCVR	REC
Recirculate	recirc.	RECIRC	RCIR, RECIR
Refrigerant (12, 22, etc.)	R-12, R-22	R12, R22	R12, R22
Relative humidity	rh	RH	RH
Resist(-ance, -ivity, -or)	res	RES	RES, OHMS
Return air	ra	RA	RA
Revolutions	rev	REV	REV
Revolutions per minute	rpm	RPM	RPM

(CONTINUED)

Table 1-3 Abbreviations for Text, Drawings, and Computer Programs (con't)

Term	Text	Drawings	Program
Revolutions per second	rps	RPS	RPS
Roughness	rgh	RGH	RGH, E
Safety factor	sf	SF	SF
Saturation	sat.	SAT	SAT
Saybolt seconds Furol	ssf	SSF	SSF
Saybolt seconds Universal	ssu	SSU	SSU
Sea level	sl	SL	SE
Second	s	s	SEC
Sensible heat	SH	SH	SH
Sensible heat gain	SHG	SHG	SHG
Sensible heat ratio	SHR	SHR	SHR
Shading coefficient	–	–	SC
Shaft horsepower	sft hp	SFT HP	SHP
Solar	–	–	SOL
Specification	spec	SPEC	–
Specific gravity	SG	SG	–
Specific heat	sp ht	SP HT	C
sp ht at constant pressure	c_p	c_p	CP
sp ht at constant volume	c_v	c_v	CV
Specific volume	sp vol	SP VOL	V, CVOL
Square	sq.	SQ	SQ
Standard	std	STD	STD
Standard time meridian	–	–	STM
Static pressure	SP	SP	SP
Suction	suct.	SUCT	SUCT, SUC
Summ(-er, -ary, -ation)	–	–	SUM
Supply	sply	SPLY	SUP, SPLY
Supply air	sa	SA	SA
Surface	–	–	SUR, S
Surface, dry	–	–	SURD
Surface, wet	–	–	SURW
System	–	–	SYS
Tabulat(-e, -ion)	tab	TAB	TAB
Tee	–	–	TEE
Temperature	temp.	TEMP	T, TEMP
Temperature difference	TD, Δt	TD	TD, TDIF
Temperature entering	TE	TE	TE, TENT
Temperature leaving	TL	TL	TL, TLEA
Thermal conductivity	k	K	K
Thermal expansion coeff.	–	–	TXPC
Thermal resistance	R	R	RES, R
Thermocouple	tc	TC	TC, TCPL
Thermostat	T STAT	T STAT	T STAT
Thick(-ness)	thkns	THKNS	THK
Thousand circular mils	Mcm	MCM	MCM
Thousand cubic feet	Mcf	MCF	MCF
Thousand foot-pounds	kip ft	KIP FT	KIPFT
Thousand pounds	kip	KIP	KIP
Time	–	T	T
Ton	–	–	TON
Tons of refrigeration	tons	TONS	TONS
Total	–	–	TOT
Total heat	tot ht	TOT HT	–
Transmissivity	–	–	TAU
U-factor	–	–	U
Unit	–	–	UNIT
Vacuum	vac	VAC	VAC
Valve	v	V	VLV
Vapor proof	vap prf	VAP PRF	–
Variable	var	VAR	VAR
Variable air volume	VAV	VAV	VAV
Velocity	vel.	VEL	VEL, V
Velocity, wind	w vel.	W VEL	W VEL
Ventilation, vent	vent	VENT	VENT
Vertical	vert.	VERT	VERT
Viscosity	visc	VISC	MU, VISC
Volt	V	V	E, VOLTS
Volt ampere	VA	VA	VA
Volume	vol.	VOL	VOL
Volumetric flow rate	–	–	VFR
Wall	–	–	W, WAL
Water	–	–	WTR
Watt	W	W	WAT, W
Watt-hour	Wh	WH	WHR
Weight	wt	WT	WT
Wet bulb	wb	WB	WB
Wet-bulb temperature	wbt	WBT	WBT
Width	–	–	WI
Wind	–	–	WD
Wind direction	wdir	WDIR	WDIR
Wind pressure	wpr	WPR	WP, WPRES
Yard	yd	YD	YD
Year	yr	YR	YR
Zone	z	Z	Z, ZN

Source: ASHRAE, 1997, *Handbook of fundamentals.*

[a]Abbreviations of most proper names use capital letters in both text and drawings.

[b]The asterisk (*) is used with "ET," effective temperature.

[c]These are surface heat transfer coefficients.

[d]The letter "L" is also used for "logarithm of" these temperature differences in computer programming.

PLUMBING TERMINOLOGY[4]

The following list of definitions and abbreviations that are frequently used in the plumbing industry has been compiled by the American Society of Plumbing Engineers for use by those working in this and related fields.

ABS Abbreviation for "acrylonitrile-butadiene-styrene."

Absolute pressure The total pressure measured from absolute vacuum. It equals the sum of gauge pressure and atmospheric pressure corresponding to the barometer, and is expressed in pounds per square inch (kiloPascals).

Absolute temperature Temperature measured from absolute zero. A point of temperature theoretically equal to -459.72°F (-273.18°C). The hypothetical point at which a substance would have no molecular motion and no heat.

Absolute zero Zero point on the absolute temperature scale. A point at which there is a total absence of heat, equivalent to -459.72°F (-273.18°C).

Absorption Immersion in a fluid for a definite period of time, usually expressed as a percent of the weight of the dry pipe.

Access door Hinged panel mounted in a frame with a lock, normally in a wall or ceiling, to provide access to concealed valves or equipment that require frequent attention.

Accessible 1. a) (When applied to a fixture, connection, appliance, or piece of equipment) Having access thereto, though access may necessitate the removal of an access panel, door, or similar obstruction; b) (readily accessible) having direct access to without the necessity of removing or moving any panel, door, or similar obstruction. 2. (re: the physically challenged) Term used to describe a site, building, facility, or portion thereof, or a plumbing fixture that can be approached, entered, and/or used by physically challenged individuals.

Accumulator A container in which fluid or gas is stored under pressure as a source of power.

Acid vent A pipe venting an acid-waste system.

Acid waste A pipe that conveys liquid waste matter containing a pH of less than 7.0.

Acme thread A screw thread, the thread section of which is between the square and V threads, used extensively for feed screws. The included angle of space is 29°, compared to 60° of the National Coarse of U.S. Thread.

Acrylonitrile-butadiene-styrene A thermoplastic compound from which fittings, pipe, and tubing are made.

Active sludge Sewage sediment, rich in destructive bacteria, that can be used to break down fresh sewage more quickly.

Adapter fitting 1. Any of various fittings designed to mate, or fit to each other, two pipes or fittings that are different in design, when the connection would otherwise be impossible. 2. A fitting that serves to connect two different tubes or pipes to each other, such as copper tube to iron pipe.

Administrative authority The individual official, board, department, or agency established and authorized by a state, county, city, or other political subdivision created by law to administer and enforce the provisions of the plumbing code. *Also known as* AUTHORITY HAVING JURISDICTION.

Aeration An artificial method of bringing water and air into direct contact with each other. One purpose is to release certain dissolved gases that often cause water to have obnoxious odors or disagreeable tastes. Also used to furnish oxygen to waters that are oxygen deficient. The process may be accomplished by spraying the liquid in the air, bubbling air through the liquid, or agitating the liquid to promote surface absorption of the air.

Aerobic (re: bacteria) Living or active only in the presence of free oxygen.

AGA Abbreviation for American Gas Association.

Air break A physical separation in which a drain from a fixture, appliance, or device indirectly discharges into a fixture, receptacle, or interceptor at a point below the flood level rim of the receptacle to prevent backflow or back-siphonage. *Also known as* AIR GAP.

Air chamber A continuation of the water piping beyond the branch to fixtures that are finished with a cap designed to eliminate shock or vibration (water hammer) of the piping when the faucet is closed suddenly.

Air, compressed Air at any pressure greater than atmospheric pressure.

Air, free Air that is not contained and subject only to atmospheric conditions.

Air gap The unobstructed vertical distance, through the free atmosphere, between the lowest opening from a pipe or faucet conveying water or waste to a tank, plumbing-fixture receptor, or other device and the flood-level rim of the receptacle. (Usually required to be a minimum of twice the diameter of the inlet.)

Air, standard Air having a temperature of 70°F (21.1°C) at standard density of 0.0075 lb/ft (0.11 kg/m) and under pressure of 14.70 psia (101.4 kPa).

The gas industry usually considers 60°F (15.6°C) the temperature of standard air.

Air test A test using compressed air or nitrogen applied to a plumbing system upon its completion but before the building is sheetrocked.

Alarm (FP) 1. Any audible or visible signal indicating existence of a fire or emergency requiring evacuation of occupants and response and emergency action on the part of the firefighting service. 2. The alarm device(s) by which fire and emergency signals are received.

Alarm check valve (FP) A check valve, equipped with a signaling device, that will annunciate a remote alarm when a sprinkler head(s) is discharging.

Alloy A substance composed of two or more metals or a metal and nonmetal intimately united, usually fused together and dissolving in each other when molten.

Alloy pipe A steel pipe with one or more elements, other than carbon, that give it greater resistance to corrosion and more strength than carbon steel pipe.

Ambient temperature The prevailing temperature in the immediate vicinity of or the temperature of the medium surrounding an object.

American standard pipe thread A type of screw thread commonly used on pipe and fittings.

Anaerobic (re: bacteria) Living or active in the absence of free oxygen.

Anchor A device used to fasten or secure pipes to the building or structure.

Angle of bend In a pipe, the angle between radial lines from the beginning and end of the bend to the center.

Angle stop Common term for right-angle valves used to control water supplies to plumbing fixtures.

Angle valve A device, usually of the globe type, in which the inlet and outlet are at right angles.

ANSI Abbreviation for American National Stan-

Backwater valve A device that permits drainage in one direction but has a check valve that closes against back pressure. Sometimes used conjunctively with gate valves designed for sewage.

Baffle plate A tray or partition placed in process equipment or tanks to direct or change the direction of flow.

Ball check valve A device used to stop the flow of media in one direction while allowing flow in an opposite direction. The closure member used is spherical or ball-shaped.

Ball valve A spherical gate valve providing very tight shut-off; a quick-closing (quarter-turn) valve.

Barrier free *See* ACCESSIBLE, def. 2.

Base The lowest portion or lowest point of a stack of vertical pipe.

Battery of fixtures Any group of two or more similar, adjacent fixtures that discharge into a common horizontal waste or soil branch.

Bell That portion of a pipe that, for a short distance, is sufficiently enlarged to receive the end of another pipe of the same diameter for the purpose of making a joint.

Bell-and-spigot joint A commonly used joint in cast-iron soil pipe. Each piece is made with an enlarged diameter or bell at one end into which the plain or spigot end of another piece is inserted. The joint is then made tight by cement, oakum, lead, or rubber caulked into the bell around the spigot. *See also* HUB-AND-SPIGOT.

Black pipe Steel pipe that has not been galvanized.

Blank flange A solid plate flange used to seal off flow in a pipe.

Boiler blow-off An outlet on a boiler to permit

Bull head tee A tee in which the branch is larger than the run.

Burst pressure That pressure that can slowly be applied to a valve at room temperature for 30 seconds without causing rupture.

Bushing A pipe fitting for connecting a pipe with a female fitting of a larger size. It is a hollow plug with internal and external threads. Used in lieu of a reducer/increaser.

Butterfly valve A device deriving its name from the wing-like action of the disc, which operates at right angles to the flow. The disc impinges against the resilient liner with low-operating torque.

Butt weld joint A welded pipe joint made with the ends of the two pipes butting each other, the weld being around the periphery.

Butt weld pipe Pipe welded along a seam butted edge to edge and not scarfed or lapped.

Bypass An auxiliary loop in a pipeline intended for diverting flow around a valve or other piece of equipment.

Bypass valve A device used to divert the flow past the part of the system through which it normally passes.

Capacity 1. The maximum or minimum flow obtainable under given conditions of media, temperature, pressure, velocity, etc. 2. The volume of media that may be stored in a container or receptacle.

Capillary The action by which the surface of a liquid, where it is in contact with a solid, is elevated or depressed, depending on the relative attraction of the molecules of the liquid for each other and for those of the solid.

Cathodic protection 1. The control of the electrolytic corrosion of an underground or underwater metallic structure by the application of an electric current in such a way that the structure is made to act as the cathode instead of the anode of an electrolytic cell. 2. The use of materials and liquid to cause electricity to flow to avoid corrosion.

Caulking The method of rendering a joint tight against water or gas by means of applying plastic substances such as lead and oakum; a method of sealing between fixtures and adjacent surfaces.

Cavitation A localized gaseous condition (usually involving air) that is found within a liquid stream.

CDA Abbreviation for Copper Development Association.

Cement joint The union of two fittings by the insertion of material. Sometimes this joint is accomplished mechanically, sometimes chemically.

Cesspool A lined excavation in the ground that receives the discharge of a drainage system, or part thereof, and is so designed to retain the organic matter and solids discharged therein but permit the liquids to seep through the bottom and sides.

Chainwheel-operated valve A device operated by a chain-driven wheel that opens and closes the valve seats. Usually required for larger valves.

Channel That trough through which any media may flow.

Chase A recess in a wall or a space between two walls in which pipes can be run.

Check valve A device designed to allow a fluid to pass through in one direction only.

Chemical waste system Piping that conveys corrosive or harmful industrial, chemical, or processed wastes to the drainage system.

Circuit The directed route taken by a flow of media from one point to another.

Circuit vent A branch vent that serves two or more traps and extends from in front of the last fixture connection of a horizontal branch to the vent stack.

CISPI Abbreviation for Cast Iron Soil Pipe Institute.

Clamp gate valve A gate valve whose body and bonnet are held together by a U-bolt clamp.

Cleanout A plug or cover (joined to an opening in a pipe) that can be removed for the purpose of cleaning or examining the interior of the pipe.

Clear-water waste Cooling water and condensate drainage from refrigeration and air-conditioning equipment; cooled condensate from steam-heating systems; cooled boiler blowdown water; waste-water drainage from equipment rooms and other areas where water is used without an appreciable addition of oil, gasoline, solvent, acid, etc.; and treated effluent in which impurities have been reduced below a minimum concentration considered harmful.

Close nipple A nipple with a length twice the length of a standard pipe thread.

Cock An original form of valve having a hole in a tapered plug that is rotated to provide passageway for fluid.

Code Those regulations, subsequent amendments thereto, and any emergency rule or regulation that the department having jurisdiction may lawfully adopt.

Coefficient of expansion The increase in unit length, area of volume for a 1-degree rise in temperature.

Coliform group of bacteria All organisms considered in the coli aerogenes group as set forth by the American Water Works Association.

Combination fixture A fixture that combines one sink and tray or a two- or three-compartment sink and/or tray in one unit.

Combined waste and vent system A specially designed system of waste piping, embodying the horizontal wet venting of one or more sinks, floor sinks, or floor drains by means of a common waste and vent pipe, adequately sized to provide free movement of air above the flow line of the drain.

Combustion efficiency The rated efficiency of a water heater or boiler determined by the equipment's ability to completely burn fuel, leaving no products of combustion in the flue gas.

Common vent A vent that connects at the junction of two fixture drains and serves as a vent for both fixtures. *Also known as a* DUAL VENT.

Companion flange A pipe flange to connect with another flange or with a flanged valve or fitting. It is attached to the pipe by threads, welding, or another method and differs from a flange that is an integral part of a pipe or fitting.

Compression joint A multi-piece joint with cup-shaped, threaded nuts that, when tightened, compress tapered sleeves so they form a tight joint on the periphery of the tubing they connect.

Compressor A mechanical device for increasing the pressure of air or gas.

Condensate Water that has liquefied (cooled) from steam.

Conductor The piping from the roof to the building storm drain, combined building sewer, or other approved means of disposal; it is located inside the building.

Conduit A pipe or channel for conveying media.

Confluent vent A vent serving more than one fixture vent or stack vent.

Contaminator A medium or condition that spoils the nature or quality of another medium.

Continuous vent A vent that is a continuation of the drain to which it connects.

Continuous waste A drain from two or three fixtures connected to a single trap.

Control A device used to regulate the function of a component or system.

Controller (FP) The cabinet containing motor starter(s), circuit breaker(s), disconnect switch(s), and other control devices for the control of electric motors and internal-combustion-engine-driven fire pumps.

Corporation cock A stopcock screwed into the street water main to supply the house service connection.

Coupling A pipe fitting with female threads used only to connect two pipes in a straight line.

CPVC Abbreviation for "chlorinated polyvinyl-chloride."

Critical level The point on a backflow-prevention device or vacuum breaker that determines the minimum elevation above the flood level rim of the fixture or receptacle served at which the device may be installed; the point conforms to approved standards and is established by the recognized (approved) testing laboratory (usually stamped or marked CL or C/L on the device by the manufacturer). When a backflow-prevention device does not bear critical-level marking, the bottom of the vacuum breaker or combination valve or the bottom of any such approved device shall constitute the critical level.

Cross A pipe fitting with four branches in pairs, each pair on one axis, and the axis at right angles.

Cross-connection Any physical connection or arrangement between two otherwise separated piping systems—one of which contains potable water and the other of which contains water or another substance of unknown or questionable safety—whereby flow may occur from one system to the other, the direction of flow depending on the pressure differential between the two systems. *See* BACKFLOW and BACK-SIPHONAGE.

Crossover A pipe fitting with a double offset, or shaped like the letter "U" with the ends turned out, used to pass the flow of one pipe past another when the pipes are in the same plane.

Cross valve A valve fitted on a transverse pipe so as to open communication between two parallel pipes.

Crown That part of a trap in which the direction of flow is changed from upward to horizontal.

Crown vent A vent pipe connected at the topmost point in the crown of a trap.

CS Abbreviation for Commercial Standards.

Curb box A device at the curb that contains a valve is used to shut off a supply line, usually of gas or water.

Dampen 1. To check or reduce. 2. To deaden vibration.

Dead end A branch leading from a soil, waste, or vent pipe; building (house) drain; or building (house) sewer that is terminated at a developed distance of 2 feet (0.6 m) or more by means of a plug or other closed fitting.

Department having jurisdiction The administrative authority—and any other law enforcement agency—affected by any provision of a code, whether such agency is specifically named or not.

Detector, smoke (FP) Listed device for sensing visible or invisible products of combustion.

Developed length The length along the center line of the pipe and fittings.

Dewpoint The temperature of a gas or liquid at which condensation or evaporation occurs.

Diameter Unless specifically stated otherwise, the nominal diameter as designated commercially.

Diaphragm A flexible disc that is used to separate the control medium from the controlled medium and actuates the valve stem.

Diaphragm-control valve A control valve having a spring-diaphragm actuator.

Dielectric fitting A fitting having insulating parts or material that prohibits the flow of electric current. Used to separate dissimilar metals.

Differential The variance between two target values, one of which is the high value of conditions, the other of which is the low value of conditions.

Digestion That portion of the sewage treatment process where biochemical decomposition of organic matter takes place, resulting in the formation of simple organic and mineral substances.

Disc That part of a valve that actually closes off the flow.

Dishwasher An appliance for washing dishes, glassware, flatware, and some utensils.

Displacement The volume or weight of a fluid, such as water, displaced by a floating body.

Disposer A motor-driven appliance for reducing food and other waste by grinding so that it can flow through the drainage system.

Domestic sewage The liquid and waterborne wastes derived from ordinary living processes that are free of industrial wastes and of such a character as to permit satisfactory disposal, without special treatment, into the public sewer or by means of a private sewage disposal system.

Dosing tank A watertight tank in a septic system placed between the septic tank and the distribution box and equipped with a pump or automatic siphon designed to discharge sewage intermittently to a disposal field. This is done so that rest periods may be provided between discharges.

Double disc A two-piece disc used in the gate valve. The wedges between the disc faces, upon contact with the seating faces in the valve, force them against the body seats to shut off the flow.

Double offset Two changes of direction installed in succession, or series, in continuous pipe.

Double-ported valve A valve having two ports to overcome line-pressure imbalance.

Double-sweep tee A tee made with easy (lon-radius) curves between body and branch.

Double wedge A device used in gate valves that is similar to a double disc, in that the last downward turn of the stem spreads the split wedges, and each seals independently.

Down Term referring to piping running through the floor to a lower level.

Downspout The rainleader from the roof to the building storm drain, combined building sewer, or other means of disposal; it is located outside of the building.

Downstream Term referring to a location in the direction of flow after passing a referenced point.

Drain Any pipe that carries waste water or waterborne wastes in a building drainage system.

Drain field The area of a piping system arranged in troughs for the purpose of disposing unwanted liquid waste.

Drainage fitting A type of fitting used for draining fluid from pipes. The fitting makes possible a smooth and continuous interior surface for the piping system.

Drainage system The drainage piping within public or private premises (usually to 5 feet outside building walls) that conveys sewage, rainwater, or other liquid wastes to an approved point of disposal but does not include the mains of a public sewer system or a private or public sewage-treatment or disposal plant.

Drift The sustained deviation in a corresponding controller resulting from the predetermined relation between values and the controlled variable and positions of the final control element. *Also known as* WANDER.

Droop The amount by which the controlled variable pressure, temperature, liquid level, or differential pressure deviates from the set value at minimum controllable flow to the rated capacity.

Drop Term referring to piping running to a lower elevation within the same floor level.

Drop elbow A small elbow having wings cast on each side, the wings having countersunk holes so they may be fastened by wood screws to a ceiling, wall, or framing timbers.

Drop tee A tee having wings of the same type as the drop elbow.

Dross 1. The solid scum that forms on the surface of a metal, as lead or antimony, when it is molten or melting, largely as a result of oxidation but sometimes because of the rising of dirt and impurities to the surface. 2. Waste or foreign matter mixed with a substance or left as a residue after that substance has been used or processed.

Dry-bulb temperature The temperature of air as measured by an ordinary thermometer.

Dry-pipe valve (FP) A valve used with a dry-pipe sprinkler system where water is on one side of the valve and air is on the other side. When a sprinkler head's fusible link melts, releasing air from the system, this valve opens, allowing water to flow to the sprinkler head.

Dry-weather flow Sewage collected during the summer that contains little or no ground water by infiltration and no storm water at the time of collection.

Dry well *See* LEACHING WELL.

Dual vent *See* COMMON VENT.

Durham system A term used to describe soil or waste systems where all piping is of threaded pipe, tubing or, other such material of rigid construction, and where recessed draining fittings corresponding to the type of piping are used.

Durion A high-silicon alloy that is resistant to practically all corrosive wastes. The silicon content is approximately 14.5 percent, and the acid resistance is in the entire thickness of the metal.

Dwelling A one-family unit with or without accessory buildings.

DWV Abbreviation for "drainage, waste, and vent."

activated, will sound audio or visual warning devices on or off the protected premises, signaling a fire.

Fire department connection (FP) A piping connection for fire department use to supplement in supplying water for standpipes and sprinkler systems. *See* STANDPIPE SYSTEM.

Fire hazard (FP) Any thing or act that increases, or will cause an increase of, the hazard or menace of fire to a degree greater than what is customarily recognized as normal by persons in the public service regularly engaged in preventing, suppressing, or extinguishing fire; or that will obstruct, delay, hinder, or interfere with the operations of the fire department or the egress of occupants in the event of fire.

Fire hydrant valve (FP) A valve that, when closed, drains at an underground level to prevent freezing.

Fire line (FP) A system of pipes and equipment used exclusively to supply water for extinguishing fires.

Fire pump types

Can pump (FP) A vertical-shaft, turbine-type pump in a can (suction vessel) for installation in a pipeline to raise water pressure.

Centrifugal pump (FP) A pump in which the pressure is developed principally by the action of centrifugal force.

End-suction pump (FP) A single-suction pump having its suction nozzle on the opposite side of the casing from the stuffing box and having the face of the suction nozzle perpendicular to the longitudinal axis of the shaft.

Excess pressure pump (FP) UL-listed and/or FM-approved, low-flow, high-head pump for sprinkler systems not being supplied from a fire pump. The pump pressurizes the sprinkler system so that the loss of water-supply pressure will not cause a false alarm.

Fire pump (FP) UL-listed and/or FM-approved pump with driver, controls, and accessories used for fire protection service. Fire pumps are of the centrifugal or turbine type and usually have an electric-motor or diesel-engine driver.

Horizontal pump (FP) A pump with the shaft normally in a horizontal position.

Horizontal split-case pump (FP) A centrifugal pump characterized by a housing that is split parallel to the shaft.

In-line pump (FP) A centrifugal pump in which the drive unit is supported by the pump, having its suction and discharge flanges on approximately the same center line.

Pressure maintenance (jockey) pump (FP) Pump with controls and accessories used to maintain pressure in a fire protection system without the operation of the fire pump. Does not have to be a listed pump.

Vertical shaft turbine pump (FP) A centrifugal pump with one or more impellers discharging into one or more bowls and a vertical educator or column pipe used to connect the bowl(s) to the discharge head on which the pump driver is mounted.

Fitting The connector or closure for fluid lines and passages.

Fitting, compression A fitting designed to join pipe or tubing by means of pressure or friction.

Fitting, flange A fitting that utilizes a radially extending collar for sealing and connection.

Fitting, welded A fitting attached by welding.

Fixture branch A pipe connecting several fixtures.

Fixture carrier A metal unit designed to support an off-the-floor plumbing fixture.

Fixture carrier fittings Special fittings for wall-mounted fixture carriers. Fittings have a sanitary drainage waterway with a minimum angle of 30 – 45 degrees so that there are no fouling areas.

Fixture drain The drain from the trap of a fixture to the junction of that drain with any other drain pipe.

Fixture, plumbing *See* PLUMBING FIXTURE.

Fixture supply A water supply pipe connecting the fixture to the fixture branch or directly to a main water supply pipe.

Fixture unit, drainage (dfu) A measure of probable discharge into the drainage system by various types of plumbing fixtures. The drainage fixture unit value for a particular fixture depends on its volume rate of drainage discharge, on the time duration of a single drainage operation, and on the average time between successive operations. Laboratory tests have shown that the rate of discharge of an ordinary lavatory with a nominal 1.2-inches (31.8-mm) outlet, trap, and waste is about 7.5 gpm (0.5 L/s). This figure is so near to 1 ft^3/min (0.5 L/s) that "1 ft^3/min" (0.5 L/s) has become the accepted flow rate of one fixture unit.

Fixture unit, supply (sfu) A measure of the probable hydraulic demand on the water supply by various types of plumbing fixtures. The supply fixture unit value for a particular fixture depends on its volume rate of supply, the time duration of a single supply operation, and the average time between successive operations.

Flange In pipe work, a ring-shaped plate on the end of a pipe at right angles to the end of the pipe and provided with holes for bolts to allow fastening the pipe to a similarly equipped adjoining pipe. The resulting joint is a flanged joint.

Flange bonnet A valve bonnet having a flange through which bolts connect it to a matching flange on the valve body.

Flange ends A valve or fitting having flanges for joining to other piping elements. Flange ends can be plain-faced, raised-face, large male-and-female, large tongue-and-groove, small tongue-and-groove, or ring-joint.

Flange faces Pipe flanges that have the entire surface of the flange faced straight across and use either a full-face or ring gasket.

Flap valve A non-return valve in the form of a hinged disc or flap, sometimes having leather or rubber faces.

Flash point The temperature at which a fluid first gives off sufficient flammable vapor to ignite when approached with a flame or spark.

Float valve A valve that is operated by means of a bulb or ball floating on the surface of a liquid within a tank. The rising and falling action operates a lever, which opens and closes the valve.

Flooded The condition when liquid rises to the flood level rim of a fixture.

Flood level rim The top edge of a receptacle or fixture from which water overflows.

Flow pressure The pressure in the water supply pipe near the water outlet while the faucet or water outlet is fully open and flowing.

Flue An enclosed passage, primarily vertical, for removal of gaseous products of combustion to the outer air.

Flush valve A device located at the bottom of a tank for the purpose of flushing water closets and similar fixtures.

Flushing-type floor drain A floor drain that is equipped with an integral water supply, enabling flushing of the drain receptor and trap.

Flushometer valve A device that discharges a predetermined quantity of water to fixtures for flushing purposes and is actuated by direct water pressure.

Footing The part of a foundation wall or column resting on the bearing soil, rock, or piling that transmits the superimposed load to the bearing material.

Foot valve A check valve installed at the base of a pump-suction pipe. Its purpose is to maintain pump prime by preventing pumped liquid from draining away from the pump.

French drain A drain consisting of an underground passage made by filling a trench with loose stones and covering with earth. *Also known as* RUBBLE DRAIN.

Fresh-air inlet A vent line connected with the building drain just inside the house trap and extending to the outer air. It provides fresh air at the lowest point of the plumbing system, and with the vent stacks, provides a ventilated system. A fresh-air inlet is not required where a septic-tank system of sewage disposal is employed.

Frostproof closet A hopper that has no water in the bowl and has the trap and control valve for its water supply installed below the frost line.

FS Abbreviation for "federal specifications."

Galvanic action When two dissimilar metals are immersed in the same electrolytic solution and connected electrically, there is an interchange of atoms carrying an electric charge between them. The anode metal with the higher electrode potential corrodes; the cathode is protected. Thus magnesium will protect iron; iron will protect copper. *See also* ELECTROLYSIS.

Galvanizing A process where the surface of iron or steel piping or plate is covered with a layer of zinc.

Generally accepted standard A document referred to in a code that covers a particular subject and is accepted by the administrative authority.

Grade The slope or fall of a line of pipe in reference to a horizontal plane. In drainage, it is expressed as the fall in a fraction of an inch or percentage slope per foot (mm/m) length of pipe.

Grease interceptor An automatic or manual device used to separate and retain grease, with a capacity greater than 50 gal (227.3 L), and generally located outside a building.

Grease trap An automatic or manual device used to separate and retain grease, with a capacity of 50 gallons (227.3 L) or less, and generally located inside a building.

Grinder pump A special class of solids-handling pump that grinds sewage solids to a fine slurry, rather than passing through entire spherical solids.

Halon 1301 (FP) Halon 1301 (bromtrifluoromethane CBrF3) is a colorless, odorless, electrically non-conductive gas that is an effective medium for extinguishing fires.

Halon system types (FP) There are two types of systems recognized in this standard: "Total flooding systems" and "local application systems."

Total flooding system Consists of a supply of Halon 1301 arranged to discharged into, and fill to the proper concentration, an enclosed space or enclosure around the hazard.

Local application system Consists of a supply of Halon 1301 arranged to discharge directly on the burning material.

Hangers *See* SUPPORTS.

Hub-and-spigot Piping made with an enlarged diameter or hub at one end and being plain or having a spigot at the other end. The joint is made tight by oakum and lead or by use of a neoprene gasket caulked or inserted in the hub around the spigot.

Hubless Soil piping with plain ends. The joint is made tight with a stainless steel or cast-iron clamp and neoprene gasket assembly.

Indirect waste pipe A pipe that does not connect directly with the drainage system but conveys liquid waste by discharging into a plumbing fixture or receptacle directly connected to the drainage system.

Individual vent A pipe that is installed to vent a fixture trap and connects with the vent system above the fixture served or terminates in the open air.

Induced siphonage Loss of liquid from a fixture trap due to pressure differential between the inlet and outlet of a trap, often caused by the discharge of another fixture.

Industrial waste All liquid or waterborne waste from industrial or commercial processes except domestic sewage.

Insanitary A condition that is contrary to sanitary principles or injurious to health.

Interceptor A device designed and installed so as to separate and retain deleterious, hazardous, or undesirable matter from normal wastes and to permit normal sewage or liquid wastes to discharge into the disposal terminal by gravity.

Invert Term referring to the lowest point on the interior of a horizontal pipe.

Labeled Term describing equipment or materials bearing a label of a listing agency.

Lateral sewer A sewer that does not receive sewage from any other common sewer except house connections.

Leaching well A pit or receptacle having porous walls that permit the contents to seep into the ground. *Also known as* DRY WELL.

Leader The water conductor from the roof to the building (house) storm drain. *Also known as* DOWNSPOUT.

Liquid waste The discharge from any fixture, appliance, or appurtenance in connection with a plumbing system that does not receive fecal matter.

Listed Term describing equipment and materials included in a list published by an organization acceptable to the authority having jurisdiction and concerned (a listing agency).

Listing agency An agency accepted by the administrative authority that lists or labels certain models of a product and maintains a periodic inspection program on the current production of listed models. It makes available a published report of its listing, including information indicating that the products have been tested, comply with generally accepted standards, and are found safe for use in a specified manner.

Load factor The percentage of the total connected fixture unit flow that is likely to occur at any point in the drainage system. The load factor represents the ratio of the probable load to the potential load and is determined by the average rates of flow of the various kinds of fixtures, the average frequency of use, the duration of flow during one use, and the number of fixtures installed.

Loop vent *See* VENT, LOOP.

Main The principal artery of a system of continuous piping to which branches may be connected.

Main vent A vent header to which vent stacks are connected.

Malleable Capable of being extended or shaped by beating with a hammer, or by the pressure of rollers. Most metals are malleable. The term "malleable iron" also has the older meaning (still universal in Great Britain) of "wrought iron," abbreviated "Mall."

Master plumber An individual who is licensed and authorized to install and assume responsibility for contractual agreements pertaining to plumbing and to secure any required permits. The journeyman plumber is allowed to install plumbing only under the responsibility of a master plumber.

MSS Abbreviation for Manufacturers Standardization Society of the Valve and Fittings Industry, Inc.

NFPA Abbreviation for National Fire Protection Association.

NSF Abbreviation for National Sanitation Founda-

Oxidized sewage Sewage in which the organic matter has been combined with oxygen and become stable in nature.

PB Abbreviation for "polybutylene."

PDI Abbreviation for Plumbing and Drainage

Public use Applies to toilet rooms and bathrooms used by employees, occupants, visitors, or patrons, in or about any premises, and locked toilet rooms or bathrooms to which several occupants or employees on the premises possess keys and have access.

Putrefaction Biological decomposition of organic matter with the production of ill-smelling products; usually takes place when there is a deficiency of oxygen.

PVC Abbreviation for "polyvinyl chloride."

Sprinkler system classification

Automatic sprinkler system types *(FP)*

1. Wet-pipe systems.
2. Dry-pipe systems.
3. Pre-action systems.
4. Deluge systems.
5. Combined dry-pipe and pre-action systems.

Sprinkler systems–special types Special-purpose systems employing departures from the requirements of standards, such as special water supplies and reduced pipe sizing, shall be installed in accordance with their listings.

Occupancy classification Relates to sprinkler installations and their water supplies only, not intended to be a general classification of occupancy hazards.

1. Extra hazard occupancies Occupancies or portions of other occupancies where quantity and combustibility of contents is very high, and flammable and combustible liquids, dust, lint, or other materials are present, introducing the probability of rapidly developing fires with high rates of heat release. Extra hazard occupancies involve a wide range of variables that may produce severe fires. The following shall be used to evaluate the severity of extra hazard occupancies:
   A. Extra hazard group 1 Includes occupancies with little or no flammable or combustible liquids.
   B. Extra hazard group 2 Includes occupancies with moderate to substantial amounts of flammable or combustible liquids or where shielding of combustibles is extensive.
2. Ordinary hazard occupancies
   A. Ordinary hazard group 1 Occupancies or portions of other occupancies where combustibility is low, quantity of combustibles does not exceed 8 feet (2.4 m), and fires with moderate rates of heat release are expected.
   B. Ordinary hazard group 2 Occupancies or portions of other occupancies where quantity and combustibility of contents is moderate, stockpiles do not exceed 12 feet (3.7 m), and fires with moderate rates of heat release are expected.
   C. Ordinary hazard group 3 Occupancies or portions of other occupancies where quantity and/or combustibility of contents is high and fires of high rates of heat release are expected.
3. Light hazard occupancies Occupancies or portions of other occupancies where the quantity and/or combustibility of contents is low and fires with relatively low rates of heat release are expected.

Sprinkler types (FP)

Concealed sprinklers Recessed sprinklers with cover plates.

Corrosion-resistant sprinklers Sprinklers with special coatings or platings to be used in an atmosphere that would corrode an uncoated sprinkler.

Dry, pendent sprinklers Sprinklers for use in a pendent position in a dry-pipe or wet-pipe system with the seal in a heated area.

Dry, upright sprinklers Sprinklers designed to be installed in an upright position, on a wet-pipe system, to extend into an unheated area with a seal in a heated area.

Extended-coverage sidewall sprinklers Sprinklers with special extended, directional, discharge patterns.

Flush sprinklers Sprinklers in which all or part of the body, including the shank thread, is mounted above the lower plane of the ceiling.

Intermediate-level sprinklers Sprinklers equipped with integral shields to protect their operating elements from the discharge of sprinklers installed at high elevations.

Large-drop sprinklers Listed sprinklers that are characterized by a K factor between 11.0 and 11.5 and a proven ability to meet the prescribed penetration, cooling, and distribution criteria prescribed in the large-drop sprinkler examination requirements. The deflector/discharge characteristics of the large-drop sprinkler generate large drops of such size and velocity as to enable effective penetration of a high-velocity fire plume.

Nozzles Devices for use in applications requiring special discharge patterns, directional spray, fine spray, or other unusual discharge characteristics.

Open sprinklers Sprinklers from which the actuating elements (fusible links) have been removed.

Ornamental sprinklers Sprinklers that have been painted or plated by the manufacturer.

Pendant sprinklers Sprinklers designed to be installed in such a way that the water stream is directed downward against the deflector.

Quick-response sprinklers A type of sprinkler that is both a fast-response and a spray sprinkler.

Recessed sprinklers Sprinklers in which all or a part of the body, other than the shank thread, is mounted within a recessed housing.

Residential sprinklers Sprinklers that have been specifically listed for use in residential occupancies.

Sidewall sprinklers Sprinklers having special deflectors that are designed to discharge most of the water away from a nearby wall in a pattern resembling a quarter of a sphere, with a small portion of the discharge directed at the wall behind the sprinkler.

Special sprinklers Sprinklers that have been tested and listed as having special limitations.

Upright sprinklers Sprinklers designed to be installed in such a way that the water spray is directed upward against the deflector.

Stack The vertical main of a system of soil, waste, or vent piping extending through one or more stories.

Stack group The location of fixtures in relation to the stack so that, by means of proper fittings, vents may be reduced to a minimum.

Stack vent The extension of a soil waste stack above the highest horizontal drain connected to the stack. *Also known as* WASTE or SOIL VENT.

Stack venting A method of venting a fixture or fixtures through the soil or waste stack.

Stale sewage Sewage that contains little or no oxygen and is free from putrefaction.

Standpipe A vertical pipe generally used for the storage and distribution of water for fire extinguishing.

Standpipe system (FP) An arrangement of piping, valves, hose connections, and allied equipment installed in a building or structure with the hose connections located in such a manner that water can be discharged in streams or spray patterns through attached hose and nozzles, for the purpose of extinguishing a fire and so protecting a building or structure and its contents as well as its occupants. This is accomplished by connections to water supply systems or by pumps, tanks, and other equipment necessary to provide an adequate supply of water to the hose connections.

Standpipe system class of service (FP)

Class I For use by fire departments and

Thermal efficiency The ratio of the energy output from the system to energy input to the system.

Trailer park sewer That part of the horizontal piping of a drainage system that begins 2 feet (0.6 m) downstream from the last trailer site connection, receives the discharge of the trailer site, and conveys it to a public sewer, private sewer, individual sewage disposal system, or other approved point of disposal.

Trap A fitting or device designed and constructed to provide, when properly vented, a liquid seal that will prevent the back passage of air without significantly affecting the flow of sewage or waste water through it.

Trap primer A device or system of piping to maintain a water seal in a trap.

Trap seal The maximum vertical depth of liquid that a trap will retain, measured between the crown weir and the top of the dip of the trap.

Turbulence Any deviation from parallel flow in a pipe due to rough inner wall surfaces, obstructions, or directional changes.

Underground piping Piping in contact with the earth below grade.

Upstream Term referring to a location in the direction of flow before reaching a referenced point.

Vacuum Any pressure less than that exerted by the atmosphere. *Also known as* NEGATIVE PRESSURE.

Vacuum breaker *See* BACKFLOW PREVENTER.

Vacuum relief valve A device to prevent excessive vacuum in a pressure vessel.

Velocity Time rate of motion in a given direction and sense.

Vent, loop Any vent connecting a horizontal branch or fixture drain with the stack vent of the originating waste or soil stack.

Vent stack A vertical vent pipe installed primarily for the purpose of providing circulation of air to and from any part of the drainage system.

Vertical pipe Any pipe or fitting installed in a vertical position or that makes an angle of not more than 45 degrees with the vertical.

Vitrified sewer pipe Conduit made of fired and glazed earthenware installed to receive waste or sewage or sewerage.

Waste The discharge from any fixture, appliance, area, or appurtenance that does not contain fecal matter.

Waste pipe The discharge pipe from any fixture, appliance, or appurtenance in connection with the plumbing system that does not contain fecal matter.

Water-conditioning or treating device A device that conditions or treats a water supply to change its chemical content or remove suspended solids by filtration.

Water-distributing pipe A pipe that conveys potable water from the building supply pipe to the plumbing fixtures and other water outlets in the building.

Water hammer The forces, pounding noises, and vibration that develop in a piping system when a column of noncompressible liquid flowing through a pipeline at a given pressure and velocity is stopped abruptly.

Water hammer arrester A device, other than an air chamber, designed to provide protection against excessive surge pressure.

Water main The water supply pipe for public or community use. Normally under the jurisdiction of the municipality or water company.

Water riser A water supply pipe that extends vertically one full story or more to convey water to branches or fixtures.

Water-service pipe The pipe from the water main or other source of water supply to the building served.

Water supply system The building supply pipe, the water distributing pipes, and the necessary connecting pipes, fittings, control valves, and all appurtenances carrying or supplying potable water in, or adjacent to, the building or premises.

Wet vent A vent that also serves as a drain.

Yoke vent A pipe connecting upward from a soil or waste stack to a vent stack for the purpose of preventing pressure changes in the stacks.

RECOMMENDED PRACTICE FOR CONVERSION TO THE INTERNATIONAL SYSTEM OF UNITS

The International System of Units was developed by the General Conference of Weights and Measures, an international treaty organization, and has been officially abbreviated "SI" from the French term, "Systeme International and d'Unites." The SI system of units is a preferred international measurement system that evolved from earlier decimal metric systems.

When President Ford signed the Metric Conversion Act (Public Law 94-168) on December 23, 1975, a metric system in the United States was declared and a United States Metric Board was established to coordinate the national voluntary conversion effort to the metric system. The Metric Conversion Act specifically defines the metric system of measurement to be used as the International System of Units (SI), established by the General Conference of Weights and Measures and as interpreted and modified by the Secretary of Commerce.

The "recommended practice" section that follows outlines a selection of SI units, including multiples and submultiples, for use in plumbing design and related fields of science and engineering. It is intended to provide the technical basis for a comprehensive and authoritative standard guide for SI units to be used in plumbing design and related fields of science and engineering.

The section also is intended to provide the basic concepts and practices for the conversion of units given in several systems of measurement to the SI system. Rules and recommendations are detailed for the presentation of SI units and their corresponding symbols and numerical values used in conjunction with the SI system.

A selection of conversion factors to SI units for use in plumbing design and related fields of science and engineering is also given. It should be noted that the SI units, rules, and recommendations listed herein comply with those provisions set forth in the American National Standard Metric Practice, ANSI Z210.1 (ASTM E380).

Terminology and Abbreviations

For uniformity in the interpretation of the provisions set forth in this recommended practice section, the following definitions and abbreviations will apply:

Accuracy The degree of conformity of a measured or calculated value to some recognized standard or specified value.

Approximate value A quantity that is nearly, but not exactly, correct or accurate.

CGPM Abbreviation for the General Conference

SI Units and Symbols[5]

The International System of Units has three types of units, as follows:

Base units These units are used for independent quantities. There are seven base units:

Quantity	Unit	Symbol
Length	meter	m
Mass	kilogram	kg
Time	second	s
Current (electric)	ampere	A
Temperature (thermodynamic)	kelvin	K
Substance (amount)	mole	mol
Intensity (luminous)	candela	cd

Supplementary units These units are used to denote angles. There are two supplementary units:

Quantity	Unit	Symbol
Plane angle	radian	rad
Solid angle	steradian	sr

Derived units These units are defined in terms of their derivation from base and supplementary units. Derived units are classified in two categories: (1) derived units with special names and symbols and (2) derived units with generic or complex names, expressed in terms of a base unit, two or more base units, base units and/or derived units with special names, or supplementary units and base and/or derived units.

Quantity	Unit	Symbol
Frequency	hertz	Hz
Force	newton	N
Pressure, stress	pascal	Pa
Energy, work, heat (quantity)	joule	J
Power	watt	W
Electricity (quantity)	coulomb	C
Electric potential, electromotive force	volt	V
Electric capacitance	farad	F
Electric resistance	ohm	Ω
Magnetic flux	weber	Wb
Illuminance	lux	lx
Electric inductance	henry	H
Conductance	siemens	S
Magnetic flux density	tesla	T
Luminous flux	lumen	lm

The following are classified as derived units with generic or complex names, expressed in various terms:

Quantity	Unit	Symbol
Linear acceleration	meter per second sq.	m/s^2
Angular acceleration	radian per second sq.	rad/s^2
Area	meter squared	m^2
Density	kilogram per cubic meter	kg/m^3
Electric charge density	coulomb per cubic meter	C/m^3
Electric permittivity	farad per meter	F/m
Electric permeability	henry per meter	H/m
Electric resistivity	ohm-meter	Ω·m
Entropy	joule per kelvin	J/K
Luminance	candela per meter sq.	cd/m^2
Magnetic field strength	ampere per meter	A/m
Mass per unit length	kilogram per meter	kg/m
Mass per unit area	kilogram per meter sq.	kg/m^2
Mass flow rate	kilogram per second	kg/s
Moment of inertia	kilogram-meter sq.	$kg·m^2$
Momentum	kilogram-meter per sec.	kg·m/s
Torque	newton-meter	N·m
Specific heat	joule per kg per kelvin	J/kg·K
Thermal conductivity	watt per meter per kelvin	W/m·K
Linear velocity	meter per second	m/s
Angular velocity	radian per second	rad/s
Dynamic viscosity	pascal-second	Pa·s
Kinematic viscosity	meter squared per second	m^2/s

Non-SI Units and Symbols for Use with the SI System

There are several (non-SI) units that are traditional and acceptable for use in the SI system of units due to their significance in specific and general applications. These units are as follows:

Quantity	Unit	Symbol
Area	hectare	ha
Energy	kilowatt-hour	kW·h
Mass	metric ton	t
Temperature	degree celsius	C
Time	minute, hour, year	min, h, y (respectively)
Velocity	kilometer per hour	km/h
Volume	liter	L

SI Unit Prefixes and Symbols

The SI unit system is based on multiples and submultiples. The following prefixes and corresponding symbols are accepted for use with SI units.

Factor	Prefix	Symbol
10^{18}	exa	E
10^{15}	peta	P
10^{12}	tera	T
10^{9}	giga	G
10^{6}	mega	M
10^{3}	kilo	k
10^{2}	hecto[a]	h
10^{1}	deka[a]	da
10^{-1}	deci[a]	d
10^{-2}	centi[a]	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p
10^{-15}	femto	f
10^{-18}	atto	a

[a]Use of these prefixes should be avoided whenever possible.

SI Units Style and Use

1. Multiples and submultiples of SI units are to be formed by adding the appropriate SI prefixes to such units.
2. Except for the kilogram, SI prefixes are not to be used in the denominator of compound numbers.
3. Double prefixes are not to be used.
4. Except for exa (E), peta (P), teca (T), giga (G), and mega (M), SI prefixes are not capitalized.
5. The use of units from other systems of measurement is to be avoided.
6. Except when the SI unit is derived from a proper name, the symbol for SI units is not capitalized.
7. SI unit symbols are always denoted in singular form.
8. Except at the end of a sentence, periods are not used after SI unit symbols.
9. Digits are placed in groups of three numbers, separated by a space to the left and to the right of the decimal point. In the case of four digits, spacing is optional.
10. A center dot indicates multiplication, and a slash indicates division (to the left of the slash is the numerator and to the right of the slash is the denominator).
11. When equations are used, such equations are to be restated using SI terms.
12. All units are to be denoted by either their symbols or their names written in full. Mixed use of symbols and names is not allowed.

SI UNIT CONVERSION FACTORS

To convert from other systems of measurement to SI values, the following conversion factors are to be used. (*Note*: For additional conversion equivalents not shown herein, refer to ANSI Z210.1–also issued as ASTM E380).

Acceleration, linear

foot per second squared = 0.3048 m/s^2	m/s^2 = 3.28 ft/s^2
inch per second squared = 0.0254 m/s^2	m/s^2 = 39.37 in/s^2

Area

acre = 4046.9 m^2	m^2 = 0.0000247 acre
foot squared = 0.0929 m^2	m^2 = 10.76 ft^2
inch squared = 0.000645 m^2 = 645.16 mm^2	m^2 = 1550.39 in^2
mile squared = 2 589 988 m^2 = 1.59	km^2 = 0.39 mi^2
yard squared = 0.836 m^2	m^2 = 1.2 yd^2

Bending movement (torque)

pound-force-inch = 0.113 N·m	N·m = 8.85 lb_f-in
pound-force-foot = 1.356 N·m	N·m = 0.74 lb_f-ft

Bending movement (torque) per unit length

pound-force-inch per inch = 4.448 N·m/m	N·m/m = 0.225 lb_f-in/in
pound-force-foot per inch = 53.379 N·m/m	N·m/m = 0.019 lb_f-ft/in

Electricity and magnetism

ampere = 1A

ampere-hour = 3600C

coulomb = 1C

farad = 1F

henry = 1H

ohm = 1Ω

volt = 1V

Energy (work)

British thermal unit (Btu) = 1055 J	J = 0.000948 Btu
foot-pound-force = 1.356 J	J = 0.74 ft-lb_f
kilowatt-hour = 3 600 000 J	J = 0.000000278 kW-h

Energy per unit area per unit time

Btu per foot squared-second = 11 349 W/m^2	W/m^2 = 0.000088 Btu/ft^2-s

Force

ounce-force = 0.287 N	N = 3.48 oz_f
pound-force = 4.448 N	N = 0.23 lb_f
kilogram-force = 9.807 N	N = 0.1 kg_f

Force per unit length

pound-force per inch = 175.1 N/m	N/m = 0.0057 lb_f/in

Heat

Btu-inch per second-foot squared-F = 519.2 W/m·K	W/m·K = 0.002 Btu-in/s-ft^{2}F
Btu-inch per hour-foot squared-F = 0.144 W/m·K	W/m·K = 6.94 Btu-in/h-ft^{2}F
Btu per foot squared = 11 357 J/m^2	J/m^2 = 0.000088 Btu/ft^2
Btu per hour-foot squared-F = 5.678 W/m^2·K	W/m^2·K = 0.176 Btu/h-ft^{2}F
Btu per pound-mass = 2326 J/kg	J/kg = 0.00043 Btu/lb$_m$
Btu per pound-mass-F = 4186.8 J/kg·K	J/kg·K = 0.000239 Btu/lb$_m$ F
F-hour-foot squared per Btu = 0.176 K·m^2/W	K·m

pounds per square inch = 0.0703 kg/cm^3	kg/cm^3 = 14.22 psi
pounds per square inch = 0.069 bars	bars = 14.50 psi

Temperature equivalent

$t_k = (t_f + 459.67)/1.8$	$t_f = 1.8\ t_k - 459.67$
$t_c = (t_f - 32)/1.8$	$t_f = 1.8\ t_c + 32$

Velocity (length per unit time)

foot per hour = 0.085 mm/s	mm/s = 11.76 ft/h
foot per minute = 5.08 mm/s	mm/s = 0.197 ft/min
foot per second = 0.3048 m/s	m/s = 3.28 ft/s
inch per second = 0.0254 m/s	m/s = 39.37 in./s
mile per hour = 0.447 m/s	m/s = 2.24 mi/h

Volume

cubic foot = 0.028 m^3 = 28.317 L	m^3 = 35.71 ft^3
cubic inch = 16 378 mL	mL = 0.061 in^3
gallon = 3.785 L	L = 0.264 gal
ounce = 29.574 mL	mL = 0.034 oz
pint = 473.18 mL	mL = 0.002 pt
quart = 946.35 mL	mL = 0.001 qt
acre-foot = 1233.49 m^3	m^3 = 0.00081 acre-ft

Volume per unit time (flow)

cubic foot per minute = 0.472 L/s	L/s = 2.12 ft^3/min

Table 1-4 Temperature Conversion Chart, °F – °C

The numbers in the center column refer to the known temperature, in either °F or °C, to be converted to the other scale. If converting from °F to °C, the number in the center column represents the known temperature, in °F, and its equivalent temperature, in °C, will be found in the left column. If converting from °C to °F, the number in the center represents the known temperature, in °C, and its equivalent temperature, in °F, will be found in the right column.

Known Temp.		
°C	(°F or °C)	°F
–59	–74	–101
–58	–73	–99
–58	–72	–98
–57	–71	–96
–57	–70	–94
–56	–69	–92
–56	–68	–90
–55	–67	–89
–54	–66	–87
–54	–65	–85
–53	–64	–83
–53	–63	–81
–52	–62	–80
–52	–61	–78
–51	–60	–76
–51	–59	–74
–50	–58	–72
–49	–57	–71
–49	–56	–69
–48	–55	–67
–48	–54	–65
–47	–53	–63
–47	–52	–62
–46	–51	–60
–45.6	–50	–58.0
–45.0	–49	–56.2
–44.4	–48	–54.4
–43.9	–47	–52.6
–43.3	–46	–50.8
–42.8	–45	–49.0
–42.2	–44	–47.2
–41.7	–43	–45.4
–41.1	–42	–43.6
–40.6	–41	–41.8
–40.0	–40	–40.0
–39.4	–39	–38.2
–38.9	–38	–36.4
–38.3	–37	–34.6
–37.8	–36	–32.8
–37.2	–35	–31.0
–36.7	–34	–29.2
–36.1	–33	–27.4
–35.5	–32	–25.6
–35.0	–31	–23.8
–34.4	–30	–22.0
–33.9	–29	–20.2
–33.3	–28	–18.4
–32.8	–27	–16.6
–32.2	–26	–14.8
–31.6	–25	–13.0
–31.1	–24	–11.2
–30.5	–23	–9.4
–30.0	–22	–7.6
–29.4	–21	–5.8

Known Temp.		
°C	(°F or °C)	°F
–28.9	–20	–4.0
–28.3	–19	–2.2
–27.7	–18	–0.4
–27.2	–17	1.4
–26.6	–16	3.2
–26.1	–15	5.0
–25.5	–14	6.8
–25.0	–13	8.6
–24.4	–12	10.4
–23.8	–11	12.2
–23.3	–10	14.0
–22.7	–9	15.8
–22.2	–8	17.6
–21.6	–7	19.4
–21.1	–6	21.2
–20.5	–5	23.0
–20.0	–4	24.8
–19.4	–3	26.6
–18.8	–2	28.4
–18.3	–1	30.2
–17.8	0	32.0
–17.2	1	33.8
–16.7	2	35.6
–16.1	3	37.4
–15.6	4	39.2
–15.0	5	41.0
–14.4	6	42.8
–13.9	7	44.6
–13.3	8	46.4
–12.8	9	48.2
–12.2	10	50.0
–11.7	11	51.8
–11.1	12	53.6
–10.6	13	55.4
–10.0	14	57.2
–9.4	15	59.0
–8.9	16	60.8
–8.3	17	62.6
–7.8	18	64.4
–7.2	19	66.2
–6.7	20	68.0
–6.1	21	69.8
–5.6	22	71.6
–5.0	23	73.4
–4.4	24	75.2
–3.9	25	77.0
–3.3	26	78.8
–2.8	27	80.6
–2.2	28	82.4
–1.7	29	84.2
–1.1	30	86.0
–0.6	31	87.8
0	32	89.6
0.6	33	91.4

Known Temp.		
°C	(°F or °C)	°F
1.1	34	93.2
1.7	35	95.0
2.2	36	96.8
2.8	37	98.6
3.3	38	100.4
3.9	39	102.2
4.4	40	104.0
5.0	41	105.8
5.6	42	107.6
6.1	43	109.4
6.7	44	111.2
7.2	45	113.0
7.8	46	114.8
8.3	47	116.6
8.9	48	118.4
9.4	49	120.2
10.0	50	122.0
10.6	51	123.8
11.1	52	125.6
11.7	53	127.4
12.2	54	129.2
12.8	55	131.0
13.3	56	132.8
13.9	57	134.6
14.4	58	136.4
15.0	59	138.2
15.6	60	140.0
16.1	61	141.8
16.7	62	143.6
17.2	63	145.4
17.8	64	147.2
18.3	65	149.0
18.9	66	150.8
19.4	67	152.6
20.0	68	154.4
20.6	69	156.2
21.1	70	158.0
21.7	71	159.8
22.2	72	161.6
22.8	73	163.4
23.3	74	165.2
23.9	75	167.0
24.4	76	168.8
25.0	77	170.6
25.6	78	172.4
26.1	79	174.2
26.7	80	176.0
27.2	81	177.8
27.8	82	179.6
28.3	83	181.4
28.9	84	183.2
29.4	85	185.0
30.0	86	186.8
30.6	87	188.6

Known Temp.		
°C	(°F or °C)	°F
31.1	88	190.4
31.7	89	192.2
32.2	90	194.0
32.8	91	195.8
33.3	92	197.6
33.9	93	199.4
34.4	94	201.2
35.0	95	203.0
35.6	96	204.8
36.1	97	206.6
36.7	98	208.4
37.2	99	210.2
37.8	100	212.0
43	110	230
49	120	248
54	130	266
60	140	284
66	150	302
71	160	320
77	170	338
82	180	356
88	190	374
93	200	392
99	210	410
100	212	414
104	220	428
110	230	446
116	240	464
121	250	482
127	260	500
132	270	518
138	280	536
143	290	554
149	300	572
154	310	590
160	320	608
166	330	626
171	340	644
177	350	662
182	360	680
188	370	698
193	380	716
199	390	734
204	400	752
210	410	770
216	420	788
221	430	806
227	440	824
232	450	842
238	460	860
243	470	878
249	480	896
254	490	914
260	500	932

Multiply	By	To Obtain
acre	0.4047	ha
atmosphere (standard)	101.325[a]	kPa
bar	100[a]	kPa
barrel (42 US gal, petroleum)	159 0.159	L m^3
Btu (International Table)	1.055	kJ
Btu/ft^2	11.36	kJ/m^2
Btu/ft^3	37.3	kJ/m^3
Btu/gal	279	kJ/m^3
$Btu \cdot ft/h \cdot ft^2 \cdot °F$	1.731	$W/(m \cdot K)$
$Btu \cdot in/h \cdot ft^2 \cdot °F$ (thermal conductivity, k)	0.1442	$W/(m \cdot K)$
Btu/h	0.2931	W
$Btu/h \cdot ft^2$	3.155	W/m^2
$Btu/h \cdot ft^2 \cdot °F$ (overall heat transfer coefficient, U)	5.678	$W/(m^2 \cdot K)$
Btu/lb_m	2.326[a]	kJ/kg
$Btu/lb_m \cdot °F$ (specific heat, c_p)	4.186	$kJ/(kg \cdot K)$
bushel	0.03524	m^3
calorie, gram	4.1868	J
calorie, kilogram (kilocalorie)	4.1868	kJ
centipoise (dynamic viscosity, μ)	1.00[a]	$mPa \cdot s$
centistokes (kinematic viscosity, v)	1.00[a]	mm^2/s

Multiply	By	To Obtain
ounce (mass, avoirdupois)	28.35	g
ounce (force, thrust)	0.278	N
ounce (liquid, US)	29.6	mL
ounce inch (torque, moment)	7.06	mN · m
ounce (avoirdupois) per gallon	7.49	kg/m^3
perm (permeance)	57.45	$ng/(s \cdot m^2 \cdot Pa)$
perm inch (permeability)	1.46	ng/(s · m · Pa)
pint (liquid, US)	473	mL
pound		
lb_m (mass)	0.4536 453.6	kg g
lb_f (force, thrust)	4.45	N
lb_m/ft (uniform load)		

2 Standards for Plumbing Materials and Equipment

A plumbing engineer's life is surrounded by codes and standards. This chapter lists the majority of codes and standards used and referenced by the profession.

Codes and standards often cross paths to the point that it is difficult to understand the difference between a code and a standard. A code typically regulates a broad part of construction, whereas a standard regulates a very specific area. Codes often include installation, material, and approval requirements. Codes rely on standards and normally reference standards for specific materials or installation requirements. State and local jurisdictions adopt codes to regulate construction. The standard only becomes a legally enforceable document when it is referenced in the adopted code.

Sometimes a standard crosses the line and becomes a code. A good example is the National Fuel Gas Code. As the name implies, the document is a code that regulates the installation of fuel gas systems. However, the National Fuel Gas Code is an NFPA standard, NFPA 54. Another document that regulates fuel gas systems is the International Fuel Gas Code. This document is a code and does not have a standard designation.

Codes and standards are continually updated. As a result, as soon as this Data Book is published, the list of standards is out-of-date. To identify the specific edition of a standard, the date is located in the numerical designation of the standard. Whenever using a standard, it is appropriate to check with the standard-promulgating organization in order to identify the latest edition of that standard.

This chapter is separated into three sections: Standards Listed By Code and Standards Listed by Category (Table 2-1), Complete List of Standards By Standard Writing Organizations, and Organization Abbreviation, Address, and Phone Number Listing (Table 2-3). The first section identifies codes and standards based on their category. For example, the heading of water distribution piping aboveground lists the standards for each given material approved for such use. In this first section, only the standard acronym and number are identified. Not every standard is listed in this section. The more complete listing of standards appears in the second portion of the chapter. The third section provides information to contact the organizations.

In the second section, the standard designation, date, and full title of the standard appear. The standards are listed in alphabetical numerical order for each standard-promulgating agency. It should be noted that the American National Standards Institute (ANSI) accredits many standards as American National Standards. ANSI is the organization in the United States that oversees the development of national consensus standards. ANSI does not develop standards; they regulate (as an oversight organization) the agencies that promulgate standards, such as ASME.

ANSI identifies the standard by the acronym of the standard-promulgating agency. For example, the vitreous china fixture standard may be written as ANSI/ASME A112.19.2; however, both ANSI and ASME will also identify the same standard as ASME A112.19.2. For ease of identification, the ANSI has not been included in the table for the ANSI-accredited standards. The only listings of ANSI standards are the few remaining standards that do not have another acronym from a promulgating agency identifying the standard. A typical example is ANSI LC-1, which regulates corrugated stainless steel tubing.

Most standards are developed through a consensus process. This would include all ANSI, ASTM, and CSA standards. A consensus process requires the standards committee to be balanced between the various interest groups. For example, material standards will have manufacturers (producers), users (engineers), and general-interest representatives on the committee. The consensus process also requires all negative comments to be resolved. As a result of the consensus process, the standards are of a higher caliber, developed through a fair and open process.

Table 2-1 Codes and Standards Listed by Category

CODES LISTED BY CATEGORY

Boiler Code	ASME BPVC, IAPMO UMC, ICC IMC
Building Code	ICC IBC, NFPA 5000
Energy Code	ASHRAE 90.1, ASHRAE 90.2, ICC IECC
Fuel Gas Code	IAPMO UPC, ICC IFGC, NFPA 54, NFPA 58
Mechanical Code	IAPMO UMC, ICC IMC
Plumbing Code	IAPMO UPC, ICC IPC, PHCC-NA NSPC

STANDARDS LISTED BY CATEGORY

Aboveground Sanitary (or Storm) Drainage and Vent Pipe

Acrylonitrile butadiene styrene (ABS) plastic pipe	ASTM D 2661; ASTM F 628; CSA B181.1
Brass pipe	ASTM B 43
Cast-iron pipe	ASTM A 74; ASTM A 888; CISPI 301
Coextruded composite ABS or PVC DWV pipe	ASTM F 1488
Copper or copper-alloy pipe	ASTM B 42; ASTM B 302
Copper or copper-alloy tubing	ASTM B 75; ASTM B 88; ASTM B 251; ASTM B 306
Galvanized steel pipe	ASTM A 53
Glass pipe	ASTM C 1053
Polyolefin pipe	CAN/CSA-B181.2
Polyvinyl chloride (PVC) plastic pipe (Type DWV)	ASTM D 2665; ASTM D 2949; ASTM F 891; CAN/CSA-B181.2; ASTM F 1488
Stainless steel drainage systems, types 304 and 316L	ASME/ANSI A112.3.

Backflow Preventers

Air gap	ASME A112.1.2, ASME A112.1.3
Backflow preventer w/intermediate atmospheric vents	ASSE 1012, CAN/CSA-B64.3
Ballcock	ASSE 1002
Carbonated beverage dispensers backflow preventer	ASSE 1022
Double check backflow prevention assembly	ASSE 1015, ASSE 1048, AWWA C510
Dual-check-valve-type backflow preventer	ASSE 1024
Faucet and fixture fitting backflow devices	ASME A112.18.3
Hose connection backflow preventer	ASSE 1052
Hose-connection vacuum breaker	ASSE 1011, ASSE 1019, CAN/CSA-B64.2.2
Laboratory faucet backflow preventer	ASSE 1035, CSA B64.7
Pipe-applied atmospheric-type vacuum breaker	ASSE 1001, CAN/CSA-B64.1.1
Pressure vacuum breaker assembly	ASSE 1020, ASSE 1056
Reduced pressure principle backflow preventer	ASSE 1013, ASSE 1047, AWWA C511, CAN/CSA-B64.4

Building Storm Sewer Pipe

Acrylonitrile butadiene styrene (ABS) plastic pipe	ASTM D 2661; ASTM D 2751; ASTM F 628
Asbestos-cement pipe	ASTM C 428
Cast-iron pipe	ASTM A 74; ASTM A 888; CISPI 301
Concrete pipe	ASTM C 14; ASTM C 76; CSA A257.1; CSA CAN/CSA A257.2
Copper or copper-alloy tubing	ASTM B 75; ASTM B 88; ASTM B 251; ASTM B 306
Polyvinyl chloride (PVC) plastic pipe	ASTM D 2665; ASTM D 3034; ASTM F 891; CSA B182.2; CAN/CSA B182.4
Stainless steel drainage systems, Type 316L	ASME/ANSI A112.3.1
Vitrified clay pipe	ASTM C 4; ASTM C 700

Fire Protection

Combustibility test	ASTM E 136
Fire pumps	NFPA 20
Fire resistance rating test	ASTM E 119
Flame spread and smoke developed	ASTM E 84
One- and two-family dwelling sprinkler design	NFPA 13D
Residential sprinkler design	NFPA 13R

(CONTINUED)

Table 2-1 Codes and Standards Listed by Category (continued)	
Sprinkler design	NFPA 13
Standpipe systems	NFPA 14
Through penetration fire test	ASTM E 814
Gas Piping	
Aluminum	ASTM B 210; ASTM B 211; ASTM B 241
Copper and copper-alloy tubing	ASTM B 88; ASTM B 280
Corrugated stainless steel tubing	ANSI LC1
Plastic pipe (underground only)	ASTM D 2513
Steel pipe	ASTM A 53; ASTM A 106
Joints and Connections	
ABS solvent cement	ASTM D 2235; CSA B181.1
Brazed filler metal	AWS A5.8
Cast iron hubless coupling	ASTM C1277; CISPI 310
CPVC solvent cement	ASTM F 493
Elastomeric Seal	ASTM C 425; ASTM C 443; ASTM C 477; ASTM C 564; ASTM C 1440; ASTM D 1869; CAN/CSA A257.3; CAN/CSA B602
Pipe thread	ASME B 1.20.1
PVC solvent cement	ASTM D 2564; CSA B137.3; CSA B181.2
PVC primer	ASTM F 656
Solder filler metal	ASTM B 32
Solder flux	ASTM B 813
Miscellaneous	
Air admittance valves	ASSE 1050, ASSE 1051
Backwater valves	ASME A112.14.1, CSA B181.1, CSA B181.2
Category II, III, IV vent systems	UL 1738
Disinfecting methods	AWWA 651, AWWA 652
Drinking water material protection	NSF 61
Factory built chimneys	UL 103
Grease traps and interceptors	ASME A112.14.3, ASME A112.14.4, PDI G101
Pipe hangers	MSS SP-58, MSS SP-69
Plastic pipe quality control	NSF 14
Type B vents	UL 441
Type L vents	UL 641
Water hammer arresters	ASSE 1010, PDI WH 201
Water heaters	ANSI Z21.10.1, ANSI Z21.10.3, UL 732, UL 1261
Pipe Nipples	
Steel	ASTM A 733
Brass-, copper-, chromium-plated	ASTM B 687
Plumbing Fixtures	
Bathtubs	ASME A112.19.1, ASME A112.19.4, ASME A112.19.7, ASME A112.19.9, ANSI Z124.1, CSA B45.2, CSA B45.3, CSA B45.5
Bidet	ASME A112.19.2, ASME A112.19.9, CSA B45.1
Dishwashing machines	ASSE 1004, ASSE 1006, NSF 3
Drinking fountains	ASME A112.19.1, ASME A112.19.2, ASME A112.19.9, ARI 1010
Emergency shower and eyewash stations	ISEA Z358.1
Faucets and fixture fittings	ASME A112.18.1, CSA B125
Fixture waste fittings	ASME A112.18.2
Floor drains	ASME A112.3.1, ASME A112.6.3, CSA B79
Food waste grinders	ASSE 1008, ASSE 1009

(CONTINUED)

Table 2-1 Codes and Standards Listed by Category (continued)

Lavatories	ASME A112.19.1, ASME A112.19.2, ASME A112.19.3, ASME A112.19.4, ASME A112.19.9, ANSI Z124.3, CSA B45.1, CSA B45.2, CSA B45.3, CSA B45.4
Pressure balancing valves	ASSE 1016, ASSE 1066
Roof drains	ASME A112.3.1, ASME A112.6.4
Showers	ASME A112.19.9, ANSI Z124.2, CSA B45.5
Sinks	ASME A112.19.1, ASME A112.19.2, ASME A112.19.3, ASME A112.19.4, ASME A112.19.9, ANSI Z124.6, CSA B45.1, CSA B45.2, CSA B45.3, CSA B45.4
Thermostatic mixing valves	ASSE 1016, ASSE 1017
Urinals	ASME A112.19.2, ANSI Z124.4, CSA B45.1, CSA B45.5
Wall carriers	ASME A112.6.1, ASME A112.6.2
Water closets	ASME A112.19.2, ANSI Z124.4, CSA B45.1, CSA B45.4, CSA B45.5
Sanitary Drainage Pipe Fittings	
Acrylonitrile butadiene styrene (ABS) plastic	ASTM D 2661; ASTM D 3311; CSA B181.1
Cast iron	ASME B16.4; ASME B16.12; ASTM A 74; ASTM A 888; CISPI 301
Copper or copper alloy	ASME B16.15; ASME B16.18; ASME B16.22; ASME B16.23; ASME B16.26; ASME B16.29; ASME B16.32
Glass	ASTM C 1053
Gray iron and ductile iron	AWWA C110
Malleable iron	ASME B16.3
Polyvinyl chloride (PVC) plastic	ASTM D 3311; ASTM D 2665
Stainless steel drainage systems	ASME/ANSI A112.3.1
Steel	ASME B16.9; ASME B16.11; ASME B16.28
Sanitary Sewer Pipe	
Acrylonitrile butadiene styrene (ABS) plastic pipe	ASTM D 2661; ASTM D 2751; ASTM F 628
Asbestos-cement pipe	ASTM C 428
Cast-iron pipe	ASTM A 74; ASTM A 888; CISPI 301
Coextruded composite ABS or PVC DWV pipe	ASTM F 1488
Concrete pipe	ASTM C 14; ASTM C 76; CSA A257.1; CAN/CSA A257.2
Copper or copper-alloy tubing	ASTM B 75; ASTM B 88; ASTM B 251
Polyvinyl chloride (PVC) plastic pipe	ASTM D 2665; ASTM D 2949; ASTM D 3034; ASTM F 891; CSA B182.2; CAN/CSA-B182.4
Stainless steel drainage systems, Type 316L	ASME/ANSI A112.3.1
Vitrified clay pipe	ASTM C 4; ASTM C 700
Subsoil Drainage Pipe	
Asbestos-cement pipe	ASTM C 508
Cast-iron pipe	ASTM A 74; ASTM A 888; CISPI 301
Polyethylene (PE) plastic pipe	ASTM F 405
Polyvinyl chloride (PVC) plastic pipe	ASTM D 2729; ASTM F 891; CSA-B182.2; CSA CAN/CSA-B182.4
Stainless steel drainage systems, Type 316L	ASME/ANSI A112.3.1
Vitrified clay pipe	ASTM C 4; ASTM C 700
Underground Building Sanitary (or Storm) Drainage and Vent Pipe	
Acrylonitrile butadiene styrene (ABS) plastic pipe	ASTM D 2661; ASTM F 628; CSA B181.1
Asbestos-cement pipe	ASTM C 428
Cast-iron pipe	ASTM A 74; ASTM A 888; CISPI 301
Coextruded composite ABS or PVC DWV pipe	ASTM F 1488

(CONTINUED)

Table 2-1 Codes and Standards Listed by Category (continued)	
Copper or copper-alloy tubing	ASTM B 75; ASTM B 88; ASTM B 251; ASTM B 306
Polyolefin pipe	CAN/CSA-B181.2
Polyvinyl chloride (PVC) plastic pipe (Type DWV)	ASTM D 2665; ASTM D 2949; ASTM F 891; CAN/CSA-B181.2
Stainless steel drainage systems, Type 316L	ASME/ANSI A112.3.1
Water Distribution Piping (Aboveground)	
Brass pipe	ASTM B 43
Chlorinated polyvinyl chloride (CPVC) plastic pipe and tubing	ASTM D 2846; ASTM F 441; ASTM F 442; CSA B137.6
Copper or copper-alloy pipe	ASTM B 42; ASTM B 302
Copper or copper-alloy tubing	ASTM B 75; ASTM B 88; ASTM B 251; ASTM B 447
Cross-linked polyethylene (PEX) plastic tubing	ASTM F 877; CAN/CSA B137.5
Cross-linked polyethylene/aluminum/cross-linked polyethylene (PEX-AL-PEX) pipe	ASTM F 1281; CAN/CSA B137.10
Galvanized steel pipe	ASTM A 53
Polybutylene (PB) plastic pipe and tubing	ASTM D 3309; CSA CAN3-B137.8
Water Pipe Fittings	
Acrylonitrile butadiene styrene (ABS) plastic	ASTM D 2468
Cast iron	ASME B16.4; ASME B16.12
Chlorinated polyvinyl chloride (CPVC) plastic	ASTM F 437; ASTM F 438; ASTM F 439
Copper or copper alloy	ASME B16.18; ASME B16.22; ASME B16.23; ASME B16.26; ASME B16.29; ASME B16.32
Gray iron and ductile iron	AWWA C110; AWWA C153
Malleable iron	ASME B16.3
(PEX) Tubing	ASTM F 1807
Polyethylene (PE) plastic	ASTM D 2609
Polyvinyl chloride (PVC) plastic	ASTM D 2464; ASTM D 2466; ASTM D 2467; CAN/CSA-B137.2
Steel	ASME B16.9; ASME B16.11; ASME B16.28
Water Service Piping (Underground)	
Acrylonitrile butadiene styrene (ABS) plastic pipe	ASTM D 1527; ASTM D 2282
Asbestos-cement pipe	ASTM C 296
Brass pipe	ASTM B 43
Copper or copper-alloy pipe	ASTM B 42; ASTM B 302
Copper or copper-alloy tubing	ASTM B 75; ASTM B 88; ASTM B 251; ASTM B 447
Chlorinated polyvinyl chloride (CPVC) plastic pipe	ASTM D 2846; ASTM F 441; ASTM F 442; CSA B137.6
Cross-linked polyethylene (PEX) plastic tubing	ASTM F 876; ASTM F 877; CSA CAN/CSA-B137.5
Cross-linked polyethylene/ aluminum/cross-linked polyethylene (PEX-AL-PEX) pipe	ASTM F 1281; CAN/CSA B137.10
Ductile iron water pipe	AWWA C115; AWWA C151
Galvanized steel pipe	ASTM A 53
Polybutylene (PB) plastic pipe and tubing	ASTM D 2662; ASTM D 2666; ASTM D 3309; CSA B137.8
Polyethylene (PE) plastic pipe	ASTM D 2239; CAN/CSA-B137.1
Polyethylene (PE) plastic tubing	ASTM D 2737; CSA B137.1
Polyethylene/aluminum/polyethylene (PE-AL-PE) pipe	ASTM F 1282; CAN/CSA-B137.9
Polyvinyl chloride (PVC) plastic pipe	ASTM D 1785; ASTM D 2241; ASTM D 2672; CAN/CSA-B137.3

Table 2-2 Complete List of Standards By Standard-Writing Organization

ANSI

American National Standards Institute
25 West 43rd Street, Fourth Floor
New York, NY 10036

www.ansi.org
(212) 642-4900
(212) 398-0023 facsimile

LC1-97 (R2001)	Interior Gas Piping Systems Using Corrugated Stainless Steel Tubing
Z4.3-95	Minimum Requirements for Nonsewered Waste-Disposal Systems
Z21.8-94 (R2000)	Installation of Domestic Gas Conversion Burners
Z21.10.1-01	Gas Water Heaters – Volume I, Storage Water Heaters with Input Ratings of 75,000 Btu per Hour or Less
Z21.10.3-98	Gas Water Heaters – Volume III, Storage Water Heaters with Input Ratings Above 75,000 Btu per hour, Circulating and Instantaneous Water Heaters—with Z21.10.3a-99 Addendum
Z21.13-99	Gas-Fired Low-Pressure Steam and Hot Water Boilers— with Addenda Z21.13a-1993 and Z21.13b-1994
Z21.15-97	Manually Operated Gas Valves for Appliances, Appliance Connector Valves, and Hose End Valves
Z21.19-90	Refrigerators Using Gas (R1999) Fuel—with Addenda Z721.19a-1992 (R1999) and Z21.19b-1995 (R1999)
Z21.22-99	Relief Valves for Hot Water Supply Systems
Z21.40.1-96	Gas-Fired Heat Activated Air Conditioning and Heat Pump Appliances—with Z21.40.1a-98 Addendum
Z21.40.2-96	Gas-Fired Work Activated Air Conditioning and Heat Pump Appliances (Internal Combustion)—with Z21.40.2a-97 Addendum
Z21.42-93	Gas-Fired Illuminating Appliances
Z21.50-98	Vented Decorative Gas Appliances
Z21.56-98	Gas-Fired Pool Heaters—with Z21.56a-99 Addendum
Z21.61-83 (R1996)	Toilets, Gas-Fired
Z21.69-97	Connectors for Movable Gas Appliances
Z21.83-98	Fuel Cell Power Plants
Z21.84-99	Manually Lighted, Natural Gas Decorative Gas Appliances for Installation in Solid Fuel Burning Fireplaces
Z21.88-99	Vented Gas Fireplace Heaters
Z83.11-00	Gas Food Service Equipment (Ranges and Unit Broilers), Baking and Roasting Ovens, Fat Fryers, Counter Appliances and Kettles, Steam Cookers, and Steam Generators
Z124.1-95	Plastic Bathtub Units
Z124.2-95	Plastic Shower Receptors and Shower Stalls
Z124.3-95	Plastic Lavatories
Z124.4-96	Plastic Water Closet Bowls and Tanks
Z124.5-97	Plastic Toilet (Water Closet) Seats
Z124.6-97	Plastic Sinks
Z124.7-97	Prefabricated Plastic Spa Shells
Z124.9-94	Plastic Urinal Fixtures

ARI

Air-Conditioning & Refrigeration Institute
4100 North Fairfax Drive, Suite 200
Arlington, VA 22203

www.ari.org
(703) 524-8800
(703) 528-3816 facsimile

700-99	Specifications for Fluorocarbon and Other Refrigerants
1010-02	Self-Contained, Mechanically Refrigerated Drinking-Water Coolers

(CONTINUED)

Table 2-2 Complete List of Standards By Standard-Writing Organization (continued)

ASHRAE

American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.
1791 Tullie Circle, NE
Atlanta, GA 30329-2305

www.ashrae.org
(404) 636-8400
(404) 321-5478 facsimile

15-2001	Safety Standard for Refrigeration Systems
34-2001	Designation and Safety Classification of Refrigerants
90.1-2001	Energy Standards for Buildings Except for Low Rise Residential Buildings
90.2-2001	Energy Efficient Design for Low Rise Residential Buildings
100-1995	Energy Conservation in Existing Buildings
118.1-2003	Method of Testing for Rating Commercial Gas, Electric, and Oil Service Water Heating Equipment
118.2-1993	Method of Testing for Rating Residential Water Heaters
124-1991	Method of Testing for Rating Combination Space Heating and Water Heating Appliances
137-1995	Method of Testing for Efficiency of Space Conditioning/Water Heating Appliances that Include a Desuperheater Water Heater
146-1998	Method of Testing and Rating Pool Heaters

ASME

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(973) 882-1717 facsimile (Inquiries)
(212) 591-7674 facsimile (NY)

A112.1.2-1991 (R2002)	Air Gaps in Plumbing Systems
A112.1.3-2000	Air Gap Fittings for Use with Plumbing Fixtures, Appliances and Appurtenances
A112.3.1-1993	Performance Standard and Installation Procedures for Stainless Steel Drainage Systems or Sanitary, Storm and Chemical Applications, Above and Below Ground
A112.3.4-2000	Macerating Toilet Systems and Related Components
A112.4.1-1993 (R2002)	Water Heater Relief Valve Drain Tubes
A112.4.3-1999	Plastic Fittings for Connecting Water Closets to the Sanitary Drainage System
A112.4.7-2002	Point of Use and Branch Water Submetering Systems
A112.6.1M-1997 (R2002)	Floor-Affixed Supports for Off-the-Floor Plumbing Fixtures for Public Use
A112.6.2-2000	Framing-Affixed Supports for Off-the-Floor Water Closets with Concealed Tanks
A112.6.3-2001	Floor and Trench Drains
A112.6.4-2003	Roof, Deck, and Balcony Drains
A112.6.7-2001	Enameled and Epoxy-Coated Cast-Iron and PVC Plastic Sanitary Floor Sinks.
A112.14.1-1975 (R1998)	Backwater Valves.
A112.14.3-2000	Grease Interceptors
A112.14.4-2001	Grease Removal Devices
A112.18.1-2003	Plumbing Fixture Fittings
A112.18.2-2002	Plumbing Fixture Waste Fittings
A112.18.3M-2003	Performance Requirements for Backflow Protection Devices and Systems in Plumbing Fixture Fittings
A112.18.6-1999	Flexible Water Connectors
A112.18.7-99-2000	Deck mounted Bath/Shower Transfer Valves with Internal Backflow Protection
A112.19.1M-1994 (R1999)	Enameled Cast Iron Plumbing Fixtures
A112.19.2M-1998	Vitreous China Plumbing Fixtures
A112.19.3-2001	Stainless Steel Plumbing Fixtures (Designed for Residential Use)
A112.19.4M-1994 (R1999)	Porcelain Enameled Formed Steel Plumbing Fixtures
A112.19.5-1999	Trim for Water-Closet Bowls, Tanks, and Urinals

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Table 2-2 Complete List of Standards By Standard-Writing Organization (continuted)

A112.19.6-1995	Hydraulic Performance Requirements for Water Closets and Urinals
A112.19.7M-1995	Whirlpool Bathtub Appliances
A112.19.8M-1987 (R1996)	Suction Fittings for Use in Swimming Pools, Wading Pools, Spas, Hot Tubs, and Whirlpool Bathtub Appliances
A112.19.9M-1991 (R1998)	Non-Vitreous Ceramic Plumbing Fixtures
A112.19.12-2000	Wall Mounted and Pedestal Mounted, Adjustable and Pivoting Lavatory and Sink Carrier Systems
A112.19.13-2001-2002	Electrohydraulic Water Closets
A112.19.14-2001	Six-Liter Water Closets Equipped With a Dual Flushing Device
A112.19.15-2001	Bathtub/Whirlpool Bathtubs with Pressure Sealed Doors
A112.19.17-2002	Manufacturers Safety Vacuum Release Systems (SVRS) for Residential and Commercial Swimming Pool, Spa, Hot Tub, and Wading Pool Suction Systems
A112.21.1M-1991 (R1998)	Floor Drains
A112.36.2M-1991 (R2002)	Cleanouts
B1.20.1-1983 (R2001)	Pipe Threads, General Purpose (inch)
B16.1-1998	Cast Iron Pipe Flanges and Flanged Fittings, Class 25, 125 and 250
B16.3-1998	Malleable Iron Threaded Fittings Classes 150 and 300
B16.4-1998	Gray Iron Threaded Fittings Classes 125 and 250
B16.5-1996	Pipe Flanges and Flanged Fittings NPS ½ through NPS 24—with B16.5a-1998 Addendum
B16.9-2001	Factory-Made Wrought Steel Buttwelding Fittings
B16.11-2001	Forged Fittings, Socket-Welding and Threaded
B16.12-1998	Cast-Iron Threaded Drainage Fittings
B16.15-1985(R1994)	Cast Bronze Threaded Fittings, Classes 125 and 250
B16.18-2002	Cast Copper Alloy Solder Joint Pressure Fittings
B16.20-1998	Metallic Gaskets for Pipe Flanges Ring-Joint, Spiral-Wound, and Jacketed—with B16.20a-2000 Addendum
B16.22-2002	Wrought Copper and Copper Alloy Solder Joint Pressure Fittings
B16.23-2002	Cast Copper Alloy Solder Joint Drainage Fittings DWV
B16.24-2002	Cast Copper Alloy Pipe Flanges and Flanged Fittings: Class 150, 300, 400, 600, 900, 1500 and 2500
B16.26-1988	Cast Copper Alloy Fittings for Flared Copper Tubes
B16.28-1994	Wrought Steel Buttwelding Short Radius Elbows and Returns
B16.29-2001	Wrought Copper and Wrought Copper Alloy Solder Joint Drainage Fittings—DWV
B16.33-1990	Manually Operated Metallic Gas Valves for Use in Gas Piping Systems up to 125 psig (Sizes ½ through 2)
B16.50-2001-2002	Wrought Copper and Copper Alloy Braze-Joint Pressure Fittings
B31.3-2002	Process Piping
B36.10M-2001	Welded and Seamless Wrought-Steel Pipe
BPVC-2001	Boiler & Pressure Vessel Code (Sections I, II, IV, V & VI)
CSD-1-1998	Control and Safety Devices for Automatically Fired Boilers with the ASME CSD-1a-1999 Addendum

ASSE

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1001 – 2002	Atmospheric Type Vacuum Breakers
1002 – 1999	Water Closet Flush Tank Ball Cocks
1003 – 2001	Water Pressure Reducing Valves for Domestic Water Supply Systems
1004 – 1990	Backflow Prevention for Commercial Dishwashing Machines
1005 – 1999	Water Heater Drain Valves
1006 – 1986	Residential Use Dishwashers
1007 – 1992	Home Laundry Equipment

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Table 2-2 Complete List of Standards By Standard-Writing Organization (continuted)

1008 – 1986	Household Food Waste Disposer Units
1009 – 1990	Commercial Food Waste Grinder Units
1010 – 1998	Water Hammer Arresters
1011 – 1995	Hose Connection Vacuum Breakers
1012 – 2002	Backflow Preventer with Intermediate Atmospheric Vent
1013 – 1999	Reduced Pressure Principle Backflow Preventers and Reduced Pressure Principle Fire Protection Backflow Preventers
1014 – 1989	Handheld Showers
1015 – 1999	Double Check Backflow Prevention Assemblies and Double Check Fire Protection Backflow Prevention Assemblies
1016 – 1996	Individual Thermostatic, Pressure Balancing and Combination Pressure Balancing and Thermostatic Control Valves for Individual Fixture Fittings
1017 – 2003	Temperature Actuated Mixing Valves for Hot Water Distribution Systems
1019 – 1997	Vacuum Breaker Wall Hydrants, Freeze Resistant, Automatic Draining Type
1020 – 1998	Vacuum Breakers, Anti-siphon, Pressure Type
1021 – 2001	Drain Air Gaps for Domestic Dishwashers
1022 – 2003	Backflow Preventer for Carbonated Beverage Dispensing Equipment
1023 – 1979	Plumbing Requirements for Hot Water Dispensers, Household Storage Type, Electrical
1024 – 2003	Dual Check Valve Type Backflow Preventers—Revised 1994
1025 – 1978	Diverters for Plumbing Faucets with Hose Spray, Anti-Siphon Type, Residential Applications
1032 – 1980	Dual Check Valve Type Backflow Preventer for Carbonated Beverage Dispensers –Post Mix Type
1035 – 2002	Laboratory Faucet Backflow Preventers
1037 – 1990	Pressurized Flushing Devices for Plumbing Fixtures
1043 – 1992	Cast Iron Sovent Sanitary Drainage Systems
1044 – 2002	Trap Seal Primer Devices—Drainage Types and Electric Design Types
1047 – 1999	Reduced Pressure Detector Fire Protection Backflow Prevention Assemblies
1048 – 1999	Double Check Detector Fire Protection Backflow Prevention Assemblies
1050 – 2002	Air Admittance Valves for DWV Systems, Stack Type Device
1051 – 2002	Air Admittance Valves for Plumbing Drainage Systems
1052 – 1994	Hose Connection Backflow Preventers
1055 – 1997	Chemical Dispensing Systems
1056 – 2001	Spill Resistant Vacuum Breakers
1057 – 2001	Freeze Resistant Sanitary Yard Hydrants with Backflow Protection
1060 – 1996	Outdoor Enclosures for Backflow Prevention Assemblies
1062 – 1997	Temperature Actuated, Flow Reduction (TAFR) Valves for Individual Fixture Fittings
1064 – 2002	Backflow Prevention Assembly Field Test Kits
1066 – 1997	Individual Pressure Balancing in-Line Valves for Individual Fixture Fittings

ASTM

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A 53/A 53M-02	Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated Welded and Seamless
A 74-03b	Specification for Cast Iron Soil Pipe and Fittings
A 106-02a	Specification for Seamless Carbon Steel Pipe for High-Temperature Service
A 126-01	Specification for Gray Iron Castings for Valves, Flanges, and Pipe Fittings
A 254-97(2002)	Specification for Copper-Brazed Steel Tubing
A 312/A 312M-03	Specification for Seamless and Welded Austenitic Stainless Steel Pipes
A 420/A 420M-03	Specification for Piping Fittings of Wrought Carbon Steel and Alloy Steel for Low-Temperature Service
A 539-99	Specification for Electric-Resistance-Welded Coiled Steel Tubing for Gas and Fuel Oil Lines

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Table 2-2 Complete List of Standards By Standard-Writing Organization (continuted)

A 733-03	Specification for Welded and Seamless Carbon Steel and Austenitic Stainless Steel Pipe Nipples
A 778-01	Specification for Welded, Unannealed Austenitic Stainless Steel Tubular Products
A 888-03	Specification for Hubless Cast Iron Soil Pipe and Fittings for Sanitary and Storm Drain, Waste and Vent Piping Applications
B 32-03	Specification for Solder Metal
B 42-02e1	Specification for Seamless Copper Pipe, Standard Sizes
B 43-98e1	Specification for Seamless Red Brass Pipe, Standard Sizes
B 68-02	Specification for Seamless Copper Tube, Bright Annealed
B 75-02	Specification for Seamless Copper Tube
B 88-03	Specification for Seamless Copper Water Tube
B 135-02	Specification for Seamless Brass Tube
B 152/B 152M-00	Specification for Copper Sheet, Strip, Plate and Rolled Bar
B 210-02	Specification for Aluminum and Aluminum-Alloy Drawn Seamless Tubes
B 211-03	Specification for Aluminum and Aluminum-Alloy Bar, Rod and Wire
B 241/B 241M-02	Specification for Aluminum and Aluminum-Alloy Seamless Pipe and Seamless Extruded Tube
B 251-02e1	Specification for General Requirements for Wrought Seamless Copper and Copper-Alloy Tube
B 280-03	Specification for Seamless Copper Tube for Air Conditioning and Refrigeration Field Service
B 302-02	Specification for Threadless Copper Pipe, Standard Sizes
B 306-02	Specification for Copper Drainage Tube (DWV)
B 447-02	Specification for Welded Copper Tube
B 687-99	Specification for Brass, Copper, and Chromium-Plated Pipe Nipples
B 813-00e01	Specification for Liquid and Paste Fluxes for Soldering of Copper and Copper Alloy Tube
B 828-02	Practice for Making Capillary Joints by Soldering of Copper and Copper Alloy Tube and Fittings
C 4-03	Specification for Clay Drain Tile and Perforated Clay Drain Tile
C 14-03	Specification for Concrete Sewer, Storm Drain, and Culvert Pipe
C 76-03	Specification for Reinforced Concrete Culvert, Storm Drain, and Sewer Pipe
C 296-00	Specification for Asbestos-Cement Pressure Pipe
C 411-97	Test Method for Hot-Surface Performance of High-Temperature Thermal Insulation
C 425-02	Specification for Compression Joints for Vitrified Clay Pipe and Fittings
C 428-97(2002)	Specification for Asbestos-Cement Nonpressure Sewer Pipe
C 443-02a	Specification for Joints for Concrete Pipe and Manholes, Using Rubber Gaskets
C 508-00	Specification for Asbestos-Cement Underdrain Pipe
C 564-03	Specification for Rubber Gaskets for Cast Iron Soil Pipe and Fittings
C 700-02	Specification for Vitrified Clay Pipe, Extra Strength, Standard Strength, and Perforated
C 913-98	Specification for Precast Concrete Water and Waste Water Structures
C 1053-00	Specification for Borosilicate Glass Pipe and Fittings for Drain, Waste, and Vent (DWV) Applications
C 1173-02	Specification for Flexible Transition Couplings for Underground Piping Systems
C 1277-03	Specification for Shielded Coupling Joining Hubless Cast Iron Soil Pipe and Fittings
C 1440-99e1	Specification for Thermoplastic Elastomeric (TPE) Gasket Materials for Drain, Waste, and Vent (DWV), Sewer, Sanitary and Storm Plumbing Systems
C 1460-00	Specification for Shielded Transition Couplings for Use with Dissimilar DWV Pipe and Fittings Above Ground
C 1461-02	Specification for Mechanical Couplings Using Thermoplastic Elastomeric (TPE) Gaskets for Joining Drain, Waste, and Vent (DWV) Sewer, Sanitary and Storm Plumbing Systems for Above and Below Ground Use
D 1527-99	Specification for Acrylonitrile-Butadiene-Styrene (ABS) Plastic Pipe, Schedules 40 and 80
D 1785-99	Specification for Poly (Vinyl Chloride) (PVC) Plastic Pipe, Schedules 40, 80 and 120
D 1869-95(2000)	Specification for Rubber Rings for Asbestos-Cement Pipe
D 2235-01	Specification for Solvent Cement for Acrylonitrile-Butadiene-Styrene (ABS) Plastic Pipe and Fittings
D 2239-03	Specification for Polyethylene (PE) Plastic Pipe (SIDR-PR) Based on Controlled Inside Diameter
D 2241-00	Specification for Poly (Vinyl Chloride) (PVC) Pressure-Rated Pipe (SDR-Series)
D 2282-99	Specification for Acrylonitrile-Butadiene-Styrene (ABS) Plastic Pipe (SDR-PR)

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Table 2-2 Complete List of Standards By Standard-Writing Organization (continuted)

D 2447-03	Specification for Polyethylene (PE) Plastic Pipe, Schedules 40 and 80, Based on Outside Diameter
D 2464-99	Specification for Threaded Poly (Vinyl Chloride) (PVC) Plastic Pipe Fittings, Schedule 80
D 2466-02	Specification for Poly (Vinyl Chloride) (PVC) Plastic Pipe Fittings, Schedule 40
D 2467-02	Specification for Poly (Vinyl Chloride) (PVC) Plastic Pipe Fittings, Schedule 80
D 2468-96a	Specification for Acrylonitrile-Butadiene-Styrene (ABS) Plastic Pipe Fittings, Schedule 40
D 2513-01A	Specification for Thermoplastic Gas Pressure Pipe, Tubing, and Fittings
D 2564-02	Specification for Solvent Cements for Poly (Vinyl Chloride) (PVC) Plastic Piping Systems
D 2609-02	Specification for Plastic Insert Fittings for Polyethylene (PE) Plastic Pipe
D 2657-03	Standard Practice for Heat Fusion Joining of Polyolefin Pipe and Fittings
D 2661-02	Specification for Acrylonitrile-Butadiene-Styrene (ABS) Schedule 40 Plastic Drain, Waste, and Vent Pipe and Fittings
D 2662-96a	Specification for Polybutylene (PB) Plastic Pipe (SDR-PR) Based on Controlled Inside Diameter
D 2665-02ae1	Specification for Poly (Vinyl Chloride) (PVC) Plastic Drain, Waste, and Vent Pipe and Fittings
D 2666-96a(2003)	Specification for Polybutylene (PB) Plastic Tubing
D 2672-96a(2003)	Specification for Joints for IPS PVC Pipe Using Solvent Cement
D 2683-98	Specification for Socket-Type Polyethylene Fittings for Outside Diameter-Controlled Polyethylene Pipe and Tubing
D 2729-96a	Specification for Poly (Vinyl Chloride) (PVC) Sewer Pipe and Fittings
D 2737-03	Specification for Polyethylene (PE) Plastic Tubing
D 2751-96a	Specification for Acrylonitrile-Butadiene-Styrene (ABS) Sewer Pipe and Fittings
D 2846/D 2846M-99	Specification for Chlorinated Poly (Vinyl Chloride) (CPVC) Plastic Hot and Cold Water Distribution Systems
D 2855-96(2002)	Standard Practice for Making Solvent-Cemented Joints with Poly (Vinyl Chloride) (PVC) Pipe and Fittings
D 2949-01a	Specification for 3.25-In Outside Diameter Poly (Vinyl Chloride) (PVC) Plastic Drain, Waste, and Vent Pipe and Fittings
D 2996-01	Specification for Filament-Wound "Fiberglass" (Glass Fiber Reinforced Thermosetting-Resin) Pipe
D 3034-00	Specification for Type PSM Poly (Vinyl Chloride) (PVC) Sewer Pipe and Fittings
D 3035-01	Specification for Polyethylene (PE) Plastic Pipe (DR-PR) Based on Controlled Outside Diameter
D 3139-98	Specification for Joints for Plastic Pressure Pipes Using Flexible Elastomeric Seals
D 3212-96a(2003)	Specification for Joints for Drain and Sewer Plastic Pipes Using Flexible Elastomeric Seals
D 3309-96a(2002)	Specification for Polybutylene (PB) Plastic Hot and Cold Water Distribution Systems
D 3311-02	Specification for Drain, Waste and Vent (DWV) Plastic Fittings Patterns
D 3350-02a	Specification for Polyethylene Plastics Pipe and Fittings Materials
D 4068-01	Specification for Chlorinated Polyethylene (CPE) Sheeting for Concealed Water-Containment Membrane
D 4551-96(2001)	Specification for Poly (Vinyl Chloride) (PVC) Plastic Flexible Concealed Water-Containment Membrane
E 84-03b	Test Method for Surface Burning Characteristics of Building Materials
E 119-00a	Test Method for Fire Tests of Building Construction and Materials
E 136-99e01	Test Method for Behavior of Materials in a Vertical Tube Furnace at 750°C
E 814-02	Test Method for Fire Tests of Through-Penetration Fire Stops
F 405-97	Specification for Corrugated Polyethylene (PE) Tubing and Fittings
F 409-02	Specification for Thermoplastic Accessible and Replaceable Plastic Tube and Tubular Fittings
F 437-99	Specification for Threaded Chlorinated Poly (Vinyl Chloride) (CPVC) Plastic Pipe Fittings, Schedule 80
F 438-02e1	Specification for Socket-Type Chlorinated Poly (Vinyl Chloride) (CPVC) Plastic Pipe Fittings, Schedule 40
F 439-02e1	Specification for Socket-Type Chlorinated Poly (Vinyl Chloride) (CPVC) Plastic Pipe Fittings, Schedule 80
F 441/F 441M-02	Specification for Chlorinated Poly (Vinyl Chloride) (CPVC) Plastic Pipe, Schedules 40 and 80
F 442/F 442M-99	Specification for Chlorinated Poly (Vinyl Chloride) (CPVC) Plastic Pipe (SDR-PR)
F 477-02e1	Specification for Elastomeric Seals (Gaskets) for Joining Plastic Pipe

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Table 2-2 Complete List of Standards By Standard-Writing Organization (continuted)

F 493-97	Specification for Solvent Cements for Chlorinated Poly (Vinyl Chloride) (CPVC) Plastic Pipe and Fittings
F 628-01	Specification for Acrylonitrile-Butadiene-Styrene (ABS) Schedule 40 Plastic Drain, Waste, and Vent Pipe with a Cellular Core
F 656-02	Specification for Primers for Use in Solvent Cement Joints of Poly (Vinyl Chloride) (PVC) Plastic Pipe and Fittings
F 714-03	Specification for Polyethylene (PE) Plastic Pipe (SDR-PR) Based on Outside Diameter
F 876-03a	Specification for Cross-Linked Polyethylene (PEX) Tubing
F 877-02e	Specification for Cross-Linked Polyethylene (PEX) Plastic Hot and Cold Water Distribution Systems
F 891-00e1	Specification for Coextruded Poly (Vinyl Chloride) (PVC) Plastic Pipe with a Cellular Core
F 1055-98e1	Specification for Electrofusion Type Polyethylene Fittings for Outside Diameter Controlled Polyethylene Pipe and Tubing
F 1281-03	Specification for Cross-Linked Polyethylene/Aluminum/Cross-linked Polyethylene (PEX-AL-PEX) Pressure Pipe
F 1282-03	Specification for Polyethylene/Aluminum/Polyethylene (PE-AL-PE) Composite Pressure Pipe
F 1488-03	Specification for Coextruded Composite Pipe
F 1807-03	Specification for Metal Insert Fittings Utilizing a Copper Crimp Ring for SDR9 Cross-Linked Polyethylene (PEX) Tubing
F 1866-98	Specification for Poly (Vinyl Chloride) (PVC) Plastic Schedule 40 Drainage and DWV Fabricated Fittings
F 1960-03	Specification for Cold Expansion Fittings with PEX Reinforcing Rings for use with Cross-Linked Polyethylene (PEX) Tubing
F 1974-02	Specification for Metal Insert Fittings for Polyethylene/Aluminum/Polyethylene and Cross-Linked Polyethylene/Aluminum/Cross-Linked Polyethylene Composite Pressure Pipe
F 2080-02	Specifications for Cold-Expansion Fittings with Metal Compression-Sleeves for Cross-Linked Polyethylene (PEX) Pipe

AWS

American Welding Society
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A5.8-92	Specifications for Filler Metals for Brazing and Braze Welding

AWWA

American Water Works Association
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Denver, CO 80235

www.awwa.org
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(303) 347-0804 facsimile

C104-95	Standard for Cement-Mortar Lining for Ductile-Iron Pipe and Fittings for Water
C110-98	Standard for Ductile-Iron and Gray-Iron Fittings, 3 Inches Through 48 Inches, for Water
C111-00	Standard for Rubber-Gasket Joints for Ductile-Iron Pressure Pipe and Fittings
C115-99	Standard for Flanged Ductile-Iron Pipe with Ductile-Iron or Gray-Iron Threaded Flanges
C151/A21.51-902	Standard for Ductile-Iron Pipe, Centrifugally Cast for Water
C153-00	Standard for Ductile-Iron Compact Fittings, 3 in. Through 24 in. and 54 in. Through 64 in. for Water Service
C510-97	Double Check Valve Backflow Prevention Assembly
C511-97	Reduced-Pressure Principle Backflow Prevention Assembly
C651-99	Disinfecting Water Mains
C652-02	Disinfection of Water-Storage Facilities

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Table 2-2 Complete List of Standards By Standard-Writing Organization (continued)

CISPI	**Cast Iron Soil Pipe Institute** 5959 Shallowford Road, Suite 419 Chattanooga, TN 37421 www.cispi.org (423) 892-0137 (423) 892-0817 facsimile
301-00	Specification for Hubless Cast Iron Soil Pipe and Fittings for Sanitary and Storm Drain, Waste and Vent Piping Applications
310-97	Specification for Coupling for Use in Connection with Hubless Cast Iron Soil Pipe and Fittings for Sanitary and Storm Drain, Waste and Vent Piping Applications
CGA	**Compressed Gas Association** 4221 Walney Rd., 5th Floor Chantilly, VA 20151-2923 www.cganet.com (703) 788-2700 (703) 961-1831 facsimile
S-1.1-(1994)	Pressure Relief Device Standards-Part 1-Cylinders for Compressed Gases
S-1.2-(1995)	Pressure Relief Device Standards-Part 2-Cargo and Portable Tanks for Compressed Gases
S-1.3-(1995)	Pressure Relief Device Standards-Part 3-Stationary Storage Containers for Compressed Gases
CSA	**Canadian Standards Association** 178 Rexdale Blvd. Toronto, Ontario, Canada M9W 1R3 www.csa-international.org (416) 747-4000 or 866-797-4272 (416) 747-4149 facsimile
B45.1-02	Ceramic Plumbing Fixtures
B45.2-02	Enameled Cast-Iron Plumbing Fixtures
B45.3-02	Porcelain Enameled Steel Plumbing Fixtures
B45.4-02	Stainless-Steel Plumbing Fixtures
B45.5-02	Plastic Plumbing Fixtures
B45.9-02	Macerating Systems and Related Components
B45.10-01	Hydromassage Bathtubs
B64.7-01	Vacuum Breakers, Laboratory Faucet Type (LFVB)
B79-94(2000)	Floor, Area and Shower Drains, and Cleanouts for Residential Construction
B125-01	Plumbing Fittings
B137.1-02	Polyethylene Pipe, Tubing and Fittings for Cold Water Pressure Services
B137.2-02	PVC Injection-Moulded Gasketed Fittings for Pressure Applications
B137.3-02	Rigid Poly (Vinyl Chloride) (PVC) Pipe for Pressure Applications
B137.5-02	Cross-Linked Polyethylene (PEX) Tubing Systems for Pressure Applications—with Revisions Through September 1992
B137.6-02	CPVC Pipe, Tubing and Fittings for Hot and Cold Water Distribution Systems—with Revisions Through May 1986
B137.8-99	Polybutylene (PB) Piping for Pressure Applications
B181.1-99	ABS Drain, Waste, and Vent Pipe and Pipe Fittings
B181.2-99	PVC Drain, Waste, and Vent Pipe and Pipe Fittings—with Revisions Through December 1993
B182.1-02	Plastic Drain and Sewer Pipe and Pipe Fittings
B182.2-02	PVC Sewer Pipe and Fittings (PSM Type)
CAN3-B137.8M-99	Polybutylene (PB) Piping for Pressure Applications—with Revisions through July 1992
CAN/CSA-A257.1M-92	Circular Concrete Culvert, Storm Drain, Sewer Pipe and Fittings
CAN/CSA-A257.2M-92	Reinforced Circular Concrete Culvert, Storm Drain, Sewer Pipe and Fittings

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Table 2-2 Complete List of Standards By Standard-Writing Organization (continuted)

CAN/CSA-A257.3M0-92	Joints for Circular Concrete Sewer and Culvert Pipe, Manhole Sections, and Fittings Using Rubber Gaskets
CAN/CSA-B64.1.1-01	Vacuum Breakers, Atmospheric Type (AVB)
CAN/CSA-B64.2-01	Vacuum Breakers, Hose Connection Type (HCVB) 608.13.6
CAN/CSA-B64.2.2-01	Vacuum Breakers, Hose Connection Type (HCVB) with Automatic Draining Feature
CAN/CSA-B64.3-01	Backflow Preventers, Dual Check Valve Type with Atmospheric Port (DCAP)
CAN/CSA-B64.4-01	Backflow Preventers, Reduced Pressure Principle Type (RP)
CAN/CSA-B64.10-01	Manual for the Selection, Installation, Maintenance and Field Testing of Backflow Prevention Devices
CAN/CSA-B137.1-99	Polyethylene Piping (PE), Tubing, and Fittings for Cold-Water Pressure Services
CAN/CSA-B137.3-99	Rigid Polyvinyl Chloride (PVC) Pipe for Pressure Applications
CAN/CSA-B137.5-99	Cross-Linked Polyethylene (PEX) Tubing Systems for Pressure Applications
CAN/CSA-B137.9-02	Polyethylene/Aluminum/Polyethylene Composite Pressure Pipe Systems
CAN/CSA-B137.10M-02	Cross-linked Polyethylene/Aluminum/Polyethylene Composite Pressure Pipe Systems
CAN/CSA-B181.2-99	PVC Drain, Waste, and Vent Pipe and Pipe Fittings
CAN/CSA-B181.3-02	Polyolefin Laboratory Drainage Systems
CAN/CSA-B182.4-02	Profile PVC Sewer Pipe and Fittings
CAN/CSA-B602-02	Mechanical Couplings for Drain, Waste, and Vent Pipe and Sewer Pipe

DOTn

Department of Transportation
400 Seventh St. SW
Washington, DC 20590

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(202) 366-4000

49 CFR	Parts 192.281(e) & 192.283 (b) Transportation of Natural and Other Gas by Pipeline: Minimum Federal Safety Standards Parts 100-180 Hazardous Materials Regulations

FS*

Federal Specification
1941 Jefferson Davis Highway, Suite 104
Arlington, VA 22202

* Standards are available from the Supt. of Documents, U.S. Government Printing Office, Washington, DC 20402-9325

TT-P-1536A(1975)	Federal Specification for Plumbing Fixture Setting Compound
WW-P-325B (1976)	Pipe, Bends, Traps, Caps and Plugs; Lead (for Industrial Pressure and Soil and Waste Applications)

IAPMO

International Association of Plumbing and Mechanical Officials
5001 E. Philadelphia St.
Ontario, CA 91761-2816

www.iapmo.org
909-472-4100
909-472-4150 facsimile

UMC-03	Uniform Mechanical Code
UPC-03	Uniform Plumbing Code
USEC-00	Uniform Solar Energy Code
USPC-00	Uniform Swimming Pool, Spa and Hot Tub Code

(CONTINUED)

Table 2-2 Complete List of Standards By Standard-Writing Organization (continued)

ICC	**International Code Council** 5203 Leesburg Pike, Suite 600 Falls Church, VA 22041 www.iccsafe.org 703-931-4533 703-379-1546 facsimile
IBC-03	International Building Code
ICC EC-03	ICC Electrical Code
IEBC-03	International Existing Building Code
IECC-03	International Energy Conservation Code
IFC-03	International Fire Code
IFGC-03	International Fuel Gas Code
IMC-03	International Mechanical Code
IPC-03	International Plumbing Code
IPSDC-03	International Private Sewage Disposal Code
IRC-03	International Residential Code
ISEA	**Industry Safety Equipment Association** 1901 N. Moore Street, Suite 808 Arlington, VA 22209-1762 www.safetyequipment.org (703) 525-1695 (703) 528-2148 facsimile
Z358.1-2004	Emergency Eyewash and Shower Equipment
MSS	**Manufacturers Standardization Society of the Valve & Fittings Industry, Inc.** 127 Park Street, N.E. Vienna, VA 22180 www.mss-hq.com (703) 281-6613 (703) 281-6671 facsimile
SP-6-2001	Standard Finishes for Contact Faces of Pipe Flanges and Connecting-End Flanges of Valves and Fittings
SP-58-2002	Pipe Hangers and Supports—Materials, Design and Manufacture
SP-69-2002	Pipe Hangers and Supports-Selection and Application
SP-70-1998	Cast Iron Gate Valves, Flanged and Threaded Ends
SP-72-1999	Ball Valves with Flanged or Butt-Welding Ends for General Service
SP-80-2003	Bronze Gate, Globe, Angle and Check Valves
NFPA	**National Fire Protection Association** 1 Batterymarch Park Quincy, MA 02269 www.nfpa.org (617) 770-3000 (617) 770-0700 facsimile
1-03 Uniform Fire Code	
13-02	Installation of Sprinkler Systems
13D-02	Installation of Sprinkler Systems in One- and Two-Family Dwellings and Manufactured Homes
13R-02	Installation of Sprinkler Systems in Residential Occupancies up to and Including 4 Stories in Height
14-03	Installation of Standpipe, Private Hydrants and Hose Systems
20-99	Installation of Stationary Pumps for Fire Protection

(CONTINUED)

Table 2-2 Complete List of Standards By Standard-Writing Organization (continuted)

24-02	Installation of Private Fire Service Mains and Their Appurtenances
25-02	Inspection, Testing and Maintenance of Water-Based Fire Protection Systems
30-03	Flammable and Combustible Liquids Code
31-01	Installation of Oil-Burning Equipment
37-02	Stationary Combustion Engines and Gas Turbines
45-00	Fire Protection for Laboratories Using Chemicals
50-01	Bulk Oxygen Systems at Consumer Sites
50A-99	Gaseous Hydrogen Systems at Consumer Sites
51-02	Design and Installation of Oxygen-Fuel Gas Systems for Welding, Cutting, and Allied Processes
54-02	National Fuel Gas Code
58-01	Liquefied Petroleum Gas Code
69-02	Explosion Prevention Systems
70-02	National Electrical Code
72-02	National Fire Alarm Code
85-01	Boiler and Construction Systems Hazards Code
88B-97	Repair Garages
96-01	Ventilation Control and Fire Protection of Commercial Cooking Operations
99-02	Standard for Health Care Facilities
101-03	Life Safety Code
211-03	Chimneys, Fireplaces, Vents, and Solid Fuel-Burning Appliances
704-01	Identification of the Hazards of Materials for Emergency Response
853-00	Installation of Stationary Fuel Cell Power Plants
5000-03	Building Construction and Safety Code
8501-01	Single Burner Boiler Operation
8502-99	Prevention of Furnace Explosions/Implosions in Multiple Burner Boiler-Furnaces
8504-96	Atmospheric Fluidized-Bed Boiler Operation

NSF

National Sanitation Foundation
789 N. Dixboro Road
P.O. Box 130140
Ann Arbor, MI 48113-0140

www.nsf.org
800-NSF-Mark
(734) 769-0109 facsimile

3-2003	Commercial Warewashing Equipment
14-2003	Plastic Piping System Components and Related Materials
18-1996	Manual Food and Beverage Dispensing Equipment
40-2000	Residential Wastewater Treatment Systems
41-1999	Non-Liquid Saturated Treatment Systems (Composting Toilets)
42-2002	Drinking Water Treatment Units—Aesthetic Effects
44-2002	Residential Cation Exchange Water Softeners
53-2002	Drinking Water Treatment Units—Health Effects
58-2002	Reverse Osmosis Drinking Water Treatment Systems
61-2002	Drinking Water System Components—Health Effects
62-2002	Drinking Water Distillation Systems

PDI

Plumbing and Drainage Institute
800 Turnpike Street, Suite 300
North Andover, MA 01845

www.pdionline.org
(978) 557-0720
(978) 557-0721 facsimile

(CONTINUED)

Table 2-2 Complete List of Standards By Standard-Writing Organization (continuted)

G101-2003	Testing and Rating Procedure for Grease Interceptors with Appendix of Sizing and Installation Data
WH201-1994	Water Hammer Arresters

PHCC-NA

Plumbing Heating and Cooling Contractors National Association
180 S. Washington St.
P.O. Box 6808
Falls Church, VA 22040

www.phccweb.org
(800) 533-7694
(703) 237-7442 facsimile

NSPC-03	National Standard Plumbing Code

UL

Underwriters Laboratories, Inc.
333 Pfingsten Road
Northbrook, IL 60062-2096

www.ul.com
(847) 272-8800
(847) 272-8129 facsimile

17-94	Vent or Chimney Connector Dampers for Oil-Fired Appliances—with Revisions Through September 1998
70-96	Septic Tanks, Bituminous Coated Metal
103-98	Factory-Built Chimneys, Residential Type and Building Heating Appliance—with Revisions Through March 1999
127-96	Factory-Built Fireplaces—with Revisions Through November 1999
174-98	Household Electric Storage Tank Water Heaters—with Revisions Through October 1999
343-97	Pumps for Oil-Burning Appliances--with Revisions Through December 22, 1999
391-95	Solid-Fuel and Combination-Fuel Central and Supplementary Furnaces—with Revisions Through May 1999
441-96	Gas Vents – With Revisions Through April 1999
536-97	Flexible metallic Hose—with Revisions Through October 2000
641-95	Type L Low-Temperature Venting Systems—with Revisions Through April 1999
710-95	Exhaust Hoods for Commercial Cooking Equipment— with Revisions Through April 1999
726-95	Oil-Fired Boiler Assemblies—with Revisions Through January 1999
727-94	Oil-Fired Central Furnaces—with Revisions Through January 1999
729-98	Oil-Fired Floor Furnaces—with Revisions Through January 1999
730-98	Oil-Fired Wall Furnaces—with Revisions Through January 1999
731-95	Oil-Fired Unit Heaters—with Revisions Through January 1999
732-95	Oil-Fired Storage Tank Water Heaters—With Revisions Through January 1999
834-98	Heating, Water Supply and Power Boilers Electric—with Revisions Through November 1998
896-93	Oil-Burning Stoves—with Revisions Through November 1999
959-01	Medium Heat Appliance Factory-Built Chimneys
1261-96	Electric Water Heaters for Pools and Tubs—with Revisions Through November 25, 1998
1453-95	Electronic Booster and Commercial Storage Tank Water Heaters—with Revisions Through September 1998
1738-93	Venting Systems for Gas Burning Appliances, Categories II, III and IV—with Revisions Through December 2000
1820-97	Fire Test of Pneumatic Tubing for Flame and Smoke Characteristics—with Revisions Through March 1999
1887-96	Fire Tests of Plastic Sprinkler Pipe for Visible Flame and Smoke Characteristics—with Revisions through June 1999

(CONTINUED)

Table 2-3 Organization Abbreviation, Address, and Phone Number Listing

ANSI
American National Standards Institute
25 West 43rd Street, Fourth Floor
New York, NY 10036
www.ansi.org
(212) 642-4900
(212) 398-0023 facsimile

ARI
Air-Conditioning & Refrigeration Institute
4100 North Fairfax Drive, Suite 200
Arlington, VA 22203
www.ari.org
(703) 524-8800
(703) 528-3816 facsimile

ASHRAE
American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.
1791 Tullie Circle, NE
Atlanta, GA 30329-2305
www.ashrae.org
(404) 636-8400
(404) 321-5478 facsimile

ASME
American Society of Mechanical Engineers
Three Park Avenue
New York, NY 10016-5990
www.asme.org
800-THE-ASME (843-2763)
(973) 882-1717 facsimile (Inquiries)
(212) 591-7674 facsimile (NY)

ASSE
American Society of Sanitary Engineering
901 Canterbury Road, Suite A
Westlake, OH 44145
www.asse-plumbing.org
(440) 835-3040
(440) 835-3488 facsimile

ASTM
ASTM International
100 Barr Harbor Drive
P.O. Box C700
West Conshohocken, PA 19428-2959
www.astm.org
(610) 832-9585
(610) 832-9555 facsimile

AWS
American Welding Society
550 N.W. LeJeune Road
Miami, FL 33126
www.aws.org
(800) 443-9353
(305) 443-5951 facsimile

AWWA
American Water Works Association
6666 West Quincy Avenue
Denver, CO 80235
www.awwa.org
(800) 926-7337
(303) 347-0804 facsimile

CISPI
Cast Iron Soil Pipe Institute
5959 Shallowford Road, Suite 419
Chattanooga, TN 37421
www.cispi.org
(423) 892-0137
(423) 892-0817 facsimile

CGA
Compressed Gas Association
4221 Walney Rd., 5th Floor
Chantilly, VA 20151-2923
www.cganet.com
(703) 788-2700
(703) 961-1831 facsimile

CSA
Canadian Standards Association
178 Rexdale Blvd.
Toronto, Ontario, Canada M9W 1R3
www.csa-international.org
(416) 747-4000 or 866-797-4272
(416) 747-4149 facsimile

DOTn
Department of Transportation
400 Seventh St. SW
Washington, DC 20590
www.dot.gov
(202) 366-4000

FS*
Federal Specification
1941 Jefferson Davis Highway, Suite 104
Arlington, VA 22202
* Standards are available from the Supt. of Documents, U.S. Government Printing Office, Washington, DC 20402-9325

IAPMO
International Association of Plumbing and Mechanical Officials
5001 E. Philadelphia St.
Ontario, CA 91761-2816
www.iapmo.org
909-472-4100
909-472-4150 facsimile

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ICC
International Code Council
5203 Leesburg Pike, Suite 600
Falls Church, VA 22041
www.iccsafe.org
703-931-4533
703-379-1546 facsimile

ISEA
Industry Safety Equipment Association
1901 N. Moore Street, Suite 808
Arlington, VA 22209-1762
www.safetyequipment.org
(703) 525-1695
(703) 528-2148 facsimile

MSS
Manufacturers Standardization
Society of the Valve & Fittings Industry, Inc.
127 Park Street, N.E.
Vienna, VA 22180
www.mss-hq.com
(703) 281-6613
(703) 281-6671 facsimile

NFPA
National Fire Protection Association
1 Batterymarch Park
Quincy, MA 02269
www.nfpa.org
(617) 770-3000
(617) 770-0700 facsimile

NSF
National Sanitation Foundation
789 N. Dixboro Road
P.O. Box 130140
Ann Arbor, MI 48113-0140
www.nsf.org
800-NSF-Mark
(734) 769-0109 facsimile

PDI
Plumbing and Drainage Institute
800 Turnpike Street, Suite 300
North Andover, MA 01845
www.pdionline.org
(978) 557-0720
(978) 557-0721 facsimile

PHCC-NA
Plumbing Heating and Cooling
Contractors National Association
180 S. Washington St.
P.O. Box 6808
Falls Church, VA 22040
www.phccweb.org
(800) 533-7694
(703) 237-7442 facsimile

UL
Underwriters Laboratories, Inc.
333 Pfingsten Road
Northbrook, IL 60062-2096
www.ul.com
(847) 272-8800
(847) 272-8129 facsimile

3 Specifications

INTRODUCTION

Plumbing drawings, plumbing specifications, general conditions, special conditions, and the addenda comprise the contract documents that make up the contract between the owner and the contractor. None of these items can stand alone: the drawings cannot serve as a contract without the specifications and vice versa. The plumbing designer must, therefore, be familiar with specification writing. If others prepare the specifications, then the plumbing designer must be able to coordinate the drawings with the project specifications.

When writing specifications, the plumbing designer must use clear, precise, and exact language in order to convey to the reader the information required. The essence of a well-written specification is clarity, brevity, correctness, and completeness.

Specification writers should follow established, uniform practices that will ensure good communication between the designer and all other segments of the construction industry. The result will be a set of documents that allow an engineer in one part of the country to converse with a supplier or contractor in another location, and the specifications contain the same language and meanings for all parties.

CONSTRUCTION CONTRACT DOCUMENTS

The Construction Specifications Institute (CSI) developed and implemented a set of documents known as the Manual of Practice that has been used nationwide for about 40 years.

This Manual is intended to provide an ordered, logical, simple, and flexible format for the specification writer to use in the preparation of specifications. One of the principles of this format, which is known as Masterformat, is to establish a standard location where only specific information is stated. This location lets the reader retrieve the information required in the least amount of time. It is essential that the plumbing specification writer be familiar with and understands all the components that constitute the Manual of Practice in order to write clear, concise specifications. The components discussed in this chapter are Uniformat, Masterformat, and Sectionformat.

DEFINITION OF TERMS

It is necessary to define some terms used in the construction contract documents so that one term, and only that one term, is used for any one part of the documents.

Bidder – The bidding and subsequent awarding of the contract.

Contractor – The successful bidder after the awarding of the contract.

Bidding documents – Construction documents issued to bidders before the owner/contractor agreement has been signed.

Bidding requirements – The explanation of procedures to follow when preparing and submitting the bid. This is also used to attract potential bidders.

Contract documents – Documents that are the legally enforceable requirements that become part of the contract when the agreement is signed.

Project manual – Bidding requirements combined with the other construction documents. These are not part of the contract documents.

Work – The performing of services, the furnishing of labor, and supplying and incorporating of materials and equipment into the construction.

Construction contract documents – The proposed construction which is referred to as the "*work.*" Many times these documents are referred to as the "*contract documents*" and erroneously, as the "plans and specifications." It should be noted that many times in these documents are neither plans nor specifications. Instead of the use of the term "plans" when referring to the graphic documents, the term "drawings" should be used. Many times the term "specifications" is expanded to generally refer to all written docu-

ments. The correct term when describing all of the documents, with the exception of the drawings, is "project manual."

PROJECT MANUAL

The project manual is an accurate and descriptive term to describe the collection of documents other than the drawings. This manual consists of the following documents:

1. *Pre-bid Information* advises those prospective bidders about the proposed project. Private work going out for bid is usually advertised to the bidders by mail or by telephone. The Architect, Engineer, or the Owner invites these bidders, and bidding is restricted to those bidders invited. This method is usually referred to as "*Bid by Invitation.*" Pre-bid information for public work is required by law to be advertised in all newspapers of general subscription in the immediate area where the work is to be bid. These public notices, which are governed by local ordinances, are published for a predetermined period of time.
2. *Instructions to Bidders* are written to inform the prospective bidders how to prepare their bid so that all bids are in the same format and can be easily and fairly compared after the bid opening.
3. *Bid Forms* are prepared by the Architect/Engineer to provide uniform bid submittals by the bidders and to facilitate the comparison and evaluation of the bids received.
4. *Bonds and Certificates* are the legal documents that bind a third party into the contract as a surety that the bidder and the owner will perform as agreed. This could also be used to insure that the contractor and subcontractors will perform as agreed. The types of bonds commonly used are:
   (a) *Bid Bond* – Assures that the bidder will enter into a contract with the owner or the contractor if the bidder is selected during the bidding phase;
   (b) *Performance Bond* – Assures that the work, once a contract has been signed, will be completed in compliance with the contract documents;
   (c) *Labor and Materials Payment Bond* – Assures that workers on this project will be paid in full, and that all suppliers that have provided materials for the project will be paid in full prior to the project closeout;
   (d) *Guaranty Bond* – Guarantees that the contractor will be paid in full for all work performed to construct the project;
   (e) *Certificates* – Certificates of insurance, or proof of insurance from the contractors and/or subcontractors, as well as certificates of compliance with applicable codes, laws, and regulations.
5. The *Agreement* is the written document signed by the owner and the contractor, or by the contractor and a subcontractor or a material supplier, that is the legal instrument binding these parties to the contract. The agreement defines the relationships as well as the obligations between the signing parties.
6. *General Conditions* are the general clauses that establish how the project is to be administered. These clauses contain provisions that are common practice in the United States. The American Institute of Architects, AIA, has developed Document A201, "*General Conditions of the Contract for Construction.*" A printed copy of which is usually included into the project manual and referenced by the other documents included in the manual. General conditions documents are available from other organizations such as the National Society of Professional Engineers (NSPE), the American Consulting Engineers Council (ACEC), the American Society of Civil Engineers (ASCE), and the Construction Specifications Institute (CSI).
7. *Supplementary Conditions* are the clauses that modify or supplement the general conditions, as needed, to provide for requirements specific to that project. They consist of modifications and/or substitutions such as insurance requirements, prevailing wage rates, etc. It is important to remember that these are not standardized documents like AIA A201 and must be prepared based on the requirements of the specific project.
8. *Specifications* verbally describe the required materials and equipment, the level of quality required for installation and equipment, and the methods by which the materials and equipment are assembled and installed, and how they interface within the project as a whole. The specifications also set the administrative requirements for the contract. All items pertaining to the work under contract should be included in the specifications. The plumbing drawings graphically illustrate the scope of the design, the equipment location, the routing of piping, the quantity of materials required, and the interface with the other trades involved.
9. *Addenda* are the written or graphic documents that are issued prior to the bid to clarify, revise, add to, or delete information in the original bidding documents or in previous addenda. It should be noted that while an addendum is typically issued prior to the bid opening, AIA document A201 allows for the issuance of an addendum any time up to the execution of the contract. This feature

allows for the negotiated adjustment of a selected bid after the bid opening. In contrast, the similar document by the Engineers Joint Contract Documents Committee (EJCDC) restricts the issuance of addenda pre-bid opening.

10. *Modifications* are the written or graphic documents that are issued after the construction agreement has been signed to allow for additions to, deletions from, or modifications of the work to be performed. These changes are accomplished by the use of *change orders*, *construction change directives*, *work change directives*, *field orders*, *architect's supplemental Instructions (ASI)*, and *written amendments* to the construction agreement. These changes or modifications can be issued anytime during the contract period.

Each of the above listed documents is a separate document, but when grouped together, they are collectively referred to as the "*Front End Documents.*" Although the specifications document usually comprises the bulk of the project manual, it is only one of the required documents. If the project is primarily plumbing, then the plumbing engineer/designer may be responsible for the preparation of the entire project manual.

SPECIFICATIONS

Originally all documentation for a given project was placed upon the drawings, but as the amount of information increased to where it would not fit the drawing, another way was needed to present this information. The designers simply started compiling all the notes that would not fit onto the drawings and over time designers have added additional information, product requirements, contractual provisions, as well as construction methods and systems to create a written document. The specification is used to define the qualitative requirements for products, materials and workmanship that will be used to construct a given project.

As the popularity of the specification grew among design professionals, so did the problems this new idea created. Among these problems, there were no "universal" guidelines to insure a uniform document. Each designer wrote specifications using their own style according to what they thought was important. Even the specifications that came from large firms were lacking in consistency between documents. Materials, methods or items that were related were not grouped together in a logical manner but were scattered throughout the document in a seemingly random manner. This practice caused great difficulty when the contractor tried to prepare a specific bid, making it very easy to overlook important and costly items. Also, coordination between the various trades and the contractor would be difficult at best. Last-minute changes were extremely difficult to accomplish.

Specifications can be generated in as many ways. They may be produced by the designer as part of the design process or by a specific individual within the firm who is employed full time to writing project specifications. Large firms may even have a full-time specifications department.

The first thing the designer must have is as much information as possible that pertains to the section to be written. This includes any reference materials that describe products and methods of construction to be described within the specification section. The project information would include the drawing set as prepared by the designer, the project notebook, the project scope of work and any applicable laws and/or building codes. Information for the products can be obtained through a variety of sources, which include: (1) previous project specifications; (2) manufacturer's information; (3) handbooks, pamphlets, etc for the various trade associations; (4) information from the manufacturer's representatives; (5) reference standards from national standards organizations, governmental agencies, and trade associations; (6) technical and professional societies; (7) commercially prepared guide specifications; (8) information obtained from the trades, contractors, etc.; and (9) personal experience.

Never edit previous specifications for use in the new project, as they may not contain required language, the standards cited may have changed, the products specified may not be available any more, or the codes and/or laws may have changed since those specifications were first written.

Once the information that will be needed has been gathered the designer must now decide what type of format will be used as the basis of the specifications to be written.

Depending on the size of the project or the project phase that the specification is being prepared for, the designer may choose a short abbreviated format such as Uniformat developed by the CSI. For the larger, more complex projects the designer may choose the full format as is found in the Masterformat developed by the CSI. Both Uniformat and Masterformat were developed in the early 1970s and 1960s, respectively.

In addition to the Uniformat and Masterformat specification format listed above, there are also specifications developed by the Engineer's Joint Contract Documents Committee (EJCDC), American Institute of Architects (AIA), National Society of Professional Engineers (NSPE), as well as various governmental agencies such as the Corps of Engineers (USACOE), the armed services, NASA, etc.

The designer needs to become knowledgeable of the different specifications that are available so they can decide which specification is best suited for the phase of the project being designed.

UNIFORMAT

Uniformat is the specification system that was developed during the early 1970s and is a system-based format. This format is used primarily during the schematic phase as well as the preliminary or "budgetary" cost estimates. The Construction Specifications Institute (CSI) and the Construction Specifications Canada (CSC) recommend the organization of project data during the preliminary project phases.

Uniformat is divided into eight broad categories or sections: (A) substructure;

(B) shell; (C) interiors; (D) services; (E) equipment and furnishings; (F) other building construction; (G) sitework; and (Z) general. For more information and the subcategories found within each of the eight categories of this format, refer to Appendix 3-A1. Additional information on Uniformat may be obtained from CSI's publication Manual of Practice.

One of the best features of Uniformat is that each category or sub-category can be easily expanded as more information is accumulated during the ongoing design process. As more information is added to the Uniformat, provides the estimator with valuable information to prepare an informed preliminary cost estimate.

Once the project progresses from the preliminary or schematic phase (where the Uniformat provides the necessary information) to the design development or "DD" phase, more detailed information is required that Uniformat is not designed to handle. At this stage of the project, outline specifications are usually introduced to organize the required information. In some projects, the use of the outline specification may be required as part of the agreement between the owner and the architect/engineer (A/E). Refer to AIA document B141 and ESCDC document 1910-1 for additional information.

Drawings that are prepared during the design development phase contain more detail, both general and specific, than the schematic phase drawings.

MASTERFORMAT

Some designers organize their outline specifications at this point around CSI's Masterformat because this format can be used from the design development phase through to the construction documents (CD).

Masterformat is a master list of the divisions numbers and titles that was developed during the Washington, D.C., conferences in 1962 and 1963 and later became the industry standard in both the United States and Canada. The core of this system is the five-digit numbers and titles that arrange construction/project data into an organized order of sequence. By having this universal standardized system, the placement and retrieval of information is greatly facilitated, and communication throughout the entire construction phase also is greatly improved. Under this format, group numbers and titles are organized under these headings: (1) introductory information; (2) bidding requirements; (3) contracting requirements; (4) facilities and spaces; (5) systems and assemblies; and (6) construction products and activities (divisions 1-16). The first five groups, while they are not specifications, are usually included in the project manual. The last group forms the construction specifications.

Under the heading (6) construction products and activities, there are four levels of detail for each division. Level One consists of the titles for the 16 divisions (see Appendix 3-A2). The Level Two titles (or sections) are referred to as "broad scope" because they provide the widest scope in describing the work to be performed or the products to be utilized (see Appendix 3-A3). Level Three titles are sometimes referred to as "medium scope" since they cover work that is more limited in scope than under the level two titles. Level Three takes the titles listed under Level Two and further divides them in order to add a more definitive scope (see Appendix 3-A4). The titles found under Level Four are the most limited in scope and are often referred to as "narrow scope". These titles cover elements of the work that are very specific (see Appendix 3-A5).

In the progression from Level One to Level Four, the titles (or sections) become more narrow or specialized. For example, using the spec for nitrogen piping, at Level One it would be 15000-Mechanical. Then, at Level Two the title is further defined to 15200-Process piping. At Level Three, this section is defined as 15210-Process Air and Gas Piping. Finally, at Level Four, the title is further defined to 15215-Nitrogen Piping.

MASTERFORMAT 2004—AN OVERVIEW

Since last being updated in 1995, CSI's MasterFormat has been the staple of the architectural and engineering community. This document, while it was good, began to show some problems with respect to supporting the entire construction industry and it had very limited room for any future expansion. In 2001 a seventeen-member task force known as the MasterFormat expansion task team (MFETT) was formed by CSI to address problems of the document currently in use. Three years and many drafts later, the revised document known as MasterFormat 2004 is

now ready and will be available in late autumn 2004 through CSI at their website (www.CSINet.org) .

Significant changes have been made in the organization of this document. The first significant change to be made in the organization of the MasterFormat 95 is the reduction of the six groups to only two groups (Procurement and Contracting Requirements Group and Specifications Group). The Procurement and Contracting Requirements Group known, by the more familiar name front end documents, contains the bidding information, project forms, contract conditions, etc. Essentially this is the same material, just with a new name and different location. The Specifications Group contains the administrative and technical requirements that govern a project. This group is divided into five subgroups, which are further divided into a total of forty-nine divisions. The five subgroups comprising the Specifications Group are: (1) General Requirements (Division 01), (2) Facility Construction (Divisions 02-19), (3) Facility Services (Divisions 20-29), (4) Site and Infrastructure (Divisions 30-39), and (5) Process Equipment (Divisions 40-49). Appendix 3-B1 contains a complete list of subgroups and divisions and a short description of any changes.

The original numbering system consisted of a five-digit number (began in 1978) that organized the information throughout the sixteen divisions. The new system utilizes a six-digit number that consists of three pairs of two digit numbers. For example, 03200 found in MasterFormat 95 was replaced by 03 20 00 (the new number for Concrete Reinforcement). Level four numbers have been removed. However, recommendations for their use have been included in the supporting documents should the specifier wish to include level four. It should be noted that each level has two digits and this alone allows ten times as many subjects as was possible under the old five digit format.

Site construction was located in Division 2 under the old system and is now listed as Division 02-Existing Conditions and all site construction subjects have been relocated to the Civil and Infrastructure Subgroup. Division 02 now contains subjects dealing with items and conditions on the job site at the start of the project including selected demolition, subsurface and site investigation, surveying, site decontamination and site remediation, etc.,

Beginning with this edition, there will be sections included to classify information for facility operations and maintenance, repairs and commissioning. This information will be located in **each** division instead of being placed in its own division.

Another change is the relocation of certain items from one Division to other Divisions. Division 15 has now been reserved for future expansion. Plumbing items have been relocated to Division 22-Plumbing and HVAC items have been moved to Division 23-Heating, Ventilation and Air Conditioning. Fire Suppression items that were located to Division 13 have been relocated to Division 21-Fire Suppression. Refer to Appendix 3-B2 for a listing of sections found in Division 21-Fire Suppression. For a more detailed breakdown of subjects listed in this Division refer to Appendix 3-B3. Appendix 3-B4 contains a listing of the sections found in Division 22-Plumbing, while Appendix 3-B5 contains a more detailed breakdown of the sections and subjects.

In conclusion, the changes discussed above and any others made to MasterFormat 2004 were made to facilitate use in the Architectural and Engineering fields for years to come. As when anything changes, there will be those who love, hate, use or ignore the new. However, MasterFormat 2004 deserves a chance.

While Masterformat provides standardization as well as the titles to be used in the project manual, it does not address the way in which information will be organized. This need for standardization within a section prompted the development of Sectionformat. This format or outline produces organization, appearance, and completeness that is consistent from one section to the next. It may be used as a checklist to gather information for each section.

A good specification section will provide the answer to the following three questions: (1) How does the work defined in the section relate to the work defined for the rest of the project? (2) What materials and/or products are to be used to complete the work under this section? (3) How are these materials and/or products to be incorporated into the work under this section and the project as a whole? The answers to these questions are grouped into three parts to form the outline for a given section. These parts are: Part I—GENERAL, Part 2—PRODUCTS, and Part 3—EXECUTION. Refer to Appendix 3-C1 for the shell outline developed by the American Institute of Architects (AIA) that conforms to the manual of practice as prepared by the Construction Specifications Institute (CSI). The order in which these parts are used within a section is fixed in both name and order, providing a consistent format throughout all sections. This, in turn, simplifies the designer's job and makes the finding of information by the reader much easier.

Masterformat and Sectionformat, when used together, will produce specifications that are clear, complete, accurate, and coordinated. This allows the information to flow from the divisions to the sections to the parts and vice versa.

METHODS OF SPECIFICATION

Specifications are written using one of the following four methods of specifying products, materials, or workmanship. These four methods include: (1) descriptive specifications; (2) performance specifications; (3) reference standard specifications; and (4) proprietary specifications.

A *descriptive specification* consists of a detailed written description of the required properties of a product, material, or piece of equipment and the workmanship required for its proper installation. When writing this type of specification, it is important to remember that proprietary or brand names of manufactured products are not to be used and the specifier assumes the burden of performance. This method of specifying was once widely used, but as projects became more complex, its use has declined. Writing this type of specification is very tedious and time consuming. Descriptive specifications are used when the use of proprietary names are prohibited by law (such as with federally funded projects) or it is not possible to write a reference standard specification due to a lack of reference standards.

In order to write a descriptive specification, the specifier needs to adhere to certain basic steps. The specifier should: (1) Research available products that will be included in this section; (2) Research the critical features that will be required in this section, then analyze and compare these requirements with the products that are available; (3) Review the features that are required and determine which features are best described by the specification and which features would be best shown on the drawings; (4) Be sure to describe features considered to be critical and the minimum acceptable requirements; and (5) be certain requirements can be met by the products to be supplied. The designer should take care in selecting and specifying unique features from different products and manufacturers (picking features from one product and combining it with others, etc). This could create a descriptive specification of a particular product that does not exist. When this happens, the designer must spend additional time to rewrite the description. *Avoid any unnecessary features and minutely detailed requirements.*

A *performance specification* is a statement or statements of the results and criteria the specifier requires to verify compliance. It should not contain unnecessary limitations on the methods for achieving the required results. All desired end results the specifier wants must be spelled out completely. An incomplete performance specification will result in the designer losing control over the quantity of materials, equipment, and workmanship that will go into the project. Criteria for verifying compliance includes criteria for measurement, test evaluation, or other means as required by the designer to assure that the standards of performance have been met.

When using the performance specification, it should be remembered that only essential restrictions are to be placed upon the system while limitations on the means should be avoided. It also should be remembered that when performance specifications are the primary method of design and contracting procedure, specialized contract documents would be required. This is because the contract documents will be far more complex and often will involve a variety of participants in the contract proceedings.

The *reference standard specification* is the use of a nationally or internationally recognized standard to specify a product, materials, or workmanship instead of writing a detailed description. A standard is generally defined as a requirement defined by a recognized authority, custom, or general consensus. Trade associations, professional societies, standards organizations, or governmental and institutional organizations usually publish these standards. A committee of architects, engineers, scientists, technicians, manufacturers, and product users very knowledgeable about that particular subject area usually author a standard.

There are six types of reference-based standards that are commonly used when writing a specification. These include: (1) basic material standards; (2) product standards; (3) design standards; (4) workmanship standards; (5) test-method standards; and (6) codes. The materials are addressed for the system. Basic material standards, such as ASTM B88-03 "Standard Specification for Seamless Copper Water Tube," were written by the American Society of Testing Materials (ASTM) and cover one item — in this case, copper water tubing suitable for general plumbing or similar applications for conveying fluids and commonly used with solder, flared, or compression fittings. Products are to conform to items identified in a standard. Product standards, such as ASME B16.22-2002 "Wrought Copper and Copper Alloy, Solder Joint, Pressure Fittings," (written by the American Society of Mechanical Engineers (ASME)), establishes specifications for wrought copper and copper alloy, solder joint, seamless fittings designed for use with copper tube that conforms to ASTM B88-03.

Design requirements are set forth for the system. A design standard, such as ACI-318 "Building Code Requirements for Reinforced Concrete," is written by the American Concrete Institute (ACI) to cover the use of reinforced concrete in building assemblies. Workmanship standards describe the construction procedures that are necessary. Workmanship standards include items such as ASTM B828-02, "Standard Practice Making Capillary Joints by Soldering Copper and Copper Alloy Tubing and Fittings."

This standard describes the procedure for making capillary ("sweat") joints using solder, copper tube, and copper or copper alloy fittings.

Test method standards establish the minimum requirements of what is being tested and how to test systems for compliance to the standard. Test standards such as ASTM E53-02, "Standard Test Methods for Determination of Copper in Alloyed Copper by Gravimetry," describe the test procedures and protocols required to obtain a chemical analysis of copper having a minimal purity of 99.75% by gravimetric analysis. A code standard contains regulations that govern materials to be used, how they are to be installed, etc. Code standards, such as the National Standard Plumbing Code published by the National Association of Plumbing-Heating-Cooling Contractors is a body of code regulations adopted by local municipalities as their plumbing code.

When a designer wants to refer to or "cite" a standard, it is not necessary to include the entire text of the referenced standard into the body of the specification to be written. The desired standard can be included in the document by referring to its number, title, or other designation. The most common form is to cite it with the initials of the organization that sponsors it and the number of the standard, such as ASTM B88-03. The last digits separated by the hyphen are the date the standard was written or last revised. Sometimes the standard will be seen with a lower case "a" after the date. This indicates an amendment to the standard. These "cited" standards become part of the document just as surely as if the standard's entire text were included.

When using the reference standard, the designer needs to remember certain things. First, there are bad reference standards as well as good ones. Next, the indiscriminate use of these standards within the document can result in duplication, contradiction, and general chaos for designer, contractor, and the owner. Finally, some of the standards may contain hidden choices that the designer may not know even exists, and their inclusion into the document may cause a myriad of problems with the enforcement of the contract conditions. These standards often only meet the minimum requirements.

Before writing a reference based specification, the designers should thoroughly familiarize themselves with the standards they plan to use and how to incorporate these standards into the document correctly, as well as how to enforce the requirements of the standard once it has been included.

Due to possible conflicts between the language of the written standard and the general conditions of the contract, the designer should include a clause in the supplementary conditions of the contract that states the contract conditions shall govern over the requirements of the cited reference standards. Another clause should state that should a conflict or discrepancy arise between the reference standard and another cited reference and the specifications, the more stringent requirement shall apply. Once the standard has been specified, it becomes necessary for the designer to be able to enforce the requirements of that particular standard once the project begins. The most common means to ensure compliance of the standard is to check the shop drawings and other submittals (including manufacturer's literature, samples, and test reports) and make regular site visits to insure compliance of the workmanship standards.

The last method of specifying is the use of the *proprietary specification*. This method identifies the products to be used by manufacturer's name, brand name, the model number, type designation, or unique characteristics. A specification is considered proprietary if the product to be specified is available from a single source.

The use of this type of specification has both advantages and disadvantages. Advantages include: allowing for closer control in the selection of the product; having more detailed and complete drawings due to the more precise information from the product supplier; having shorter specifications which result in shorter production time; allowing for removal of product pricing as a major variable; and narrowing of the competition which will simplify the bidding process. Disadvantages to the use of this method include: the elimination or narrowing down of the competition (preferential treatment might be shown for one product over another and resentment might be directed back to the designer); forcing the contractor to do work with a product with which they have very little or no prior experience (this could result in poor performance by the contractor); and possibly specifying a product to be provided by a manufacturer that no longer exists.

There are two types of proprietary specifications: closed and open. The difference between them lies in how the subject of substitutions of the specified products is handled. Open specifications usually allow substitution of the products, while closed specifications usually do not allow any substitutions but restrict the selection to a limited number of choices.

The closed proprietary specification allows the design to be completed with higher-level detail while reducing the variables, thus promoting more accurate bids. It will not, however, provide protection against higher costs caused by a supplier of a specified product taking an unfair advantage of his proprietary position and increasing the price. The closed proprietary specification may either list one product or multiple products as the designer sees fit, and there are no substitutions allowed. The designer can control the

product selection through the use of the instructions found in section 01630-("Product Substitution Procedures"), which provides requirements for the use of the product or products specified. Under a closed proprietary specification, when only a single product is specified, the substitution of another product is not allowed, and the bids submitted will be based upon this product only. When a product is specified by naming several manufacturers, the substitution of other products shall not be allowed, and the bids submitted will be based on the products specified. The successful bidder is usually required to submit a list of the product or products they intend to use; within a specified time following the bid for approval, but prior to purchase and installation. If there are at least three products named and competition is achieved in the bid process, it is up to the designer to make sure the products are equal and acceptable for the purpose to which they are being specified.

The open proprietary specification specifies or names products or materials in the same manner as the closed specification. The difference is that alternatives for the specified products or materials are also listed. The bidder must bid on those specified items and may also provide prices for the alternative items specified. These prices are usually included on the bid form in the spaces provided. To clarify bidding processes, the designer might include instructions to the bidder such as the following: "When the product is specified to only one manufacturer, substitution of products will not be allowed. If alternates to the base bid are requested, then the bidder may submit bids for the alternate items. These bid prices shall include the amount required to incorporate the alternate product into the project. Requests for additional monies for alternate products or materials shall not be considered after the agreement has been executed." The open proprietary specification removes the problem of overpricing, which is common in sole-source product or material bids. It also allows for the selection of alternate items and price quotations for those items.

The major problem with proprietary specifications is the attempts by some bidders to introduce products or materials inferior in quality to those that were specified originally. This problem is the greatest when the bidder is allowed to specify substitutions after the award of the contract. This leads to the practice known as "bid shopping." This is unfair to those who submitted bids originally and pressure is put on the designer to accept these inferior product substitutions.

In order to prevent this situation, the designer must maintain control over the bidding process by including requirements in the specifications similar to the following: (1) All substitution requests are to be in writing from the bidders, only and any requests from manufacturers and suppliers will not be considered. (2) The setting of a definite deadline for the submission of substitution requests by the bidder. This deadline should be a minimum of ten (10) days prior to the bid opening. (3) All requests for substitutions shall be submitted with the request for approval. Submissions without supporting documentation shall not be considered. (4) The designer shall review all submissions and issue notification of any accepted substitutions to all bidders by addendum. The time period between the deadline for requests and the addendum is at the discretion of the designer, but should not be less than three (3) days to allow proper examination of the submitted materials.

The federal government and other public authorities forbid the use of the proprietary or other exclusionary specifications except under special conditions.

CREATING THE SPECIFICATION SECTION

Having examined the methods by which products, materials, or workmanship are specified, we shall now look at how these methods are used to create a specification section for the project manual. Refer to Appendix 3-C1, *Section Shell Outline,* to help illustrate a specification section, in conformance with the Manual of Practice.

Beginning at the top, the first item to be completed is the section number. The section number is a five-digit number corresponding to MasterFormat. This number may refer to any level from Level Two to Level Four, depending on how specific this section will be. Following the section number is the section title. The designer should keep this to a maximum of one line, 6-8 words.

Under Sectionformat as discussed earlier, a specification section is divided into three parts. These are (1) PART 1—GENERAL; PART 2—PRODUCTS; PART 3—EXECUTION. The section number is usually either Level Two or Level Three. Level Four section numbers are not assigned. This provides the user with greater flexibility by allowing a location for the designer to add specifications if necessary.

PART 1—GENERAL includes: the scope of and, any necessary references to the related work, codes, and standards that are to be in force during the project; qualifications for both manufacturers and workmanship; required submittals, including the format required for submission of the submittals; any samples required for examination by the designer; required information on product manufacturing and shipping schedules; receiving and storage requirements; as well as any other information found to be necessary.

PART 2—PRODUCTS includes those products to be used on the project that are part of the work described by this specification section. These products should be described as accurately, completely, and, above all, briefly as possible to give the reader the facts needed in least amount of text. Any descriptions of these products shall be to describe the product to be used and present any pertinent data required for the use of that product. The designer should not include installation instructions and like information in this part, but should include it in PART 3—EXECUTION.

PART 3—EXECUTION contains the detailed instructions of how the products listed in PART 2 are to be used or installed in the work being performed. Each product listed in PART 2 should have information as to its use in this part. Also, included in this section: any testing that is to be performed (be sure to include instructions on who pays for the testing, as well as what tests and the number required); instructions for the coordination between the various trades; the acceptance of the substrate; and any required tolerances for installations.

PART 1

Section *1.1 Summary*

The first section of Part 1 is the summary. In this section, there is the description of the work to be performed, the listing of any products to be furnished but not installed, and products that are not furnished but are to be installed. This also is sometimes a clause referred to as "owner furnished, contractor installed." The next item found in PART 1 is the listing of the related sections. It is here that other sections in the specifications containing requirements related to this particular section are listed. Some designers choose to omit this part because during last-minute changes, this often fails to get updated resulting in a confusing, flawed document. Also found in the summary are allowances, unit prices, and alternates. An allowance is a predetermined monetary amount agreed to by both the designer and the owner to be inserted into the bid for certain items such as art work, furniture or even plumbing fixtures. A unit price is a fixed bid price amount for an item such as a water closet, lavatory, and per-foot price on a four-inch cast iron pipe, etc. An alternate is a defined portion of the work that is priced separately and provides the owner an option for to select for the final scope of the work. Alternates usually allow choices among the products to be used or to add or delete portions of the work from the project.

Section *1.2 References*

Another item found in the first section is the references. It is here that the reference standards that have been cited in this section are listed alphabetically. Standards are usually written in the following manner: (1) Standard number; (2) Standard title; (3) Standard society or agency; and (4) Date of the last revision. For example: ASME B16.22, Wrought Copper and Copper Alloy Solder Joint, Pressure Fittings, American Society of Mechanical Engineers (ASME), 2002. When there are multiple references by the same organization those references are arranged in ascending numerical order.

Section *1.3 Definition*

After the references, any special definitions required to explain the work or products used are listed alphabetically.

Section *1.4 System Description*

The system description is used by some designers and omitted by others. This is usually a brief but accurate description of how this spec section fits into the work.

Section *1.5 System Performance Criteria*

The system performance requirements give the performance criteria, if necessary, for this work. This section is usually omitted unless a performance specification is desired.

Section *1.6 Submittals*

The next portion of PART 1 is probably one of the most important ones because it governs the submittals. It tells what is required for all products used in the project. The designer must decide what information will be submitted for review and approval. On some government projects the submittal process will be under governmental control not the designer. The information required for the submittal can include: (1) Product data as prepared by the manufacturer or third-party organization; (2) Shop drawings from either the manufacturer or the contractor; (3) Coordination drawings; (4) Wiring or piping diagrams from the manufacturer or contractor; (5) Product certification from manufacturers that these products have been tested and are compliant with the appropriate standard cited by the manufacturer; (6) Test reports from an independent (or third party) test laboratory certifying those products; (7) Qualification data for manufacturers, firms, or individuals as required in Section 1.7 Quality Assurance; and (8) Maintenance data for the materials and products used for inclusion into the operation and maintenance (O&M) manuals for the owner (if required).

Section *1.7 Quality Assurance*

This is the quality control for the project. In this section the designer can include what he feels is needed to assure the project is completed cor-

rectly. Included in this section are manufacturer and installer qualifications. It is here the level of experience, usually a set number of years, is spelled out. The normal experience for a manufacturer is five years minimum; for an installer three years minimum is usual. Requirements for supervision and licensure can be included as well. For example, "all work required by this specification section shall be performed by licensed, experienced tradesmen working under the direct supervision of a licensed, experienced supervisor with a minimum of 10 years experience. No unsupervised work by unlicensed workers shall be allowed." Requirements for testing laboratories, welding and welder certifications, compliance with U. L. standards, compliance with NFPA 70 (NEC), ASME compliance, and others are also included within this section.

Section *1.8 Delivery, Storage, and Handling*

This section includes the instructions on shipping and handling of materials or equipment from the manufacturer to the jobsite, as well as lifting and rigging instructions, onsite storage requirements, and coordination between shipping schedules, delivery dates, and installation dates.

Section *1.9 Project Conditions*

Site condition disclaimers and disclaimers for field measurements that direct the contractor to verify all measurements prior to start of work fall under this category. This section is optional at the decision of the designer.

Section *1.10 Sequence and Scheduling*

This coordinates the various portions of the project and can cross trades. The section is optional as well because it is up to the general contractor, not the plumbing designer, to schedule and coordinate work that is under the contract.

Section *1.11 Warranty*

The designer lists any special warranties required or any warranty condition that is different from the manufacturer's standard warranty.

Section *1.12 Maintenance*

Contains any special maintenance requirements for the equipment installed under this section.

Section *1.13 Extra Materials*

A list of extra materials including those such as valve repair kits, faucet repair parts, extra belts, handles, lubricants, seals, elements, etc. Item and quantity required to be supplied to the owner by the contractor are also listed.

PART 2

This section deals with the products, materials, and equipment, as well as the manufacturers that will be included in the work.

Section *2.1 Manufacturers*

Under paragraph A, the contractor may supply products by any manufacturer that are compliant with the specification section covering that portion of the work. Most of the time the products to be supplied comply with the specifications but sometimes they do not. Paragraph B states that the designer decides which manufacturers of a particular product will be allowed and which will not. Under this paragraph, the contractor is given a list of approved manufacturers to choose from. The designer has both researched the product and tested manufacturers to make sure the products meet or exceed the standards set forth by that section of the specification. For example, a listing for a water closet would be:

1. Water closet, floor outlet, flushometer
   a) Manufacturer "A"
   b) Manufacturer "B"
   c) Manufacturer "C"
   d) Manufacturer "D"
   e) Substitutions

Under this arrangement, the contractor would have to supply the water closet by one of the four manufacturers listed above. With the use of a substitution option, the designer may elect to allow substitutions of a water closet by a non-listed manufacturer *as long as it is proven to be equal to the others*. Many designers feel that allowing no substitutions levels the bidding field and takes away the problems of a bidder getting a lower bid by using substandard product. Under this section, the decision can be made about the product as well as the manufacturer. Only one of these methods should be used—either specify the manufacturer or product by an "open" as seen in paragraph A (of Appendix 3-C1) or "closed" as seen in paragraph B. The same is true for paragraphs C and D. As stated earlier in this chapter, the closed method gives the designer more control over the quality of the products being included in this project.

Sections 2.2, 2.3, and 2.4 are similar to Section 2.1. In Section 2.3 the materials that will be used are specified using either a descriptive specification or a performance specification. Both the performance and descriptive specification types were discussed earlier.

Sections 2.5, 2.6, 2.7, 2.8, and 2.9 are not usually included in plumbing specifications. However, that

does not mean they cannot be used if the designer feels they are needed.

PART 3

Section *3.1 Examination*

This section is concerned with the installation of the products or materials into the project. The first part involves instructions to the contractor to examine the sites, plans, existing or constructed walls, floors and ceilings that must be installed. This section should also instruct the contractor not to proceed with the work until all unsatisfactory items have been corrected. Following sections deal with the general and specific installation requirements of the products and/or materials being used. Often included, but not mandatory by CSI standards, is a section on connections (shown as Section 3.5). It is in this section that connection requirements for owner furnished, contractor installed (often seen as OFCI or GFCI on government projects) are found. A good example of this would be in the case of a commercial kitchen where the kitchen equipment supplier sets the equipment but the plumber connects them to the utilities.

Section *3.6 Field Quality Control*

The designer deals with testing laboratory services (including who pays for it), which tests are to be made, and which standard(s) must be met. Also included is what remedy must be made if the tests prove that the products and/or materials are not compliant with the standard set forth in the specification section. In addition, if a piece of equipment that is assembled onsite appears to be complicated, etc., this is where the designer could put a requirement for the services of a factory-authorized service technician to supervise the assembly.

Section *3.7 Adjusting and Cleaning*

A section that covers the adjustment, cleaning, and calibration of the products included in this project is well advised. One of the most common sections would probably be the cleaning and disinfection of the potable water system.

Section *3.8 Commissioning*

Another section that is not mandated by the current CSI format, but is gaining in use and will probably be included as part of the new CSI format (tentatively scheduled for release late 2004) is *Commissioning* or placing the building into service for the owner to use. Items that should be addressed include: (1) Equipment start up by factory authorized service technicians; (2) Testing and adjusting of controls and safeties with the replacement of all malfunctioning parts; (3) Providing adequate training to the owner's maintenance staff with regard to the start up and shut down of equipment, troubleshooting, servicing, and maintenance; and (4) Reviewing the data in the O&M manuals with the maintenance staff.

USE OF COMPUTERS IN PRODUCING SPECIFICATIONS

Very few plumbing specifications today are written as an original document, otherwise known as "from scratch." In most cases, the project specifications are created using an office prepared "master specification," or a set of commercially prepared specifications that have been published by various industry organizations such as Masterspec or Spectext. The American Institute of Architects (AIA) publishes Masterspec. Spectext is published by the Constructed Science Research Foundation, which is affiliated with the Construction Specifications Institute (CSI). The use of a master specification to prepare a project specification is certainly more cost efficient than "starting from scratch" with each new project.

The process begins with the designer or specifier choosing the sections that will be needed for the project manual. This list is then given to the word-processing department to put together the copy for each section and return it to the designer. It is then reviewed and rewritten as required to suit the project's particular requirements. The revised "master" copy is then returned to the word-processing department to make the necessary rewrite to the master copy. This revised copy will be returned to the designer, who will proofread it and make any further changes that might be required. This process continues until the project is finalized. As you see, this method of specification is very labor intensive.

Fortunately for specification writers, there are computerized or computer assisted specification programs to aid in the writing of specifications. These programs do for specification writing what computer aided drafting and design (CADD) did for drafting. One of the first computer aids was utilizing word-processing programs to write, edit, and more importantly, store finished documents in an electronic format. This allows documents to be copied instantaneously instead of spending a lengthy time at the typewriter and/or copy machine. Another benefit that came with the use of computers is the size of space required to store the specifications. A specification that might require an entire file cabinet drawer of information can be reduced to one or two floppy disks or one CD-ROM disk.

The specification programs that have evolved over past years and are available today have merged word processing, data storage, and acquisition programs into single powerful programs that allow specifications to be produced by a single person. This is a drastic

change from the past when it took the designer(s) and several other personnel to produce the specification. One of the best features of the new master specification programs is that there are periodic updates with new sections being added and obsolete sections being deleted. Also, in these updates, the reference standards that are included in each section are updated to the latest standard. For any specifier who has spent several hours searching these standards, this feature is worth the price of the program.

Computer programs continue to improve at a dizzying speed. What was cutting edge technology five years ago is now obsolete. These programs have evolved beyond just being a specialized word processing program to an interactive program that contains checklists or interactive input dialogue for the specifier to utilize. Also, there are programs being written and developed that will interface with the CADD systems to produce the specifications and even estimates.

CONCLUSION

Writing good, effective specifications requires broad experience as a plumbing designer. In most engineering offices, specifications are prepared by the project engineer or team leader. The designer must remember that the essence of plumbing specifications is communication between the persons involved with the project. Plumbing specifiers must develop skills to communicate the project requirements in a clear, concise, and easy-to-understand manner. This requires the ability to write in a clear, precise, technical style and a precise legal style *combined into a single style*.

The one thing that probably has changed the least in specification writing is the amount of time allotted by the project managers to complete the specifications. The amount of time given is never enough.

Like most plumbing engineering skills, specification writing is "learned on the job." This is because university level courses in specification writing are rare (actually almost non-existent). Classes may be available as continuing education programs offered by the Construction Specifications Institute (CSI) at both the national and local level. Local chapter members of CSI teach local courses. Interested parties should contact their local CSI chapters for more information about what is available.

Plumbing designers who have at least five years of specification writing experience can demonstrate their proficiency and understanding by taking the Certified Construction Specifier (CCS) Examination that is given by CSI. Successful completion of this exam will earn the designer the title of Certified Construction Specifier (CCS). There is a growing number of plumbing engineers that can include "CCS" after "CPD" (Certified Plumbing Designer) when citing their professional credentials.

In this world of continually changing work places and corporate restructuring, the plumbing designer who demonstrates the ability to produce a clear, concise set of specification documents is a valuable asset to the project design teams.

APPENDIX 3-A1

CSI UNIFORMAT – UNIFORM CLASSIFICATION – (1995 Edition)

SUBSTRUCTURE
- A10 Foundations
- A20 Basement Construction

SHELL
- B10 Superstructure
- B20 Exterior Closure
- B30 Roofing

C. INTERIORS
- C10 Interior Construction
- C20 Stairways
- C30 Interior Finishes

D. SERVICES
- D10 Conveying Systems
- D20 Plumbing Systems
- D30 Heating Ventilation and Air Conditioning (HVAC) systems
- D40 Fire Protection Systems
- D50 Electrical Systems

E. EQUIPMENT and FURNISHINGS
- E10 Equipment
- E20 Furnishings

F. OTHER BUILDING CONSTRUCTION
- F10 Special Construction
- F20 Selective Demolition

BUILDING SITEWORK
- G10 Site Preparation
- G20 Site Improvements
- G30 Site Plumbing Utilities
- G40 Site Heating, Ventilation, and Air Conditioning (HVAC) Utilities
- G50 Site Electrical Utilities
- G60 Other Site Construction

Z. GENERAL
- Z10 General Requirements
- Z20 Bidding Requirements, Contract Forms, and Conditions
- Z90 Project Cost Estimate

APPENDIX 3-A2

CSI MASTERFORMAT – LEVEL ONE DIVISION TITLES – (1995 Edition)

- 01000 DIVISION 1 GENERAL REQUIREMENTS
- 02000 DIVISION 2 SITE CONSTRUCTION
- 03000 DIVISION 3 CONCRETE
- 04000 DIVISION 4 MASONRY
- 05000 DIVISION 5 METALS
- 06000 DIVISION 6 WOOD and PLASTICS
- 07000 DIVISION 7 THERMAL and MOISTURE PROTECTION
- 08000 DIVISION 8 DOORS AND WINDOWS
- 09000 DIVISION 9 FINISHES
- 10000 DIVISION 10 SPECIALTIES
- 11000 DIVISION 11 EQUIPMENT
- 12000 DIVISION 12 FURNISHINGS
- 13000 DIVISION 13 SPECIAL CONSTRUCTION
- 14000 DIVISION 14 CONVEYING SYSTEMS
- 15000 DIVISION 15 MECHANICAL
- 16000 DIVISION 16 ELECTRICAL

APPENDIX 3-A3

CSI MASTERFORMAT – LEVEL TWO SECTION TITLES – (1995 Edition)

DIVISION 1 GENERAL REQUIREMENTS
- 01100 SUMMARY OF WORK
- 01200 PRICE and PAYMENT PROCEEDURES
- 01300 ADMINISTRATIVE REQUIREMENTS
- 01400 QUALITY PROCEDURES
- 01500 TEMPORARY FACILITIES and CONTROLS
- 01600 PRODUCT REQUIREMENTS
- 01700 EXECUTION REQUIREMENTS
- 01800 FACILITY OPERATION
- 01900 FACILITY DECOMMISSIONING

DIVISION 2 SITE CONSTRUCTION
- 02050 BASIC SITE MATERIALS and METHODS
- 02100 SITE REMEDIATION
- 02200 SITE PREPARATION
- 02300 EARTHWORK
- 02400 TUNNELING, BORING, and JACKING
- 02450 FOUNDATION and LOAD BEARING ELEMENTS
- 02500 UTILITY SERVICES
- 02600 DRAINAGE and CONTAINMENT
- 02700 BASES, BALLASTS, PAVEMENTS, and APPURTENANCES
- 02800 SITE IMPROVEMENTS and AMENITIES
- 02900 PLANTING
- 02950 SITE RESTORATION and REHABILITATION

DIVISION 3 CONCRETE
- 03050 CONCRETE MATERIALS AND METHODS
- 03100 CONCRETE FORMS and ACCESSORIES
- 03200 CONCRETE REINFORCEMENT
- 03300 CAST-IN-PLACE CONCRETE
- 03400 PRE-CAST CONCRETE
- 03500 CEMENTITOUS DECKS and UNDERLAYMENT
- 03600 GROUTS
- 03700 MASS CONCRETE
- 03900 CONCRETE RESTORATION and CLEANING

DIVISION 4 MASONRY
- 04050 BASIC MASONRY MATERIALS AND METHODS
- 04200 MASONRY UNITS
- 04400 STONE
- 04500 REFRACTORIES
- 04600 CORROSION RESISTANT MASONRY
- 04700 SIMULATED MASONRY
- 04800 MASONRY ASSEMBLIES

04900 MASONRY RESTORATION AND CLEANING

DIVISION 5 METALS
05050 BASIC METAL MATERIALS AND METHODS
05100 STRUCTURAL METAL FRAMING
05200 METAL JOISTS
05300 METAL DECK
05400 COLD FORMED METAL FRAMING
05500 METAL FABRICATIONS
05600 HYDRAULIC FABRICATIONS
05650 RAILROAD TRACK AND ACCESSORIES
05700 ORNAMENTAL METAL
05800 EXPANSION CONTROL
05900 METAL RESTORATION AND CLEANING

DIVISION 6 WOOD AND PLASTICS
06050 BASIC WOOD AND PLASTIC MATERIALS AND METHODS
06100 ROUGH CARPENTRY
06200 FINISH CARPENTRY
06400 ARCHITECTURAL WOODWORK
06500 STRUCTURAL PLASTICS
06600 PLASTIC FABRICATIONS
06900 WOOD AND PLASTIC RESTORATION AND CLEANING

DIVISION 7 THERMAL AND MOISTURE PROTECTION
07050 BASIC THERMAL & MOISTURE PROTECTION MATERIALS AND METHODS
07100 DAMPPROOFING AND WATERPROOFING
07200 THERMAL PROTECTION
07300 SHINGLES, ROOF TILES AND ROOF COVERINGS
07400 ROOFING AND SIDING TILES
07500 MEMBRANE ROOFING
07600 FLASHING AND SHEET METAL
07700 ROOF SPECIALTIES AND ACCESSORIES
07800 FIRE AND SMOKE PROTECTION
07900 JOINT SEALERS

DIVISION 8 DOORS AND WINDOWS
08050 BASIC DOORS AND WINDOWS MATERIALS AND METHODS
08100 METAL DOORS AND FRAMES
08200 WOOD AND PLASTIC DOORS
08300 SPECIALTY DOORS
08400 ENTRANCES AND STORE FRONTS
08500 WINDOWS
08600 SKYLIGHTS
08700 HARDWARE
08800 GLAZING
08900 GLAZED CURTAIN WALL

DIVISION 9 FINISHES
09050 BASIC FINISHES MATERIALS AND METHODS
09100 METAL SUPPORT ASSEMBLIES
09200 PLASTER AND GYPSUM BOARD
09300 TILE
09400 TERRAZZO
09500 CEILINGS
09600 FLOORING
09700 WALL FINISHES
09800 ACOUSTICAL TREATMENT
09900 PAINTS AND COATINGS

DIVISION 10 SPECIALTIES
10100 VISUAL DISPLAY BOARDS
10150 COMPARTMENTS AND CUBICLES
10200 LOUVERS AND VENTS
10240 GRILLS AND SCREENS
10250 SERVICE WALLS
10260 WALL AND CORNER GUARDS
10270 ACCESS FLOORING
10290 PEST CONTROL
10300 FIREPLACES AND STOVES
10340 MANUFACTURED EXTERIOR SPECIALTIES
10350 FLAG POLES
10400 IDENTIFICATION DEVICES
10450 PEDESTRIAN CONTROL DEVICES
10500 LOCKERS
10520 FIRE PROTECTION SPECIALTIES
10530 PROTECTIVE COVERS
10550 POSTAL SPECIALTIES
10600 PARTITIONS
10670 STORAGE SHELVING
10700 EXTERIOR PROTECTION
10750 TELEPHONE SPECIALTIES
10800 TOILET, BATH AND LAUNDRY ACCESSORIES
10880 SCALES
10900 WARDROBE AND CLOSET SPECIALTIES

DIVISION 11 EQUIPMENT
11010 MAINTENANCE EQUIPMENT
11020 SECURITY AND VAULT EQUIPMENT
11030 TELLER AND SERVICE EQUIPMENT
11040 ECCLESIASTICAL EQUIPMENT
11050 LIBRARY EQUIPMENT
11060 THEATER AND STAGE EQUIPMENT
11070 INSTRUMENTAL EQUIPMENT
11080 REGISTRATION EQUIPMENT
11090 CHECK ROOM EQUIPMENT
11100 MERCANTILE EQUIPMENT
11110 COMMERCIAL LAUNDRY AND DRY CLEANING EQUIPMENT
11120 VENDING EQUIPMENT
11130 AUDIO VISUAL EQUIPMENT
11140 VEHICLE SERVICE EQUIPMENT
11150 PARKING CONTROL EQUIPMENT
11160 LOADING DOCK
11170 SOLID WASTE HANDLING EQUIPMENT
11190 DETENTION EQUIPMENT
11200 WATER SUPPLY AND TREATMENT EQUIPMENT
11280 HYDRAULIC GATES AND VALVES
11300 FLUID WASTE TREATMENT AND DISPOSAL EQUIPMENT

11400 FOOD SERVICE EQUIPMENT
11450 RESIDENTIAL EQUIPMENT
11460 UNIT KITCHENS
11470 DARK ROOM EQUIPMENT
11480 ATHLETIC, RECREATIONAL AND THERAPEUTIC EQUIPMENT
11500 INDUSTRIAL AND PROCESS EQUIPMENT
11600 LABORATORY EQUIPMENT
11650 PLANETARIUM EQUIPMENT
11660 OBSERVATORY EQUIPMENT
11680 OFFICE EQUIPMENT
11700 MEDICAL EQUIPMENT
11780 MORTUARY EQUIPMENT
11850 NAVIGATION EQUIPMENT
11870 AGRICULTURAL EQUIPMENT
11900 EXHIBIT EQUIPMENT

DIVISION 12 FURNISHINGS

12050 FABRICS
12100 ART
12300 MANUFACTURED CASEWORK
12400 FURNISHINGS AND ACCESSORIES
12500 FURNITURE
12600 MULTIPLE SEATING
12700 SYSTEMS FURNITURE
12800 INTERIOR PLANTS AND PLANTERS
12900 FURNISHINGS RESTORATION AND REPAIR

DIVISION 13 SPECIAL CONSTRUCTION

13010 AIR SUPPORTED STRUCTURES
13020 BUILDING MODULES
13030 SPECIAL PURPOSE ROOMS
13080 SOUND, VIBRATION AND SEISMIC CONTROL
13090 RADIATION PROTECTION
13100 LIGHTNING PROTECTION
13110 CATHODIC PROTECTION
13120 PRE-ENGINEERED STRUCTURES
13150 SWIMMING POOLS
13160 AQUARIUMS
13165 AQUATIC PARK FACILITIES
13170 TUBS AND POOLS
13175 ICE RINKS
13185 KENNELS AND ANIMAL SHELTERS
13190 SITE CONSTRUCTED INCINERATORS
13200 STORAGE TANKS
13220 FILTER UNDERDRAINS AND MEDIA
13230 DIGESTER COVERS AND APPURTENANCES
13240 OXYGENATION SYSTEMS
13260 SLUDGE CONDITIONING SYSTEMS
13280 HAZARDOUS MATERIAL REMEDIATION
13400 MEASUREMENT AND CONTROL INSTRUMENTATION
13500 RECORDING INSTRUMENTATION
13550 TRANSPORTATION CONTROL INSTRUMENTATION
13600 SOLAR AND WIND ENERGY EQUIPMENT\
13700 SECURITY ACCESS AND SURVEILLANCE
13800 BUILDING AUTOMATION AND CONTROL
13850 DETECTION AND ALARM
13900 FIRE SUPPRESSION

DIVISION 14 CONVEYING SYSTEMS

14100 DUMBWAITERS
14200 ELEVATORS
14300 ESCALATORS AND MOVING WALKS
14400 LIFTS
14500 MATERIAL HANDLING
14600 HOISTS AND CRANES
14700 TURNTABLES
14800 SCAFFOLDING
14900 TRANSPORTATION

DIVISION 15 MECHANICAL

15050 BASIC MECHANICAL MATERIALS AND METHODS
15100 BUILDING SERVICES PIPING
15200 PROCESS PIPING
15300 FIRE PROTECTION PIPING (SEE 13900)
15400 PLUMBING FIXTURES AND EQUIPMENT
15500 HEAT GENERATION EQUIPMENT
15600 REFRIGERATION EQUIPMENT
15700 HEATING, VENTILATION AND AIR CONDITIONING EQUIPMENT
15800 AIR DISTRIBUTION
15900 HVAC INSTRUMENTATION
15950 TESTING, ADJUSTING AND BALANCING

DIVISION 16 ELECTRICAL

16050 BASIC ELECTRICAL MATERIALS AND METHODS
16100 WIRING METHODS
16200 ELECTRICAL POWER
16300 TRANSMISSION AND DISTRIBUTION
16400 LOW VOLTAGE DISTRIBUTION
16500 LIGHTING
16700 COMMUNICATIONS
16800 SOUND AND VIDEO

APPENDIX 3-A4

CSI MASTERFORMAT – LEVEL THREE SECTION TITLES – (1995 Edition) (SELECTED SECTIONS)

13900 FIRE SUPPRESSION
13920 BASIC FIRE SUPPRESSION MATERIALS AND METHODS
13930 WET-PIPE FIRE SUPPRESSION SPRINKLERS
13935 DRY-PIPE FIRE SUPPRESSION SPRINKLERS
13940 PRE-ACTION FIRE SUPPRESSION SPRINKLERS
13945 COMBINATION DRY-PIPE AND PRE-ACTION F.S.S.
13950 DELUGE FIRE SUPPRESSION SPRINKLERS
13955 FOAM FIRE EXTINGUISHING
13960 CARBON DIOXIDE FIRE EXTINGUISHING
13965 ALTERNATIVE FIRE EXTINGUISHING SYSTEMS
13970 DRY CHEMICAL FIRE EXTINGUISHING
13975 STANDPIPES AND HOSES

15100 BUILDING SERVICES PIPING
15105 PIPES AND TUBES
15110 VALVES
15120 PIPING SPECIALTIES
15130 PUMPS
15140 DOMESTIC WATER PIPING
15150 SANITARY WASTE AND VENT PIPING
15160 STORM DRAINAGE PIPING
15170 SWIMMING POOL AND FOUNTAIN PIPING
15180 HEATING AND COOLING PIPING
15190 FUEL PIPING

15200 PROCESS PIPING
15210 PROCESS AIR AND GAS PIPING
15220 PROCESS WATER AND WASTE PIPING
15230 INDUSTRIAL PROCESS PIPING

15400 PLUMBING FIXTURES AND EQUIPMENT
15410 PLUMBING FIXTURES
15440 PLUMBING PUMPS
15450 POTABLE WATER STORAGE TANKS
15460 DOMESTIC WATER CONDITIONING EQUIPMENT
15470 DOMESTIC WATER FILTRATION EQUIPMENT
15480 DOMESTIC WATER HEATERS
15490 POOL AND FOUNTAIN EQUIPMENT

APPENDIX 3-A5

CSI MASTERFORMAT – LEVEL FOUR SECTION TITLES – (1995 Edition) (SECTION SELECTED FROM DIVISION 15; SECTION 200)

15200 PROCESS PIPING
15210 PROCESS AIR AND GAS PIPING
15211 AIR COMPRESSORS
15212 COMPRESSED AIR PIPING
15213 GAS EQUIPMENT
15214 GAS PIPING
15215 NITROGEN PIPING
15216 NITROUS OXIDE PIPING
15217 OXYGEN PIPING
15218 VACUUM PUMPS
15219 VACUUM PIPING

15220 PROCESS WATER AND WASTE PIPING
15221 DEIONIZED WATER PIPING
15223 DISTILLED WATER PIPING
15225 LABORATORY ACID WASTE AND VENT PIPING
15227 PROCESS PIPING INTERCEPTORS
15229 REVERSE OSMOSIS WATER PIPING

15230 INDUSTRIAL PROCESS PIPING
15231 DRY PRODUCT PIPING
15232 FLUID PRODUCT PIPING

APPENDIX 3-B1

CSI MASTERFORMAT DIVISIONS (2004 EDITION) PROCUREMENT and CONTRACTING DOCUMENTS GROUP

DIVISION 00 – PROCUREMENT and CONTRACTING REQUIREMENTS: *This Division is essentially the same in scope as it was in MasterFormat95.*

SPECIFICATIONS GROUP

GENERAL REQUIREMENTS SUBGROUP

DIVISION 01 – GENERAL REQUIREMENTS: *The area for performance requirements was added to allow for the writing of performance requirements for the elements that are found in more than one work section such as building envelope, structure, etc. This new feature will allow for the specifier to include a mixture of broad performance specifications and descriptive specifications into the project manual.*

FACILITY CONSTRUCTION SUBGROUP

DIVISION 02 – EXISTING CONDITIONS: *Division 2 is now restricted to the "existing conditions" that is, construction tasks that relate to the items at the site when the project commences – selective demolition, subsurface and other investigations, surveying , site decontamination and/ or remediation to mention a few. (ALL site construction as well as heavy civil and infrastructure items including pavement and utilities has been relocated to the Site and Infrastructure Subgroup)*

DIVISION 03 – CONCRETE: *This division will remain essentially as it was under MasterFormat95*

DIVISION 04 – MASONRY: *This division will remain essentially as it was under MasterFormat95*

DIVISION 05 – METALS: This *division will remain essentially as it was under MasterFormat95*

DIVISION 06 – WOOD, PLASTICS and COMPOSITES: *This Division will remain essentially as it was under MasterFormat95, but also will include expanded areas for plastics and other composite materials.*

DIVISION 07 – THERMAL and MOISTURE PROTECTION: *This division will remain essentially as it was Under MasterFormat95.*

DIVISION 08 – OPENINGS: *This section was Doors and Windows under MasterFormat95, and remains essentially unchanged but was renamed to with the addition of other openings such as louvers and grilles*

DIVISION 09 – FINISHES: *This division will remain essentially as it was under MasterFormat95*

DIVISION 10 – SPECIALTIES: *This division will remain essentially as it was under MasterFormat95*

DIVISION 11 – EQUIPMENT: *This Division will remain as is with the exception of that equipment related to process engineering has been relocated to the Process Equipment Subgroup and that equipment related to Infrastructure has been relocated to the Site and Infrastructure subgroup.*

DIVISION 12 – FURNISHINGS: *This division will remain essentially as it was under MasterFormat95*

DIVISION 13 – SPECIAL CONSTRUCTION: *This division will remain essentially as it was under MasterFormat95 except that special construction related to process engineering has been relocated to the Process Equipment Subgroup. Security, building automation, detection and alarm as well as fire suppression have been relocated to the Facility Services Subgroup.*

DIVISION 14 – CONVEYING EQUIPMENT: *This division has been renamed with process related material Handling equipment relocated to the Process Equipment Subgroup*

DIVISION 15 – RESERVED FOR FUTURE EXPANSION: *This Division has been assigned for any future expansion and Division 15 has been separated and relocated to Division 22 – Plumbing a and Division 23 – Heating, Ventilation, and Air Conditioning in the Facility Services Subgroup.*

DIVISION 16 – RESERVED FOR FUTURE EXPANSION: *This Division has been assigned for any future expansion and Division 16 has been separated and relocated to Division 26 – Electrical and Division 27 – Communications in the Facility Services Subgroup.*

DIVISION 17 – RESERVED FOR FUTURE EXPANSION

DIVISION 18 – RESERVED FOR FUTURE EXPANSION

DIVISION 19 – RESERVED FOR FUTURE EXPANSION

FACILITY SERVICES SUBGROUP

DIVISION 20 – RESERVED

DIVISION 21 – FIRE SUPPRESSION: *This division contains the Fire Suppression sections relocated from Division 13 in MasterFormat95.*

DIVISION 22 – PLUMBING: *This division contains the Plumbing sections relocated from Division 15 in MasterFormat95.*

DIVISION 23 – HEATING, VENTILATION and AIR CONDITIONING: *This division contains the Heating Ventilation and Air Conditioning Sections from Division 15 in MasterFormat95*.

DIVISION 24 – RESERVED

DIVISION 25 – INTEGRATED AUTOMATION: *This Division contains the expanded integrated automation sections that were relocated from Division 13 in MasterFormat95*.

DIVISION 26 – ELECTRICAL: *This Division contains the Electrical and Lighting sections relocated from Division 16 in MasterFormat95*

DIVISION 27 – COMMUNICATIONS: *This Division contains the expanded Communications sections relocated from Division 16 in MasterFormat95*

DIVISION 28 – ELECTRONIC SAFETY and SECURITY: *This Division contains the expanded Electronic Safety and Security sections relocated from Division 13 in MasterFormat95*

DIVISION 29 – RESERVED

SITE and INFRASTRUCTURE SUBGROUP

DIVISION 30 – RESERVED FOR FUTURE EXPANSION

DIVISION 31 – EARTHWORK: *Site Construction sections, predominately below grade, that have been relocated from Division 02 in MasterFormat95*.

DIVISION 32 – EXTERIOR IMPROVEMENTS: *Site Construction sections, predominately above grade, that have been relocated from Division 02 in MasterFormat95*

DIVISION 33 – UTILITIES: *Utility sections with expansions that have been relocated from Division 02 in MasterFormat95*.

DIVISION 34 – TRANSPORTATION: *Transportation sections with expansions relocated from the various divisions in MasterFormat95*

DIVISION 35 – WATERWAY and MARINE: *Expanded waterway and other marine section from Division 02 and other divisions in MasterFormat95*.

DIVISION 36 – RESERVED FOR FUTURE EXPANSION

DIVISION 37 – RESERVED FOR FUTURE EXPANSION

DIVISION 38 – RESERVED FOR FUTURE EXPANSION

DIVISION 39 – RESERVED FOR FUTURE EXPANSION

PROCESS EQUIPMENT SUBGROUP

DIVISION 40 – RESERVED FOR FUTURE EXPANSION

DIVISION 41 – MATERIAL PROCESSING and HANDLING EQUIPMENT: *Equipment for the processing and conditioning of raw materials; material handling equipment for bulk materials as well as discrete units; manufacturing equipment and machinery; test equipment and packaging/ shipping systems.*

DIVISION 42 – PROCESSING HEATING, COOLING and DRYING EQUIPMENT: *Equipment for process heating, cooling and drying of materials, liquids, gases, and manufactured items and/or materials.*

DIVISION 43 – PROCESS GAS and LIQUID HANDLING, PURIFICATION and STORAGE EQUIPMENT: *Equipment for handling purification and storage of process liquids, gases, and slurries including atmospheric tanks as well as pressure vessels.*

DIVISION 44 – POLLUTION CONTROL EQUIPMENT: *Equipment for controlling emission of contaminants from manufacturing processes and treatment of air, soil, and water contaminants.*

DIVISION 45 – INDUSTRY SPECIFIC MANUFACTURING EQUIPMENT*: A division in which the owners can specify equipment that is used ONLY within a single industry. (All industries currently identified in the North American Industry Classification System, NAICS, are allocated space within this division).*

DIVISION 46 – SOLID WASTE EQUIPMENT: *Not defined at this time*

DIVISION 47 – RESERVED FOR FUTURE EXPANSION

DIVISION 48 – ELECTRICAL POWER GENERATION: *Plants and equipment for the generation and control of electrical power from fossil fuel, nuclear energy, hydroelectric, wind, solar energy, geothermal energy, electrochemical energy and fuel cells*.

DIVISION 49 – RESERVED FOR FUTURE EXPANSION

APPENDIX 3-B2

MASTERFORMAT 2004

FACILITY CONSTRUCTION SUBGROUP

DIVISION 21 – FIRE SUPPRESSION

21 00 00 – FIRE SUPPRESSION

21 01 00 – OPERATION and MAINTENANCE of FIRE SUPPRESSION
21 02 00 – RESERVED
21 03 00 – RESERVED
21 04 00 – RESERVED
21 05 00 – COMMON WORK RESULTS for FIRE SUPPRESSION
21 06 00 – SCHEDULES for FIRE SUPPRESSION
21 07 00 – FIRE SUPPRESSION SYSTEMS INSULATION
21 08 00 – COMMISIONING of FIRE SUPPRESSION SYSTEMS
21 09 00 – INSTRUMENTATION and CONTROL for FIRE SUPPRESSION SYSTEMS

21 10 00 – WATER BASED FIRE SUPPRESSION SYSTEMS

21 11 00 – FACILITY FIRE SUPPRESSION WATER SERVICE PIPING
21 12 00 – FIRE SUPPRESSION STANDPIPES
21 13 00 – FIRE SUPPRESSION SPRINKLER SYSTEMS
21 14 00 – RESERVED
21 15 00 – RESERVED
21 16 00 – RESERVED
21 17 00 – RESERVED
21 18 00 – RESERVED
21 19 00 – RESERVED

21 20 00 – FIRE EXTINGUISHING SYSTEMS

21 21 00 – CARBON DIOXIDE FIRE EXTINGUISHING SYSTEMS
21 22 00 – CLEAN AGENT FIRE EXTINGUISHING SYSTEMS
21 23 00 – WET CHEMICAL FIRE EXTINGUISHING SYSTEMS
21 24 00 – DRY CHEMICAL FIRE EXTINGUISHING SYSTEMS
21 25 00 – RESERVED
21 26 00 – RESERVED
21 27 00 – RESERVED
21 28 00 – RESERVED
21 29 00 – RESERVED

21 30 00 – FIRE PUMPS

21 31 00 – CENTRIFUGAL FIRE PUMPS
21 32 00 – VERTICAL TURBINE FIRE PUMPS
21 33 00 – POSITIVE DISPLACEMENT FIRE PUMPS
21 34 00 – RESERVED
21 35 00 – RESERVED
21 36 00 – RESERVED
21 37 00 – RESERVED
21 38 00 – RESERVED
21 39 00 – RESERVED

21 40 00 – FIRE SUPPRESSION WATER STORAGE

21 41 00 – STORAGE TANKS for FIRE SUPPRESSION WATER
21 42 00 – RESERVED
21 43 00 – RESERVED
21 44 00 – RESERVED
21 45 00 – RESERVED
21 46 00 – RESERVED
21 47 00 – RESERVED
21 48 00 – RESERVED
21 49 00 – RESERVED

21 50 00 – RESERVED

21 60 00 – RESERVED

21 70 00 – RESERVED

21 80 00 – RESERVED

21 90 00 – RESERVED

APPENDIX 3-B3

MASTERFORMAT 2004

FACILITY CONSTRUCTION SUBGROUP

DIVISION 21 – FIRE SUPPRESSION

21 00 00 – FIRE SUPPRESSION

21 01 00 – OPERATION and MAINTENANCE of FIRE SUPPRESSION

21 01 10 – OPERATION and MAINTENANCE OF WATER BASED FIRE SUPPRESSION SYSTEMS
21 01 20 – OPERATION and MAINTENANCE of FIRE EXTINGUISHING SYSTEMS
21 01 30 – OPERATION and MAINTENANCE of FIRE SUPPRESSION EQUIPMENT

21 02 00 – RESERVED

21 03 00 – RESERVED

21 04 00 – RESERVED

21 05 00 – COMMON WORK RESULTS for FIRE SUPPRESSION

21 05 13 – COMMON MOTOR REQUIREMENTS for FIRE SUPPRESSION EQUIPMENT
21 05 16 – EXPANSION FITTINGS and LOOPS for FIRE SUPPRESSION PIPING
21 05 19 – METERS and GAGES for FIRE SUPPRESSION SYSTEMS
21 05 23 – GENERAL DUTY VALVES for WATER BASED FIRE SUPPRESSION PIPING
21 05 29 – HANGERS and SUPPORTS for FIRE SUPPRESSION PIPING and EQUIPMENT
21 05 33 – HEAT TRACING FOR FIRE SUPPRESSION PIPING
21 05 48 – VIBRATION and SEISMIC CONTROLS for FIRE SUPPRESSION PIPING and EQUIPMENT
21 05 53 – IDENTIFICATION for FIRE SUPPRESSION PIPING and EQUIPMENT

21 06 00 – SCHEDULES for FIRE SUPPRESSION

21 06 10 – SCHEDULES for WATER BASED FIRE SUPPRESSION SYSTEMS
21 06 20 – SCHEDULES for FIRE EXTINGUISHING SYSTEMS
21 06 30 – SCHEDULES for FIRE SUPPRESSION EQUIPMENT

21 07 00 – FIRE SUPPRESSION SYSTEMS INSULATION

21 07 10 – FIRE SUPPRESSION EQUIPMENT INSULATION
21 07 20 – FIRE SUPPRESSION PIPING INSULATION

21 08 00 – COMMISIONING of FIRE SUPPRESSION SYSTEMS

21 09 00 – INSTRUMENTATION and CONTROL for FIRE SUPPRESSION SYSTEMS

21 10 00 – WATER BASED FIRE SUPPRESSION SYSTEMS

21 11 00 – FACILITY FIRE SUPPRESSION WATER SERVICE PIPING

21 11 16 – FACILITY FIRE HYDRANTS
21 11 19 – FIRE DEPARTMENT CONNECTIONS

21 12 00 – FIRE SUPPRESSION STANDPIPES

21 12 13 – FIRE SUPPRESSION HOSES and NOZZLES
21 12 16 – FIRE SUPPRESSION HOSE REELS
21 12 19 – FIRE SUPPRESSION HOSE RACKS
21 12 23 – FIRE SUPPRESSION HOSE VALVES
21 12 26 – FIRE SUPPRESSION VALVE and HOSE CABINETS

21 13 00 – FIRE SUPPRESSION SPRINKLER SYSTEMS

21 13 13 – WET PIPE SPRINKLER SYSTEMS
21 13 16 – DRY PIPE SPRINKLER SYSTEMS
21 13 19 – PRE-ACTION SPRINKLER SYSTEMS
21 13 23 – COMBINED DRY and PRE-ACTION SPRINKLER SYSTEMS
21 13 26 – DELUGE FIRE SUPPRESSION SPRINKLER SYSTEMS
21 13 29 – WATER SPRAY FIXED SYSTEMS
21 13 36 – ANTIFREEZE SPRINKLER SYSTEMS
21 13 39 – FOAM-WATER SYSTEMS

21 14 00 – RESERVED

21 15 00 – RESERVED

21 16 00 – RESERVED

21 17 00 – RESERVED

21 18 00 – RESERVED

21 19 00 – RESERVED

21 20 00 – FIRE EXTINGUISHING SYSTEMS

21 21 00 – CARBON DIOXIDE FIRE EXTINGUISHING SYSTEMS

21 21 13 – CARBON DIOXIDE FIRE EXTINGUISHING PIPING
21 21 16 – CARBON DIOXIDE FIRE EXTINGUISHING EQUIPMENT

21 22 00 – CLEAN AGENT FIRE EXTINGUISHING SYSTEMS

21 22 13 – CLEAN AGENT FIRE EXTINGUISHING PIPING
21 22 16 – CLEAN AGENT FIRE EXTINGUISHING EQUIPMENT

21 23 00 – WET CHEMICAL FIRE EXTINGUISHING SYSTEMS

21 23 13 – WET CHEMICAL FIRE EXTINGUISHING PIPING
21 23 16 – WET CHEMICAL FIRE EXTINGUISHING EQUIPMENT

21 24 00 – DRY CHEMICAL FIRE EXTINGUISHING SYSTEMS

21 24 13 – DRY CHEMICAL FIRE EXTINGUISHING PIPING
21 24 16 – DRY CHEMICAL FIRE EXTINGUISHING EQUIPMENT

21 25 00 – RESERVED

21 26 00 – RESERVED

21 27 00 – RESERVED

21 28 00 – RESERVED

21 29 00 – RESERVED

21 30 00 – FIRE PUMPS

21 31 00 – CENTRIFUGAL FIRE PUMPS

21 31 13 – ELECTRIC DRIVE, CENTRIFUGAL FIRE PUMPS
21 31 16 – DIESEL DRIVE, CENTRIFUGAL FIRE PUMPS

21 32 00 – VERTICAL TURBINE FIRE PUMPS

21 32 13 – ELECTRIC DRIVE, VERTICAL TURBINE FIRE PUMPS
21 32 16 – DIESEL DRIVE, VERTICAL TURBINE FIRE PUMPS

21 33 00 – POSITIVE DISPLACEMENT FIRE PUMPS

21 33 10 – ELECTRIC DRIVE, POSITIVE DISPLACEMENT FIRE PUMPS
21 33 16 – DIESEL DRIVE, POSITIVE DISPLACEMENT FIRE PUMPS

21 34 00 – RESERVED

21 35 00 – RESERVED

21 36 00 – RESERVED

21 37 00 – RESERVED

21 38 00 – RESERVED

21 39 00 – RESERVED

21 40 00 – FIRE SUPPRESSION WATER STORAGE

21 41 10 – STORAGE TANKS for FIRE SUPPRESSION WATER
21 41 13 – PRESSURIZED STORAGE TANKS for FIRE SUPPRESSION WATER
21 41 16 – ELEVATED STORAGE TANKS for FIRE SUPPRESSION WATER
21 41 19 – ROOF MOUNTED STORAGE TANKS for FIRE SUPPRESSION WATER
21 41 23 – GROUND SUCTION STORAGE TANKS for FIRE SUPPRESSION WATER
21 41 26 – UNDERGROUND STORAGE TANKS for FIRE SUPPRESSION WATER
21 41 29 – STORAGE TANKS for FIRE SUPPRESSION WATER ADDITIVES
21 42 00 – RESERVED
21 43 00 – RESERVED
21 44 00 – RESERVED
21 45 00 – RESERVED
21 46 00 – RESERVED
21 47 00 – RESERVED
21 48 00 – RESERVED
21 49 00 – RESERVED
21 50 00 – RESERVED
21 60 00 – RESERVED
21 70 00 – RESERVED
21 80 00 – RESERVED
21 90 00 – RESERVED

APPENDIX 3-B4

MASTERFORMAT 2004

FACILITY CONSTRUCTION SUBGROUP

22 00 00 – PLUMBING

22 01 00 – OPERATION and MAINTENANCE of PLUMBING
22 01 10 – OPERATION and MAINTENANCE of PLUMBING PIPING and PUMPS
22 01 20 – RESERVED
22 01 30 – OPERATION and MAINTENANCE of PLUMBING EQUIPMENT
22 01 40 – OPERATION and MAINTENANCE of PLUMBING FIXTURES
22 01 50 – OPERATION and MAINTENANCE of POOL and FOUNTAIN PLUMBING SYSTEMS
22 01 60 – OPERATION and MAINTENANCE of LABORATORY and HEALTHCARE SYSTEMS
22 01 70 – RESERVED
22 01 80 – RESERVED
22 01 90 – RESERVED
22 02 00 – RESERVED
22 03 00 – RESERVED
22 04 00 – RESERVED
22 05 00 – COMMON WORK RESULTS for PLUMBING
22 05 13 – COMMON MOTOR REQUIREMENTS for PLUMBING EQUIPMENT
22 05 16 – EXPANSION FITTINGS and LOOPS for PLUMBING PIPING
22 05 19 – METERS and GAGES for PLUMBING PIPING
22 05 23 – GENERAL DUTY VALVES for PLUMBING PIPING
22 05 29 – HANGERS and SUPPORTS for PLUMBING PIPING and EQUIPMENT
22 05 33 – HEAT TRACING for PLUMBING PIPING
22 05 48 – VIBRATION and SEISMIC CONTROLS for PLUMBING PIPING and EQUIPMENT
22 05 53 – IDENTIFICATION for PLUMBING PIPING and EQUIPMENT
22 05 73 – FACILITY DRAINAGE MANHOLES
22 05 76 – FACILITY DRAINAGE CLEANOUTS
22 06 00 – SCHEDULES for PLUMBING
22 06 10 – SCHEDULES for PLUMBING PIPING and PUMPS
22 06 12 – SCHEDULES for FACILITY POTABLE WATER STORAGE
22 06 15 – SCHEDULES for GENERAL SERVICE COMPRESSED AIR EQUIPMENT
22 06 30 – SCHEDULES for PLUMBING EQUIPMENT
22 06 40 – SCHEDULES for PLUMBING FIXTURES
22 06 50 – SCHEDULES for POOL and FOUNTAIN PLUMBING SYSTEMS
22 06 60 – SCHEDULES for LABORATORY and HEALTHCARE SYSTEMS
22 07 00 – PLUMBING INSULATION
22 07 16 – PLUMBING EQUIPMENT INSULATION
22 07 19 – PLUMBING PIPING INSULATION
22 08 00 – COMMISSIONING of PLUMBING
22 09 00 – INSTRUMENTATION and CONTROL of PLUMBING

22 10 00 – PLUMBING PIPING and PUMPS

22 11 00 – FACILITY WATER DISTRIBUTION
22 11 13 – FACILITY WATER DISTRIBUTION PIPING
22 11 16 – DOMESTIC WATER PIPING
22 11 19 – DOMESTIC WATER PIPING SPECIALTIES
22 11 23 – DOMESTIC WATER PUMPS
22 12 00 – FACILITY POTABLE WATER STORAGE TANKS
22 12 13 – FACILITY ROOF MOUNTED, POTABLE WATER STORAGE TANKS
22 12 16 – FACILITY ELEVATED, POTABLE WATER STORAGE TANKS
22 12 19 – FACILITY GROUND MOUNTED, POTABLE WATER STORAGE TANKS

22 12 23 – FACILITY INDOOR POTABLE WATER STORAGE TANKS

22 13 00 – FACILITY SANITARY SEWERAGE

22 13 13 – FACILITY SANITARY SEWERS
22 13 16 – SANITARY WASTE and VENT PIPING
22 13 19 – SANITARY WASTE PIPING SPECIALTIES
22 13 23 – SANITARY WASTE INTERCEPTORS
22 13 26 – SANITARY WASTE SEPARATORS
22 13 29 – SANITARY SEWERAGE PUMPS
22 13 33 – PACKAGED, SUBMERSIBLE SEWERAGE PUMP UNITS
22 13 36 – PACKAGED, WASTEWATER PUMP UNITS
22 13 43 – FACILITY PACKAGED SEWAGE PUMPING STATIONS
22 13 53 – FACILITY SEPTIC TANKS

22 14 00 – FACILITY STORM DRAINAGE

22 14 13 – FACILITY STORM DRAINAGE PIPING
22 14 16 – RAINWATER LEADERS
22 14 19 – SUMP PUMP DISCHARGE PIPING
22 14 23 – STORM DRAINAGE PIPING SPECIALTIES
22 14 26 – FACILITY STORM DRAINS
22 14 29 – SUMP PUMPS
22 14 33 – PACKAGED, PEDESTAL, DRAINAGE PUMP UNITS
22 14 36 – PACKAGED, SUBMERSIBLE, DRAINAGE PUMP UNITS

22 15 00 – GENERAL SERVICE COMPRESSED AIR SYSTEMS

22 15 13 – GENERAL SERVICE COMPRESSED AIR PIPING
22 15 16 – GENERAL SERVICE COMPRESSED AIR VALVES
22 15 19 – GENERAL SERVICE PACKAGED AIR COMPRESSORS and RECEIVERS

22 16 00 – RESERVED

22 17 00 – RESERVED

22 18 00 – RESERVED

22 19 00 – RESERVED

22 20 00 – RESERVED

22 30 00 – PLUMBING EQUIPMENT

22 31 00 – DOMESTIC WATER SOFTENERS

22 31 13 – RESIDENTIAL DOMESTIC WATER SOFTENERS
22 31 16 – COMMERCIAL DOMESTIC WATER SOFTENERS

22 32 00 – DOMESTIC WATER FILTRATION EQUIPMENT

22 32 13 – DOMESTIC WATER BAG TYPE FILTERS
22 32 16 – DOMESTIC WATER FREE STANDING CARTRIDGE FILTERS
22 32 19 – DOMESTIC WATER OFF FLOOR CARTRIDGE FILTERS
22 32 23 – DOMESTIC WATER CARBON FILTERS
22 32 26 – DOMESTIC WATER SAND FILTERS

22 33 00 – ELECTRIC DOMESTIC WATER HEATERS

22 33 13 – INSTANTANEOUS ELECTRIC DOMESTIC WATER HEATERS
22 33 30 – RESIDENTIAL, ELECTRIC DOMESTIC WATER HEATERS
22 33 33 – LIGHT COMMERCIAL ELECTRIC DOMESTIC WATER HEATERS
22 33 36 – COMMERCIAL DOMESTIC WATER ELECTRIC BOOSTER HEATERS

22 34 00 – FUEL FIRED DOMESTIC WATER HEATERS

22 34 13 – INSTANTANEOUS, TANKLESS, GAS DOMESTIC WATER HEATERS
22 34 30 – RESIDENTIAL GAS DOMESTIC WATER HEATERS
22 34 36 – COMMERCIAL GAS DOMESTIC WATER HEATERS
22 34 46 – OIL FIRED DOMESTIC WATER HEATERS
22 34 56 – DUAL FUEL FIRED DOMESTIC WATER HEATERS

22 35 00 – DOMESTIC WATER HEAT EXCHANGERS

22 35 13 – INSTANTANEOUS DOMESTIC WATER HEAT EXCHANGERS
22 35 23 – CIRCULATING DOMESTIC WATER HEAT EXCHANGERS
22 35 29 – NON-CIRCULATING DOMESTIC WATER HEAT EXCHANGERS
22 35 36 – DOMESTIC WATER BRAZED PLATE HEAT EXCHANGERS
22 35 39 – DOMESTIC WATER PLATE and FRAME HEAT EXCHANGERS
22 35 43 – DOMESTIC WATER HEAT RECLAIMERS

22 36 00 – RESERVED

22 37 00 – RESERVED

22 38 00 – RESERVED

22 39 00 – RESERVED

22 40 00 – PLUMBING FIXTURES

22 41 00 – RESIDENTIAL PLUMBING FIXTURES

22 41 13 – RESIDENTIAL WATER CLOSETS, URINALS and BIDETS
22 41 16 – RESIDENTIAL LAVATORIES and SINKS
22 41 19 – RESIDENTIAL BATHTUBS
22 41 23 – RESIDENTIAL SHOWER RECEPTORS and BASINS
22 41 26 – RESIDENTIAL DISPOSERS
22 41 36 – RESIDENTIAL LAUNDRY TRAYS
22 41 39 – RESIDENTIAL FAUCETS, SUPPLIES and TRIM

22 42 00 – COMMERCIAL PLUMBING FIXTURES

22 42 13 – COMMERCIAL WATER CLOSETS, URINALS and BIDETS
22 42 16 – COMMERCIAL LAVATORIES and SINKS
22 42 19 – COMMERCIAL BATHTUBS
22 42 23 – COMMERCIAL SHOWER RECEPTORS and BASINS
22 42 26 – COMMERCIAL DISPOSERS
22 42 29 – SHAMPOO BOWLS
22 42 33 – WASH FOUNTAINS
22 42 36 – COMMERCIAL LAUNDRY TRAYS
22 42 39 – COMMERCIAL FAUCETS, SUPPLIES and TRIM
22 42 43 – FLUSHOMETERS

22 43 00 – HEALTHCARE PLUMBING FIXTURES

22 43 13 – HEALTHCARE WATER CLOSETS
22 43 16 – HEALTHCARE SINKS
22 43 19 – HEALTHCARE BATHTUBS and SHOWERS
22 43 23 – HEALTHCARE SHOWER RECEPTORS and BASINS
22 43 26 – HEALTHCARE FAUCETS
22 43 43 – HEALTHCARE PLUMBING FIXTURE FLUSHOMETERS

22 44 00 – RESERVED

22 45 00 – EMERGENCY PLUMBING FIXTURES

22 45 13 – EMERGENCY SHOWERS
22 45 16 – EYEWASH EQUIPMENT
22 45 19 – SELF CONTAINED EYEWASH EQUIPMENT
22 45 23 – PERSONAL EYEWASH EQUIPMENT
22 45 26 – EYE/ FACE WASH EQUIPMENT
22 45 29 – HAND HELD EMERGENCY DRENCH HOSES
22 45 33 – COMBINATION EMERGENCY FIXTURE UNITS
22 45 36 – EMERGENCY FIXTURE WATER TEMPERING UNITS

22 46 00 – SECURITY PLUMBING FIXTURES

22 46 13 – SECURITY WATER CLOSETS and URINALS
22 46 16 – SECURITY LAVATORIES and SINKS
22 46 39 – SECURITY FAUCETS, SUPPLIES and TRIM
22 46 43 – SECURITY PLUMBING FIXTURE FLUSHOMETERS
22 46 53 – SECURITY PLUMBING FIXTURE SUPPORTS

22 47 00 – DRINKING FOUNTAINS and WATER COOLERS

22 47 13 – DRINKING FOUNTAINS
22 47 16 – PRESSURE WATER COOLERS
22 47 19 – WATER STATION WATER COOLERS
22 47 23 – REMOTE WATER COOLERS

22 48 00 – RESERVED

22 49 00 – RESERVED

22 50 00 – POOL and FOUNTAIN PLUMBING SYSTEMS

22 51 00 – SWIMMING POOL PLUMBING SYSTEMS

22 51 13 – SWIMMING POOL PIPING
22 51 16 – SWIMMING POOL PUMPS
22 51 19 – SWIMMING POOL WATER TREATMENT EQUIPMENT
22 51 23 – SWIMMING POOL EQUIPMENT CONTROLS

22 52 00 – FOUNTAIN PLUMBING SYSTEMS

22 52 13 – FOUNTAIN PIPING
22 52 16 – FOUNTAIN PUMPS
22 52 19 – FOUNTAIN WATER TREATMENT EQUIPMENT
22 52 23 – FOUNTAIN EQUIPMENT CONTROLS

22 53 00 – RESERVED

22 54 00 – RESERVED

22 55 00 – RESERVED

22 56 00 – RESERVED

22 57 00 – RESERVED

22 58 00 – RESERVED

22 59 00 – RESERVED

22 60 00 – GAS and VACUUM SYSTEMS for LABORATORY and HEALTHCARE FACILITIES

22 61 00 – COMPRESSED AIR SYSTEMS for LABORATORY and HEALTHCARE FACILITIES

22 61 13 – COMPRESSED AIR PIPING for LABORATORY and HEALTHCARE FACILITIES
22 61 19 – COMPRESSED AIR EQUIPMENT for LABORATORY and HEALTHCARE FACILITIES

22 62 00 – VACUUM SYSTEMS for LABORATORY and HEALTHCARE FACILITIES

22 62 13 – VACUUM PIPING for LABORATORY and HEALTHCARE FACILITIES
22 62 19 – VACUUM EQUIPMENT for LABORATORY and HEALTHCARE FACILITIES
22 62 23 – WASTE ANESTHESIA GAS PIPING

22 63 00 – GAS SYSTEMS for LABORATORY and HEALTHCARE FACILITIES

22 63 13 – GAS PIPING for LABORATORY and HEALTHCARE FACILITIES
22 63 19 – GAS STORAGE TANKS for LABORATORY and HEALTHCARE FACILITIES

22 64 00 – RESERVED

22 65 00 – RESERVED

22 66 00 – CHEMICAL WASTE SYSTEMS for LABORATORY and HEALTHCARE FACILITIES

22 66 53 – LABORATORY CHEMICAL WASTE and VENT PIPING
22 66 70 – HEALTH CARE CHEMICAL WASTE and VENT PIPING
22 66 83 – CHEMICAL WASTE TANKS

22 67 00 – PROCESSED WATER SYSTEMS for LABORATORY and HEALTHCARE FACILITIES

22 67 13 – PROCESSED WATER PIPING for LABORATORY and HEALTHCARE FACILITIES
22 67 19 – PROCESSED WATER EQUIPMENT for LABORATORY and HEALTHCARE FACILITIES

22 68 00 – RESERVED

22 69 00 – RESERVED

22 70 00 – RESERVED

22 80 00 – RESERVED

22 90 00 – RESERVED

APPENDIX 3-B5

MASTERFORMAT 2004

FACILITY CONSTRUCTION SUBGROUP

22 00 00 – PLUMBING

22 01 00 – OPERATION and MAINTENANCE of PLUMBING
22 01 10 – OPERATION and MAINTENANCE of PLUMBING PIPING and PUMPS
22 01 20 – RESERVED
22 01 30 – OPERATION and MAINTENANCE of PLUMBING EQUIPMENT
22 01 40 – OPERATION and MAINTENANCE of PLUMBING FIXTURES
22 01 50 – OPERATION and MAINTENANCE of POOL and FOUNTAIN PLUMBING SYSTEMS
22 01 60 – OPERATION and MAINTENANCE of LABORATORY and HEALTHCARE SYSTEMS
22 01 70 – RESERVED
22 01 80 – RESERVED
22 01 90 – RESERVED

22 02 00 – RESERVED

22 03 00 – RESERVED

22 04 00 – RESERVED

22 05 00 – COMMON WORK RESULTS for PLUMBING
22 05 13 – COMMON MOTOR REQUIREMENTS for PLUMBING EQUIPMENT
22 05 16 – EXPANSION FITTINGS and LOOPS for PLUMBING PIPING
22 05 19 – METERS and GAGES for PLUMBING PIPING
22 05 23 – GENERAL DUTY VALVES for PLUMBING PIPING
22 05 29 – HANGERS and SUPPORTS for PLUMBING PIPING and EQUIPMENT
22 05 33 – HEAT TRACING for PLUMBING PIPING
22 05 48 – VIBRATION and SEISMIC CONTROLS for PLUMBING PIPING and EQUIPMENT
22 05 53 – IDENTIFICATION for PLUMBING PIPING and EQUIPMENT
22 05 73 – FACILITY DRAINAGE MANHOLES
22 05 76 – FACILITY DRAINAGE CLEANOUTS

22 06 00 – SCHEDULES for PLUMBING
22 06 10 – SCHEDULES for PLUMBING PIPING and PUMPS
22 06 10 13 – Plumbing Pump Schedule
22 06 12 – SCHEDULES for FACILITY POTABLE WATER STORAGE
22 06 15 – SCHEDULES for GENERAL SERVICE COMPRESSED AIR EQUIPMENT
22 06 30 – SCHEDULES for PLUMBING EQUIPMENT
22 06 30 13 – Domestic Water Heater Schedule
22 06 40 – SCHEDULES for PLUMBING FIXTURES
22 06 40 13 – Plumbing Fixture Schedule
22 06 50 – SCHEDULES for POOL and FOUNTAIN PLUMBING SYSTEMS
22 06 60 – SCHEDULES for LABORATORY and HEALTHCARE SYSTEMS

22 07 00 – PLUMBING INSULATION
22 07 16 – PLUMBING EQUIPMENT INSULATION
22 07 19 – PLUMBING PIPING INSULATION

22 08 00 – COMMISSIONING of PLUMBING

22 09 00 – INSTRUMENTATION and CONTROL of PLUMBING

22 10 00 – PLUMBING PIPING and PUMPS

22 11 00 – FACILITY WATER DISTRIBUTION
22 11 13 – FACILITY WATER DISTRIBUTION PIPING
22 11 16 – DOMESTIC WATER PIPING
22 11 19 – DOMESTIC WATER PIPING SPECIALTIES
22 11 23 – DOMESTIC WATER PUMPS
22 11 23 13 – *Domestic Water Packaged Booster Pumps*
22 11 23 23 – *Close Coupled, In-Line, Seal-Less Centrifugal Domestic Water Pumps*
22 11 23 26 – *Close Coupled, Horizontally Mounted, In-Line, Centrifugal Domestic Water Pumps*
22 11 23 29 – *Close Coupled, Vertically Mounted, In-Line, Centrifugal Domestic Water Pumps*
22 11 23 33 – *Separately Coupled, In-Line, Centrifugal Domestic Water Pumps*
22 11 23 36 – *Separately Coupled, Horizontally Mounted, In-Line, Centrifugal Domestic Water Pumps*

22 12 00 – FACILITY POTABLE WATER STORAGE TANKS
22 12 13 – FACILITY ROOF MOUNTED, POTABLE WATER STORAGE TANKS
22 12 16 – FACILITY ELEVATED, POTABLE WATER STORAGE TANKS
22 12 19 – FACILITY GROUND MOUNTED, POTABLE WATER STORAGE TANKS
22 12 23 – FACILITY INDOOR POTABLE WATER STORAGE TANKS
22 12 23 13 – Facility Steel, Indoor Potable Water Storage, Pressure Tanks
22 12 23 16 – Facility Steel, Indoor Potable Water Storage, Non-Pressure Tanks

22 12 23 23 – Facility Plastic, Indoor Potable Water Storage, Pressure Tanks
22 12 23 26 – Facility Plastic, Indoor Potable Water Storage, Non-Pressure Tanks

22 13 00 – FACILITY SANITARY SEWERAGE

22 13 13 – FACILITY SANITARY SEWERS
22 13 16 – SANITARY WASTE and VENT PIPING
22 13 19 – SANITARY WASTE PIPING SPECIALTIES
22 13 19 13 – Sanitary Drains
22 13 19 23 – Fats, Oils, and Grease Disposal Systems
22 13 19 26 – Grease Removal Devices
22 13 19 33 – Backwater Valves
22 13 19 36 – Air Admittance Valves
22 13 23 – SANITARY WASTE INTERCEPTORS
22 13 26 – SANITARY WASTE SEPARATORS
22 13 29 – SANITARY SEWERAGE PUMPS
22 13 29 13 – Wet Pit Mounted, Vertical Sewerage Pumps
22 13 29 16 – Submersible Sewerage Pumps
22 13 29 23 – Sewerage Pump Reverse Flow Assemblies
22 13 29 33 – Sewerage Pump Basins and Pits
22 13 33 – PACKAGED, SUBMERSIBLE SEWERAGE PUMP UNITS
22 13 36 – PACKAGED, WASTEWATER PUMP UNITS
22 13 43 – FACILITY PACKAGED SEWAGE PUMPING STATIONS
22 13 43 13 – Facility Dry Well Packaged Sewage Pumping Stations
22 13 43 16 – Facility Wet Well Packaged Sewage Pumping Stations
22 13 53 – FACILITY SEPTIC TANKS

22 14 00 – FACILITY STORM DRAINAGE

22 14 13 – FACILITY STORM DRAINAGE PIPING
22 14 16 – RAINWATER LEADERS
22 14 19 – SUMP PUMP DISCHARGE PIPING
22 14 23 – STORM DRAINAGE PIPING SPECIALTIES
22 14 23.23 – Fats, Oils, and Grease Disposal Systems
22 14 23.26 – Grease Removal Devices
22 14 23.33 – Backwater Valves
22 14 23.36 – Air Admittance Valves
22 14 26 – FACILITY STORM DRAINS 22 14 26.13 – Roof Drains 22 14 26.16 – Facility Area Drains 22 14 26.19 – Facility Trench Drains
22 14 29 – SUMP PUMPS
22 14 29.13 – Wet Pit Mounted, Vertical Sump Pumps
22 14 29.16 – Submersible Sump Pumps
22 14 29.19 – Sump Pump Basins and Pits
22 14 33 – PACKAGED, PEDESTAL, DRAINAGE PUMP UNITS
22 14 36 – PACKAGED, SUBMERSIBLE, DRAINAGE PUMP UNITS

22 15 00 – GENERAL SERVICE COMPRESSED AIR SYSTEMS

22 15 13 – GENERAL SERVICE COMPRESSED AIR PIPING
22 15 16 – GENERAL SERVICE COMPRESSED AIR VALVES
22 15 19 – GENERAL SERVICE PACKAGED AIR COMPRESSORS and RECEIVERS
22 15 19.13 – General Service Packaged Reciprocating Air Compressors
22 15 19.16 – General Service Packaged Liquid Ring Air Compressors
22 15 19.19 – General Service Packaged Rotary Screw Air Compressors
22 15 19.23 – General Service Packaged Sliding Vane Air Compressors

22 16 00 – RESERVED

22 17 00 – RESERVED

22 18 00 – RESERVED

22 19 00 – RESERVED

22 20 00 – RESERVED

22 30 00 – PLUMBING EQUIPMENT

22 31 00 – DOMESTIC WATER SOFTENERS

22 31 13 – RESIDENTIAL DOMESTIC WATER SOFTENERS
22 31 16 – COMMERCIAL DOMESTIC WATER SOFTENERS

22 32 00 – DOMESTIC WATER FILTRATION EQUIPMENT

22 32 13 – DOMESTIC WATER BAG TYPE FILTERS
22 32 16 – DOMESTIC WATER FREE STANDING CARTRIDGE FILTERS
22 32 19 – DOMESTIC WATER OFF FLOOR CARTRIDGE FILTERS
22 32 23 – DOMESTIC WATER CARBON FILTERS
22 32 26 – DOMESTIC WATER SAND FILTERS
22 32 26.13 – Domestic Water Circulating Sand Filters
22 32 26.16 – Domestic Water Multimedia Sand Filters
22 32 26 19 – Domestic Water Greensand Filters

22 33 00 – ELECTRIC DOMESTIC WATER HEATERS

22 33 13 – INSTANTANEOUS ELECTRIC DOMESTIC WATER HEATERS
22 33 13.13 – Flow Control, Instantaneous Electric Domestic Water Heaters
22 33 13.16 – Thermostat Controlled, Instantaneous Electric Domestic Water Heaters
22 33 30 – RESIDENTIAL, ELECTRIC DOMESTIC WATER HEATERS
22 33 30.13 – Residential, Small Capacity Electric Domestic Water Heaters
22 33 30.16 – Residential, Storage Electric Domestic Water Heaters
22 33 30.23 – Residential, Collector to Tank, Solar – Electric Domestic Water Heaters

22 33 30.26 – Residential, Collector to Tank, Heat Exchanger Coil, Solar-Electric Domestic Water Heaters
22 33 33 – LIGHT COMMERCIAL ELECTRIC DOMESTIC WATER HEATERS
22 33 36 – COMMERCIAL DOMESTIC WATER ELECTRIC BOOSTER HEATERS
22 33 36.13 – Commercial Domestic Water Electric Booster Heaters
22 33 36.16 – Commercial Storage Electric Domestic Water Heaters

22 34 00 – FUEL FIRED DOMESTIC WATER HEATERS

22 34 13 – INSTANTANEOUS, TANKLESS, GAS DOMESTIC WATER HEATERS
22 34 30 – RESIDENTIAL GAS DOMESTIC WATER HEATERS
22 34 30.13 – Residential, Atmospheric, Gas Domestic Water Heaters
22 34 30.16 – Residential, Direct Vent, Gas Domestic Water Heaters
22 34 30.19 – Residential, Power Vent, Gas Domestic Water Heaters
22 34 36 – COMMERCIAL GAS DOMESTIC WATER HEATERS
22 34 36.13 – Commercial, Atmospheric, Gas Domestic Water Heaters
22 34 36.16 – Commercial, Power Burner, Gas Domestic Water Heaters
22 34 36.19 – Commercial, Power Vent, Gas Domestic Water Heaters
22 34 36.23 – Commercial, High Efficiency, Gas Domestic Water Heaters
22 34 36.26 – Commercial, Coil Type, Finned Tube, Gas Domestic Water Heaters
22 34 36.29 – Commercial, Grid Type, Finned Tube, Gas Domestic Water Heaters
22 34 46 – OIL FIRED DOMESTIC WATER HEATERS
22 34 46.13 – Large Capacity, Oil Fired Domestic Water Heaters
22 34 56 – DUAL FUEL FIRED DOMESTIC WATER HEATERS

22 35 00 – DOMESTIC WATER HEAT EXCHANGERS

22 35 13 – INSTANTANEOUS DOMESTIC WATER HEAT EXCHANGERS
22 35 13.13 – Heating Fluid in Coil, Instantaneous Domestic Water Heat Exchanger
22 35 13.16 – Domestic Water in Coil, Instantaneous Domestic Water Heat Exchanger
22 35 13.19 – Heating Fluid in a U-Tube Coil, Instantaneous Domestic Water Heat Exchanger
22 35 23 – CIRCULATING DOMESTIC WATER HEAT EXCHANGERS
22 35 23.13 – Circulating, Compact Domestic Water Heat Exchangers
22 35 23.16 – Circulating, Storage Domestic Water Heat Exchangers
22 35 29 – NON-CIRCULATING DOMESTIC WATER HEAT EXCHANGERS
22 35 29.13 – Non-Circulating, Compact Domestic Water Heat Exchangers
22 35 29.16 – Non-Circulating, Storage Domestic Water Heat Exchangers
22 35 36 – DOMESTIC WATER BRAZED PLATE HEAT EXCHANGERS
22 35 39 – DOMESTIC WATER PLATE and FRAME HEAT EXCHANGERS
22 35 43 – DOMESTIC WATER HEAT RECLAIMERS

22 36 00 – RESERVED

22 37 00 – RESERVED

22 38 00 – RESERVED

22 39 00 – RESERVED

22 40 00 – PLUMBING FIXTURES

22 41 00 – RESIDENTIAL PLUMBING FIXTURES

22 41 13 – RESIDENTIAL WATER CLOSETS, URINALS and BIDETS
22 41 16 – RESIDENTIAL LAVATORIES and SINKS
22 41 19 – RESIDENTIAL BATHTUBS
22 41 23 – RESIDENTIAL SHOWER RECEPTORS and BASINS
22 41 26 – RESIDENTIAL DISPOSERS
22 41 36 – RESIDENTIAL LAUNDRY TRAYS
22 41 39 – RESIDENTIAL FAUCETS, SUPPLIES and TRIM

22 42 00 – COMMERCIAL PLUMBING FIXTURES

22 42 13 – COMMERCIAL WATER CLOSETS, URINALS and BIDETS
22 42 16 – COMMERCIAL LAVATORIES and SINKS
22 42 19 – COMMERCIAL BATHTUBS
22 42 23 – COMMERCIAL SHOWER RECEPTORS and BASINS
22 42 26 – COMMERCIAL DISPOSERS
22 42 29 – SHAMPOO BOWLS
22 42 33 – WASH FOUNTAINS
22 42 36 – COMMERCIAL LAUNDRY TRAYS
22 42 39 – COMMERCIAL FAUCETS, SUPPLIES and TRIM
22 42 43 – FLUSHOMETERS

22 43 00 – HEALTHCARE PLUMBING FIXTURES

22 43 13 – HEALTHCARE WATER CLOSETS
22 43 16 – HEALTHCARE SINKS
22 43 19 – HEALTHCARE BATHTUBS and SHOWERS
22 43 23 – HEALTHCARE SHOWER RECEPTORS and BASINS
22 43 26 – HEALTHCARE FAUCETS
22 43 43 – HEALTHCARE PLUMBING FIXTURE FLUSHOMETERS

22 44 00 – RESERVED

22 45 00 – EMERGENCY PLUMBING FIXTURES

22 45 13 – EMERGENCY SHOWERS
22 45 16 – EYEWASH EQUIPMENT
22 45 19 – SELF CONTAINED EYEWASH EQUIPMENT
22 45 23 – PERSONAL EYEWASH EQUIPMENT
22 45 26 – EYE/ FACE WASH EQUIPMENT
22 45 29 – HAND HELD EMERGENCY DRENCH HOSES
22 45 33 – COMBINATION EMERGENCY FIXTURE UNITS
22 45 36 – EMERGENCY FIXTURE WATER TEMPERING UNITS

22 46 00 – SECURITY PLUMBING FIXTURES

22 46 13 – SECURITY WATER CLOSETS and URINALS
22 46 16 – SECURITY LAVATORIES and SINKS
22 46 39 – SECURITY FAUCETS, SUPPLIES and TRIM
22 46 43 – SECURITY PLUMBING FIXTURE FLUSHOMETERS
22 46 53 – SECURITY PLUMBING FIXTURE SUPPORTS

22 47 00 – DRINKING FOUNTAINS and WATER COOLERS

22 47 13 – DRINKING FOUNTAINS
22 47 16 – PRESSURE WATER COOLERS
22 47 19 – WATER STATION WATER COOLERS
22 47 23 – REMOTE WATER COOLERS

22 48 00 – RESERVED

22 49 00 – RESERVED

22 50 00 – POOL and FOUNTAIN PLUMBING SYSTEMS

22 51 00 – SWIMMING POOL PLUMBING SYSTEMS

22 51 13 – SWIMMING POOL PIPING
22 51 16 – SWIMMING POOL PUMPS
22 51 19 – SWIMMING POOL WATER TREATMENT EQUIPMENT
22 51 23 – SWIMMING POOL EQUIPMENT CONTROLS

22 52 00 – FOUNTAIN PLUMBING SYSTEMS

22 52 13 – FOUNTAIN PIPING
22 52 16 – FOUNTAIN PUMPS
22 52 19 – FOUNTAIN WATER TREATMENT EQUIPMENT
22 52 23 – FOUNTAIN EQUIPMENT CONTROLS

22 53 00 – RESERVED

22 54 00 – RESERVED

22 55 00 – RESERVED

22 56 00 – RESERVED

22 57 00 – RESERVED

22 58 00 – RESERVED

22 59 00 – RESERVED

22 60 00 – GAS and VACUUM SYSTEMS for LABORATORY and HEALTHCARE FACILITIES

22 61 00 – COMPRESSED AIR SYSTEMS for LABORATORY and HEALTHCARE FACILITIES

22 61 13 – COMPRESSED AIR PIPING for LABORATORY and HEALTHCARE FACILITIES
22 61 13.53 – Laboratory Compressed Air Piping
22 61 13.70 – Healthcare Compressed Air Piping
22 61 13.74 – Dental Compressed Air Piping
22 61 19 – COMPRESSED AIR EQUIPMENT for LABORATORY and HEALTHCARE FACILITIES
22 61 19.53 – Laboratory Compressed Air Equipment
22 61 19.70 – Healthcare Compressed Air Equipment
22 61 19.74 – Dental Compressed Air Equipment

22 62 00 – VACUUM SYSTEMS for LABORATORY and HEALTHCARE FACILITIES

22 62 13 – VACUUM PIPING for LABORATORY and HEALTHCARE FACILITIES
22 62 13.53 – Laboratory Vacuum Piping
22 62 13.70 – Healthcare, Surgical Vacuum Piping
22 62 13.74 – Dental Vacuum Piping
22 62 19 – VACUUM EQUIPMENT for LABORATORY and HEALTHCARE FACILITIES
22 62 19.53 – Laboratory Vacuum Equipment
22 62 19.70 – Healthcare Vacuum Equipment
22 62 19.74 – Dental Vacuum and Evacuation Equipment
22 62 23 – WASTE ANESTHESIA GAS PIPING

22 63 00 – GAS SYSTEMS for LABORATORY and HEALTHCARE FACILITIES

22 63 13 – GAS PIPING for LABORATORY and HEALTHCARE FACILITIES
22 63 13.53 – Laboratory Gas Piping
22 63 13.70 – Healthcare Gas Piping
22 63 19 – GAS STORAGE TANKS for LABORATORY and HEALTHCARE FACILITIES
22 63 19.53 – Laboratory Gas Storage Tanks
22 63 19.70 – Healthcare Gas Storage Tanks

22 64 00 – RESERVED

22 65 00 – RESERVED

22 66 00 – CHEMICAL WASTE SYSTEMS for LABORATORY and HEALTHCARE FACILITIES

22 66 53 – LABORATORY CHEMICAL WASTE and VENT PIPING
22 66 70 – HEALTH CARE CHEMICAL WASTE and VENT PIPING
22 66 83 – CHEMICAL WASTE TANKS
22 66 83.13 – Chemical Waste Dilution Tanks
22 66 83.16 – Chemical Waste Neutralization Tanks

22 67 00 – PROCESSED WATER SYSTEMS for LABORATORY and HEALTHCARE FACILITIES

22 67 13 – PROCESSED WATER PIPING for LABORATORY and HEALTHCARE FACILITIES
22 67 13.13 – Distilled Water piping
22 67 13.16 – Reverse Osmosis Water Piping
22 67 13.19 – De-ionized Water Piping
22 67 19 – PROCESSED WATER EQUIPMENT for LABORATORY and HEALTHCARE FACILITIES
22 67 19.13 – Distilled Water Equipment
22 67 19.16 – Reverse Osmosis Water Equipment
22 67 19.19 – De-ionized Water Equipment
22 68 00 – RESERVED
22 69 00 – RESERVED
22 70 00 – RESERVED
22 80 00 – RESERVED
22 90 00 – RESERVED

APPENDIX 3-C
SECTION SHELL OUTLINE

This shell outline has been developed by the American Institute of Architects conforming to the CSI *Manual of Practice*.

SECTION XXXXX
XXXXXXXXXXXXXXXXXXXX

PART 1—GENERAL

1.1 SUMMARY

A. This section includes [description of essential unit of work included in section].

B. Products furnished but not installed under this section include [description].

C. Products installed but not furnished under this section include [description].

D. Related Sections: The following relate to this section:
   1. Division [#] Section ["Title"] for [description of related unit of work].
   2. Division [#] Section ["Title"] for [description of related unit of work].
   3. Division [#] Section ["Title"] for [description of related unit of work].
   4. Division [#] Section ["Title"] for [description of related unit of work].

E. Allowances:

F. Unit Prices:

G. Alternates:

1.2 REFERENCES

1.3 DEFINITIONS

1.4 SYSTEM DESCRIPTION

1.5 SYSTEM PERFORMANCE REQUIREMENTS

A. Performance Requirements: Provide [system] complying with performance requirements specified.

1.6 SUBMITTALS

A. General: Submit the following:

B. Product data for each type of [products] specified, including details of construction relative to materials, dimensions of individual components, profiles, and finishes.

C. Product data for the following products:
   1. [Product].
   2. [Product].

3. [Product].
4. [Product].

D. Shop drawings from manufacturer detailing equipment assemblies and indicating dimensions, weights, loadings, required clearances, method of field assembly, components, utility requirements, and location and size of each field connection.

E. Include setting drawings, templates, and directions for installation of anchor bolts and other anchorages to be installed as unit of work of other sections.

F. Coordination drawings for [unit of work].

G. Coordination drawings for reflected ceiling plans drawn accurately to scale and coordinating penetrations and ceiling-mounted items, including sprinklers, diffusers, grilles, light fixtures, speakers, and access panels.

H. Wiring diagrams from manufacturer for electrically operated equipment.

I. Wiring diagrams detailing wiring for power, signal, and control systems, differentiating between manufacturer and field-installed wiring.

J. Material certificates signed by manufacturer certifying that each material item complies with requirements, in lieu of laboratory test reports, when permitted by architect.

K. Product certificates signed by manufacturers of [products] certifying that their products comply with requirements.

L. Welder certificates signed by contractor certifying that welders comply with requirements of "quality-assurance" article.

M. Qualifications data for firms and persons specified in "quality-assurance" article to demonstrate their capabilities and experience. Include list of completed projects with project name, addresses, name of architects and owners, plus other information specified.

N. Test reports from, and based on tests performed by, qualified independent testing laboratory evidencing compliance of [product] with requirements based on comprehensive testing.

O. Maintenance data for [materials and products], for inclusion in operating and maintenance manuals.

1.7 QUALITY ASSURANCE

A. Installer Qualifications: Engage an experienced installer who has successfully completed [unit of work] similar in material, design, and extent to that indicated for project.

B. Installer's Field Supervision: Require installer to maintain an experienced full-time supervisor who is on jobsite during times that [unit of work] is in progress.

C. Testing Laboratory Qualifications: Demonstrate experience and capability to conduct testing indicated without delaying progress of the work based on evaluation of laboratory-submitted criteria conforming to ASTM E 699.

D. Qualify welding process and welding operators in accordance with ASME "Boiler and Pressure Vessel Code," Section IX, "Welding and Brazing Qualifications."

E. Regulatory Requirements: Fabricate and stamp [product] to comply with [code].

F. Regulatory requirements: Comply with following codes.

1. [Itemize codes in form of separate subparagraphs under above].

G. UL Standard: Provide [products] complying with UL [designation, title].

H. Electrical Component Standard: Provide components complying with NFPA 70 "National Electrical Code" and which are listed and labeled by UL where available.

I. UL and NEMA Compliance: Provide [components] required as part of [product or system] which are listed and labeled by UL and comply with applicable NEMA standards.

J. ASME Compliance: Fabricate and stamp [product] to comply with ASME Boiler and Pressure Vessel Code, Section VIII, Division 1.

K. Single Source Responsibility: Obtain [system] components from single source having responsibility and accountability to answer and resolve problems regarding proper installation, compatibility, performance, and acceptance.

L. Manufacturer and Product Selection: The drawings indicate sizes, profiles, and dimensional requirements of [product or system]. A [product or system] having equal performance characteristics with deviations from indicated dimensions and profiles may be considered, provided deviations do not change the design concept or intended performance. The burden of proof of equality is on the proposer.

1.8 DELIVERY, STORAGE, AND HANDLING

A. Deliver materials and equipment to site in such quantities and at such times to ensure continuity of installation. Store them at site to prevent cracking, distortion, staining, and other physical damage and so that markings are visible.

B. Lift and support equipment only at designated lifting or supporting points as shown on final shop drawings.

C. Deliver [product] as a factory assembled unit with protective crating and covering.

D. Store [products] on elevated platforms in a dry location.

E. Coordinate delivery of [product] in sufficient time to allow movement into building.

1.9 PROJECT CONDITIONS

A. Site Information: Data on indicated subsurface conditions are not intended as representations or warranties of accuracy or continuity of these conditions {between soil borings}. It is expressly understood that owner and engineer will not be responsible for interpretations or conclusions drawn therefrom by contractor. Data are made available for convenience of contractor (and are not guaranteed to represent conditions that may be encountered).

B. Field Measurements: Verify dimensions by field measurements. Verify that [name of system, product, or equipment] may be installed in compliance with the original design and referenced standards.

1.10 SEQUENCING AND SCHEDULING

A. Coordinate the size and location of concrete equipment pads. Cast anchor bolt inserts into pad. Concrete reinforcement and formwork requirements are specified in Division 3.

B. Coordinate the installation of roof penetrations. Roof specialties are specified in Division 7.

1.11 WARRANTY

A. Special Project Warrant: Submit written warranty, executed by manufacturer, agreeing to repair or replace [product] which fails in materials or workmanship within specified warranty period. This warranty shall be in addition to, and not limitation of, other rights the owner may have against the contractor under the contract documents.

1. Warranty period is 1 year after date of substantial completion.

1.12 MAINTENANCE

1.13 EXTRA MATERIALS

A. Deliver extra materials to owner. Furnish extra materials described below matching products installed, packaged with protective covering for storage and identified with labels clearly describing contents.

PART 2—PRODUCTS

2.1 MANUFACTURERS

A. *Available Manufacturers:* Subject to compliance with requirements, manufacturers offering products which may be incorporated in the work include, but are not limited to, the following:

B. *Manufacturers:* Subject to compliance with requirements, provide products by one of the following:

1. [Name of Product]:
   a. [Manufacturer's Name].
   b. [Manufacturer's Name].
   c. [Manufacturer's Name].
2. [Name of Product]:
   a. [Manufacturers Name].
   b. [Manufacturer's Name].
3. [Name of Product]:
   a. [Manufacturer's Names].
4. [Name of Product]:
   a. [Manufacturer's Names].

C. *Available Products:* Subject to compliance with requirements, products which may be incorporated in the work include, but are not limited to, the following:

D. *Products:* Subject to compliance with requirements, provide one of the following:

E. *Manufacturer:* Subject to compliance with requirements, provide product by [Manufacturer's Name].

2.2 MATERIALS [PRODUCT NAME]

A. [Material or Product Name]: [Nonproprietary description of material] complying with [standard designation] (for type, grade, etc.).

B. [Material or Product Name]: [Nonproprietary description of material] complying with [standard designation] (for type, grade, etc.).

C. [Material or Product Name]: [Standard designation], [type, grade, etc. as applicable to referenced standard].

D. [Material or Product Name]: [Standard designation], [type, grade, etc. as applicable to referenced standard].

2.3 MATERIALS, GENERAL [PRODUCTS, GENERAL]

A. [Description] Standard: Provide [product or material] which complies with [standard designation].

B. [Description] Standard: Provide [product or material] which complies with [standard designation].

C. [Kind of Performance] Characteristics: [Insert requirements for kind of performance involved and test method as applicable unless requirements included under Part 1 Article ("System Description).]

D. [Kind of Performance] Characteristics: [Insert requirements for kind of performance involved and test method as applicable unless requirements included under Part 1 Article ("System Description").]

2.4 EQUIPMENT [NAME OF MANUFACTURED UNIT]

A. [Equipment or Unit Name]: [Nonproprietary description of…] complying with [standard designation] (for type, grade, etc.).

B. [Equipment or Unit Name]: [Nonproprietary description of…] complying with [standard designation] (for type, grade, etc.).

C. [Equipment, Unit, or Product Name]: [standard designation], (type, grade, etc. as applicable to referenced standard).

D. [Equipment, Unit, or Product Name]: [standard designation], (type, grade, etc. as applicable to referenced standard).

2.5 COMPONENTS

A. [Component Name]:… [Nonproprietary description of…] complying with [standard designation] (for type, grade, etc.).

B. [Component Name]: [Nonproprietary description of…] complying with [standard designation] (for type, grade, etc.).

2.6 ACCESSORIES

A. Manufacturer's standard factory finish.

2.7 MIXES

2.8 FABRICATION

2.9 SOURCE OF QUALITY CONTROL

PART 3—EXECUTION

3.1 EXAMINATION

A. Examine [substrates] [areas] [and] [conditions] [with Installer present] for compliance with requirements for [maximum moisture content], installation tolerances, [other specific conditions], and other conditions affecting performance of [unit of work of this section]. Do not proceed with installation until unsatisfactory conditions have been corrected.

B. Examine rough-in drawings for [name] piping systems to verify actual locations of piping connections prior to installation.

C. Examine walls, floors, roof, and [description] for suitable conditions where [name of products or system] are to be installed.

D. Do not proceed until unsatisfactory conditions have been corrected.

3.2 PREPARATION

A. Protection:

3.3 INSTALLATION, GENERAL [APPLICATION, GENERAL]

A. [Description] Standard: Install [name of product, material, or system] to comply with [standard designation].

3.4 INSTALLATION {OF [NAME]} {APPLICATION OF [NAME]}

A. Install [name of unit of work] level and plumb, in accordance with manu-facturer's written instructions, rough-in drawings, the original design, and referenced standards.

3.5 CONNECTIONS (NOT A CSI ARTICLE—BUT USEFUL FOR DIVISION 15)

A. Piping installation requirements are specified in other sections. Drawings indicate general arrangement of piping, fittings, and specialties. The following are specific connection requirements:

B. Install piping adjacent to equipment to allow servicing and maintenance.

3.6 FIELD QUALITY CONTROL

A. Testing Laboratory: Owner will employ and pay an independent testing laboratory to perform field quality control testing.

B. Testing Laboratory: Provide the services of an independent testing laboratory experienced in the testing of [unit of work] and acceptable to the engineer, to perform field quality control testing.

C. Extent and Testing Methodology: Arrange for testing of completed [unit of work] in successive stages in areas of extent described below; do not proceed with [unit of work] of next area until test results for previously completed work verify compliance with requirements.

D. Testing laboratory shall report test results promptly and in writing to contractor and engineer.

E. Repair or replace [unit of work] within areas where test results indicate [unit of work] does not comply with requirements.

F. Manufacturer's Field Service: Provide services of a factory-authorized service representative to supervise field assembly of components, installation of [products] including piping and electrical connections, and to report results in writing.

3.7 ADJUSTING [CLEANING] [ADJUSTING AND CLEANING]

3.8 COMMISSIONING (NOT A CSI ARTICLE — BUT USEFUL FOR DIVISION 15 [DEMONSTRATION])

A. Start-Up Services, General: Provide services of a factory-authorized service representative to provide start-up service and to demonstrate and train owner's maintenance personnel as specified below.

B. Test and adjust controls and safeties. Replace damaged or malfunctioning controls and equipment.

C. Train owner's maintenance personnel on procedures and schedules related to start-up and shut-down, troubleshooting, servicing, and preventative maintenance.

D. Review data in operating and maintenance manuals. Refer to Division 1, Section ["Project Closeouts"] ["Operating and Maintenance Manuals"].

E. Schedule training with owner through architect, with at least 7 days advance notice.

3.9 PROTECTION

3.10 SCHEDULES

4 Plumbing Cost Estimation

to 1.12 to reflect a 10 to 12% overhead for the plumbing contractor. The final installed cost will include the additional overhead of the general contractor ranging from 6 to 15%. If geography and job size are ideal, but the design is incomplete, then a 15% contingency may be considered as well as the 10% overhead. Thus, **m** = 1.15 x1.10 = 1.265. The geography factor ranges from 0.87 to 1.10 for most of North America. Sales tax ranges from 0 to 7% with state and local variations of how it is applied. The size of a job causes the largest range of factors and is discussed later in the chapter. Thus, a job's mark-up on its sum of costs for geography, job size, contingency, sales tax, and plumbing contractor overhead may be 1.12, 1.00, 1.02, 1.06, and 1.10, respectively, resulting in **m** = 1.33 (m = 1.12 x 1.00 x 1.02 x 1.06 x 1.10).

Some estimators prefer to consider each factor separately in terms of the amount of additional costs for each factor. Thus, in the last example, 12% of the sum of costs is derived to give the added cost for geography. Then the geography factor is added to the sum of costs. The 2% contingency is derived from this last sum. Then the 6% sales tax is similarly derived. The overhead may be derived before or after adding the sales tax, depending on local practice.

It should be noted how mark-ups are considered in estimates for alternative materials or construction methods. The application of mark-ups should be the same to the original cost and to the alternate cost. If an alternate is presented without the mark-up, it may erroneously appear to be attractive over the original. Conversely, beware of an alternate including the mark-up when it is compared to the original that is part of a larger estimate. The original will not have the mark-up included if it is only a line item because the mark-up is applied later in the estimate. Hence, the alternate may not appear attractive, even though it is.

Example 1

Table 4-1 Piping Take-off Sample

Item	Qty.	Unit Material	Total	Joints	Unit Labor	Total
1-in. [25mm] copper L , 50/50 solder						
ft. [m] of pipe	237 [72.2]	$2.05	$486			
couplings	24	1.56	$ 37	2	0.25	12 hr
elbows	19	1.78	$ 34	2	0.25	9.5
tees	5	4.03	$20	3	0.25	3.8
ball valves	2	31.80	$64	2	0.25	1
hangers (ring type)	46	3.48	$160		0.50	23
Sub-total			$801			49.3 hr
		Deduct Discount	$280			
		Elevated work adjustment	(10%)			54.2 hr
		Wage rate ($/hr per person)				$55/hr
Sub-Total (Materials and Installation)			$520			$2980
Total						$3500

LABOR COSTS

The following parts of a labor rate are applied to the gross wage rate to reflect a labor cost of construction.

- Social Security and Medicare taxes that employers pay
- Workmens compensation insurance premium
- Unemployment tax
- Health insurance premium
- Holiday and vacation pay
- Retirement cost

The estimated cost of labor is the labor rate multiplied by the estimated time to complete the work.

TAKE-OFF ESTIMATING METHOD

The take-off method requires measuring the length of each size and type of pipe using scaled drawings. In addition, the method requires counting all fittings, valves, fixtures, appurtenances, and other material. This tedious process is then combined with known material costs, expected productivity rates, and labor rates to obtain the sum of costs. The method has an established record of providing accurate cost estimates.

One method to create the tabular take-off sheet is shown in Table 4-1. The material quantity vector [A] is in the second column. The product of the second column and the fifth column will create the labor quantity vector. This method reflects some fittings having 2 joints while others have 3. The time accounted for preparing the hangers and joints will cover the labor for installing the pipe. Various work situations can be adjusted. Table 4-1 shows an extra 10 percent adjustment to reflect work on a scissors lift. When piping is installed at two elevations, separate sheets are utilized to analyze cost at each level.

Each category of construction is put into a table in a similar manner. Tabulation sheets are then added together before being adjusted by the factor **m** to give the final estimate. If necessary, premium labor rates are applied for non-standard working hours. Overtime labor rates are further adjusted to reflect lower productivity for longer workdays.

Another aspect of take-off estimation reflects the fact construction consists of crews of varying skills and labor rates. The database shows productivity of certain sizes of crews. For

Table 4-2 Hours to Excavate 100 Feet [30.5 m] of Trench

Depth (ft)	Width (in)	Volume (yd^3)	All Work by Hand			Mechanical		Chain Trenchera	Final Hand Grading[b]
			Sandy	Medium	Hard	Modest Length	Long Length		
1	18	6	7	11	16	1	1	2	3
1½	18	8	11	17	24	2	1	3	3
2	18	11	14	22	32	2	1	3	3
2½	18	14	18	28	40	3	2	4	4
3	24	22	21	34	48	3	2	4	4
3½	24	26	25	40	56	3	2	-	4
4	24	30	28	44	64	4	3	-	4
4½	24	33	32	50	72	4	3	-	4
5	24	37	48	76	105	6	5	-	4
5½	24	41	53	84	116	6	5	-	4
6	48	89	57	90	124	7	6	-	4
6½	48	96	62	100	138	7	6	-	6
7	48	104	91	130	208	8	7	-	6
7½	48	111	100	143	228	8	7	-	6
8	48	118	106	150	240	9	7	-	6
8½	48	126	113	160	256	9	8	-	6
9	48	133	120	170	272	10	9	-	6
10	48	148	134	188	300	11	10	-	8
11	48	163	148	208	332	12	11	-	8
12	48	178	163	228	364	13	12	-	8
13	48	192	275	455	675	14	13	-	8
14	48	207	303	500	751	16	14	-	8

Conversion factors: 1 in. = 25.4 mm, 1 ft. = 0.3048 m, 1 yd^3 = 0.7646 m^3, 1 ft^3 = 0.037 yd^3

Notes:

a "Chain Trencher" refers to a gasoline-driven trenching machine, which digs a maximum of 10 in. wide x 3 1⁄3 ft deep.

b Add hand grading for mechanical trenching only if required.

example, one plumber and one apprentice, each with their own wage, can install so many feet of 3-inch [75 mm] PVC pipe per day.

PRODUCTIVITY RATES

Tables 4-2 through 4-8 provide labor units for estimating a plumbing project. Table 4-9 provides some modifiers for various job conditions. The information was originally derived from the National Association of Plumbing-Heating-Cooling Contractors (NAPHCC) based on surveys solicited of 150 plumbing contractors from all areas of the United States.

Notice the cost difference between hand trenching and machine trenching in Table 4-2. For example, a trench 3 feet [0.91 m] deep 100 feet [30.5 m] long takes 2 or 3 hours by machine and up to 48 man-hours by hand. Four hours of additional time is applied to the machine method if hand grading is required. The trench width and material volume are revised in Table 2 from earlier "Data Book" editions to reflect excavation with trench boxes and other shoring methods. For handwork, the volume should be adjusted to reflect a typical 24-inch trench width for excavation and backfill volumes. For exterior work or other clear spaces accommodating larger machinery, hours may be reduced substantially from that indicated. Sawcutting may be faster than as shown in Table 4-3 if space allows for larger equipment. Breaking pavement with heavier pneumatics or removing whole pieces of sawcut concrete will reduce the times shown in Table 4-4.

Table 4-5 shows the time for one laborer to hand backfill and mechanically hand-tamper medium backfill (a trench 3 feet [0.91 m] deep 100 feet [30.5 m] long) is 17 hours. The same table shows the time to do it by machine is 1.8 hours. However, 12 additional hours are required for hand tamping the first layer of a 4-inch [100 mm] pipe and 0.8 hours of labor to assist the backfilling. If certain types of fill material are used, such as ¾- to 1-inch [19 to 25 mm] stone, compacting the fill is not required.

Notice in Table 4-6 that a single 4-inch [100 mm] brazed joint takes the most time (1.11 hours), and a single hubless joint takes the least time (0.4 hours).

Example 2

Using Tables 4-2 and 4-5, estimate the cost to excavate and backfill a trench 5 feet [1.52 m] deep 210

Table 4-3 To Sawcut 100 Feet [30.5 m] of ConcreteTrench

Depth			
Inches	3	4	5
mm	75	100	125
Hours	5	6	7

Table 4-4 To Break 100 Feet [30.5 m] of Pavement

Method	Pavement	Width	Hours
Hand Pneumatic	Concrete	24 in. [600 mm]	10

Table 4-5 Hours to Backfill 100 Feet [30.5 m] of Trench

Depth (ft)	Volume (yd^3)	All Work by Hand			Pipe Bedding		Mechanical Backfill[a]	Mechanical Compaction
		Sandy	Medium	Hard	3″ dia	4-10″ dia		
1	6	5	6	7	8	12	0.3	-
1½	8	7	8	11	8	12	0.4	0.5
2	11	9	11	15	8	12	0.5	0.5
2½	14	11	14	20	8	12	0.6	0.5
3	23	14	17	24	8	12	0.8	1
3½	26	16	20	28	8	12	0.9	1
4	30	18	22	29	8	12	1	1
4½	33	20	25	33	8	12	2	1
5	37	31	38	50	8	12	2	1
5½	41	34	42	55	8	12	2	1
6	89	36	45	59	8	12	2	2
6½	96	40	49	63	8	12	3	2
7	104	42	52	68	8	12	3	2
7½	111	46	57	74	8	12	3	2
8	118	48	60	78	8	12	3	3
8½	126	51	64	83	8	12	3	4
9	133	55	68	89	8	12	4	4
10	144	60	75	98	8	12	4	5
11	164	67	83	108	8	12	5	[b]
12	178	73	91	119	8	12	5	[b]
13	192	80	99	130	8	12	6	[b]
14	207	88	110	143	8	12	6	[b]

Conversion factors: 1 in. = 25.4 mm, 1 ft. = 0.3048 m, 1 yd3 = 0.7646 m3, 1 ft3 = 0.037 yd3

Notes:

a Must add for stand-by hand laborer.

b Call equipment company for hours to compact backfill.

Table 4-6 Hours to Complete 100 Joints

Method	Size														Note
Inch	½	¾	1	1¼	1½	2	2½	3	4	5	6	8	10	12	
Mm	13	19	25	32	38	51	64	76	102	127	152	203	254	305	
Screw thread	25	27	30	36	38	40	90	95	100	145	150	200	-	-	
50/50 solder	20	21	25	27	30	32	63	75	85	123	127	170	-	-	
DWV solder	-	-	-	33	36	39	76	90	102	148	153	204	-	-	
Brazed	26	27	33	35	39	42	82	96	111	160	165	-	-	-	
Groove steel	-	-	30	36	38	40	72	76	80	116	120	160	184	208	
Groove copper	-	-	30	36	38	40	72	76	80	116	120	160	184	208	
Plastic	20	21	25	26	27	28	40	50	60	98	101	136	162	216	1
Hub and caulk	-	-	-	-	-	50	-	55	60	65	70	120	130	150	2
Hub and gasket	-	-	-	-	-	40	-	45	50	55	60	100	110	125	2
Hubless	-	-	-	-	30	30	-	35	40	45	50	80	90	100	-
Water main, mech. Joint	-	-	-	-	-	-	-	60	62	-	70	72	80	82	3, 4
Water main, compression	-	-	-	-	-	-	-	47	48	-	50	52	54	56	3

Notes:

1 Solvent joint. For heat fusion, multiply value by 1.5

2 Hub and spigot, service weight cast-iron pipe. For extra heavy, multiply value by 1.02.

3 Labor for 300 feet [90 m] minimum. Add crane cost.

4 Material weighing more than 150 lb. (68.2kg)

Table 4-7 Hours to Install 100 Pipe Hangers

Type	Size												
Inch	¾	1	1¼	1½	2	2½	3	4	5	6	8	10	12
mm	19	25	32	38	51	64	76	102	127	152	203	254	305
Ring[a]	50	50	50	50	50	60	60	70	70	80	100	100	100
Roller						140	140	160	160	180	220	220	220

Notes:

a Included in hanger, rod, and insert

feet [64 m] long by machine. Final hand grading will be required. The pipe will be 4-inch [100 mm], and spoils will be backfilled.

Solution: Select the required unit hours and apply it to the trench length of this example. Add equipment rental charge (or ownership hourly rate). Table 4-10 shows the take-off tabulation.

Example 3

Using Tables 4-2 and 4-5, estimate the cost to excavate and backfill trenches, by machine, totaling 120 feet, of 3-foot average depth; 130 feet, of 2-foot average depth; and a variety of trenches totaling 250 feet of 18 inch average depth. Excavated material will be dumped offsite and replaced by new fill. Final hand grading will be required and the pipe will be 4-inch [100 mm].

Solution: Determine the required unit hours and apply it to the various trench lengths. Add equipment rental charge (or ownership hourly rate). Add hauling cost of excavated material and delivery of backfill material. Since excavated material increases in volume by the excavation process, appropriately adjust the volume to account for this swelling. Table 4-11 shows the take-off tabulation for each step.

OTHER ESTIMATING METHODS

A less-precise estimating method is to count fixtures and major appurtenances and apply time-proven costs per fixture or appurtenance to arrive at the total cost. Piping and material costs are included in the per-fixture cost. The particular level of trim and quality of the specific project should be comparable with those of the database. For example, if the project requires cast-brass faucets, caulked cast-iron piping, and frequent valves on the supply distribution, then apply a per-fixture cost derived from a project that used similar material.

The advantage of the per-fixture method is it can be performed without a piping layout. A disadvantage is it fails to distinguish between projects with fixtures concentrated in a few areas compared to fixtures spread about the building.

Another less-precise estimating method is the square foot [m^2] method. This method provides a reasonable cost estimate even with little project information. A cost estimate is determined simply by multiplying the building area by a per-area cost. Per-area cost must be carefully selected to the level of trim and quality of the particular project. Additionally, the concentration or dispersed distribution of fixtures and the building application for fixtures must be addressed when per-area cost is applied. For example, a medical

Table 4-8 Hours to Install Fixtures

Fixture	Type	Time
Bathtub	-	3.0
Drinking Fountain	Wall mount	2.0
Lavatory	Wall mount	2.0
Lavatory	Counter	2.5
Mop Basin	-	2.0
Shower	Built-up stall	1.0
Sink	Single compartment	2.0
Sink	Double compartment	2.5
Service Sink	-	3.0
Urinal	Wall mount	2.8
Urinal	Stall	3.8
Water closet	Floor mount	1.8
Water closet	Wall mount	2.7
Water cooler	Wall mount	2.5

Table 4-9 Adjustments From Standard Conditions

Activity	Condition	Multiplier
Crawl space or tunnel	3-foot [1 m] high	1.50
Distribution of material		
Distance from stock:	100 feet [30 m]	1.00
	300 feet [90 m]	1.03
	500 feet [150 m]	1.04
	1000 feet [300 m]	1.05
Equipment room piping	-	1.20
Food service piping	-	1.10
Laboratory piping	-	1.10
Overhead piping	8-foot [2.5 m] ladder	1.00
	10-foot [3 m] ladder	1.03
	powered lift	1.10
Trench piping	3-foot [1 m] deep	1.00
	5-foot [1.5 m] deep	1.10
	8-foot [2.44 m] deep-shored	2.00
	10-foot [3.05 m] deep-shored	2.25
	12-foot [3.66 m] deep-shored	2.50

Table 4-10 Solution to Example 2

Item	Length, feet [m]	Unit Hours	Total hours
Excavate	210 [64]	0.05	10.5
Hand grading	210 [64]	0.04	8.4
Pipe bedding	210 [64]	0.12	25.2
Backfill	210 [64]	0.02	4.2
Added labor	210 [64]	0.02	4.2
Compaction	210 [64]	0.01	2.1
Total labor hours			54.6
Labor rate [$/hr per person]			$55/hr
Total labor cost [$55/hr x 54.6 hrs]			$3003
Total machine hours			17
Machine cost [$120/hr x 17 hrs]			$2040
Total cost			$5043

Table 4-11 Solution to Example 3

Item	Length, feet [m]	Unit Hours	Hours	Volume
Trenches 1½ feet [457mm] deep				
Excavate	250 [76]	0.02	5	
Hand grading	250 [76]	0.03	7.5	
Pipe bedding	250 [76]	0.12	30	
Backfill	250 [76]	0.004	1	
Added labor	250 [76]	0.004	1	
Compaction	250 [76]	0.005	1.25	
Hours			**45.8**	
Cubic Yards [m^3]	250 [76]	0.08 [0.06]		**20 [15.3]**
Trenches 2 feet [610mm] deep				
Excavate	130 [40]	0.02	2.6	
Hand grading	130 [40]	0.03	3.9	
Pipe bedding	130 [40]	0.12	15.6	
Backfill	130 [40]	0.005	0.65	
Added labor	130 [40]	0.005	0.65	
Compaction	130 [40]	0.005	0.65	
Hours			**24.1**	
Cubic Yards [m^3]	130 [40]	0.11 [0.08]		**14.3 [10.93]**
Trenches 3 feet [915mm] deep				
Excavate	120 [37]	0.03	3.6	
Hand grading	120 [37]	0.04	4.8	
Pipe bedding	120 [37]	0.12	14.4	
Backfill	120 [37]	0.008	0.96	
Added labor	120 [37]	0.008	0.96	
Compaction	120 [37]	0.01	1.2	
Hours			**25.9**	
Cubic Yards [m^3]	120 [37]	0.22 [0.17]		**26.4 [20.19]**
Total labor hours			**95.7**	
Cubic Yards [m^3]				**60.7 [46.41]**
Adjusted Cu. Yards [m^3] (~15%)				**69.8 [53.4]**
Labor Rate [$/hr per person]			$55/hr	
Total labor cost			$5265	
Total machine hours			16.9	
Machine cost @ $120/hour			$2028	
Haul excavated material @ $6/cubic yard [$8/m^3]			$ 364	
Fill-material cost @ $8/cubic yard [$10/m^3]			$ 486	
Total			$8142	

office usually has a higher number of fixtures per building area than an ordinary office building. Regulations and probable demand vary with different types of occupancy and will influence infrastructure requirements.

More-precise estimating methods are now available through computer programs and certain types of hardware peripherals. While the value of using an appropriate database has already been emphasized, several vendors are now addressing entering precise counts and lengths. The value of accurate data entry helps avoid costly errors and speeds up the estimating process. Some peripherals allow the user to overlay scaled drawings over a digitizing pad so pipes can be picked at each end and the software accounts for its length. Other software works with electronic versions of the drawing, and the users highlight each pipe as they enter key information such as its diameter. When the counts and lengths of material are accurately and quickly gathered, a more-precise cost estimate can be determined. However, a selected estimating package should address current needs without being too complicated. The vendor should be experienced with building construction and offer upgrades as the estimating technology evolves.

OTHER COST FACTORS

Most cost estimating assumes certain conditions in establishing the estimator's database. Among such assumptions are quality of work, standard working hours, general crew productivity, size of a project, allotment of a reasonable time frame for construction, new or renovation of existing plumbing systems, geographic location of the project, weather, season of the year, contractor management, collective bargaining agreements, utility availability, and general business conditions. The size of a job favors larger projects because of economies of scale. The location of a job affects shipping costs as well as the market for skilled labor.

For repair work and renovations, consider slower work productivity because of limited physical access, material-handling restrictions, more-precise cutting to match existing systems, efforts to protect existing finishes, non-standard work hours, unexpected delays, unplanned piping offsets, and general economies of scale. Existing job conditions are probably the most common reason for inaccurate estimates.

For cost-estimating changes to an ongoing construction project, other cost factors may be necessary to consider even though they may not have been applicable to the original project. For example, the size may be smaller and out of a planned sequence, the time frame may be constricted, or the plumbing change is now within a finished space.

In conclusion, cost estimating involves the matching of specific project information with a database of known construction costs. Variations from the database affect the cost estimate, and an appropriate adjustment is used to arrive at an accurate estimate. The amount of adjustment involves many factors, from geography to job size. The estimator's experience determines the best adjustment, while the estimator's careful examination of the specific project gives the needed information to match with established unit costs. Hence, seasoned judgment with tedious review of the project documents yields a precise and accurate prediction of plumbing costs.

5 Job Preparation, Drawings, and Field Reports

A significant portion of time spent on a project is devoted to communication. While good design practices and accurate engineering analyses are important, it will be of little benefit if communication fails to reach the receiver. Hence, effective means are required to assure information is passed faithfully among the design team, contractors, and building owner. In proper preparation of a job, general expectations of the job are established including scope of work, regulatory requirements, specification formats (see Chapter 3), drawing title blocks, and design-team directory.

The drawings are prepared as the primary method to communicate the design of the plumbing. Then, as construction proceeds, the engineer provides feedback to the plumbing contractor after observing progress of the plumbing work. To assist in providing thorough communication, engineering offices frequently use lists to prepare quality documents and to make field observations during construction.

(Note: Refer to Chapter 1 for definitions of terms. Refer to other data book chapters for further design information.)

JOB-PREPARATION GUIDELINES

1. Identify relevant codes and standards, including local amendments and date of issue. Relevant issues include:
   - Energy and water conservation
   - Hot-water production and maintenance
   - Cross-connection control
   - Interceptors
   - Clearwater disposal
   - Rainfall rates
   - Secondary drainage
   - Storm-water management
   - Fire sprinklers and standpipes (occupancy class)
   - Fuel gas code
   - Medical gases and other healthcare matters
2. Establish directory of project team members. Organize project schedule with staff availability.
3. Contact the plumbing-code official and fire-protection authority having jurisdiction. Contact water, sewer, and gas utilities, and establish connection requirements.
4. Identify phasing issues and whether there will be concurrent occupancy.
5. Review survey and other documents for size, location, and depth of sanitary and storm sewers, water mains, and gas mains. (Work with civil engineer as well.)
6. Obtain water flow and pressure data (static and residual) at given elevation. Determine if a fire pump and a domestic booster pump are required. Select and size pumps as required.
7. For building alteration or addition, check if existing plumbing services, distribution, and equipment are adequate (capacity and life of systems or equipment), including water heaters, water-treatment equipment, pumps, compressors, water meter, backflow preventers, and interceptors.
8. Identify the energy source: gas, electric, steam, hydronic.
9. Determine if water treatment is required. Obtain water-quality analysis.
10. Determine if there are unusual occupancy-related plumbing requirements.
11. Within the limits of the code, determine the architect's preferred method of cleanout design.
12. Establish and coordinate electrical voltages and phases for motors and controls with the electrical engineer.
13. Determine the need for other systems, such as compressed air, vacuum, deionized water, acid waste, fuel oil, and steam.
14. Review the cost estimate and time estimate against recent project developments.

PLUMBING DRAWING GUIDELINES

1. Review elevation of storm and sanitary sewers to determine that gravity flow is feasible or if lift stations are needed. Determine that storm and sanitary drain pipes do not conflict. Consider backwater valves where appropriate.
2. Review utility regulations and provide water-service requirements. Provide an approved backflow preventer where required. Provide pressure-reducing valves for domestic water systems where the static pressure exceeds 80 psi (550 kPa).
3. Review fire-protection standards and local requirements, including class of standpipes and classification of occupancy. Determine water demand, including flow at required residual pressure. Provide service with an approved backflow preventer or other approved cross-connection control. Select wet, dry, or anti-freeze type sprinkler system. Special extinguishing systems may be required.
4. Coordinate fire-department-connection location and fire-hydrant requirements with the architect, site civil engineer, and landscape designer.
5. Review the code-minimum rainfall rate and whether a higher rate should be considered. Size roof drains, conductors, and storm drain accordingly. Review secondary drainage requirements and coordinate them with the architect.
6. Determine size and extent of subsoil drainage based on soils report and wall structural requirements.
7. Review storm-water management issues. Review clearwater disposal restrictions.
8. Send electrical-control and power requirements of plumbing and fire-protection equipment to the electrical engineer. These requirements may include pumps, air compressors, water heaters, water coolers, heat tracing, solenoids, high-water alarms, medical gas alarms and manifolds, fire-sprinkler switches, and fire-alarm bells. Among various pumps consider fire pumps, domestic boosters, circulation pumps, vacuum pumps, sump pumps, and sewage ejectors.
9. Evaluate hot-water-demand requirements. Select and size water heater, mixing valve, and circulation pump. Provide hot-water system with a circulating return unless the distance between the heater and the farthest fixture is relatively short.
10. Determine combustion air requirements for atmospheric gas-fired water heaters.
11. Address scald-hazard concerns and pathological hazards within the hot-water system.
12. Determine water-treatment requirements. Select and size treatment equipment for anticipated occupancy demand and client preferences.
13. Review selection of pipe material for each part of the plumbing system from supply systems to drain systems. Consider purity requirements, corrosion issues, fluid temperature, fluid pressure, joining methods, hanger spacing, code issues, and physical protection.
14. Coordinate drawing details with specifications.
15. Review pipe-insulation requirements thermally and acoustically.
16. Review noise and vibration considerations of piping systems and plumbing equipment. Review water-hammer requirements. Review noise concerns from rotary vacuum pumps and similar equipment.
17. Consider building-expansion requirements and design concerns that affect tenant-occupancy changes. (Coordinate plumbing-system locations with architect.)
18. Arrange plumbing piping logically while considering obstructions, occupancy restrictions, accessibility, control, future expansion, designer's preferences, other building systems (existing or new), and economics. In general, run piping clear of structural beams. Where necessary, in consultation with the structural engineer, penetrate through the web of steel beams and the middle third of wood or concrete beams. Keep piping out of elevator shafts, electric and data communication rooms, similar restricted rooms, as well as stairs and exit discharge corridors. Size piping for required supply and drainage fixture units.
19. Provide pipe-expansion loops or expansion joints where required.
20. Provide valves on distribution branches, on branches off supply risers, and at the base of supply risers. Provide drain valves with hose threads at the base of risers and in the low portions of piping.
21. Provide hose bibs around the building. Select frost-proof hose bibs if required. Review landscape irrigation connection point where required. Confirm if hose bibs are to be key-operated.
22. Note piping elevation changes on plans. Pipes rising within a story should be noted as "rise". Pipes rising to another story should be noted as "up". Pipes dropping to another story should be noted as "down". Pipes at ceiling should be noted as "at ceiling" when exposed and "above ceiling" when concealed. Pipes under the floor, other than obvious fixture drain pipes, should be noted as "below floor," "at ceiling below," or "above ceiling below."

23. Select location and spacing of cleanouts. Confirm compliance with local authority having jurisdiction.
24. Locate fire standpipes and hose connections.
25. Locate alarm panels and motor controllers.
26. Locate roof leaders, main stacks, and supply risers. Coordinate wall thicknesses, beam clearances, and footing clearances with the architect and structural engineer.
27. Coordinate structural penetrations and housekeeping pads with the architect and structural engineer. Review weight of water heater and other equipment with the structural engineer.
28. Select fixtures and fixture trim, including faucets, shut-off valves, flush valves, carriers, strainers, drains, traps, and wall flanges. Send fixture cut sheets to the architect. Include dimensioned drawings of fixtures and fixture trim.
29. Select sprinkler-head designs including escutcheons or covers, finish type or color. Send sprinkler-head cut sheets to the architect.
30. Determine medical gas outlet types, shut-off valve box designs, and alarm panel layouts. Send equipment cut sheets to the architect. Include dimensioned drawings and selection of options.
31. Review plans for mop-basin, drinking fountain, and floor-drain requirements.
32. Provide floor drains for public toilet rooms, at least one floor drain at the lowest floor level of the building, and in pits such as elevator pits.
33. Review and coordinate water-supply connection and drain requirements for:
    - Backflow preventers (adequate drain for relief port)
    - Beverage machines
    - Boilers
    - Chillers
    - Compressors
    - Cooling towers
    - Cooling coils (drain only)
    - Emergency eyewash/shower
    - Fire sprinklers and fire pumps
    - Food-service areas, including dishwashers, walk-in refrigerators and freezers, steam kettles, scullery sinks
    - High-efficiency burners (drain only)
    - Humidifiers
    - Ice machines
    - Laboratory equipment
    - Laundry
    - Pressure relief valves (drain only)
    - Sterilizers
    - Vacuum pumps
    - Other equipment
34. Review and coordinate natural-gas connections for water heaters, food-service equipment, and other equipment as required.
35. Select size and design of floor drains and receptors to meet requirements. If required, segregate clearwater wastes from sanitary wastes. Connect clearwater system to the storm-drain system.
36. Identify infrequently used drains and provide with trap primers.
37. Offset roof drains and vent terminals 12 to 18 inches [0.3 to 0.5 m] away from parapet walls, roof openings, and other roofing elements.
38. Review canopies and porte-cocheres for adequate drainage.
39. Provide cross-connection control for potable water supply connections to building equipment and systems, for all fixtures, and for appurtenances as required. In particular, provide air gaps or approved backflow preventers for connections to boilers and to sprinkler supplies. Provide air gaps for relief ports of backflow preventers, for pressure-relief valves, and generally for fixture faucet outlets.
40. Provide interceptors as required, including subsoil receivers, exterior-pavement catch basins, garage catch basins, grease interceptors, oil and sand interceptors, laundry interceptors, plaster interceptors, acid and caustic dilution or neutralization basins, and special industrial treatment systems.

PLUMBING-DRAWINGS CHECKLIST

Modify checklist to suit client requirements and the policy of your firm. Initial checked items. Label NA where not applicable.

Plans

1. ____ Is it evident that the architectural back-

6. ____ Do pipes clear structural members, high ceilings, skylights, and clerestories?
7. ____ Do all pipes show sizes? Are fixture units shown? Are invert elevations shown?
8. ____ Are valves and cleanouts accessible?
9. ____ Are all fixtures connected to supply, waste, and vent piping?
10. ____ Do toilet rooms have floor drains where required? Lowest level, elevator pit, and other pits?
11. ____ Is piping kept out of elevator shafts, electric and data-communication rooms, similar restricted rooms, stairs, and exit-discharge corridors? Are pipes clear of ductwork?
12. ____ Are stacks, conductors, and risers within interior partitions of sufficient thickness?
13. ____ Are ceiling spaces and similar concealed spaces prone to freezing?
14. ____ Is cutting and patching addressed clearly?
15. ____ Do roof-drain locations coordinate with architectural requirements?
16. ____ Are drawing notes complete and edited for the specific job?
17. ____ Are plumbing vents spaced sufficiently from air intakes and operable windows?
18. ____ Is the mechanical room coordinated and well laid out with sufficient access to service equipment, including equipment removal? Are equipment connections and drains coordinated?
19. ____ Does the direction of the north arrow agree with the architect's plans?

Risers and Details

1. ____ Are risers legible? Are references, such as drawing references, room numbers and fixture tags, clearly presented? Are fixture traps oriented correctly?
2. ____ Are all vents properly connected? Are vent stacks, relief vents, and yoke vents shown where required?
3. ____ Are pipe sizes consistent between risers and plans?
4. ____ Are details shown for accessible fixtures, interceptors, backflow preventers, water heaters, water-treatment systems, sump pumps, and sewage ejectors?
5. ____ Are pipe supports, sleeves and fire-stopping systems detailed properly?
6. ____ Is the water-service design detailed properly and coordinated with the utility?
7. ____ Does the fire-riser design meet requirements?
8. ____ Are detail references coordinated with the plans?

Schedules and Specifications

1. ____ Is the inclusion of fixtures and equipment consistent in both the drawings and the specifications?
2. ____ Are fixtures and equipment consistently referenced on plans, risers, schedules, and specifications?
3. ____ Are pumps selected for proper flow and head?
4. ____ Is voltage and other electric data consistent with schedules, the equipment supplier, and the electrical engineer?
5. ____ Does the schedule of supply and drainage-fixture units show the original total, removed total, and new total?
6. ____ Is a water-supply uniform-pressure calculation or other sizing method included? Is the street pressure correct? Is the controlling-fixture pressure correct? Is the maximum length accurate?
7. ____ Do faucets and flush valves meet water-conservation requirements? Does the fixture trim meet requirements for handle design, strainer design, and spout height? Does the client accept the vendor selection?
8. ____ Are legends, symbols, and abbreviations included?

FIELD CHECKLIST

Field visits can be broken down into three phases: Underground, rough-in, and final. Important items to observe when visiting a job site are listed as follows and shall be in reference to requirements of the construction documents. Initial observed items. Label NA where not applicable. Add comments regarding deficiencies.

Building Drains

1. ____ General alignment and conformity to plans
2. ____ Workmanship of joints, general compactness of soil below, and around pipe
3. ____ General slope of piping
4. ____ Spacing and accessibility of cleanouts
5. ____ Vent connections
6. ____ Branch to building drain not connected near base of stack or conductor
7. ____ Pipe sleeves and water stopping
8. ____ Pipe sizes and invert elevations

9. ____ Manholes, sumps, receivers, grease interceptors, sand and oil interceptors, trench drains, and other structures; workmanship, specified size, invert elevations, and rim elevations
10. ____ Trap-primer connections
11. ____ Temporary terminations covered or capped to prevent entry of foreign material
12. ____ Acid-waste and vent piping and acid-dilution tank

Water and Gas Services

1. ____ Compliance with water-service requirements, including service location, pipe depth, thrust blocks, and shut-off valves
2. ____ Compliance with natural-gas-service requirements, such as service location and shut-off valves

Above Grade Rough-in

1. ____ Compliance with water-service requirements such as location, shut-off valves, meters, meter registers, pressure-reducing valves, bypasses, backflow preventers, pressure gauges, and testing ports
2. ____ Compliance with natural-gas-service requirements such as location, shut-off valves, meters, meter registers, pressure-reducing valves, vent ports, and bypasses
3. ____ Piping at booster pumps, water heaters, and water-treatment devices
4. ____ Fire-protection-system piping
5. ____ Medical-gas-system piping, valves, outlets, panels, and source equipment such as cryogenic systems, high-pressure manifolds, vacuum pumps, air compressors as well as attendant dew-point and carbon-monoxide monitors, air dryers, and inlet, discharge, or relief piping to the exterior
6. ____ Adequacy of sump pumps, sub-soil receivers, and sewage ejectors
7. ____ General alignment, arrangement, and sizes of piping in conformity to plans
8. ____ Workmanship of joints
9. ____ Installation of pipe supports, expansion joints or expansion loops, and pipe swing joints
10. ____ Location of valves
11. ____ Clearances around pipes within sleeves
12. ____ Spacing and accessibility of cleanouts
13. ____ Fire stopping at fire walls, fire-rated floors, and other locations as required
14. ____ Vent connections: Close enough to trap to avoid air lock, above flood level, vertical where required
15. ____ Branch to stack offset not connected near upstream end of offset
16. ____ Pipe labeling and valve tags
17. ____ Installation of pipe insulation, including covers over valves and fittings.
18. ____ Adequacy of cooling-coil-condensate drains, combustion-condensate drains, relief-valve drains, and indirect waste pipes; supported properly and air break or air gap as required
19. ____ Adequacy of floor slope to floor drains and floor sinks; rims of indirect waste receptors are elevated to prevent entrance of debris
20. ____ Installation of small interceptors
21. ____ Vent terminals properly flashed, located away from air intakes and operable windows
22. ____ Motor starters, magnetic and manual
23. ____ Connection of plumbing to other building equipment, including boilers, chillers, cooling towers, air handlers or fan coils, food service, medical, laundry, and similar equipment; arrangement of piping, valves, cross-connection control, and drainage.

Final

1. ____ Adequacy of hot water at remote fixture
2. ____ ADA accessibility requirements
3. ____ Fixture support
4. ____ Water-closet bowl type and seat design
5. ____ Flush-valve performance
6. ____ Strainers and traps
7. ____ Faucet handles, outlet flow rating, outlet air gap
8. ____ Fixture supply-stop location
9. ____ Fixture mixing-valve location and temperature setting
10. ____ Mop-basin accessories
11. ____ Caulking at fixture
12. ____ Access panels for valves and cleanouts
13. ____ Cross-connection control type, application, installation, approval, product listing, drainage
14. ____ Sprinkler heads and standpipe hose connections
15. ____ Medical-gas valves, outlets, panels
16. ____ Owner equipment manuals
17. ____ Record drawings and/or as-built drawings
18. ____ Training and commissioning

COMMENTS:

6 Plumbing for People (or Persons) with Disabilities

Standard (UFAS) and the U.S. Architectural and Transportation Barriers Compliance Board (ATBCB) requirements.

As part of an ongoing review process, the A117.1 committee was reconvened in 1989 with the intention of reissuing the standard in 1990. The magnitude of the changes, both in technical data and in format, resulted in a delay in publication of the standard until December 15, 1992. This standard was the most comprehensive to date and the involvement from disability advocates and interested parties was remarkable. The 1992 standard is now referenced in several model codes and has resulted in improved accessibility in many regards.

In 1995, the A117.1 committee was called again and charged with the task of reviewing the standard for changes. The makeup of the committee had grown to include many disability advocacy groups, model code representatives, and associations—including the American Society of Plumbing Engineers (ASPE)—and design professionals. The committee worked for more than three (3) years, through three (3) public reviews, examining over 1,000 proposed changes, during 23 days of meetings, to produce the 1998 ANSI A117.1-1998 standard. The 1998 standard has been developed to work in harmony with federal accessibility laws, including the current *Fair Housing Accessibility Guidelines* and the proposed *Americans with Disabilities Act Accessibility Guidelines* (ADAAG).

New provisions for Type B dwelling units are intended to provide technical requirements consistent with the Fair Housing Accessibility Guidelines of the U.S. Department of Housing and Urban Development. HUD is currently in the process of reviewing the 1998 standard to determine equivalency with the guidelines. In addition, the A117.1 committee worked closely with the ADAAG Review Federal Advisory Committee to harmonize the 1998 edition with proposed revisions to ADAAG. The U.S. Architectural and Transportation Barriers Compliance Board (Access Board) published a "notice of proposed rule making" in the *Federal Register*, November 16, 1999. Twenty-five-hundred comments were received for the proposed rule. Until the rule is published in final form and the Federal Department modifies its standard to reflect the revised guidelines, the current standard would be in effect.

LEGISLATION

In 1969, Public Law 90-480 (known as the Architectural Barriers Act of 1968) was signed by President Lyndon B. Johnson. The main thrust of this legislation was that any building constructed, in whole or in part, with federal funds must be made accessible to, and usable by, the physically challenged. Public Law 93-112, known as the Rehabilitation Act of 1973, was passed by the federal government in 1973.

State and municipal governments also began issuing their own ordinances regarding architectural barriers. These legislative acts were usually modified versions of the ANSI A117.1 document. At the present time, just about every state has adopted some legislation covering this subject; however, there are major differences from one ordinance to another. Like the federal government, the original legislation usually applied to government-owned or government-financed structures, but now the requirements generally apply to all public accommodations.

The Americans with Disabilities Act (ADA) was enacted by the Congress and signed by President George Bush on July 26, 1990. The ADA prohibits discrimination based on physical or mental disabilities in private places of employment and public accommodation, in addition to requiring transportation systems and communication systems to facilitate access by the disabled. The Act is modeled, to a considerable extent, on the Rehabilitation Act of 1973, which applies to federal grantees and contractors.

The ADA is essentially civil rights legislation, but its implementation has a major impact on the construction industry. In order to clarify construction requirements, the Attorney General's office commissioned the U.S. Architectural and Transportation Barrier Compliance Board (ATBCB) to prepare architectural guidelines to ensure that the construction industry understood what was required in order to comply with the Act. The ATBCB, which is represented on the A117.1 committee, used much of the completed how-to data that was available from A117.1, and where-to data from the ongoing scoping work being done by the Board for Coordination of Model Codes (BCMC), its governmental experiences, and public comments to produce the guidelines commonly referred to as "ADAAG."

After incorporating public comments, the "final rule" was issued on July 26, 1991, in the federal register (28 CFR Part 36) as "Nondiscrimination on the Basis of Disability by Public Accommodations and in Commercial Facilities." The Act became effective on January 26, 1992, and applies to all construction with application for permit after January 26, 1992. This "final rule" preempted state and local laws affecting entities subject to the ADA, to the extent that those laws directly conflict with the statutory requirements of the ADA. The attorney general's office established as a procedure for the certification of state and local accessibility codes or ordinances that they meet or exceed the requirements of the ADA. It was hoped that, with such a certified code enforced by local inspectors, compliance with ADA would not be decided in the courts.

In 1994, the ATBCB commissioned a new committee to make recommendations for an improved document to replace the current *Americans with Disabilities Act Accessibility Guidelines* (ADAAG). This committee met for more than two (2) years to review proposed changes to the document and remove the ambiguities that have been a cause of contention to designers as well as code-enforcement officials. This new committee included 22 members representing: Advocacy groups (American Council of the Blind; Disability Rights Education and Defense Fund, Inc; Eastern Paralyzed Veterans Association; Maryland Association of the Deaf; World Institute on Disability), code enforcement officials [Virginia Building and Code Officials Association; Texas Department of Licensing and Regulation; Southern Building Code Congress International, Inc. (SBCCI); National Fire Protection Association (NFPA); National Conference of States on Building Codes and Standards; International Conference of Building Officials (ICBO); Council of American Building Officials (CABO); Building Officials and Code Administrators International, Inc. (BOCA)], and designers [American Institute of Architects (AIA), American Society of Interior Designers (ASID)]. The document that came from this committee's work was presented to the ATBCB on October 10, 1996. Design professionals must continue to review the ADA in its entirety, and forthcoming revisions, as well as state and local codes for application to their projects. Some states require preapproval of accessible plumbing fixtures. Approval of the fixtures is the responsibility of the fixture manufacturers, but the specifier must specify and approve only those fixtures that have received approval.

There are still a number of concerns regarding whether the established standards properly address the specific needs of children and the elderly. Children cannot necessarily reach fixtures set at established heights for people with disabilities. Also, the elderly may have trouble accessing fixtures set low to meet established height requirements for people with disabilities.

DESIGN

Although plumbing is only a small portion of the overall effort to create a totally barrier-free environment, it is one of the most important areas to be dealt with by engineers.

The following are the various classifications of disabilities:

- *Non-ambulatory disabilities*—Those that confine individuals to wheelchairs.
- *Semi-ambulatory disabilities*—Those that necessitate individuals to require the aid of braces, crutches, walkers, or some other type of device in order to walk.
- *Sight disabilities*—Total blindness and other types of impairment affecting an individual's sight.
- *Hearing disabilities*—Total deafness and other types of impairment affecting an individual's hearing.
- *Coordination disabilities*—Those caused by palsy due to cerebral, spinal, or peripheral nerve injury.
- *Aging disabilities*—Those brought on by the natural process of aging, which reduces mobility, flexibility, coordination, and perceptiveness in individuals. (Note: To some extent, various national standards—e.g., HUD's *Minimum Property Standards*—differentiate the elderly from "people with disabilities.")

The disability classifications that affect the plumbing engineer the most, in terms of design, are the non-ambulatory and the semi-ambulatory groups. Adequate plumbing facilities must be provided for these individuals. The architect is responsible for analyzing the needs of a person confined to a wheelchair and those forced to use walking aids such as crutches and braces. However, the plumbing designer should become familiar with the characteristics of the wheelchair and various associated types of equipment. At the present time, there are many variations in wheelchair design available on the market. The specifications in these guidelines are based on adult dimensions and anthropometrics. An illustration of a typical wheelchair design is shown in Figure 6-1 (Refer to Table 6-1 for graphic conventions).

In addition to the dimensions of the wheelchair, the plumbing engineer must take into consideration how wheelchairs are employed and how the person in a wheelchair utilizes plumbing fixtures.

The following information on fixture requirements for the use of people with disabilities is based on the recommended design criteria contained in the proposed ANSI A117.1-1998. A117.1-2003 is proposed to be published May of 2004. For convenient reference to the ANSI A117.1 text, the corresponding ANSI article numbers have been used (e.g., "601.1" and "602.5"). Illustrations, in most cases, are the same as or similar to those in ANSI A117.1. Therefore, A117.1 figure numbers (such as "Figure B4.15.2.1" and "Figure B4.20.3.1") have been included with the "Plumbing Engineering Design Handbook" figure numbers.

Explanatory notes have been added after the recommendations for each fixture, where deemed of value. Where there are differences between A117.1 and ADAAG other than of an editorial nature, it is also noted.

Table 6-1 Graphic Conventions

Convention	Description
36 / 915	Typical dimension line showing US customary units (in in.) above the line and SI units (in mm) below.
9 / 230	Dimensions for short distances indicated on extended line.
9 / 230 — 36 / 915	Dimension line showing alternate dimensions required.
⇦	Direction of approach.
max	Maximum.
min	Minimum.
– – – – – – – – –	Boundary of clear floor area.
——— – ——— – ——— – ℄	Centerline.

Note: Dimensions that are not marked "minumum" or "maximum" are absolute, unless indicated otherwise in text or captions.

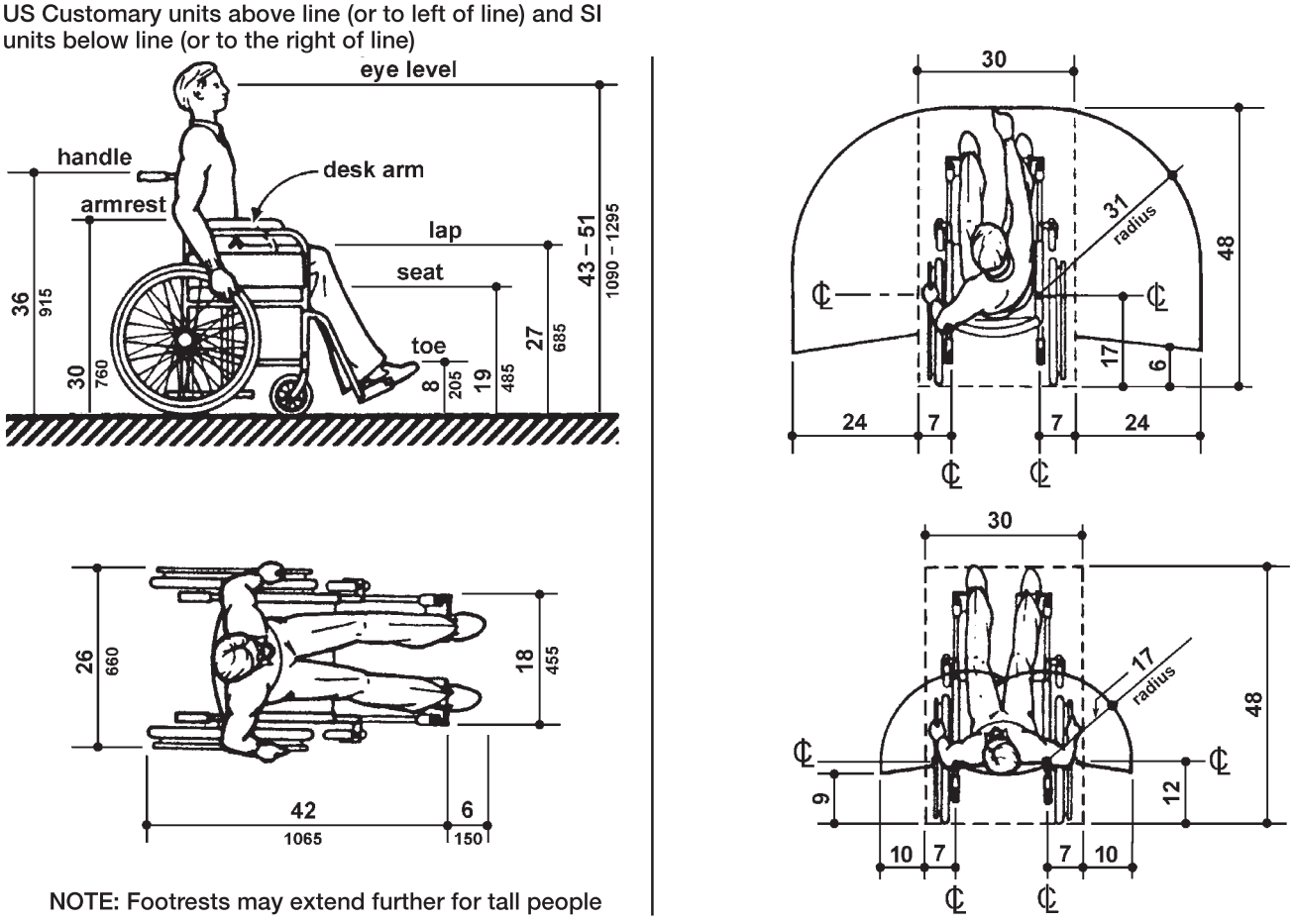


Figure 6-1 Dimensions of Adult-Sized Wheelchairs

CLEAR FLOOR OR GROUND SPACE FOR WHEELCHAIRS

The minimum clear floor or ground space required to accommodate a single, stationary wheelchair and occupant is 30 inches – 48 inches (760 mm – 1220 mm). (See Figure 6-2-B4.2.4.1.) The minimum clear floor or ground space for wheelchairs may be positioned for forward or parallel approach to an object (see Figure 6-3-B4.2.4.2). Clear floor or ground space for wheelchairs may be part of the knee space required under some objects. One full, unobstructed side of the clear floor or ground space for a wheelchair shall adjoin another wheelchair clear floor space. If a clear floor space is located in an alcove or otherwise confined on all or part of three sides, additional maneuvering clearances shall be provided as shown in Figure 6-4 (B4.2.4.4).

Anthropometrics

Forward reach If the clear floor space only allows forward approach to an object, the maximum high forward reach allowed shall be 48 inches (1220 mm). (See Figure 6-5-B4.2.5.1.) The minimum low forward reach is 15 inches (380 mm). If the high forward reach is over an obstruction, reach and clearances shall be as shown in Figure 6-6 (B4.2.5.2).

Side reach If the clear floor space allows parallel approach by a person in a wheelchair, the maximum high side reach allowed shall be 48 inches (1220 mm), and the low side reach shall be 15 inches (380 mm) (see Figure 6-7-B4.2.6.1). If the side reach is over an obstruction, the reach and clearances shall be as shown in Figure 6-8 (B4.2.6.2).

PLUMBING ELEMENTS AND FACILITIES[1]

601 General

601.1 Scope Plumbing elements and facilities required to be accessible by scoping provisions adopted by the administrative authority shall comply with the applicable provisions of this chapter.

602 Drinking Fountains and Water Coolers

602.1 General Accessible fixed drinking fountains and water coolers shall comply with 602.

602.2 Clear floor or ground space A clear floor or ground space complying with 305 shall be provided.[2]

602.2.1 Forward approach Where a forward approach is provided, the clear floor or ground space shall be centered on the unit and shall include knee and toe clearance complying with 306.[2]

602.2.2 Parallel approach Where a parallel approach is provided, the clear floor or ground space shall be centered on the unit.

602.3 Operable parts Operable parts shall comply with 309.[2]

602.4 Spout height Spout outlets shall be 36 inches (915 mm) maximum above the floor or ground. (See Figure 6-9A-B4.15.2.1A.)

602.5 Spout location Units with a parallel approach shall have the spout 3½ inches (89 mm) maximum from the front edge of the unit, including bumpers. Units with a forward approach shall have the spout 15 inches (380 mm) minimum from the vertical support and 5 inches (125 mm) maximum from the front edge of the unit, including bumpers.

602.6 Water flow The spout shall provide a flow

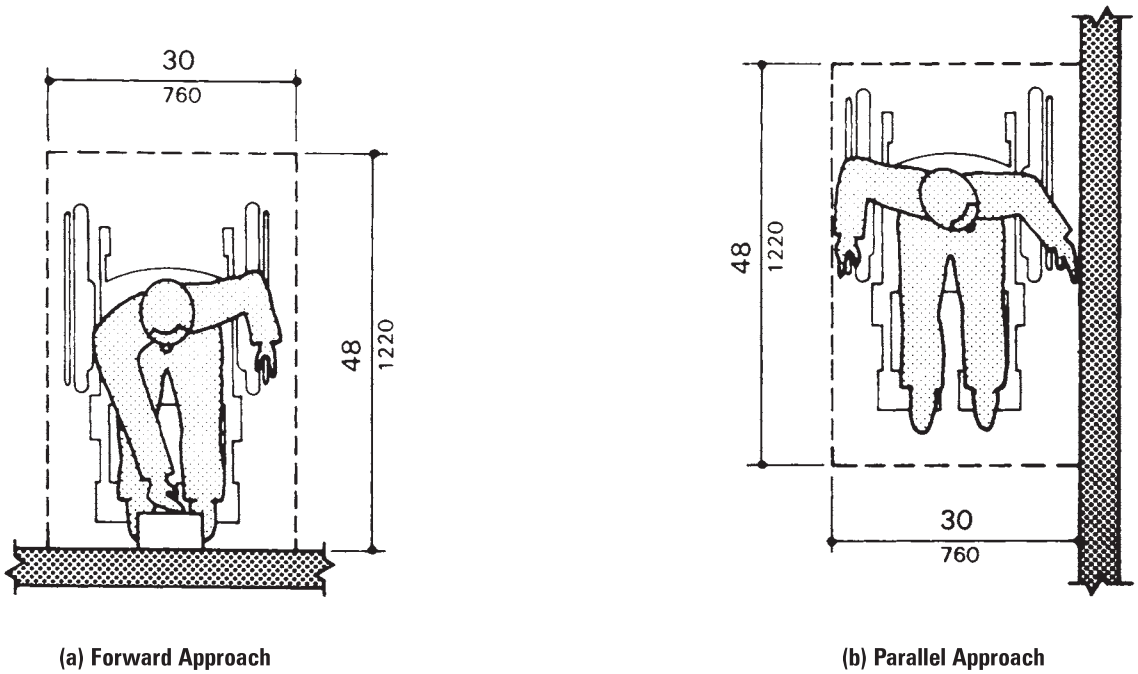


Figure 6-3 Wheelchair Approaches

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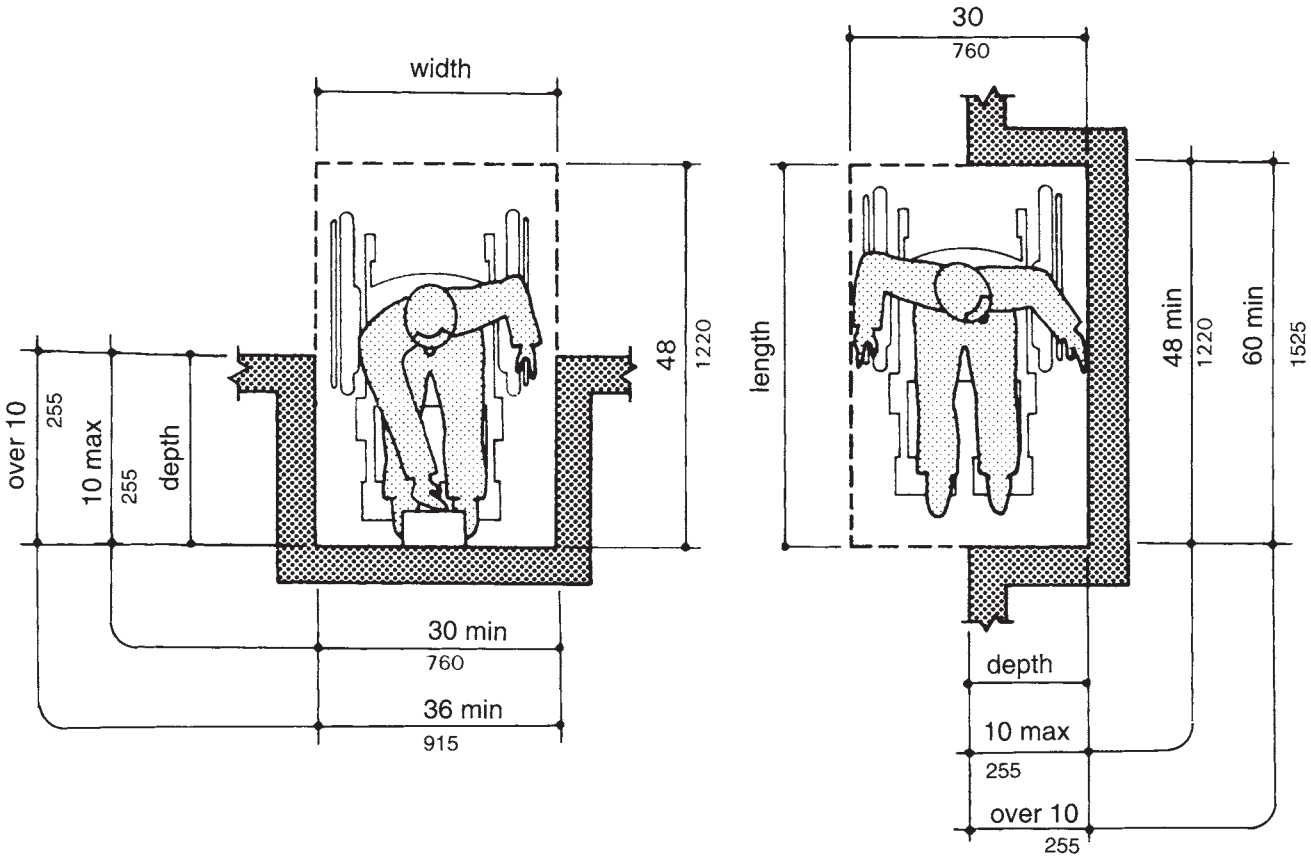


Figure 6-4 Clear Floor Space in Alcoves

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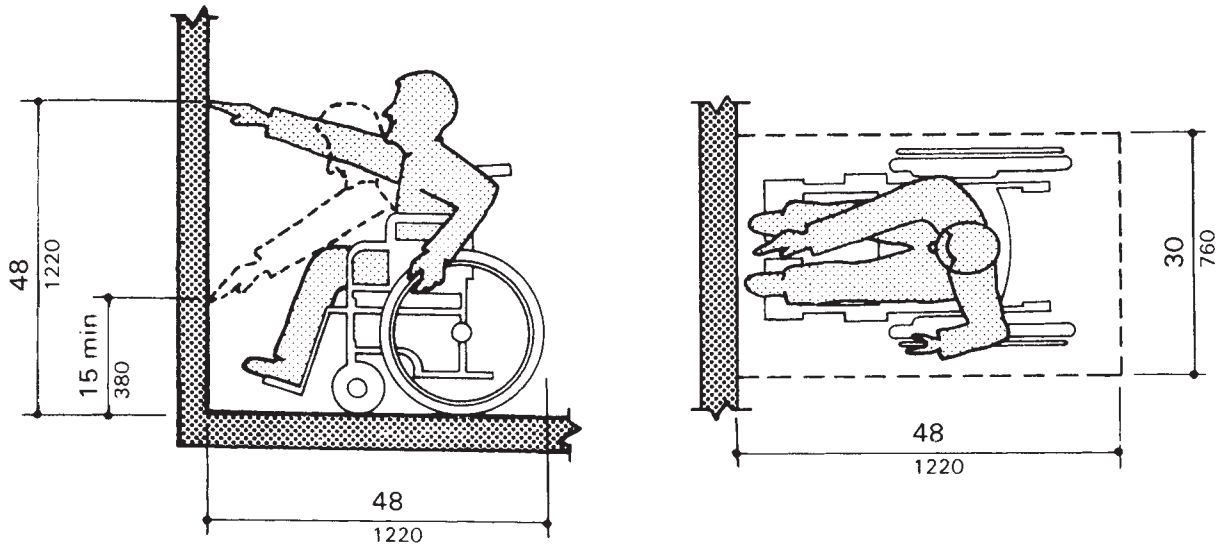


Figure 6-5 Unobstructed Forward Reach Limit

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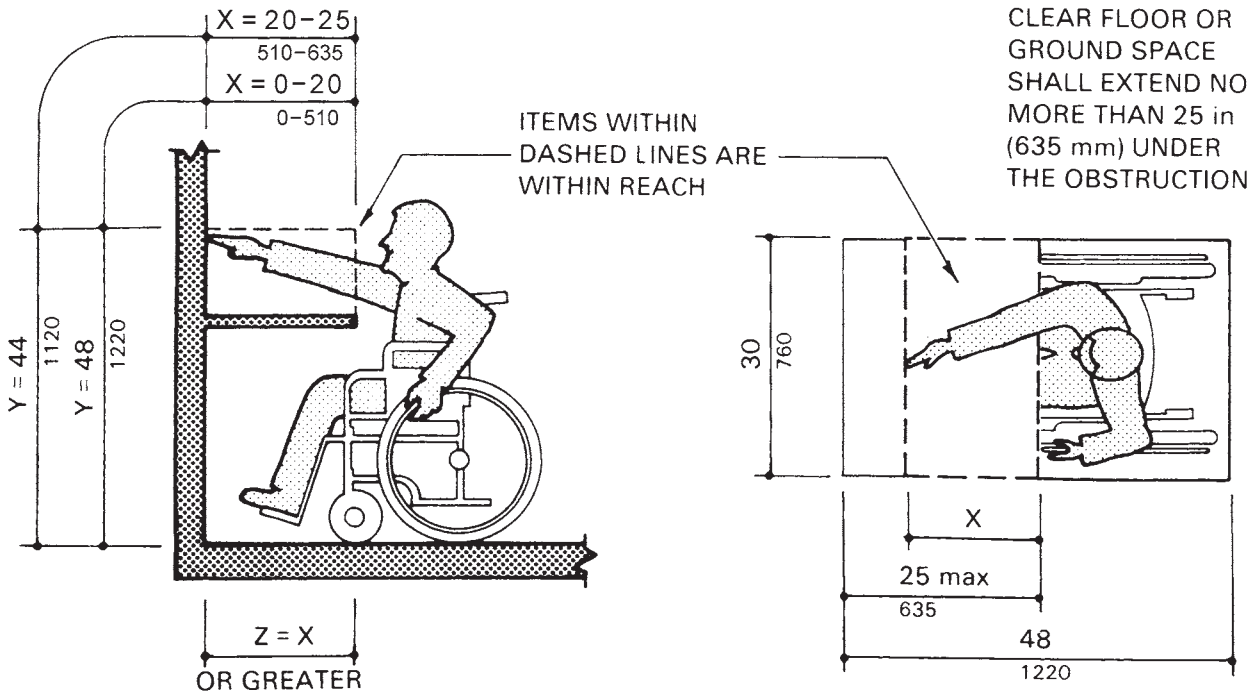


Figure 6-6 Forward Reach Over an Obstruction

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Note: X = Reach depth, Y = Reach height, Z = Clear knee space.
Z is the clear space below the obstruction, which shall be at least as deep as the reach distance, X.

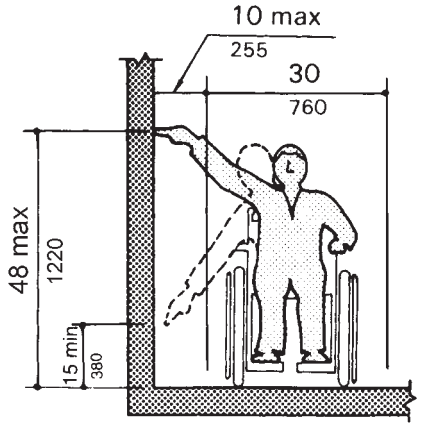


Figure 6-7 Unobstructed Side Reach Limit

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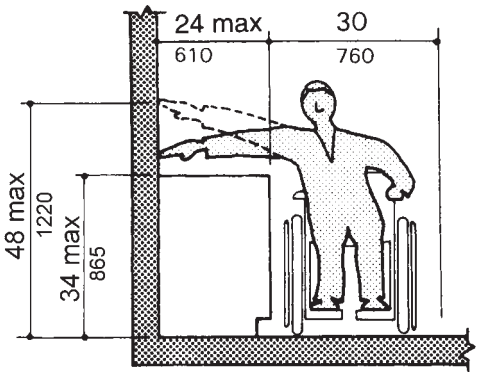
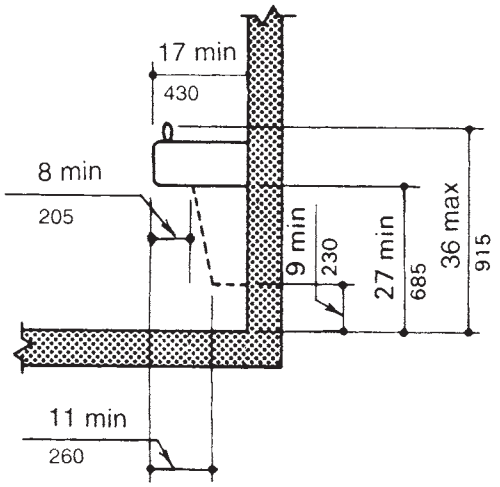
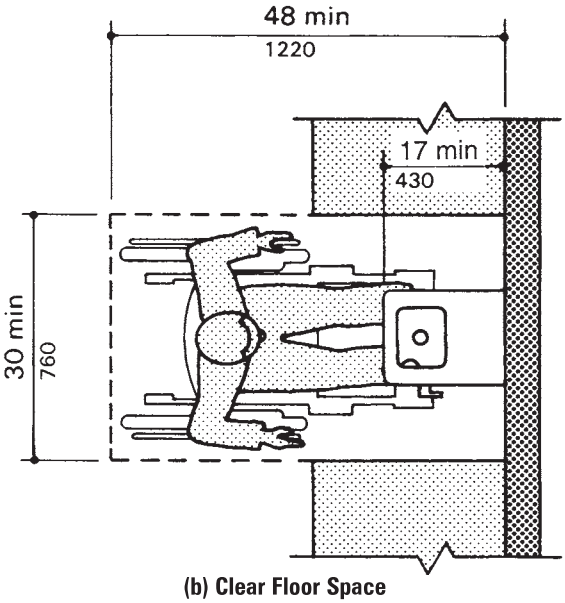


Figure 6-8 Obstructed Side Reach Limit

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(a) Spout Height and Leg Clearance



(b) Clear Floor Space

Figure 6-9 Cantilevered Drinking Fountains and Water Coolers

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Note: Figure 6-9a only: Equipment permitted within dashed lines if mounted below apron.

close to the front edge and as low as possible. There are self-contained units available that can be mounted so that spout heights of 33 to 34 inches (839 to 864 mm) can be obtained, without interfering with required leg clearances.

Parallel approach units are more difficult to use than the cantilevered type and should be avoided if possible. If used, the spout should be mounted as close to 30 inches (762 mm) as the fountain will permit.

It is desirable to provide some water coolers or fountains with spout heights of approximately 42 inches (1067 mm) to serve semi-ambulatory users who can have difficulty bending to lower elevations.

Drinking fountains must be provided not only for wheelchair-bound individuals but also for back-disabled individuals (ADAAG section 4.1.3, item no. 10, and appendix A4.15.2). Where only one (1) fountain is required by code, it must be an accessible bi-level unit, or two (2) separate accessible units mounted at different heights must be provided. Where more than one (1) fountain is required by code, 50 percent must be installed for wheelchair-bound individuals.

603 Toilet and Bathing Rooms

603.1 General Accessible toilet and bathing rooms shall comply with 603.

603.2 Clearances

603.2.1 Wheelchair turning space A wheelchair turning space complying with 304 shall be provided within the room.[2]

[1] Text source: CABO/ANSI A117.1-1998

[2] See CABO/ANSI A117.1-1998

603.2.2 Overlap Clear floor or ground spaces, clearances at fixtures, and wheelchair turning spaces shall be permitted to overlap.

603.2.3 Doors Doors shall not swing into the clear floor or ground space or clearance for any fixture.

EXCEPTION: Where the room is for individual use, and a clear floor or ground space complying with 305.3 is provided within the room beyond the arc of the door swing.[2]

603.3 Mirrors Mirrors shall be mounted with the bottom edge of the reflecting surface 40 inches (1015 mm) maximum above the floor or ground. (See Figure 6-11-B4.20.3.1.)

603.4 Coat hooks and shelves Coat hooks provided within toilet rooms shall accommodate a forward reach or side reach complying with 308.[2] Where provided, a fold-down shelf shall be 40 inches (1015 mm) minimum and 48 inches (1220 mm) maximum above the floor or ground.

Toilet and bathing rooms note:

When a door opens into a bathroom, sufficient maneuvering space is provided within the room for a person using a wheelchair to enter, close the door, use the fixtures, reopen the door, and exit without undue difficulty.

The wheelchair maneuvering space overlaps the required clear floor space at fixtures and extends under the lavatory 19 inches (480 mm) maximum because knee space is provided. However, because toe or knee space is not available at the toilet, the wheelchair maneuvering space is clear of the toilet. Design and location of floor drains should not impede the use of plumbing fixtures.

Medical cabinets or other methods for storing medical and personal care items are very useful to people with disabilities. Shelves, drawers, and floor-mounted cabinets should be within the reach ranges of a physically challenged person.

If mirrors are to be used by both ambulatory people and wheelchair users, then they should be 74 inches (1880 mm) high minimum at their topmost edge and 40 inches (1015 mm) maximum at their lowest edge. A single full-length mirror accommodates all people, including children.

604 Water Closets and Toilet Compartments

604.1 General Accessible water closets and toilet compartments shall comply with 604.

604.2 Location The water closet shall be positioned

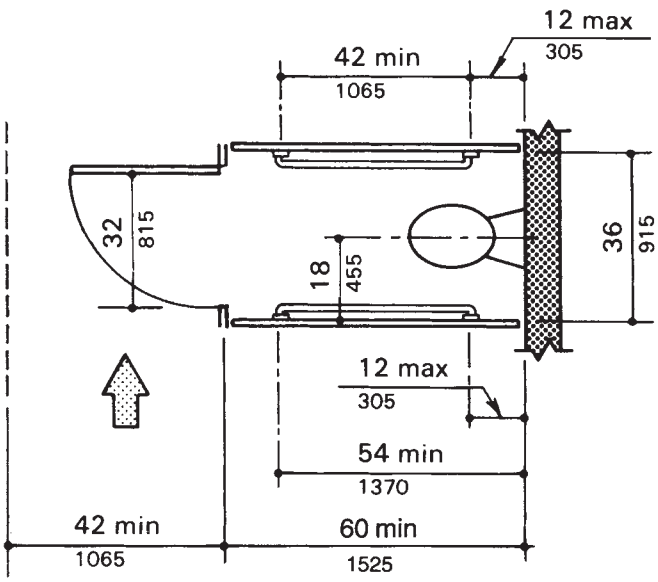


Figure 6-12 Ambulatory Accessible Stall

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within the water closet clearance. (See Figure 6-13-B4.18.3.1.)

604.3.2 Overlap The clearance around the water closet shall be permitted to overlap the fixture, associated grab bars, tissue dispensers, accessible routes and clear floor or ground space or clearances at other fixtures and the wheelchair turning space. Clear floor space shall comply with Figure 6-14 (B4.17.2).

604.4 Height The top of water closet seats shall be 17 inches (430 mm) minimum and 19 inches (485 mm) maximum above the floor or ground. Seats shall not return automatically to a lifted position. (See Figure 6-15-B4.17.3.)

604.5 Grab bars Grab bars for water closets shall comply with 609. Grab bars shall be provided on the rear wall and on the side wall closest to the water closet.

604.5.1 Side wall Side wall grab bar shall be 42 inches (1065 mm) long minimum, 12 inches (305 mm) maximum from the rear wall and extending 54 inches (1370 mm) minimum from the rear wall. (See Figure 6-15-B4.17.3.)

604.5.2 Rear wall The rear wall grab bar shall be 24 in. (610 mm) long minimum, centered on the water closet. Where space permits, the bar shall be 36 in. (915 mm) long minimum, with the additional length provided on the transfer side of the water closet. (See Figure 6-16-B4.17.4.)

604.6 Flush controls Flush controls shall be hand operated or automatic. Hand-operated flush controls shall comply with 309.[2]

604.7 Dispensers Toilet paper dispensers shall comply with 309.4 and shall be 7 inches (180 mm) minimum and 9 inches (230 mm) maximum in front of the water closet.[2] The outlet of the dispenser shall be 15 inches (380 mm) minimum and 48 inches (1220 mm) maximum above the floor or ground. There shall be a clearance of 1½ inches. (38 mm) minimum below and 12 inches (305 mm) minimum above the grab bar. Dispensers shall not be of a type that control delivery, or that do not allow continuous paper flow.

604.8 Toilet compartments Accessible toilet compartments shall comply with 604.8.1 through 604.8.5. Compartments containing more than one plumbing fixture shall comply with 603. Water closets in accessible toilet compartments shall comply with 604.1 through 604.7.

604.8.1 Wheelchair accessible compartments

604.8.1.1 Size Wheelchair accessible compartments shall be 60 inches (1525 mm) wide minimum measured perpendicular to the side wall, and 56 inches (1420 mm) deep minimum for wall-hung water closets and 59 inches (1500 mm) deep minimum for floor-

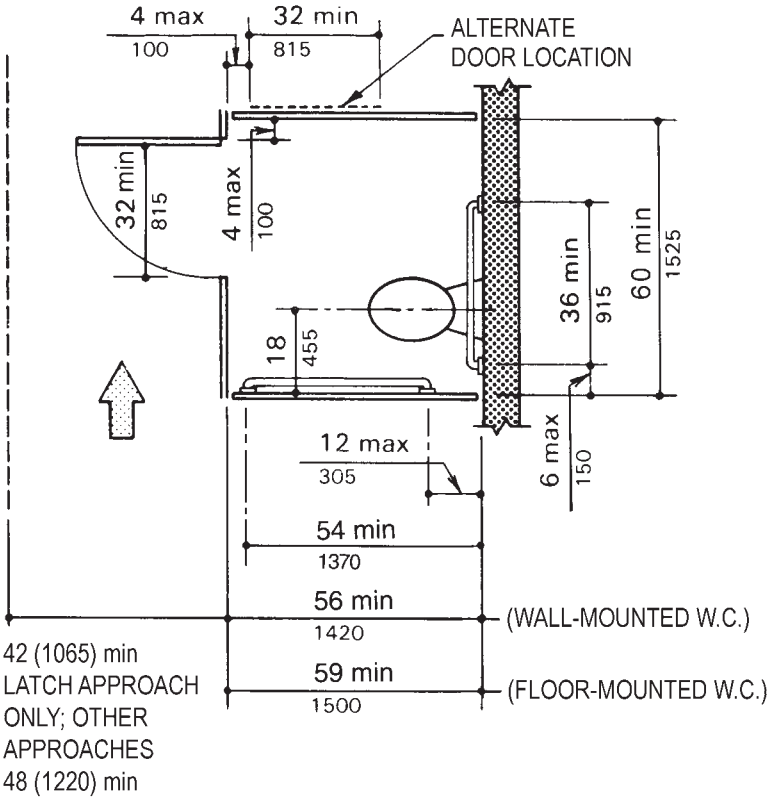


Figure 6-13 Wheelchair Accessible Toilet Stalls — Door Swing Out

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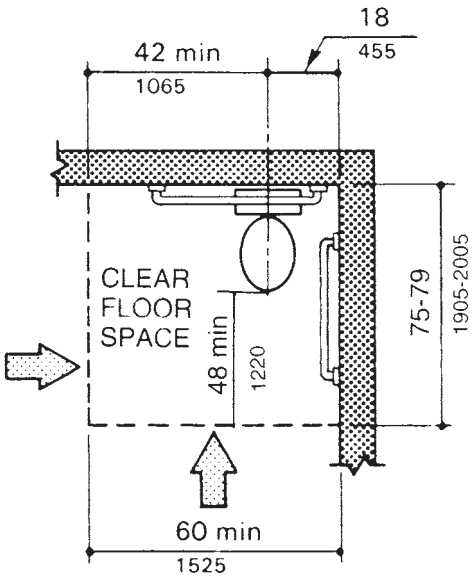


Figure 6-14 Clear Floor Space at Water Closets

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mounted water closets, measured perpendicular to the rear wall. (See Figure 6-13-B4.18.3.1.)

604.8.1.2 Doors Compartment doors shall not swing into the minimum required compartment area. (See Figure 6-17-B4.18.3.2.)

604.8.1.3 Approach Compartment arrangements shall be permitted for left-hand or right-hand approach to the water closet.

604.8.1.4 Toe clearance In wheelchair-accessible compartments, the front partition and at least one side partition shall provide a toe clearance complying with 306.2 and extending 6 inches (150 mm) deep beyond the compartment-side face of the partition, exclusive of partition support members.[2] Toe clearance at the front of the partition is not required in a compartment greater than 62 inches (1575 mm) deep with a wall-hung water closet or 65 inches (1650 mm) deep with a floor-mounted water closet. Toe clearance at the side partition is not required in a compartment greater than 66 inches (1675 mm) wide.

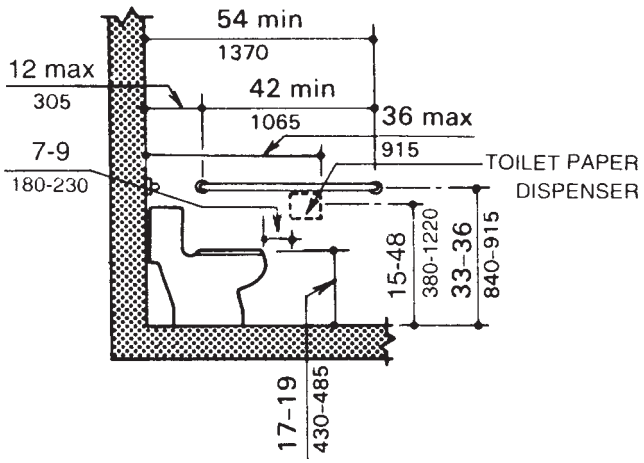
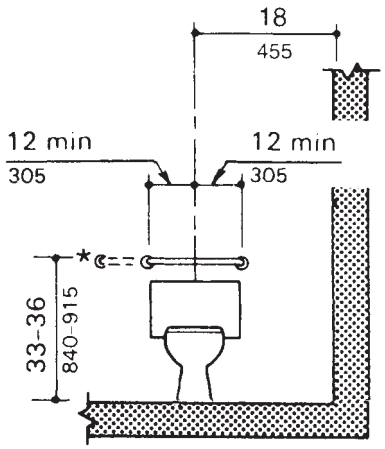


Figure 6-15 Water Closet — Side View

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604.8.2 Ambulatory-accessible compartments Ambulatory-accessible compartments shall be 60 inches (1525 mm) deep minimum and 36 inches (915 mm) wide. Compartment doors shall not swing into the minimum required compartment area. (See Figure 6-12-B4.18.4.)

604.8.3 Doors Toilet compartment doors shall comply with 404, except that if the approach is to the latch side of the compartment door, the clearance between the door side of the compartment and any obstruction shall be 42 inches (1065 mm) minimum. The door shall be hinged 4 inches (100 mm) maximum from the adjacent wall or partition farthest from the water closet. The door shall be self-closing. A door pull complying with 404.2.7 shall be placed on both sides of the door near the latch.[2]



* Where space permits, extend grab bar on transfer side.

Figure 6-16 Water Closet — Front View

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604.8.4 Grab bars Grab bars shall comply with 609.

604.8.4.1 Wheelchair-accessible compartments A side-wall grab bar complying with 604.5.1 shall be provided on the wall closest to the water closet, and a rear-wall grab bar complying with 604.5.2 shall be provided. (See Figure 6-13-B4.18.3.1.)

604.8.4.2 Ambulatory-accessible compartments A side-wall grab bar complying with 604.5.1 shall be provided on both sides of the compartment. (See Figure 6-12-B4.18.4.)

604.8.5 Coat hooks and shelves Coat hooks provided within toilet compartments shall be 48 inches

(1220 mm) maximum above the floor or ground. Where provided, a fold-down shelf shall be 40 inches (1015 mm) minimum and 48 inches (1220 mm) maximum above the floor or ground.

Water closets and toilet compartments note:

The centerline requirement for water closets has been adjusted to allow a range of 16 to 18 inches (407 to 457 mm) from the centerline of the fixture to the side wall, eliminating the fixed 18 inches (457 mm) dimensional requirement. Code enforcement officials in the field have successfully argued this change on the merits of allowing some flexibility. The greater or lesser accessibility of a water closet installed 16 inches (407 mm) from the side wall to the centerline of the toilet versus a water closet installed 18 inches (457 mm) from the side wall has yet to be answered to a majority of either committee.

The toilet seat height of 17 to 19 inches (432 to 483 mm) in public areas is intended to minimize the difference between the seat and the standard wheelchair seat height to aid the transfer process, without elevating the toilet seat to the point that stability problems are created.

The 60 inches (1525 mm) wide wheelchair-accessible compartment is preferred and should be designed. In the design of alterations to existing structures, it may not be possible to create the preferred compartment by combining two existing compartments, or physical conditions may not permit the full 60 inches (1525 mm) width. In these cases, the authority having jurisdiction may permit a narrower compartment. In no case should a width of less than 48 inches (1220 mm) be used.

The needs of a semi-ambulatory user are best served by a narrower, 36 inches max. (915 mm max.), compartment which premises use of grab bars on either or both sides of the compartment.

ADAAG note:

ADAAG has an exception to the height requirement of water closets and grab bars for water closets located in a toilet room for a single occupant, accessed only through a private office and not for common or public use. Where six (6) or more compartments are provided in a toilet room, one (1) must be a 60 inch (1525 mm) wheelchair-accessible compartment, and one (1) must be a 36 inch (915 mm) ambulatory compartment.

The flush valve handles should not exceed 44 inches (1118 mm) above the floor. The handles in standard accessible stalls must be at the wide side of the stall (ADAAG section 4.16.5). This means, depending on how the stall is configured, the handle must be on either the right or left side of the flush valve. This does not apply to tank-type units, although several manufacturers have now come up with a right-hand operator.

605 Urinals

605.1 General Accessible urinals shall comply with 605.

605.2 Height Urinals shall be of the stall type or shall be of the wall-hung type with the rim at 17 inches (430 mm) maximum above the floor or ground.

605.3 Clear floor or ground space A clear floor or ground space complying with 305 positioned for forward approach shall be provided.[2]

605.4 Flush controls Flush controls shall be hand operated or automatic. Hand-operated flush controls shall comply with 309.[2]

Urinal note:

It should be understood that the referenced urinal is not intended to be used by a wheelchair occupant for the normal urination process. It is intended for the drainage of bladder bags, a function normally performed in a water closet compartment, if available. Where an accessible urinal is required, it can serve as a child's urinal. Urinals must be provided with an elongated rim (ADAAG section 4.18.2). Although ADAAG does not define what constitutes an elongated urinal, the Department of Justice deferred to ANSI, which defines these fixtures as having a lip that protrudes a minimum of 14 in. (356 mm) from

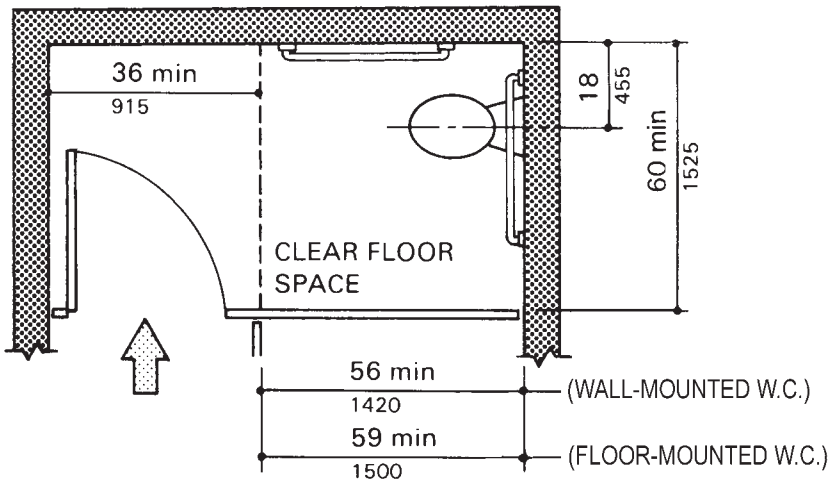


Figure 6-17 Wheelchair Accessible Toilet Stalls — Door Swing In

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the wall. Flush valve handles should not exceed 48 inches (1220 mm) above the floor.

606 Lavatories and Sinks

606.1 General Accessible lavatories and sinks shall comply with 606.

606.2 Clear floor or ground space A clear floor or ground space complying with 305.3, positioned for forward approach, shall be provided. Knee and toe clearance complying with 306 shall be provided.[2] (See Figure 6-18-B4.20.3.2.)

EXCEPTIONS:

1. A parallel approach shall be permitted to a kitchen sink in a space where a cook-top or conventional range is not provided.
2. The dip of the overflow shall not be considered in determining knee and toe clearances.

606.3 Height and clearances The front of lavatories and sinks shall be 34 inches (865 mm) maximum above the floor or ground, measured to the higher of the fixture rim or counter surface.

606.4 Faucets Faucets shall comply with 309.[2] Hand-operated, self-closing faucets shall remain open for 10 seconds minimum.

606.5 Bowl depth Sinks shall be 6½ inches (165 mm) deep maximum. Multiple-compartment sinks shall have at least one compartment complying with this requirement.

606.6 Exposed pipes and surfaces Water supply and drain pipes under lavatories and sinks shall be insulated or otherwise configured to protect against contact. (See Figure 6-11-B4.20.3.1.) There shall be no sharp or abrasive surfaces under lavatories and sinks.

Lavatories and sinks note:

Conventional slab-type lavatories are available to meet the dimensional requirements of A117.1, since the dip of the overflow can be ignored.

Built-in lavatories in countertops should be placed as close as possible to the front edge of the countertop to minimize the reach to the faucet. Single-lever faucets are preferred, but where aesthetics or fear of vandalism precludes their use, conventional quarter-turn handles are a good choice. Avoid faucets that require finger dexterity for grasping or twisting.

Both hot and cold water pipes, as well as drain pipes that are in the vicinity of the designated clear floor space under the fixture, must be concealed or insulated to protect wheelchair users who have no functioning sensory nerves. Insulation is not required on pipes beyond possible contact.

607 Bathtubs

607.1 General Accessible bathtubs shall comply with 607.

607.2 Clearance Clearance in front of bathtubs shall extend the length of the bathtub and shall be 30 inches (760 mm) wide minimum. A lavatory complying with 606 shall be permitted at the foot end of the clearance. (See Figure 6-19-B4.21.2.) Where a permanent seat is provided at the head end of the bathtub, the clearance shall extend a minimum of 15 inches (380 mm) beyond the wall at the head end of the bathtub.

607.3 Seat A permanent seat at the head end of the bathtub or a removable in-tub seat shall be provided. Seats shall comply with 610.

607.4 Grab bars Grab bars shall comply with 607.4 and 609.

607.4.1 Bathtubs with permanent seats For bathtubs with permanent seats, grab bars complying with 607.4.1.1 and 607.4.1.2 shall be provided.

607.4.1.1 Back wall Two grab bars shall be provided on the back wall, one complying with 609.4 and the other 9 inches (230 mm) above the rim of the bathtub. Each grab bar shall be 15 inches (380 mm) maximum from the head-end wall and 12 inches (305 mm) maximum from the foot-end wall.

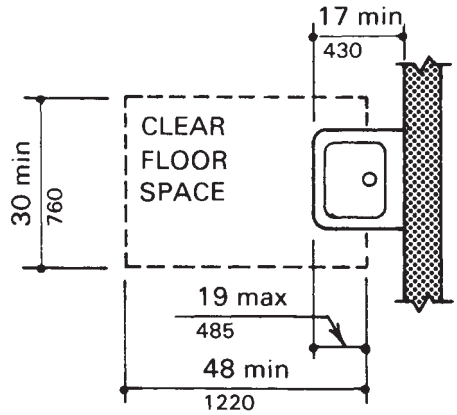


Figure 6-18 Clear Floor Space at Lavatories and Sinks

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607.4.1.2 Foot-end wall A grab bar 24 inches (610 mm) long minimum shall be provided on the foot-end wall at the front edge of the bathtub.

607.4.2 Bathtubs without permanent seats For bathtubs without permanent seats, grab bars complying with 607.4.2.1 through 607.4.2.3 shall be provided.

607.4.2.1 Back wall Two grab bars shall be provided on the back wall, one complying with 609.4 and the other 9 inches (230 mm) above the rim of the bathtub. Each grab bar shall be 24 inches (610 mm) long minimum and shall be 24 inches (610 mm) maximum from the head-end wall and 12 inches (305 mm) maximum from the foot-end wall.

607.4.2.2 Foot-end wall A grab bar 24 inches (610 mm) long minimum shall be provided on the foot-end wall at the front edge of the bathtub.

607.4.2.3 Head-end wall A grab bar 12 inches (305 mm) long minimum shall be provided on the head-end wall at the front edge of the bathtub.

607.5 Controls Controls, other than drain stoppers, shall be on an end wall. Controls shall be between the bathtub rim and grab bar, and between the open side of the bathtub and the midpoint of the width of the bathtub. Controls shall comply with 309.4.[2] (See Figure 6-20-B4.21.4.)

607.6 Shower unit A shower spray unit shall be provided, with a hose 59 inches (1500 mm) long minimum, that can be used as a fixed shower head and as a hand-held shower. If an adjustable-height shower head on a vertical bar is used, the bar shall not obstruct the use of grab bars.

607.7 Bathtub enclosures Bathtub enclosures shall not obstruct controls or transfer from wheelchairs onto bathtub seats or into bathtubs. Bathtub enclosures shall not have tracks on the rim of the bathtub.

Bathtub note:

A fixed seat at the head of the tub adds safety and convenience for transfer purposes, as does the 17 to 19 inches (432 to 483 mm) rim height. The rim height that is more in line with the tub seat does not require the use of a deeper tub; it is better to use a tub with a deeper apron or use a tile filler.

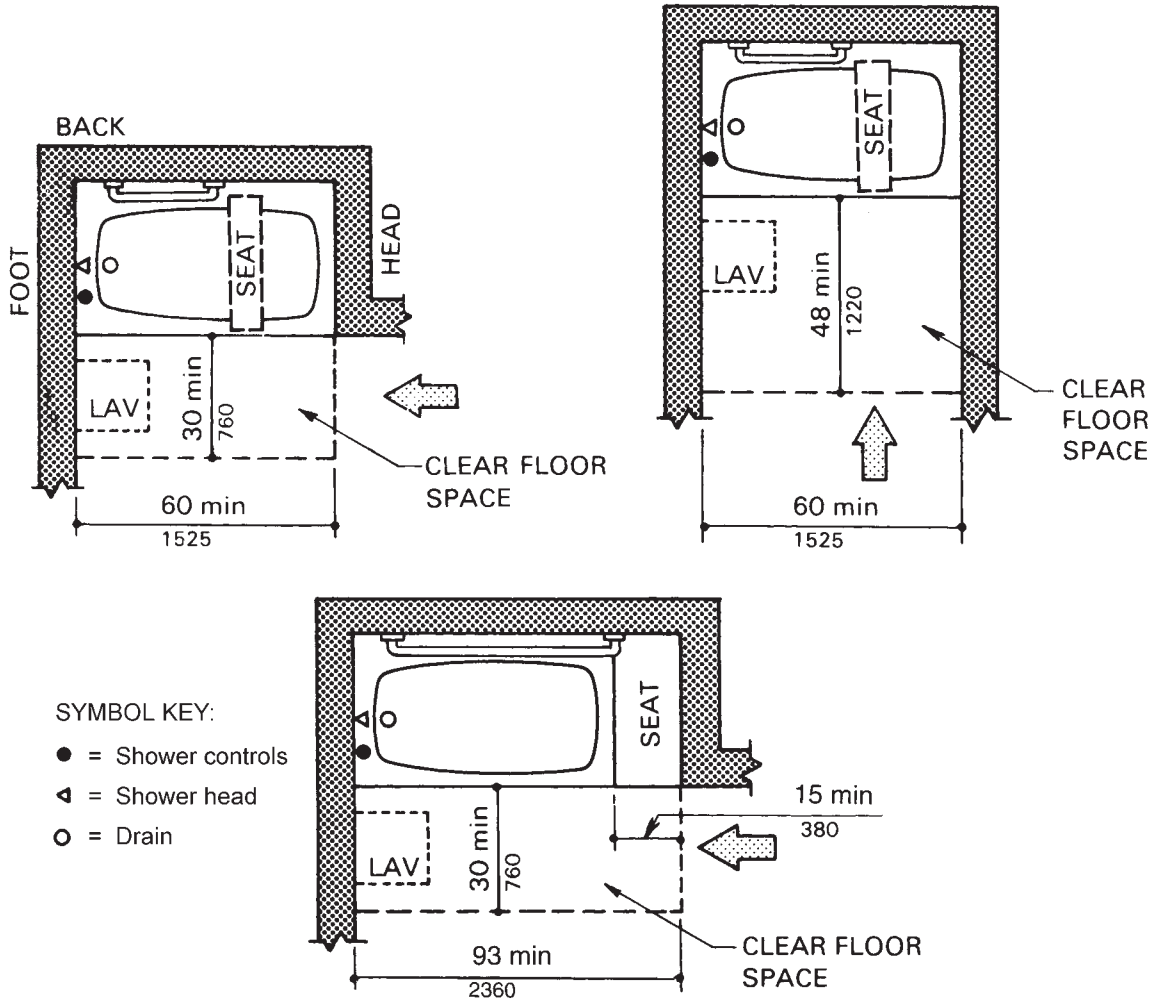


Figure 6-19 Clear Floor Space at Bathtubs

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Due to the probable lack of maneuverability of the user, it is recommended that the plumbing engineer specify a temperature and/or pressure-balanced, water-blending valve with temperature-limit stops.

608 Shower Compartments

608.1 General Accessible shower compartments shall comply with 608.

608.2 Size and clearances

608.2.1 Transfer-type shower compartments Transfer-type shower compartments shall be 36 inches (915 mm) wide by 36 inches (915 mm) deep inside finished dimension, measured at the centerpoint of opposing sides, and shall have a minimum 36 inches (915 mm) wide entry on the face of the shower compartment. The clearance in front of the compartment shall be 48 inches (1220 mm) long minimum measured from the control wall and 36 inches (915 mm) wide minimum. (See Figure 6-21-B4.22.2.1.)

608.2.2 Standard roll-in type shower compartments Roll-in type shower compartments shall be 30 inches (760 mm) wide minimum by 60 inches (1525 mm) deep minimum, clear inside dimension, measured at the centerpoint of opposing sides and shall have a minimum 60 inches (1220 mm) wide entry on the face of the shower. A 30 inches (760 mm) wide minimum by 60 inches (1525 mm) long minimum clearance shall be provided adjacent to the open face of the shower compartment. A lavatory complying with 606 shall be permitted at the end of the clear space, opposite the shower-compartment side where shower controls are positioned. (See Figure 6-22-B4.22.2.2.)

608.2.3 Alternate roll-in type shower compartments Alternate roll-in shower compartments shall

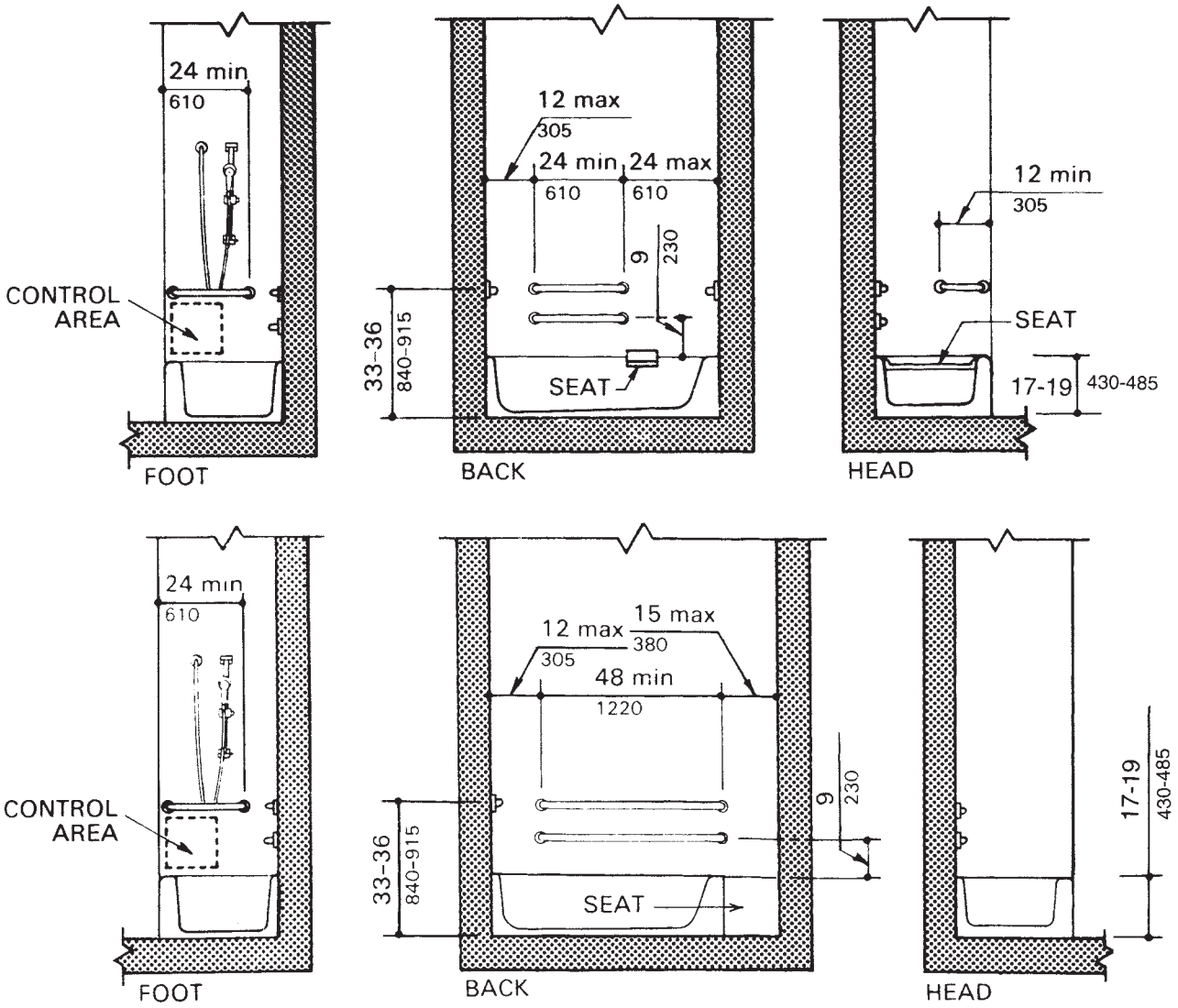


Figure 6-20 Bathtub Accessories

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be 36 inches (915 mm) wide and 60 inches (1220 mm) deep minimum. A 36 inches (915 mm) wide minimum entry shall be provided at one end of the long side of the compartment. The shower unit and controls shall be mounted on the end wall farthest from the compartment entry.

608.3 Grab bars Grab bars shall comply with 608.3 and 609 and shall be provided.

608.3.1 Transfer-type showers Grab bars shall be provided across the control wall and on the back wall to a point 18 inches (455 mm) from the control wall. (See Figure 6-23A-B4.22.4A.)

608.3.2 Roll-in type showers Grab bars shall be provided on the three walls of the shower. (See Figure 6-23B-B4.22.4B.) Grab bars shall be 6 inches (150 mm) maximum from the adjacent wall.

EXCEPTIONS:

1. Where a seat is provided in a roll-in shower, grab bars shall not extend over the seat at the control wall and shall not be behind the seat.
2. In alternate roll-in type showers, grab bars shall not be required on the sidewall opposite the control wall and shall not be behind the seat.

608.4 Seats An attachable or integral seat shall be provided in transfer-type shower compartments. Seats shall comply with 610.

608.5 Controls Shower or bathtub/shower facilities shall deliver water that is thermal-shock protected to 120°F (49°C) maximum. Faucets and controls shall comply with 309.4.[2] Controls in roll-in showers shall be above the grab bar but no higher than 48 inches (1220 mm) above the shower floor. (See Figure 6-23B-B4.22.4B.) In transfer type shower compartments, controls, faucets, and the shower unit shall be on the side wall opposite the seat 38 inches (965 mm) minimum and 48 inches (1220 mm) maximum above the shower floor. (See Figure 6-23A-B4.22.4A.)

608.6 Shower unit A shower spray unit shall be provided, with a hose 59 inches (1500 mm) long minimum, that can be used as a fixed shower head and as a hand-held shower. In transfer-type showers, the controls and shower unit shall be on the control wall within 15 inches (380 mm), left or right, of the centerline of the seat. In roll-in type showers, shower spray units mounted on the back wall shall be 27 inches (685 mm) maximum from the side wall. If an adjustable-height shower head mounted on a vertical bar is used, the bar shall not obstruct the use of grab bars.

608.7 Thresholds Shower compartment thresholds shall be ½ inches (13 mm) high maximum and shall comply with 303.[2]

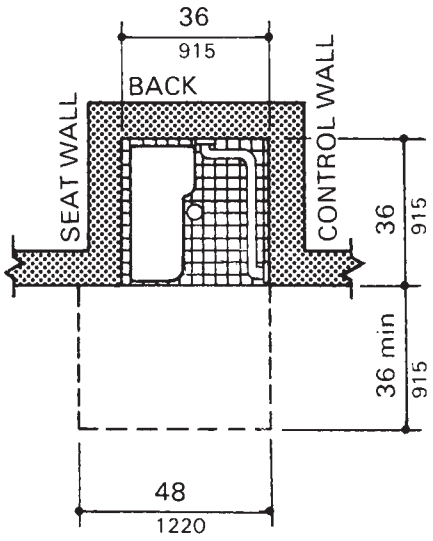


Figure 6-21 Transfer Type Shower Stall

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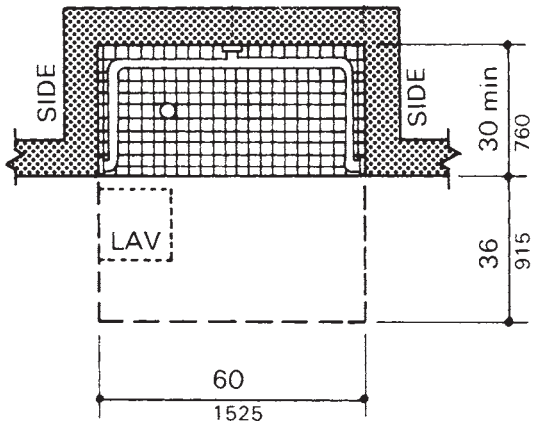


Figure 6-22 Roll-in Type Shower Stall

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608.8 Shower enclosures Shower compartment enclosures for shower compartments shall not obstruct controls or obstruct transfer from wheelchairs onto shower seats.

Shower compartments note:

The recommended shower compartments are for independent use by an individual. Compartments between the two recommended sizes do not effectively serve people with disabilities who wish to use a shower without assistance.

Transfer-type shower compartments that are 36 inches by 36 inches (915 mm by 915 mm) provide additional safety to people who have difficulty maintaining balance because all grab bars and walls are within easy reach. Seated people use the walls of these showers for back support.

The shower compartment with inside finish dimensions of 36 inches by 36 inches (915 mm by 915 mm) has been designated a transfer-type compartment to indicate that wheelchair users can transfer from their chair to the required seat. These dimensions will allow a person of average size to reach and operate the controls without difficulty, while providing reasonable knee space for larger users. A transfer-type shower is also intended to serve persons without disabilities so a folding seat would provide more space for a standing person. Temperature may be limited to 105 to 110°F (40.5 to 43°C), depending on local code requirements.

609 Grab Bars

609.1 General Grab bars in accessible toilet or bathing facilities shall comply with 609.

609.2 Size Grab bars shall have a circular cross section with a diameter of 1¼ in. (32 mm) minimum and 2 inches (51 mm) maximum, or shall provide equivalent grasp ability complying with 505.7.1.[2]

609.2.1 Noncircular cross sections Grab bars with other shapes shall be permitted, provided they have a perimeter dimension of 4 inches (100 mm) minimum and 4.8 inches (160 mm) maximum and edges having an 8 inches (3.2 mm) minimum radius.

609.3 Spacing The space between the wall and

EXCEPTION: The space between the grab bars and shower controls, shower fittings, and other grab bars above shall be 1½ inches (38 mm) minimum.

609.4 Position of grab bars Grab bars shall be mounted in a horizontal position, 33 inches (840 mm) minimum and 36 inches (915 mm) maximum above the floor.

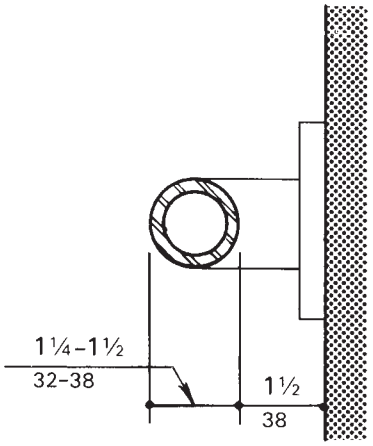


Figure 6-24 Size and Spacing of Grab Bars

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EXCEPTION: Height of grab bars on the back wall of a bathtub shall comply with 607.4.1.1 and 607.4.2.1.

609.5 Surface hazards Grab bars and any wall or other surfaces adjacent to grab bars shall be free of sharp or abrasive elements. Edges shall have a radius of 8 inches (3 mm) minimum.

609.6 Fittings Grab bars shall not rotate within their fittings.

609.7 Installation Grab bars shall be installed in any manner that provides a gripping surface at the locations specified in this standard and that does not obstruct the clear floor space.

609.8 Structural strength Allowable stresses in bending, shear, and tension shall not be exceeded for materials used where a vertical or horizontal force of 250 pounds (113.5 kg) is applied at any point on the grab bar, fastener mounting device, or supporting structure.

Grab bars note:

Many people with disabilities rely heavily upon grab bars to maintain balance and prevent serious falls. Many people brace their forearms between supports and walls to give them more leverage and stability in maintaining balance or for lifting. The grab bars clearance of 1½ inches (38 mm) required in this standard is a safety clearance to prevent injuries from arms slipping through the opening. This clearance also provides a minimum space for gripping.

Grab bars that are wall mounted do not affect the measurement of required clear floor space where the space below the grab bar is clear and does not present a knee space encroachment.

610 Seats

610.1 General Seats in accessible bathtubs and shower compartments shall comply with 610.

610.2 Bathtub seats A removable in-tub seat shall be 15 inches (380 mm) minimum and 16 inches (405 mm) deep maximum, and shall be capable of secure placement. A permanent seat shall be 15 inches (380 mm) deep minimum and be positioned at the head end of the bathtub. The top of the seat shall be 17 inches (430 mm) minimum and 19 inches (485 mm) maximum above the bathroom floor.

610.3 Shower compartment seats Where a seat is provided in a roll-in shower compartment, it shall be a folding type and shall be on the wall adjacent to the controls. Seats shall be L-shaped or rectangular. The top of the seat shall be 17 inches (430 mm) minimum and 19 inches (485 mm) maximum above the bathroom floor. In a transfer-type shower, the seat shall extend from the back wall to a point within 3 inches (75 mm) of the compartment entry. In a roll-in type shower, the seat shall extend from the control wall to a point within 3 inches (75 mm) of the minimum required seat wall width.

610.3.1 Rectangular seats The rear edge of a rectangular seat shall be 2½ inches (64 mm) maximum from the seat wall, and the front edge 15 inches (380 mm) minimum and 16 inches (405 mm) maximum from the seat wall. In a transfer-type shower, the side edge of a rectangular seat shall be 1½ inches (38 mm) maximum. In a roll-in type shower, the side edge of a rectangular seat shall be 1½ inches (38 mm) maximum from the control wall.

610.3.2 L-shaped seats The rear edge of an L-shaped seat shall be 2½ in. (64 mm) maximum from the seat wall, and the front edge 15 inches (380 mm) minimum and 16 inches (405 mm) maximum from the seat wall. The rear edge of the "L" portion of the seat shall be 1½ inches (38 mm) maximum from the wall and the front edge shall be 14 inches (355 mm) minimum and 15 inches. (380 mm) maximum from the wall. The end of the "L" shall be 22 inches (560 mm) minimum and 23 inches (585 mm) maximum from the main seat wall. (See Figure 6-25-B4.22.3.)

610.4 Structural strength Allowable stresses in bending, shear, and tension shall not be exceeded for materials used where a vertical or horizontal force of

250 lb (113.5 kg) is applied at any point on the seat, fastener mounting device, or supporting structure.

Seats note:

The seat in a shower is required to be nearly the full depth of the compartment; it should be as close to the front edge of the seat wall as possible to minimize the distance between the seat and the wheelchair so as to facilitate a transfer. The seat wall must be free of grab bars to allow a person to slide onto the seat, and a portion of the adjacent back wall must be without a grab bar so the person's back can be placed against the walls for support.

611 Laundry Equipment

611.2 Clear floor or ground space A clear floor or ground space complying with 305 positioned for parallel approach shall be provided. The clear floor or ground space shall be centered on the appliance.[2]

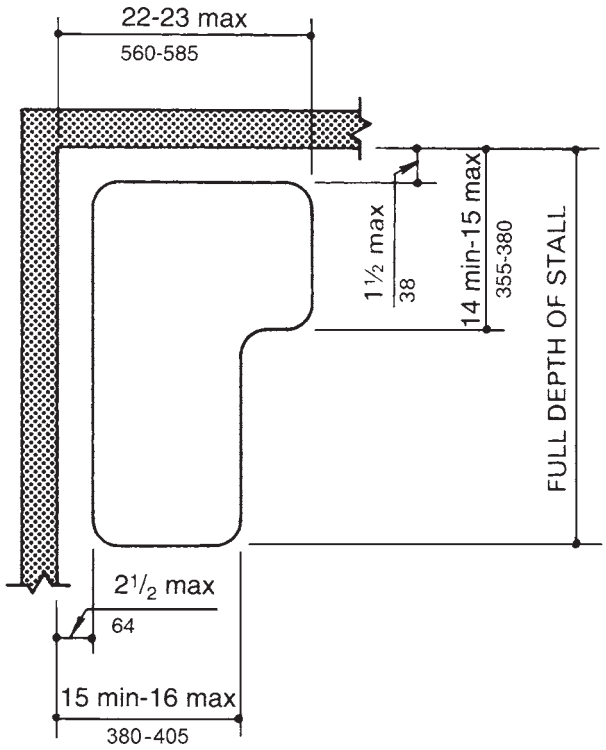


Figure 6-25 Shower Seat Design

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611.3 Operable parts Operable parts, including doors, lint screens, detergent and bleach compartments, shall comply with 309.[2]

611.4 Height Top-loading machines shall have the door to the laundry compartment 34 inches (865 mm) maximum above the floor or ground. Front-loading machines shall have the bottom of the opening to the laundry compartment 15 inches (380 mm) minimum and 34 inches (865 mm) maximum above the floor or ground.

REFERENCES

1. ADAAG Review Federal Advisory Committee. September 30, 1996. Recommendations for a new ADAAG.

2. Council of American Building Officials (CABO)/ International Code Council, Inc. 1998 [1992]. CABO/ANSI A117.1, Accessible and usable buildings and facilities. Falls Church, Va.

7 Energy and Resource Conservation in Plumbing Systems

INTRODUCTION

Prior to the 1973-1974 OPEC oil embargo, energy was considered inexhaustible and expendable. As energy costs grew, society turned its attention toward energy conservation. The Energy Policy and Conservation Act (EPCA) of 1975 was the first major piece of legislation that addressed federal energy management. Additional laws soon followed such as: The Resource Conservation and Recovery Act of 1976, the National Energy Conservation Policy Act of 1978, the Federal Energy Management Improvement Act (FEMIA) of 1988, and the Energy Policy Act (EPACT) of 1992 that expanded upon the EPCA of 1975. Along with the federal government, other sectors of society made strides to reduce energy consumption. The automotive industry, which was heavily impacted by the oil embargo, was quick to adapt by producing smaller, lighter, more fuel-efficient cars. The construction market also made strides by adopting model energy codes, efficiency standards, and alternate fuel sources. One of the highest energy-consuming plumbing systems is domestic hot water, often consuming 2 percent to 4 percent of the total energy used in an office building and 8 percent of residential properties. This plumbing system has a great need for energy-conservation measures.

Just as important as energy conservation is resource conservation. A resource greatly affected by plumbing-system design is water management. Water use in the United States has more than doubled in the past half-century from approximately 180 billion gallons per day in 1950 to more than 400 billion gallons a day in 1995. It has been determined that 39 percent of water use in commercial buildings is for domestic purposes. It is important to note that by reducing hot water use both energy and water is conserved.

This chapter is intended to provide a plumbing engineer with design techniques that conserve both energy and water and assist them in selecting energy and water-efficient equipment and systems. Where the recommendations set forth in this chapter do not meet the minimum provisions of the local code, the code shall apply.

DOMESTIC HOT WATER SYSTEM ENERGY CONSERVATION

Design Techniques

Hot water use can vary from hand washing, showering, and janitorial needs, to cooking, dishwashing, and laundering needs. Design techniques that can be employed to conserve energy when creating hot water are:

1. Eliminate Leaks
2. Reduce Domestic Hot Water Temperature
3. Reduce Fixture Flow Rates
4. Apply Economical Thermal Insulation
5. Limit Water-Heater and Circulation-Pump Operation
6. Consume Off-Peak Power
7. Upgrade to More Efficient Equipment
8. Water Heater Location

1. *Eliminate Leaks*
   One of the first and easiest actions to take to conserve energy is repairing leaky faucets and hot water piping. This will reduce the amount of hot water being wasted and avoid more expensive repairs later due to faucet valve-stem and valve-seat corrosion and water damage from leaky piping.

2. *Reduce Domestic Hot Water Temperature*
   Many domestic water-heating systems are designed to deliver 140°F water based on the anticipated needs of kitchen and janitorial uses, though water for human contact is normally delivered at 105°F. Often 105°F water is produced by blending 140°F hot water with cold water (see ASPE's Plumbing Engineering Design Handbook Chapter *"Domestic Water Heating*

System Fundamentals"). While this reduces the amount of hot water required it does not decrease the energy required to heat the water. Many energy codes and standards for new buildings require the domestic hot water system be set at 110°F under the impression that this will automatically reduce energy in direct proportion to the reduced temperature differential (delta T). It is important to note that setting a water heater below 120°F to avoid blending may allow Legionella bacteria to grow inside the domestic hot water tank. Also, if the building is provided with a kitchen dishwasher requiring 180°F water, a booster heater will need to be sized carefully to adequately function at the increased delta T. This is due to the reduction of the building domestic water-system temperature.

The temperature, after mixing two or more volumes (or flows) of water is calculated using the following equation:

Equation 7-1

$$t_m = \frac{Q_1 \times t_1 + Q_2 \times t_2}{Q_1 + Q_2}$$

where:

t_m = Temperature of mixture
t_1 = Temperature of flow Q_1
t_2 = Temperature of flow Q_2
Q_1 = Cold water, gpm (L/s)
Q_2 = Hot water, gpm (L/s)

Example 7-1

What is the temperature of 45 gpm (2.84 L/s) of 155°F (68.5°C) water mixed with 55 gpm (3.47 L/s) of 75°F (23.9°C) water?

$$\frac{45 \times 155 + 55 \times 75}{45 + 55} = 111°F$$

in SI units:

$$\left(\frac{2.84 \times 68.5 + 3.47 \times 23.9}{2.84 + 3.47} = 44°C\right)$$

The ratio (%) of hot water required to be mixed with cold water to provide a mixed water requirement is determined using the following equation:

Equation 7-2

$$\text{Ratio HW} = \frac{t_m - t_1}{t_2 - t_1}$$

Example 7-2

(A) How much hot water is required to provide 80 gph (0.084 L/s) of 110°F (43°C) mixed water with 155°F (68.5°C) hot water and 75°F (23.9°C) cold water?

$$\frac{110 - 75}{155 - 75} = .44 \text{ or } 44\% \text{ hot water}$$

80 gph × 0.44 = 35 gph of 155°F hot water

(0.084 L/s × 0.44 = 0.037 L/s of 68.5°C hot water)

(B) How much hot water is required to provide 80 gph (0.084 L/s) of 110°F (43°C) mixed water with 125°F (51.5°C) hot water and 75°F (23.9°C) cold water?

$$\frac{110 - 75}{125 - 75} = .70 \text{ or } 70\% \text{ hot water}$$

80 gph × 0.70 = 56 gph of 125°F hot water

(0.084 L/s × 0.70 = 0.059 L/s of 51.5°C hot water)

As shown, the reduction in domestic-water temperature, in itself, does not necessarily result in a reduction in energy input related to the water consumed.

3. *Reduce Fixture Flow Rates*

The Energy Policy Act (EPACT) of 1992 set maximum water usages for specific fixtures (e.g. 1.6 gallons per flush for water closets). Reduced flow rates result in less water needing to be pumped and heated, smaller pipe sizes, and less heat loss from piping, consequently saving energy. Fixture flow rates vary depending upon the supply fitting design and water pressure. Manufacturers' test results have shown that flows for lavatories and showers can be quite high, making them prime candidates for fixture-flow reduction. Providing automatic flow-control fittings can reduce fixture flow rates. On lavatories the type of faucet and spout usually dictates the location of these fittings. In showers, the type of head and arm determines the fitting location. After being fitted with a flow-control device, reduced flow rates of one gallon per minute or less are usually seen in lavatories and 3 gallons per minute or less for showers.

Figure 7-1 provides a way to translate fixture flow rate to annual consumption and is useful in determining the most energy efficient design flow rate. By varying the percent of hot water at the fixture, annual energy consumption can be predicted.

Example 7-3

Faucet use at 3.25 gal (12.3 L) of 150°F (66°C) hot water per day with a 100% faucet flow rate equates to an annual energy use of 800×10^3 Btu (844×10^3 kJ) per year. A 67% flow rate reduces energy use to 475×10^3 Btu (507×10^3 kJ) per year, and a 33% flow rate reduces energy use to 225×10^3 Btu (237.4×10^3 kJ) per year or a 62% reduction from full faucet flow rate.

Figure 7-1 can be used as a design tool for many purposes, some of which are to predict energy consumption, anticipated utility costs, and payback calculations for fixture replacement.

Manufacturers of flow-control devices describe in greater detail their design and installation requirements. The installation of this water-

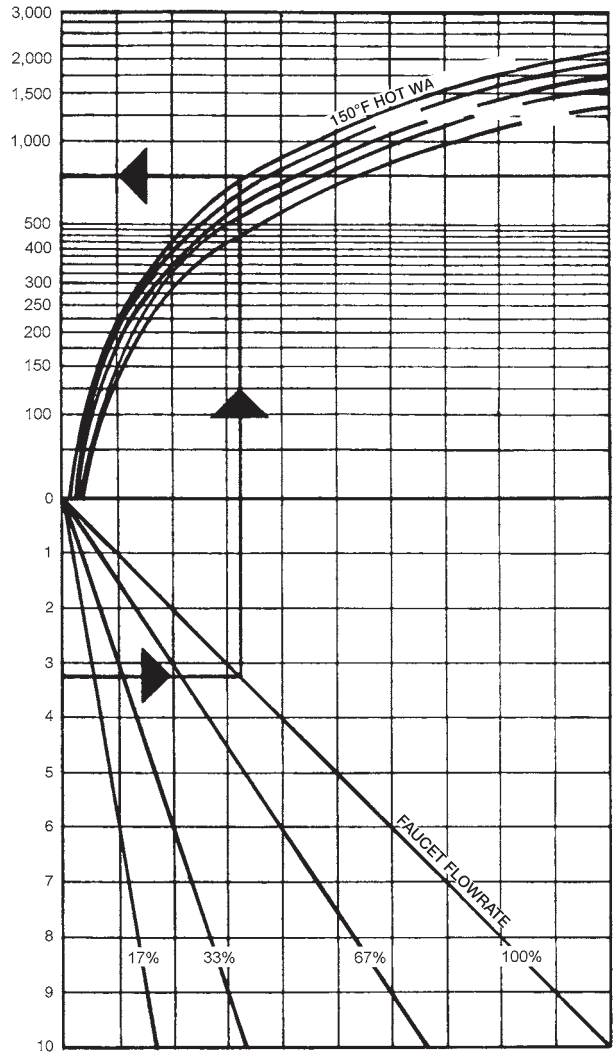


Chart allows user to estimate domestic hot water heating use in terms of water temperature and faucet flow rate.

Figure 7-1 Energy Savings from Reduced Faucet Flow Rates

Source: Cassidy 1982.

conserving device has resulted in the savings of millions of gallons of water per year throughout the country. This reduction in water demand translates into water the local utility company does not have to pump, the purification plant does not have to handle and process, and the waste-treatment plant does not have to treat.

4. *Apply Economical Thermal Insulation*
Economical thermal insulation is the amount of insulation that annually produces the lowest sum of energy lost versus the annual cost of insulation (see the *"Piping Insulation"* chapter of ASPE's Plumbing Engineering Design Handbook for the proper selection criteria). In addition to conserving energy by retarding heat loss, insulation provides such additional benefits as protection against burns, reduction of noise, and control of condensation. The National Insulation Contractors' Association (NICA) is currently using and promoting a computer program called "Economic Thickness of Insulation" (ETI). This program determines the cost-effective insulation thickness for a project and allows the designer to factor in the effects of rising utility costs.

Energy savings, in BTUs, can be determined by the following formula:

Equation 7-3

$$S = g \times L$$

where:
S = Energy savings, Btu/h (kJ/h)
g = Factors taken from Table 7-1 or 7-2 at a particular ΔT, Btu/h/ft (kJ/h/m)
L = System length, ft (m)

Hot water pipes should be continuously insulated from the heater to the end use, while cold water lines should be insulated near the water heater tank to minimize convective losses.

5. *Limit Water-Heater and Circulation-Pump Operation*
Buildings with large hot water distribution systems use circulating loops to ensure hot water is available to all fixtures within a timely manner. By limiting the hours of operation of these pumps and water heaters, substantial savings can be realized. There are 113 hours of "off" time per week in a building if it is occupied 50 hours per week, and the system is brought up to operating temperature one hour prior to the building opening each day. Assuming the domestic hot water system can be shut off for 113 hours per week and the system contains 2,000 gallons of hot water, Table 7-3 indicates the energy saved by limiting the hours of circulation. However, if a fossil-fuel water heater is used, one must take into account the formation of condensation when the system is brought up to temperature.

Time clocks can be used to control the hot water circulating pumps. The energy saved when using time clocks can be calculated as follows:

Table 7-1 Energy Savings Chart for Steel Hot Water Pipes and Tanks

ΔT °F (°C)	Pipe Size, in. (mm)							Hot Water Tanks, Btu/h/ft² (kJ/h/m²)	
	½ (12.7)	¾ (19.1)	1 (25.4)	1¼ (31.8)	1½ (38.1)	2 (50.8)	2½ (63.5)	w/ Insulation	w/o Insulation
40 (4.4)	14 (48.44)	17 (58.8)	21 (72.7)	26 (90.0)	29 (100.3)	35 (121.1)	42 (145.3)	6 (68.1)	57 (647.3)
45 (7.2)	16 (55.36)	20 (69.2)	24 (83.0)	30 (103.8)	33 (114.2)	41 (141.9)	48 (166.1)	6 (68.1)	65 (738.2)
50 (10.0)	18 (62.28)	22 (76.1)	27 (93.4)	34 (117.6)	38 (131.5)	47 (162.6)	55 (190.3)	7 (79.5)	73 (829.1)
55 (12.8)	20 (69.20)	25 (86.5)	31 (107.3)	38 (131.5)	42 (145.3)	52 (179.9)	62 (214.5)	7 (79.5)	83 (942.6)
60 (13.6)	23 (79.58)	28 (96.9)	35 (121.1)	42 (145.3)	48 (166.1)	58 (200.7)	69 (238.7)	9 (102.2)	92 (1044.8)
65 (18.3)	25 (86.50)	31 (107.3)	38 (131.5)	47 (162.6)	53 (183.4)	65 (224.9)	77 (266.4)	9 (102.2)	102 (1158.4)
70 (21.1)	28 (96.88)	34 (117.6)	42 (145.3)	52 (179.9)	58 (200.7)	71 (245.7)	84 (290.6)	10 (113.6)	112 (1272.0)
75 (23.9)	30 (103.8)	36 (124.6)	46 (159.2)	56 (193.8)	64 (221.4)	78 (269.9)	91 (314.9)	11 (124.9)	122 (1385.6)
80 (26.7)	33 (114.2)	41 (141.9)	50 (173.0)	61 (211.1)	69 (238.7)	84 (290.6)	99 (342.5)	11 (124.9)	132 (1499.1)
85 (28.4)	36 (124.6)	44 (152.2)	54 (186.8)	67 (231.8)	74 (256.0)	91 (314.9)	107 (370.2)	12 (136.3)	142 (1612.7)
90 (32.2)	38 (131.5)	47 (162.6)	58 (200.7)	72 (249.1)	80 (276.8)	98 (339.1)	116 (401.4)	12 (136.3)	154 (1749.0)
95 (35.0)	42 (145.3)	51 (176.5)	62 (214.5)	77 (266.4)	86 (297.6)	105 (363.3)	124 (429.0)	14 (159.0)	164 (1862.5)
100 (37.8)	45 (155.7)	54 (186.8)	66 (228.4)	82 (283.7)	93 (321.8)	113 (391.0)	133 (460.2)	14 (159.0)	175 (1987.5)
105 (38)	47 (162.6)	58 (200.7)	72 (249.1)	87 (301.0)	98 (339.1)	120 (415.2)	141 (487.9)	15 (170.4)	187 (2123.8)
110 (43)	51 (176.5)	62 (214.5)	75 (259.5)	93 (321.8)	104 (359.8)	128 (442.9)	150 (519)	16 (181.7)	198 (2248.7)
115 (46)	54 (186.8)	65 (224.9)	80 (276.8)	98 (339.1)	110 (380.6)	135 (467.1)	159 (550.1)	16 (181.7)	210 (2385.0)
120 (49)	56 (193.8)	69 (238.7)	85 (294.1)	104 (359.8)	117 (404.8)	143 (494.8)	169 (584.7)	17 (193.1)	222 (2521.3)

Source: San Diego Gas & Electric Co.

Notes:

1. Savings are in Btu/h/linear ft. (kJ/h/linear m), unless otherwise indicated.
2. Figures are based on an assumption of 1 in. (25.4 mm) of insulation.
3. $\Delta T = t_o - t_a$ where t_o = Hot water circulating temperature and t_a = Air temperature surrounding piping system.

Table 7-2 Energy Savings Chart for Copper Hot Water Pipes

ΔT °F (°C)	Pipe Size, in. (mm)							
	½ (12.7)	¾ (19.1)	1 (25.4)	1¼ (31.8)	1½ (38.1)	2 (50.8)	2½ (63.5)	3 (76.2)
40 (4.4)	8 (27.68)	12 (41.5)	14 (48.4)	17 (58.8)	20 (69.2)	25 (86.5)	30 (103.8)	35 (121.1)
45 (7.2)	10 (34.6)	13 (45.0)	16 (55.5)	20 (69.2)	23 (79.6)	29 (100.3)	35 (121.1)	40 (138.4)
50 (10.0)	12 (41.5)	15 (51.9)	19 (65.7)	23 (79.6)	26 (90.0)	33 (114.2)	40 (138.4)	46 (159.2)
55 (12.8)	13 (45.0)	17 (58.8)	21 (72.7)	26 (90.0)	30 (103.8)	38 (131.5)	45 (155.7)	52 (179.9)
60 (13.6)	15 (51.9)	20 (69.2)	24 (83.0)	29 (100.3)	34 (117.6)	42 (145.3)	51 (176.5)	58 (200.7)
65 (18.3)	16 (55.4)	21 (72.7)	27 (93.4)	32 (110.7)	37 (128.0)	47 (162.6)	56 (193.8)	65 (224.9)
70 (21.1)	18 (62.3)	24 (83.0)	30 (103.8)	35 (121.1)	41 (141.9)	52 (180.0)	62 (214.5)	71 (245.7)
75 (23.9)	20 (69.2)	26 (90.0)	33 (114.2)	39 (134.9)	44 (152.2)	56 (193.8)	67 (231.8)	76 (263.0)
80 (26.7)	21 (72.7)	28 (96.7)	35 (121.1)	42 (145.3)	49 (169.5)	61 (211.1)	73 (252.6)	85 (294.1)
85 (29.4)	22 (76.1)	31 (107.3)	38 (131.5)	45 (155.7)	53 (183.4)	66 (228.4)	79 (273.3)	92 (318.3)
90 (32.2)	24 (83.0)	33 (114.2)	41 (141.9)	49 (169.5)	57 (197.2)	71 (245.7)	85 (294.1)	99 (342.5)
95 (35.0)	26 (90.0)	36 (124.6)	44 (152.2)	53 (183.4)	61 (211.1)	76 (263.0)	91 (314.9)	106 (366.7)
100 (37.8)	28 (96.7)	38 (131.5)	48 (166.1)	57 (197.2)	65 (224.9)	82 (283.7)	98 (339.1)	113 (391.0)
105 (38)	30 (103.8)	41 (141.9)	51 (176.5)	60 (207.6)	70 (242.2)	87 (301.0)	104 (359.8)	121 (418.7)
110 (43)	32 (110.7)	43 (148.8)	54 (186.8)	65 (224.9)	74 (256.0)	93 (321.8)	111 (384.1)	128 (442.9)
115 (46)	34 (117.6)	46 (159.2)	57 (197.2)	68 (235.3)	78 (269.9)	98 (339.1)	118 (408.3)	136 (470.6)
120 (49)	36 (124.6)	49 (169.5)	61 (211.1)	72 (249.1)	83 (287.2)	104 (359.8)	125 (432.5)	144 (498.2)

Source: San Diego Gas & Electric Co.

Notes:

1. Savings are in Btu/h/linear ft (kJ/h/linear m).
2. Figures are based on an assumption of 1 in. (25.4 mm) of insulation.
3. $\Delta T = t_o - t_a$ where t_o = Hot water circulating temperature and t_a = Air temperature surrounding piping system.

Equation 7-4

Motor kW × off hours × electric rate ($/kWh) = total savings ($)

6. *Consume Off-Peak Power*

One of a plumbing engineer's responsibilities is to size the domestic water-heating equipment to meet the needs of the building's occupants in the most energy efficient manner. While using off-peak power to heat and circulate water does not change the number of British thermal units (Btu) required, it does allow the building's owner and tenants to benefit from lower utility costs. Power companies encourage their commercial customers to purchase power during off peak hours in hopes of flattening or evening out the demand on their generating equipment. Some utility companies not only offer lower rates for electricity purchased during off- and semi-peak periods but in many instances have no customer demand charges. The plumbing engineer can obtain electric-rate schedules from the utility serving the site and observe the off-peak periods to program the operation of domestic water-

heating equipment. Typically the highest demand for hot water takes place when electrical costs are at their peak. To account for this, the hot water system will maintain the heated water at an elevated temperature, which is blended to achieve the desired temperature levels, saving the system from having to operate during the day. Depending upon the difference in electrical rates, an off-peak powered hot water system can generally pay (in a few years) for the additional equipment required, including the effects of equipment heat losses during periods of standby.

7. *Upgrade to More Efficient Equipment*
Equipment specifications need to be examined to ensure only hot water heating equipment that meets minimum energy standards is approved for installation. The following factors contribute to the efficiency of gas-fired water heaters and need to be taken into consideration when selecting this equipment: Combustion equipment and its adjustment, tank insulation, heat exchanger effectiveness, firing rate, pickup and demand, and standby stack losses.

8. *Water Heater Location*
Many hot water heaters are installed in central locations requiring long supply and return piping runs to reach plumbing fixtures. Moving these heaters close to the most-frequent points of use will minimize piping heat loss.

Domestic Hot Water Heating Equipment

There are many different means of generating hot water. Each has its own advantages and disadvantages, and, as plumbing engineers, it is our responsibility to determine which technology is best suited for an application. In addition, the performance efficiency of equipment specified by the plumbing engineer should match the recommendations of the *Domestic Water Heating System Fundamentals* chapter of the "ASPE Plumbing Engineering Design Handbook". The recovery efficiency and standby losses of water-heating equipment should comply with the latest codes and regulations for the manufacturer, e.g. American National Standards Institute (ANSI) C72.1, ANSI Z22.10.3, latest editions. State energy codes also mandate the use of energy-efficient equipment and should be checked by the plumbing engineer prior to the preparation of specifications. Listed below are several hot water heating technologies.

1. Tank-Type Water Heaters
   A. Electric
   B. Gas-Fired
2. Tankless-Type Water Heaters
   A. Electric
   B. Gas-Fired
   C. Condensing
   D. Steam-Fired
   E. Direct-Fired
3. Alternative Resources
   A. Solar Energy
   B. Solid-Waste-Disposal Energy
   C. Geothermal Energy
4. Heat Recovery
   A. Air Conditioning and Commercial Refrigeration
   B Steam Condensate
   C. Cogeneration Plants
   D. Heat Pumps
   E. Drainline Heat Reclaim Systems

1. *Tank-Type Water Heaters*
Tank-type water heaters are self-contained units that heat and store water within the same storage tank. Insulation is added around the exterior of the tank to prevent heat from escaping. Many older tank-type water heaters were originally supplied with insufficient insulation. Making it energy efficient consisted of either replacing the insulation or the entire unit.

   A. *Electric*
   The heating element for electric tank-type water heaters is immersed directly into the water, allowing energy to transfer from the element to the water fast and efficiently. They can be used for many applications ranging from commercial and industrial to booster heaters for dishwashing needs.

   B. *Gas-Fired*
   A gas-fired tank-type water heater uses natural or propane gas to heat stored water. Unlike an electric heater, there are standby losses associated with the heater's flue, which carries the unit's products of combustion to the atmosphere. The flue is internal to the heater and not insulated, acting as a heat exchanger, allowing energy to escape from the heated water.

2. *Tankless-Type Water Heaters*
Tankless-type water heaters, as their name suggests, do not store water. They are instantaneous heaters that provide hot water only when there is a demand. Because they have no water storage capability, these units eliminate standby heat loss and may reduce the risk of Legionella bacteria growth.

   A. *Electric*
   Electric tankless-type water heaters consume large amounts of energy when operating. This has relegated their use to remote areas with

low fixture counts and infrequent use. They are usually installed near the point of use to minimize pipe heat loss.

B. *Gas-Fired*
These heaters can be found in commercial, industrial, and residential applications. They have been gaining popularity among new construction and retrofitting of residential properties in warmer climate areas such as California, Florida, Tennessee, and Texas, where the incoming water temperatures are high. There are various models that can produce anywhere from 4 to 10 gallons per minute of hot water at a temperature rise of 77°F. They also can be combined to provide higher flow rates and temperature increases. Similar to electric tankless heaters, these units are typically installed near the point of use but are not recommended for remote areas with low fixture counts that are infrequently used. These applications are better left for the electric type because of the cost associated with the routing of gas piping and its flue.

C. *Condensing*
Condensing gas water heaters recover the heat created by the combustion gases. The recovered heat is referred to as the latent heat of vaporization and is directed back into the water, increasing the unit's efficiency. A condensing water heater operates at approximately 95 percent efficiency compared to 80 percent – 85 percent for a non-condensing water heater. The condensate generated from a condensing unit needs to be drained, but care must be taken to account for its acidic nature. With a pH rating of approximately 5, the condensate is either diluted until it reaches an acceptable pH range or drained to a neutralization tank.

D *Steam-Fired*
Steam-fired tankless-type water heaters generate hot water through the use of a heat exchanger. They are used in hospitals, industrial plants, restaurants, apartment houses, laundries, universities, and hotels among other applications. They can be combined in parallel to meet high flow requirements while requiring less space than comparable tank-type units. The installation of a mixing valve is recommended to ensure that steam does not enter the hot water system in the event of a heat-exchanger breach.

E. *Direct-Fired*
Gas-fired heaters are used in applications where several hundred gallons of hot water are needed per minute. These units use a direct exchange between the water and combustion products produced by the burner assembly. This process eliminates standby losses and can achieve operating efficiencies in excess of 98 percent.

3. *Alternative Resources*
As the consumption of fossil fuels increases so does the need to develop alternative fuel sources. One of these sources is solar energy. Energy from the sun can be converted to operate cars, power lighting, and heat domestic water. Other forms of alternative energy are geothermal and solid wastes, which have been used to heat water while reducing the load placed on mainstream resources. The designer may choose to use alternative energy resources for all or part of the hot water system. This helps to meet restrictions placed upon the domestic water heating systems by energy codes in many parts of the country.

A. *Solar Energy*
Solar water heating is often thought of for warm and sunny climates only; however, an the climate in an area is one of many factors that determine the effectiveness of a solar system. Factors such as the cost of the fuels being replaced, hot water demand, usage patterns, and incoming water temperature help determine the effectiveness of a solar heating system. For most areas of the United States, solar heating can meet the domestic hot water demand during the summer months but often require supplemental heating during the winter. It has been estimated that a solar heating system can meet 40 percent to 80 percent of a building's annual hot water demand. Refer to ASPE's *"Solar Energy System Design"* manual as a source of information in the use and selection of solar heating equipment.

B. *Solid-Waste-Disposal Energy*
Solid-waste collection and disposal systems produce various gases during decomposition. One of these is methane. It can be recovered and burned to produce heat. A second source of methane is leachate evaporation systems in landfill closures. Lastly, solid-waste incineration systems constructed to stringent pollution-control rules and regulations are a source of methane. These systems can potentially provide large volumes of steam and/or domestic hot water. The use of these

alternate energy sources should be within reasonable proximity to the resource. Typical applications include industrial plants with large volumes of burnable materials such as trash, paper, scrap wood, plastics, etc. A solid-waste incinerator system typically consists of a waste-disposal plant with a conveyer, loading system, boiler, ash-disposal equipment, heat exchanger, insulated piping, circulating pump, and controls.

C. *Geothermal Energy*

Geothermal energy is heat from the earth. In states where this form of energy is believed to be available at reasonable depths, the U.S. Department of Energy (DOE) is supporting various state energy commissions in their funding of geothermal assessment programs. The temperature of the available liquid or gas (created when water flows through heated, permeable rock) and the cost of retrieval dictate the viability of geothermal energy. Some geothermal energy uses include steam in the generation of electricity, hot water with a minimum temperature of 150°F for building domestic hot water systems, and industrial parks for space and water heating needs. Three prime areas of concern must be addressed when planning and developing geothermal energy:

1. Competitive Institutional Processes
2. Adequate Temperature and Flow Rate
3. Thermal Loads To Make the System Economically Viable

A geothermal energy system typically consists of production and disposal wells, water-to-water heat exchangers [usually shell-and-tube type, two are required—one for operation while the other is being cleaned of deposits], insulated piping, a circulating pump, and a control system. The plumbing engineer should consult with the state energy office (Department of Energy or the Geothermal Resources Council) for resource information to apply this high-capital, low-operating-cost, alternate energy source.

4. *Heat Recovery*

Heat recovery is the capture and reuse of energy that would normally be lost from a facility. It could be in the form of a liquid or a gas. Common waste heat sources are:

1. Heat rejected from air conditioning and commercial refrigeration processes
2. Heat reclaimed from steam condensate
3. Heat generated by cogeneration plants
4. Heat pumps and heat reclamation systems
5. Heat from wastewater

When considering heat recovery, it is important to determine if the hot water demand justifies the equipment and maintenance costs, and if the heat recovered is sufficient to serve as a heat source. Facilities that typically have the proper blend of demand and waste heat are hospitals, military bases, and industrial facilities.

A. *Air Conditioning and Commercial Refrigeration*

Systems with air- or water-cooled or evaporative condensers reject heat from air conditioning and refrigeration systems that can be reclaimed.

Within the refrigerant cycle there is a condenser that rejects heat while an evaporator creates a cooling effect. For example, for every 1 Btu/h of cooling effect produced by a 40°F evaporator, a 105°F condensing unit rejects 1.15 Btu/h of heat. Systems with an air-cooled or evaporative condensor can be supplemented with a heat exchanger in the compressor's hot gas discharge line to capture the rejected heat. (Refer to Figure 7-2.)

Systems with water-cooled condensers can be supplemented with a heat exchanger in the hot water return line from the condenser to the cooling tower. (Refer to Figure 7-3.) System efficiency can be improved by providing a storage tank with a tube bundle. (Refer to Figure 7-4.)

An advantage of the system shown in Figure 7-4 is that simultaneous use of the domestic water and refrigeration systems does not need to occur for heat recovery. Another advantage of the system shown in Figure 7-4 is when there is an insufficient amount of heat rejected, a backup water heater can be used to bring the water in the storage tank to the proper design temperature. The backup heater can operate on fossil fuel, electricity, steam, or may be fitted with a tube bundle utilizing hot water.

B. *Steam Condensate*

When steam is used as a source for space heating, water heating, or process work there is generally steam condensate. The heat content of the condensate can be captured and reused for heating with the use of a heat exchanger. Laundries are a prime example of facilities where heat reclaimed from steam condensate can be put to use in heat recovery. It is essential to select a system with adequate storage to compensate for fluctuations in

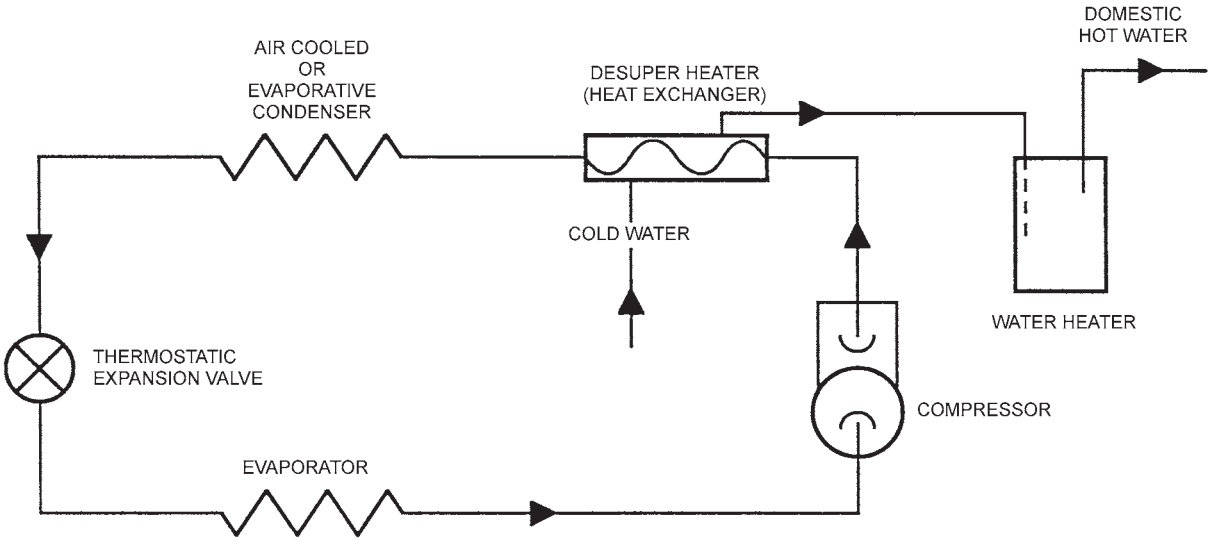


Figure 7-2 Refrigeration Waste-Heat Recovery

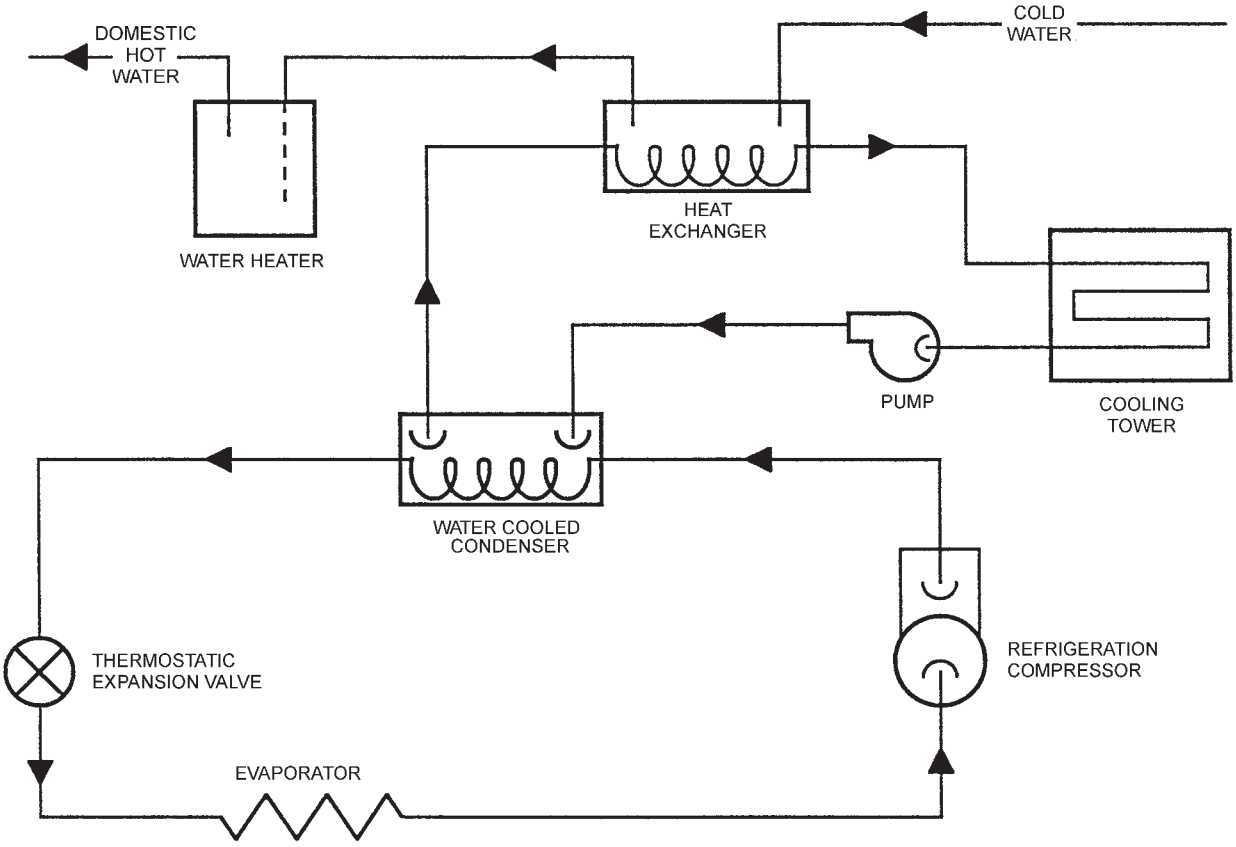


Figure 7-3 Condenser Water Heat Recovery

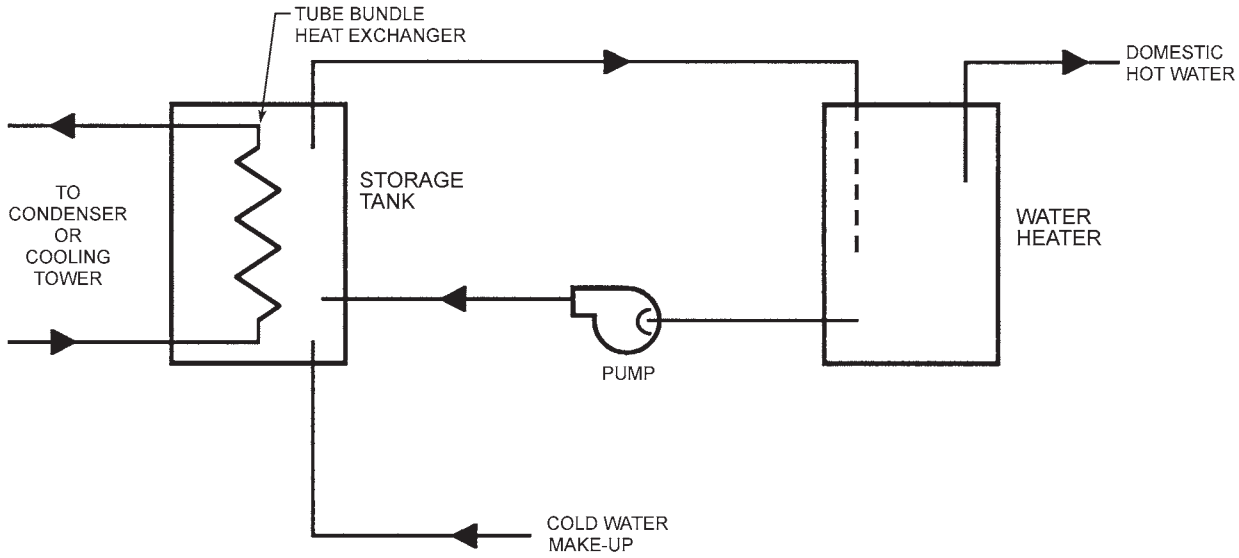


Figure 7-4 Condenser Water Heat Recovery with Storage Tank

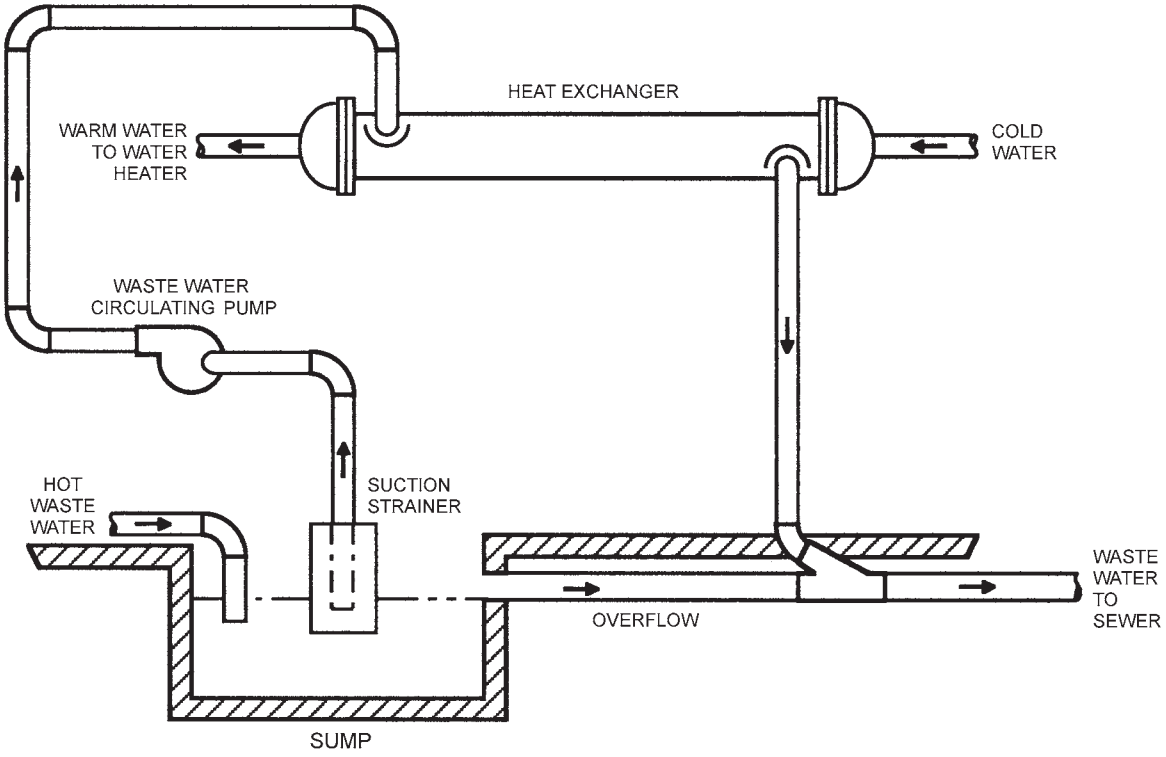


Figure 7-5 Waste Water Heat Recovery

the condensate and domestic water flow. When deciding whether to capture and reuse steam condensate, remember that energy will not be saved if the boiler used to raise the temperature of the returned condensate is less efficient than the primary water heater.

C. *Cogeneration Plants*
The heat produced as a byproduct of generating electricity from reciprocating engines or gas turbines can be reclaimed from the cooling systems and exhaust gases by using a waste heat boiler and heat exchanger. The heat can then be used to produce steam or medium temperature water. To be economically viable, most systems must have a year-round thermal heat load. Reheating makeup water and maintaining temperature in a domestic hot water system are excellent ways to maintain high overall thermal efficiencies.

D. *Heat Pumps*
In today's buildings where computer rooms are continuously generating heat and industrial plants are producing waste heat, heat pumps can be used to transfer this heat to the domestic hot water systems, resulting in energy conservation.

Either direct-expansion or chilled-water-type heat pumps can be used to transfer heat through the refrigeration process from the surrounding air to a water storage tank. The mechanics of this system are to extract heat from a warm environment directly, either through a heat exchanger or cooling coil.

E. *Drainline Heat Reclaim Systems*
It has been estimated that 80 percent to 90 percent of all hot water energy is wasted. The U.S. DOE estimates this amount of energy to be 235 billion kWh a year. One method of recouping some of this energy is using a drainline heat reclaim system. This device can be a passive or active piece of equipment installed in the wastewater drain line of a building. Passive devices use a copper coil wrapped around a vertical portion of a waste line. Domestic water is fed through the copper coil to the hot water heater. As hot water is drained, heat is transferred from the drain line to the incoming domestic water. It has been estimated that these exchangers have an operating efficiency of up to 60 percent and can raise the incoming water temperature by as much as 36°F. Active systems utilize a wastewater circulating pump in conjunction with the heat exchanger. This system is shown in Figure 7-5.

WATER MANAGEMENT

Design Techniques

Conserving water provides benefits to the building's owner and local municipality. The owner saves by having lower utility costs, while the municipality saves resources by having to treat and circulate less water and wastewater. In order to realize these savings, the plumbing engineer must provide designs that reduce water consumption without compromising the fixture's operation. Some design techniques previously mentioned are:

1. Eliminate Faucet and Pipe Leaks
2. Reduce Fixture Flow Rates

Other methods of unique water management are:

3. Alternate Sources of Fresh Water
4. Reclaimed and Graywater

For a water management program to be successful in renovation projects, it is important to first establish the building's current water consumption. The U.S. DOE has developed 8 steps to make a successful water management plan:

1. Gather Information
2. Conduct a Comprehensive Facility Survey
3. Explore and Evaluate Water Management Options
4. Conduct Life Cycle Cost Analysis and Explore Financing Options
5. Develop a Water Management Plan and Work Schedule
6. Inform Building Occupants about Water Management
7. Implement the Water Management Plan
8. Monitor the Water Management Plan

For more information refer to page 135 of the U.S. DOE's *Greening Federal Facilities Guide* second edition.

1. Eliminate Faucet and Pipe Leaks
Similar to hot water conservation, this is one of the easiest and first actions that should be taken. Leaks in both the cold and hot water piping should be repaired as well as any leaking faucets. This will reduce the amount of water being wasted and avoid more expensive repairs later.

2. Reduce Fixture Flow Rates
Toilets and urinals account for almost half of a typical building's water consumption. Within a group of New York City apartment buildings, 1.3 million toilets were replaced with ultra low flow (ULF) toilets and resulted in a 29 percent

reduction in water consumption. There are many different types of toilets and urinals and each has its own benefits, which will be discussed later in this chapter.

Additional fixtures whose flow rates can be reduced are showers and faucets. In addition to applying flow-restrictor fittings, as previously discussed, metered faucets can be installed which provide water for a pre-determined time and then automatically close. The Americans with Disabilities Act specifies that these faucets must operate for at least 10 seconds.

Electronic sensor controls can be used on toilet and urinal flush valves and faucets. They reduce water consumption and are often used in prisons, military barracks, sporting facilities, and hospitals. Batteries or hard wiring can power these controls. Battery controlled valves and faucets are typically used for renovation projects while new construction is hard wired.

3. *Alternate Sources of Fresh Water*
Rainwater harvesting is the collection, storage, treatment, and use of rainwater. Harvested water can be used for irrigation, non-potable, and potable uses. A rainwater harvesting system typically starts with a catch area that collects rainwater, usually a building's roof. To ensure potential contaminants and pollutants do not enter the system's storage tank, a wash system is installed which diverts the initial portion of the rainfall away from the storage tank while cleaning the catch area. A screen is usually installed in the catch area to keep out debris. Piping routes the collected rainwater to a storage tank, which can be located indoors, outdoors, aboveground, or underground. It is important to provide a lid on the storage tank to keep light out to discourage algae growth. If the collected water is intended to be the sole source of water for the building, the storage tank should be sized based on a 30-year rainfall event. Water is typically delivered to the building through the use of a domestic water booster pump system, and final water treatment may be needed depending upon the application and quality of water collected.

4. *Reclaimed and Graywater*
Reclaimed water and graywater collection systems can be used to reduce the amount of domestic water consumed by a building. Wastewater treatment plants provide reclaimed or recycled water to buildings through a second municipal water system where two water lines enter a building. One line is used to deliver potable water for domestic use and a second to provide treated wastewater that can be used for non-potable applications such as landscape irrigation, cooling tower make up, toilet flushing, and fire protection.

Graywater is typically collected from showers, tubs, lavatories, washing machines, and drinking fountains. It contains a minimal amount of contamination and is reused in certain landscape applications such as subsurface irrigation of lawns, flowers, trees, and shrubs, but should not be used for vegetable gardens because of the potential absorption of cleaning and washing chemicals. Similar to rainwater harvesting, graywater is collected, stored, and filtered prior to use. A graywater storage container should be fitted with overflow protection that is connected to the sanitary sewer system in the event the amount of water collected is more than the amount of water being consumed, a distribution pipe becomes clogged, or collected water is not used in a timely manner. If graywater is stored for extended periods of time it often produces an offensive smell.

Water-Management Equipment

As previously stated, toilets and urinals account for almost half of a typical building's water consumption. The U.S. Environmental Protection Agency (EPA) has determined that 4.8 billion gallons of water are flushed each day. Replacing or retrofitting water closets, urinals, showerheads, and faucets with low flow versions can considerably lower a building's water consumption.

1. *Water Closets and Urinals*
Ultra low flow (ULF) water closets consume 1.6 gallons per flush (gpf) and are available in three different classifications:
   A. Tank Type
   B. Flush Valve
   C. Specialties

   While the problems associated with ULF toilets when they first became available have been corrected, some low-cost models continue to maintain poor performance.

   A. Tank Type
   Water is drained from this water closet by gravity and is most commonly used in residential applications. Prior to ULF models these fixtures consumed 3.5 gpf. A low-cost method of conserving water in these earlier models and in today's ULF is using a refill diverter. When a tank type water closet is flushed, water starts to refill the tank as it is emptying. The time elapsed between the open and closed position of the flapper, allows excess water to flow through the bowl, into

the bowl, and consequently, the drain. While refilling the tank, this water is wasted. A diverter keeps this water in the tank saving one-half to 1 gallon when installed on older toilets and a ¼ gallon on ULF models.

B. *Flush Valve*
Flush-valve water closets use the building's water pressure to exert a force when operating. They typically require 25 to 40 psig to operate and are most commonly used in commercial buildings. Older, non-ULF models can be retrofitted by adjusting the flush valve, but care must be used to not overly constrain the valve causing it to malfunction. Early closure devices also can be used to cause the flush valve to stop the flow of water sooner than normal, limiting the amount of water discharged.

C. *Specialties*
Some specialty water closets are pressure-assisted tank-type, dual flush, and composting. Pressure-assist tank-type water closets can be used in applications where it is desired to use a gravity tank-type water closet, but there is a concern about flushing performance. When water conservation beyond ULF is desired, dual flush water closets can be used. These have two flush settings, one for normal operation to flush solids and a second reduced amount for liquids, saving approximately 1 gallon per flush. Composting systems are high capital ventures that require a lot of space and are typically used in unique locations where there is no water supply. They are popular choices in state or county parks, camping facilities, and national parks. Composting toilets are gaining acceptance in other areas of the world for mainstream use in households.

ULF urinals consume 1 gallon per flush, but there are water conservation methods that can go beyond this level. Flush valves that consume a one-half gallon per flush have been employed with success, and waterless urinals that do not consume any water are being used. Waterless urinals use a specially designed trap that uses biodegradable oil. This oil allows waste to pass through while maintaining the trap's seal. Regular maintenance is required to refill the oil, as a small portion of it becomes entrained in the waste when the fixture is used. If routine maintenance is not provided, enough oil could be removed to where it no longer seals the fixture's trap, causing odors to enter the room.

2. *Showerheads and Faucets*
The 1992 Energy Policy Act set the maximum flow rates for showerheads and faucets at 2.5 gallons per minute. Prior to the Energy Policy Act, showerhead flow rates were between 3 gallons per minute and 7 gallons per minute. Water conserving showerheads incorporate a more narrow spray jet and introduce a greater volume of air when compared to conventional heads. Additional measures that can be taken are temporary stop levers that control the shower valve to reduce or inhibit water flow when used. This feature would be used while a person is soaping or shampooing him or herself. The use of flow restrictors in conventional showerheads is not recommended. They typically restrict the showerhead too much, providing poor water pressure from the head.

Faucets manufactured after 1993 consume no more than 2.5 gallons per minute at 80 psig, meeting the requirements of the 1992 Energy Policy Act. Replacing the faucet's tip with an aerator, which mixes air into the faucet's discharge and reduces its flow rate to 2.5 gpm, can retrofit older faucets, which consume between 3 gallons per minute and 5 gallons per minute. Aerators are typically used in residential faucets and prohibited from health care facilities because of their potential for harboring germs and pathogens. In these applications, low flow tips are used.

GLOSSARY

British thermal unit (Btu) *A heat unit equal to the amount of heat required to raise 1 pound of water 1 degree Fahrenheit.*

Coefficient of performance (COP) *The ratio of the rate of heat removal to the rate of energy input, in consistent units, generally relating to a refrigeration system under designated operating conditions.*

Condenser *A heat exchanger that removes heat from a vapor changing it to its liquid state.*

Delta T (DT) *Temperature differential.*

Domestic-water heating *Supply of hot water for domestic or commercial purposes other than comfort heating.*

Domestic-water heating demand *The maximum design rate of energy withdrawal from a domestic-water heating system in a specified period of time.*

Efficiency, thermal (overall system) *The ratio of useful energy at the point of ultimate use to the energy input.*

Energy *The force required for doing work.*

Energy, nondepletable *Energy derived from incoming solar radiation and phenomena resulting therefrom, including wind, waves, and tides, and lake or pond thermal differences, and energy derived from the internal heat of the earth (geothermal)—including nocturnal thermal exchanges.*

Energy, recovered *A byproduct of energy used in a primary system that would otherwise be wasted from an energy utilization system.*

Heat, latent *The quantity of heat required to effect a change in state.*

Heat, sensible *Heat that results in a temperature change but not a change in state.*

Life-cycle cost *The cost of the equipment over its entire life, including operating and maintenance costs.*

Makeup *Water supplied to a system to replace that lost by blowdown, leakage, evaporation, etc.*

Solar energy source *Source of chemical, thermal, or electrical energy derived from the conversion of incident solar radiation.*

System *An arrangement of components (including controls, accessories, interconnecting means, and terminal elements) by which energy is transformed to perform a specific function***.**

Terminal element *The means by which the transformed energy from a system is ultimately delivered.*

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3. U.S. Department of Energy, *Greening Federal Facilities An Energy, Environmental, and Economic Resource. Guide for Federal Facility Managers and Designers* (May 2001)

8 Corrosion

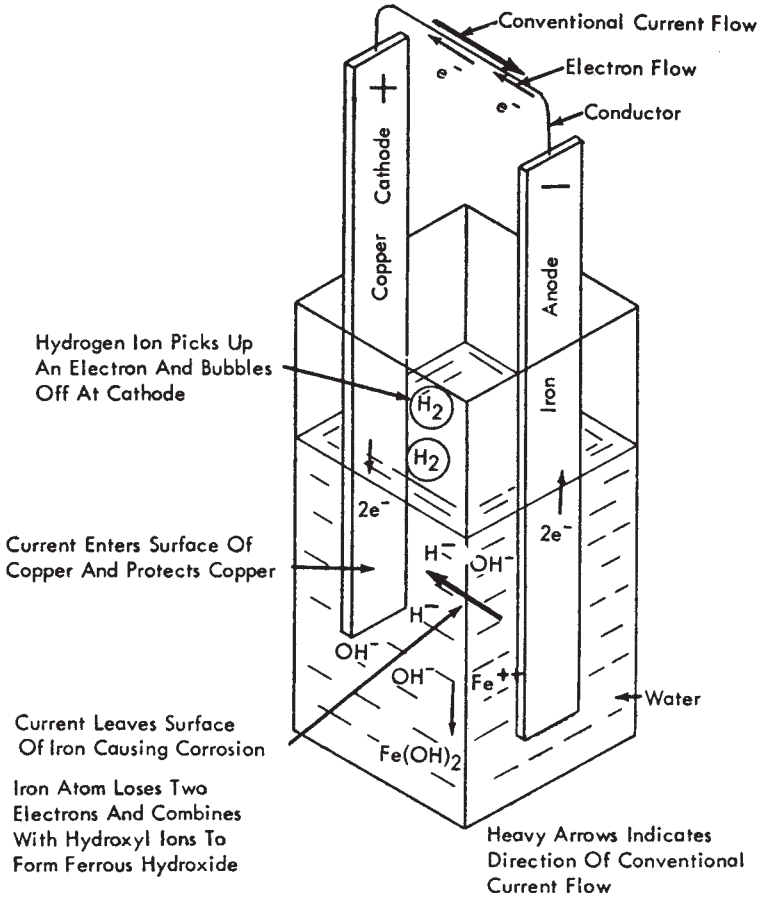


Figure 8-1 Basic Corrosion Cell

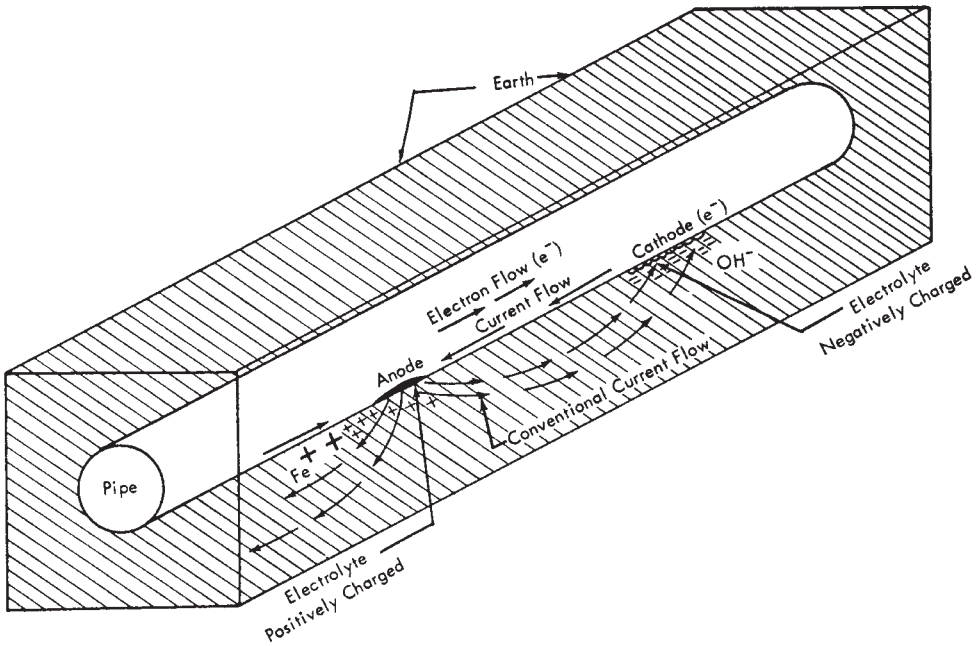


Figure 8-2 Basic Cell Applied to an Underground Structure

COMMON FORMS OF CORROSION

Corrosion occurs in a number of common forms as follows:

Uniform attack (Figure 8-3) Uniform attack is characterized by a general dissolving of the metal wall. The material and its corrosion products are readily dissolved in the corrosive media.

Pitting corrosion (Figure 8-4) Pitting corrosion is usually the result of the localized breakdown of a protective film or layer of corrosion products. Anodic areas form at the breaks in the film and cathodic areas form at the unbroken portion of the film. The result is localized, concentrated corrosion, which forms deep pits.

Galvanic corrosion (Figure 8-5) Galvanic corrosion occurs when two dissimilar metals are in contact with an electrolyte. The example shown is iron and copper in a salt solution, the iron being the

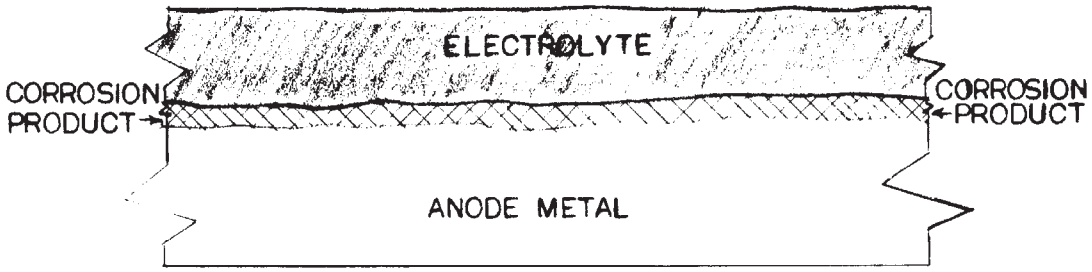


Figure 8-3 Uniform Attack

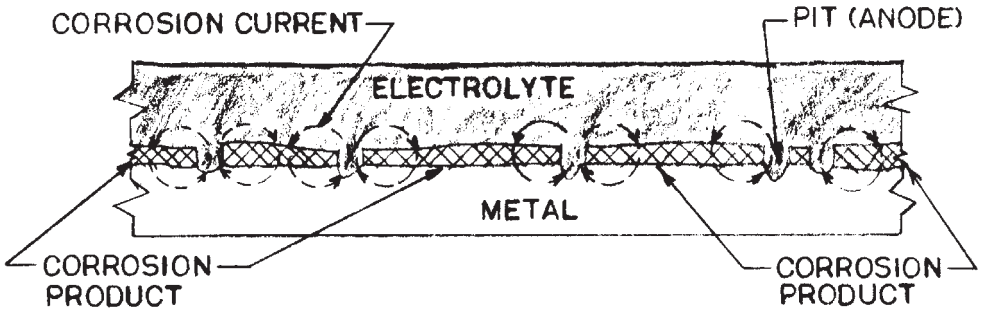


Figure 8-4 Pitting Corrosion

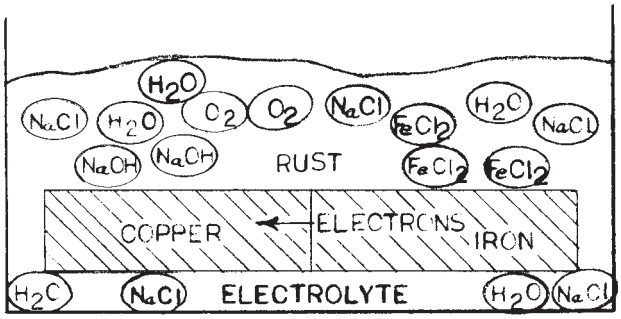


Figure 8-5 Galvanic Corrosion

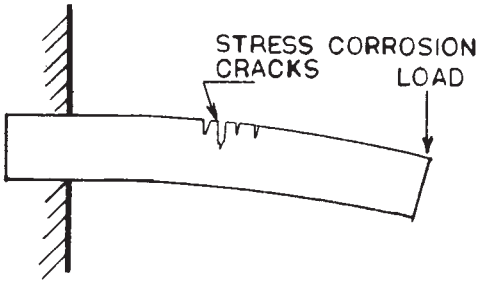


Figure 8-8 Stress Corrosion

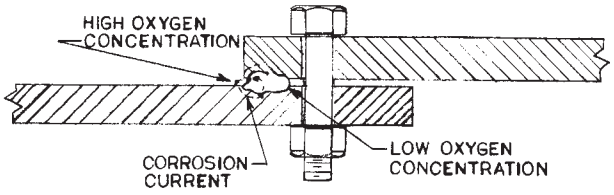


Figure 8-6 Concentration Cells

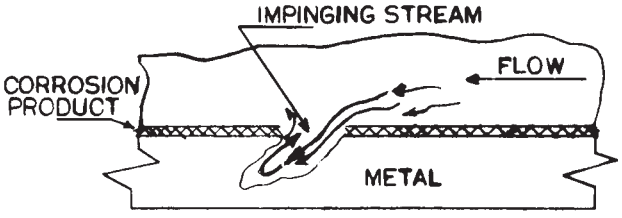


Figure 8-7 Impingement Attack

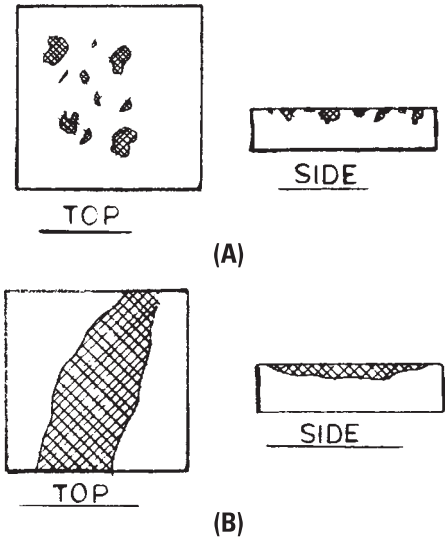


Figure 8-9 (A) Plug-Type Dezincification
(B) Layer-Type Dezincification

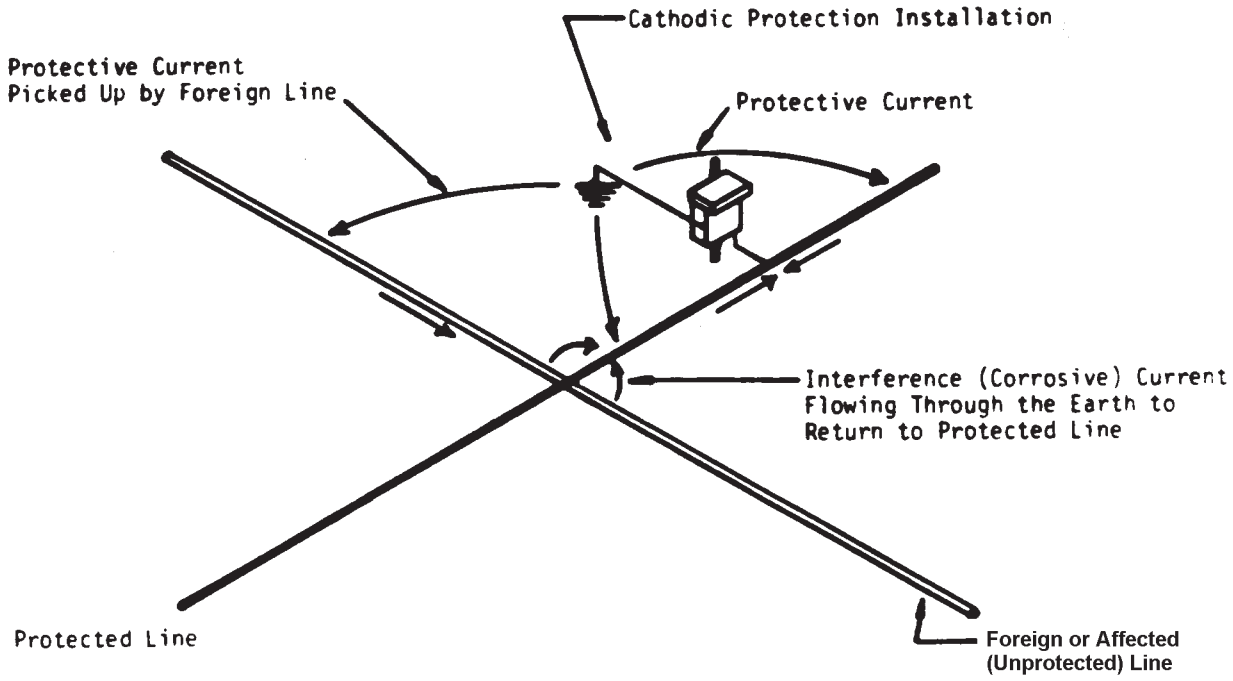


Figure 8-10 Stray Current Corrosion

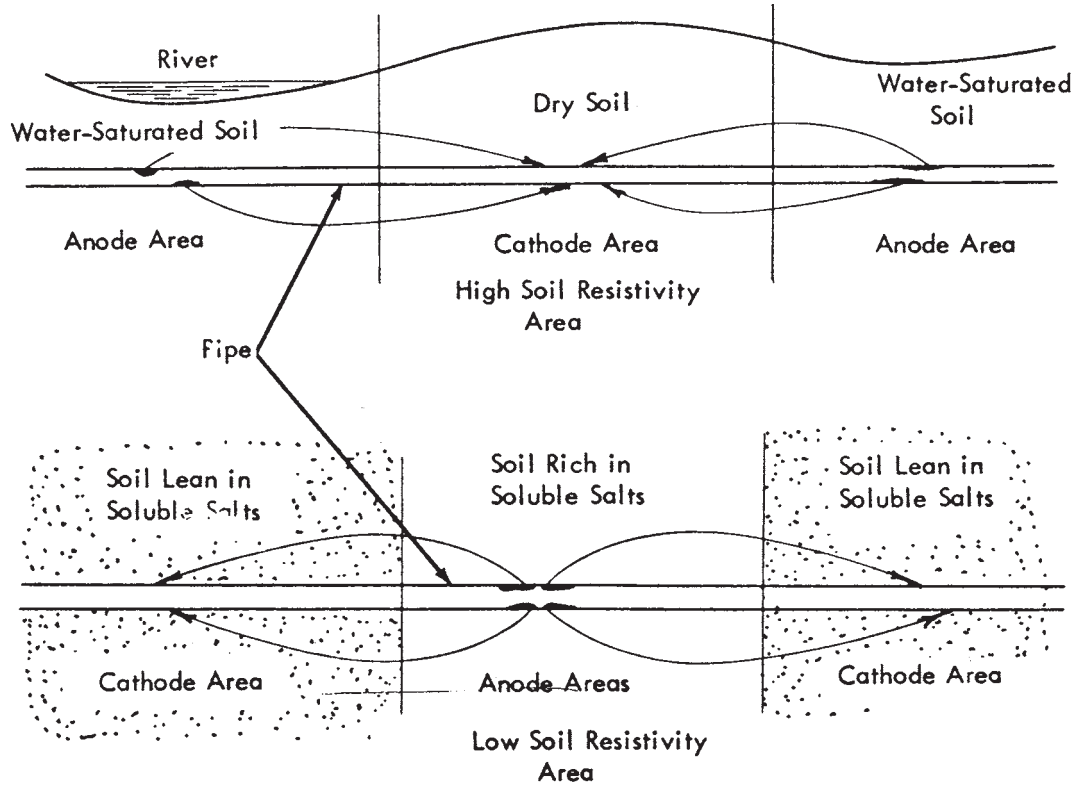


Figure 8-11 Corrosion by Differential Environmental Conditions

ELECTROMOTIVE FORCE SERIES

An "electromotive force" is defined as a force that tends to cause a movement of electrical current through a conductor. Table 8-3, known as the "electromotive force series," lists the metals in their electromotive force order and defines their potential with respect to a saturated copper-copper sulfite half-cell. This list is arranged according to their standard electrode potentials, with positive potentials (greater than 1.0) for elements that are cathodic to a standard hydrogen electrode and negative potentials (less than 1.0) for elements that are anodic to a standard hydrogen electrode. In most cases, any metal in this series will displace the more positive metal from a solution and thus corrode to protect the more positive metal. There are exceptions to this rule because of the effect of ion concentrations in a solution and because of different environments found in practice. This exception usually applies to metals close together in the series, which may suffer reversals of potential. Metals far apart in the series will behave as expected, the more negative will corrode to the more positive. In an electrochemical reaction, the atoms of an element are changed to ions. If an atom loses one or more electrons (e-), it becomes an ion that is positively charged and is called a cation (example: Fe2+). An atom that takes on one or more electrons also becomes an ion, but it is negatively charged and is called an anion (example: OH-). The charges coincide with the valence of the elements.

The arrangement of a list of metals and alloys according to their relative potentials in a given environment is a galvanic series. By definition, a different series could be developed for each environment.

Table 8-3 Electromotive Force Series

	Potential of Metals
Magnesium (galvomag alloy)[a]	1.75
Magnesium (H-I alloy)[a]	1.55
Zinc	1.10
Aluminum	1.01
Cast iron	0.68
Carbon steel	0.68
Stainless steel type 430 (17% Cr)[b]	0.64
Ni-resist cast iron (20% Ni)	0.61
Stainless steel type 304 (18% Cr, 8% Ni)[b]	0.60
Stainless steel type 410 (13% Cr)[b]	0.59
Ni-resist cast iron (30% Ni)	0.56
Ni-resist cast iron (20% $Ni^{+}Cu$)	0.53
Naval rolled brass	0.47
Yellow brass	0.43
Copper	0.43
Red brass	0.40
Bronze	0.38
Admiralty brass	0.36
90:10 $Cu^{-}Ni^{+}$ (0.8% Fe)	0.35
70:30 $Cu^{-}Ni^{+}$ (0.06% Fe)	0.34
70:30 $Cu^{-}Ni^{+}$ (0.47% Fe)	0.32
Stainless steel type 430 (17% Cr)[b]	0.29
Nickel	0.27
Stainless steel type 316 (18% Cr, 12% Ni, 3% Mo)[b]	0.25
Inconel	0.24
Stainless steel type 410 (13% Cr)[b]	0.22
Titanium (commercial)	0.22
Silver	0.20
Titanium (high purity)	0.20
Stainless steel type 304 (18% Cr, 8% Ni)[b]	0.15
Hastelloy C	0.15
Monel	0.15
Stainless steel type 316 (18% Cr, 12% Ni, 3% Mo)[b]	0.12

Note: Based on potential measurements in sea water, velocity of flow 13 ft/s (3.96 m/s), temperature 77°F (25°C).
a Based on data provided by the Dow Chemical Co.
b The stainless steels, as a class, exhibited erratic potentials depending on the incidence of pitting and corrosion in the crevices formed around the specimen supports. The values listed represent the extremes observed and, due to their erratic nature, should not be considered as establishing an invariable potential relation among the alloys that are covered.

FACTORS AFFECTING THE RATE OF CORROSION

General

The rate of corrosion is directly proportional to the amount of current leaving the anode surface. This current is related to both the potential (voltage) between the anode and cathode and the circuit resistance. Voltage, resistance, and current are governed by Ohm's Law:

Equation 8-1

$$I = \frac{E}{R}$$

where:
I = Current (A or mA)
E = Voltage (V or mV)
R = Resistance (Ω)

Essentially, Ohm's Law states that current is directly proportional to the voltage and inversely proportional to the resistance.

Effect of the Metal Itself

For a given current flow, the rate of corrosion of a metal depends on Faraday's Law.

Equation 8-2

$$w = KIt$$

where:
w = Weight loss
K = Electrochemical equivalent
I = Current
t = Time

For practical purposes, the weight loss is usually expressed in pounds per ampere year (kilograms per coulomb). Loss rates for some common metals are given in Table 8-4.

Table 8-4 Corrosion Rates for Common Metals

Metal	Loss Rate, lb/A-yr (kg/C)
Iron or steel	20 (6.1)
Lead	74 (22.5)
Copper	45 (162.0)
Zinc	23 (7.0)
Aluminum	6.5 (23.4)
Carbon	2.2 (7.9)

This indicates that if 1 ampere is discharged from a steel pipeline over a period of 1 year, 20 pounds (6.1 kilograms) of steel will be lost.

Corrosion of metals in aqueous solutions is also influenced by the following factors: Acidity, oxygen content, film formation, temperature, velocity, and homogeneity of the metal and the electrolyte. These factors are discussed below, since they are factors that can be measured or detected by suitable instruments.

Acidity

The acidity of a solution represents the concentration of hydrogen ions or the pH. In general, low pH (acid) solutions are more corrosive than neutral (7.0 pH) or high pH (alkaline) solutions. Iron or steel, for example, suffers accelerated corrosion in solutions where the pH is 4.5 or less. Exceptions to this rule are amphoteric materials such as aluminum or lead, which corrode more rapidly in alkaline solutions.

Oxygen Content

The oxygen content of aqueous solutions causes corrosion by reacting with hydrogen at the metal surface to depolarize the cathode, resulting in the exposure of additional metal. Iron or steel corrodes at a rate proportional to the oxygen content. Most natural waters originating from rivers, lakes, or streams are saturated with oxygen. Reduction of oxygen is a part of the corrosion process in most of the corrosion found in practice. The possibility of corrosion being influenced by atmospheric oxygen should not be overlooked in design work.

Film Formation

Corrosion and its progress are often controlled by the corrosion products formed on the metal surface. The ability of these films to protect metal depends on how they form when the metal is originally exposed to the environment. Thin, hard, dense, tightly adherent films afford protection, whereas thick, porous, loose films allow corrosion to proceed without providing any protection. As an example, the iron oxide film that usually forms on iron pipe in contact with water is porous and easily washed away to expose more metal to corrosion. The effective use of corrosion inhibitors in many cases depends on the type of film it forms on the surface to be protected.

Temperature

The effect of temperature on corrosion is complex because of its influence on other corrosion factors. Temperature can determine oxygen solubility, content of dissolved gases, and nature of protective-film formation, thereby resulting in variations in the corrosion rate. Generally, in aqueous solutions, higher temperatures increase corrosion rates. In domestic hot water systems, for example, corrosion rates double for each 10°F (6°C) rise above 140°F (60°C) water temperature. Temperature can also reverse potentials, such as in the case of zinc-coated iron at approximately 160°F (71.1°C) water temperature, when the zinc coating can become cathodic to the iron surface, accelerating the corrosion of iron.

Velocity

Velocity of the solution in many cases controls the rate of corrosion. Increasing velocity usually increases corrosion rates. The more rapid movement of the solution causes corrosion chemicals, including oxygen, to be brought into contact with the metal surface at an increased rate. Corrosion products or protective films are carried away from the surface at a faster rate.

Another important effect of high velocity is that turbulence can result in local differential oxygen cells or metal-ion concentration cells causing severe local attack. High velocities also tend to remove protective films causing rapid corrosion of the metal surfaces.

Homogeneity

The homogeneity of the metal and of the electrolyte is extremely important to corrosion rates. In general, nonhomogeneous metals or electrolytes cause local attack or pitting, which occurs at concentrated areas and is, therefore, more serious than the general overall corrosion of a material. Examples include: Concentration cells, galvanic cells, microstructural differences, and differences in temperature and velocity.

CORROSION CONTROL

Corrosion control is the regulation, control, or prevention of a corrosion reaction for a specific goal. This may be accomplished through any one or a combination of the following factors:

1. Materials selection.
2. Design to reduce corrosion.
3. Passivation.
4. Coating.
5. Cathodic protection.
6. Inhibitors (water treatment).

Materials Selection

Corrosion resistance, along with other important properties, must be considered in selecting a material for any given environment. When a material is to be specified, the following steps should be used:

1. Determine the application requirements.
2. Evaluate possible material choices that meet the requirements.
3. Specify the most economical method.

Factors to be considered include:

1. Material cost.
2. Corrosion-resistance data.
3. Ability to be formed or joined by welding or soldering.
4. Fabricating characteristics (bending, stamping, cutting, etc.).
5. Mechanical properties (tensile and yield strength, impact resistance, hardness, ductility, etc.).
6. Availability of material.
7. Electrical or thermal properties.
8. Compatibility with other materials in system.
9. Specific properties, such as nuclear-radiation absorption, low or high-temperature properties.

Initial cost is an important consideration, but the life cost as applied to the system, as a whole, is more important. For example, if an inexpensive part must be periodically replaced, the cost of downtime and labor to install it may make the inexpensive part the most expensive part when all factors are considered.

Design to Reduce Corrosion

Corrosion can be eliminated or substantially reduced by incorporating some basic design suggestions in the system design. The following five design suggestions can minimize corrosive attack:

1. *Provide dielectric insulation between dissimilar metals*, when dissimilar metals such as copper and steel are connected together, e.g., at a water heater. In a pipeline, for example, dielectric insulation should be installed to prevent contact of the two metals. Without such insulation, the metal higher in the galvanic series (steel) will suffer accelerated corrosion because of the galvanic cell between copper and steel. When designing systems requiring dissimilar metals, the need for dielectric insulation should be investigated.
2. *Avoid surface damage or marking.* Areas on surfaces that have been damaged or marked can initiate corrosion. These areas usually become anodic to the adjacent untouched areas and can lead to failures. The designer, therefore, should consider this when there is a need for machining or fabrication so that unnecessary damage does not occur.
3. *Do not use excessive welding or soldering heat.* Areas that are heated excessively during welding or soldering can result in changes to the metals' microstructure. Large grain growth can result in accelerated corrosion. The grain growth changes the physical properties of the metal and results in nonhomogeneity of the metal wall. Designs can minimize this effect by using heavier wall thicknesses in areas to be welded.
4. *Crevices should be avoided.* Concentration cells usually form in crevices and can cause premature failures. Regardless of the amount of force applied in bolting two plates together, it is not possible to prevent gradual penetration of liquid into the crevice between the plates. This forms concentration cells where the fluid in the crevices is depleted and forms anodic areas. The most practical way of avoiding crevices is to design

film occurs. Passivating solutions should be free of contaminants to prevent this from happening.

New methods are being discovered and tested to protect other material surfaces such as aluminum. Periodic testing after passivation ensures the metal surfaces is maintained.

Coating

Materials exposed to the atmosphere that do not have the ability to form natural protective coatings, such as nickel and aluminum, are best protected by the application of artificial protective coatings. The coating is applied to keep the corroding material from the surface at all times.

One of the most important considerations in coating application is surface preparation. The surface must be properly cleaned, free of scale, rust, grease, and dirt to allow the coating to bond properly to the surface. The best coating in the world will give unsatisfactory results if the surface is poorly prepared. The surface may require pickling, sandblasting, scratch brushing, or flame cleaning to properly prepare it for application of a coating.

The actual coating that is applied depends on the application and may be either a metallic (such as galvanizing) or nonmetallic, organic (such as vinyl or epoxy) coating. The coating may actually be a coating system, such as primer, intermediate coat (to bond primer and top coat), and finish or top coat. Coating manufacturers' literature should be consulted regarding coating performance, surface preparatory application, handling of coated surfaces, etc.

For atmospheric exposure, coatings alone are relied on to provide protection in many applications. Coatings by themselves, however, are not considered adequate for corrosion control of buried or submerged structures because there is no such thing as a perfect coating. All coatings have inherent holes or holidays. Often the coating is damaged during installation or adjacent construction. Concentrated corrosion at coating breaks often causes failures sooner on coated structures than on bare ones. In stray current areas, severe damage occurs frequently on coated pipe because of the high density of discharge current at coating faults.

The most important function of coating is in its relation to cathodic protection. Cathodic protection current requirements, and hence operating costs, are proportional to the amount of bare surface exposed to soil. When structures are coated, it is necessary only to protect the small areas of coating faults. Careful applications of coating and careful handling of coated structures lead to maximum coating effectiveness, thus minimizing protective current requirements and costs. Also, lower current usage generally means less chance of stray current effects on other structures.

Cathodic Protection

Cathodic protection is an effective tool to control corrosion of metallic structures, such as water lines and tanks, buried or immersed in a continuous electrolyte by making the metal structure the cathode and applying direct current from an anode source. By making the entire structure the cathode, all anode areas from the local corrosion cells are eliminated, and DC current is prevented from leaving the structure, thereby stopping further corrosion.

The most common sacrificial anode is made of magnesium. Magnesium has the highest natural potential of the metals listed in the electromotive series and, therefore, the greatest current-producing capacity of the series. Zinc anodes are sometimes used in very low-resistivity soils where current-producing capacity such as that of magnesium is not required.

The two proven methods of applying cathodic protection are with (1) galvanic anodes and (2) impressed current systems. The basic difference between the two types of protection is as follows: The galvanic anode system depends on the voltage difference generated between the anode material and the structure material to cause a flow of DC current to the structure. The impressed current system utilizes an AC/DC rectifier to provide current to relatively inert anodes and can be adjusted to provide the necessary voltage to drive the required current to the structure surfaces. Choice of the proper system depends on a number of factors. Each has its advantages, which are discussed below.

Galvanic anodes Galvanic anodes are used most advantageously on coated structures in low soil resistivity where current requirements are low. Some advantages and disadvantages of galvanic anodes are as follows:

Advantages:

1. Relatively low installation cost.
2. Do not require external power source.
3. Low maintenance requirements.
4. Usually do not cause adverse effects on foreign structures.
5. Can be installed with pipe, minimizing right-of-way cost.

Disadvantages:

1. Driving voltage is low (approximately 0.15 V).
2. Current output is limited by soil resistivity.
3. Not applicable for large current requirements.

The galvanic anode system of an active metal anode, such as magnesium or zinc, is placed in the electrolyte (soil or water) near the structure and connected to it with a wire. This is illustrated in Figures 8-12 and 8-13. Cathodic protection is achieved by

current flow due to the potential difference between the anode (metal) and the cathode (structure). A corrosion cell or battery is created, and current flows from the corroding anode material through the soil to the cathode or protected structure. Hence the galvanic anode is deliberately caused to waste itself to prevent corrosion of the protected structure. Because the galvanic anode system relies on the difference in voltage between two metals, which in most cases is limited to 1.0 V or less, the current generated by the anodes is usually low (approximately 0.1 to 0.5 A per anode).

Galvanic anode systems are usually used for structures having small current requirements, such as well-coated, small-diameter pipes; water heaters; sewage lift stations; some offshore structures; and structures in congested areas where currents must be kept low to avoid detrimental effects on other structures. Galvanic anodes may be installed in banks at specific locations. They are, however, usually distributed around protected structures because of their limited current output.

As an example, considering a pipe-to-soil potential of 0.85 V as protection for a steel pipeline, the driving potential of zinc anodes is 0.25 V and for magnesium is 500 A-h/lb (1795 C/kg). The actual life of anodes of a given weight at a known current output can be calculated using the following formulas:

Equation 8-3

$$LM = \frac{57.08 \times w}{i}$$

Equation 8-4

$$Lz = \frac{38.2 \times w}{i}$$

where:

LM = Life of magnesium anode (yr)
Lz = Life of zinc anode (yr)
w = Weight of anode, lb (kg)
i = Output of anode (mA)

The controlling factor for current output of zinc and magnesium anodes is soil resistivity. When soil resistivity is known or determined, then the current output of variously sized anodes for either magnesium or zinc can be estimated as follows:

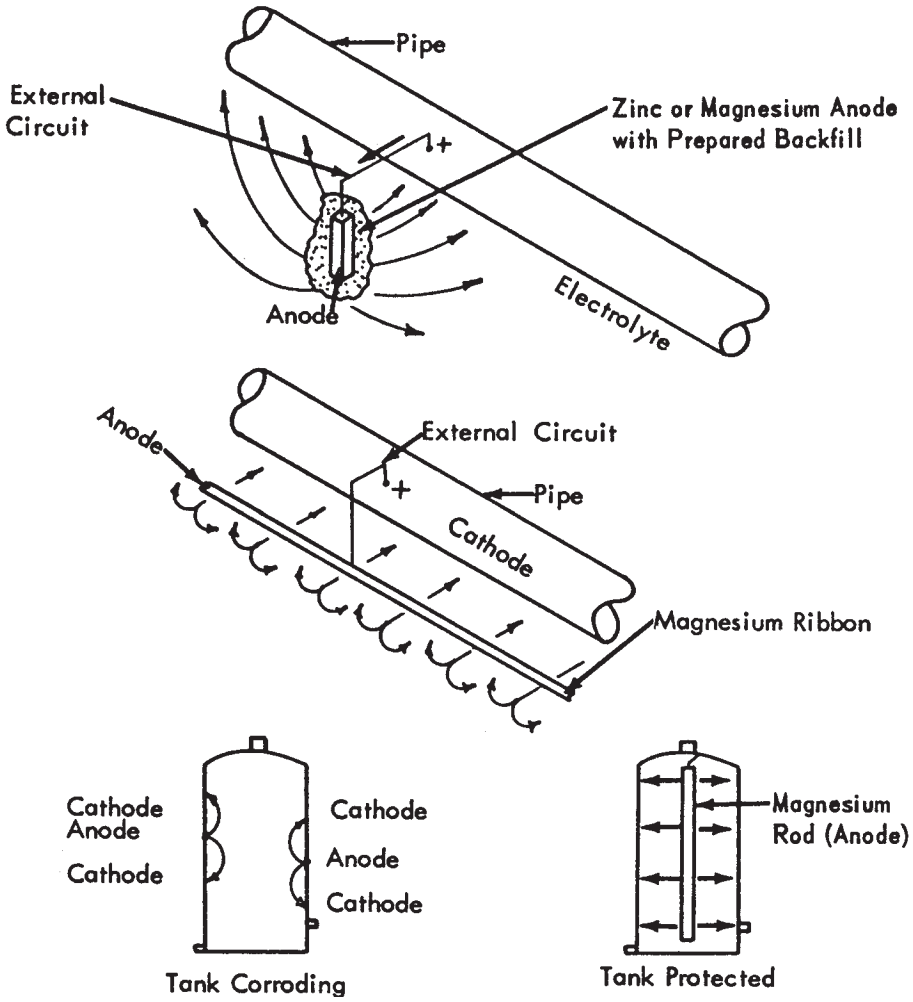


Figure 8-12 Cathodic Protection by the Sacrificial Anode Method

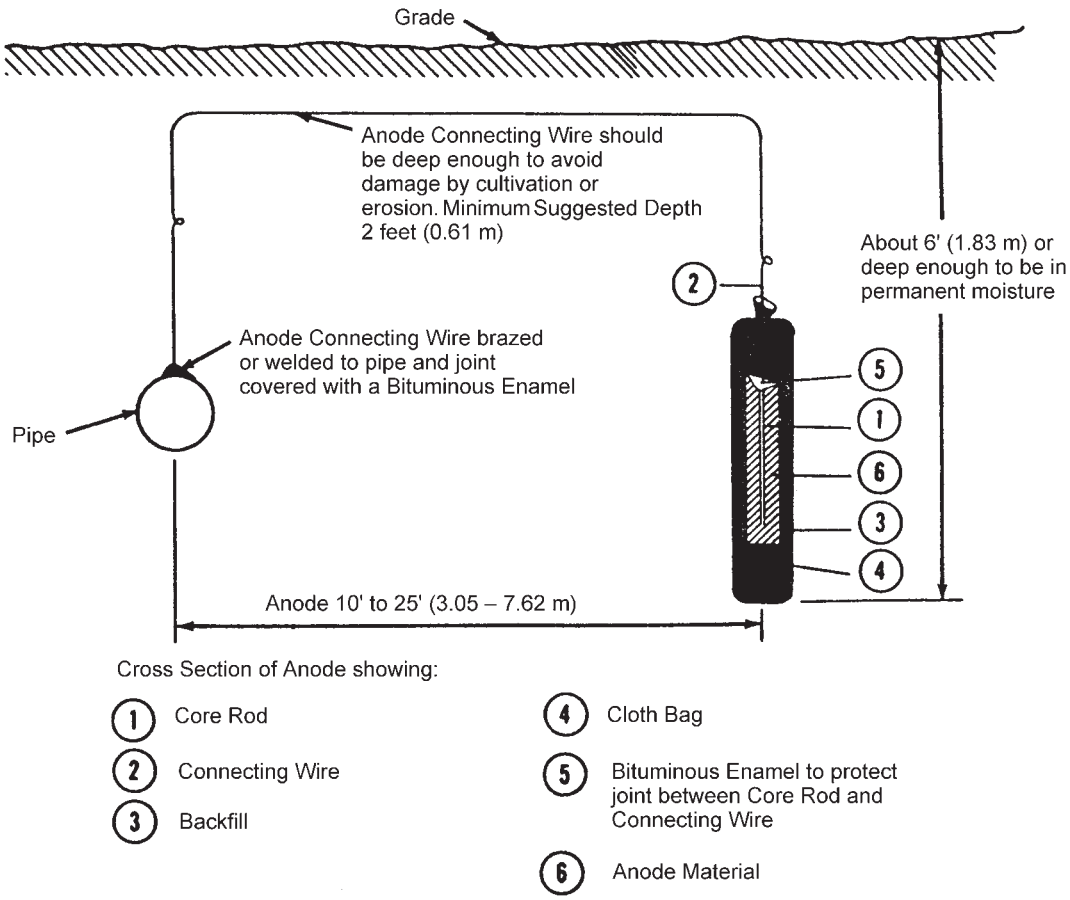


Figure 8-13 Typical Sacrificial Anode Installation

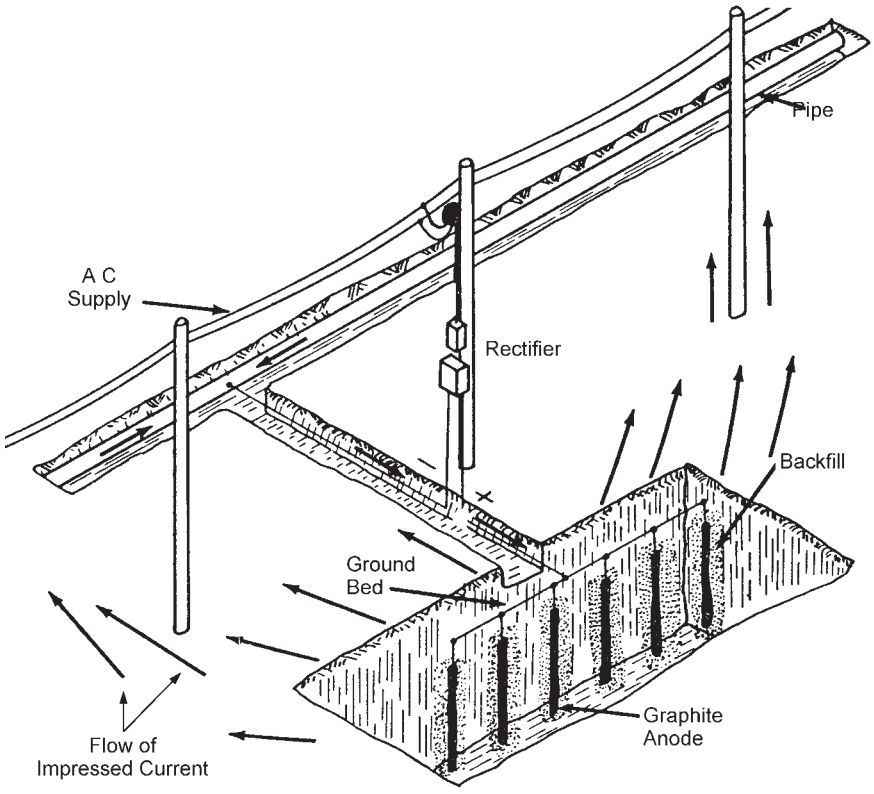


Figure 8-14 Cathodic Protection by the Impressed Current Method

Equation 8-5

$$iM = \frac{150{,}000 \times f}{p}$$

Equation 8-6

$$iZ = \frac{150{,}000 \times f \times 0.27}{p}$$

where:

iM = Current output of magnesium (mA)
iZ = Current output of zinc (mA)
p = Soil resistivity (Ω-cm)
f = Anode size factor

Cost of galvanic cathodic protection generally favors the use of zinc anodes over magnesium at soil resistances below 1500 Ω-cm and the use of magnesium at soil resistances over 1500 Ω-cm.

Impressed current The impressed current system, illustrated in Figure 8-14, differs substantially from the galvanic anode system in that it is externally powered, usually by an AC-DC rectifier, which allows great freedom in adjustment of current output. Current requirements of several hundred amperes can be handled by impressed current systems. The impressed current system usually consists of graphite or high-silicon iron anodes connected to an AC-DC rectifier, which, in turn, is wired to the structure being protected. Current output is determined by adjustment of the rectifier voltage to provide current as required. The system is not limited by potential difference between metals, and voltage can be adjusted to provide adequate driving force to emit the necessary current. Impressed current systems are used for structures having large current requirements, such as bare pipe; tank farms; large-diameter, cross-country pipe lines; cast-iron water lines; and many offshore facilities.

Impressed current cathodic protection has the following advantages and disadvantages:

Advantages:

1. Large current output.
2. Voltage adjustment over a wide range.
3. Can be used with a high soil resistivity environment.
4. Can protect uncoated structures.
5. Can be used to protect larger structures.

Disadvantages:

1. Higher installation and maintenance cost.
2. Power costs.
3. Can cause adverse effects (stray current) with foreign structures.

When designing impressed current cathodic protection systems, the engineer must determine the type and condition of the structure. Obtaining knowledge of the presence or lack of coating, size of structure, electrical continuity, and location is a necessary first step. Next, the availability of power and ease of installing the ground bed are required. After all of the above are satisfactorily done, it is generally necessary to perform a current-requirement test utilizing a portable DC generator or storage batteries. This defines an apparent DC current requirement to protect the structure. Tests to determine any adverse effects should also be conducted on foreign structures at this time. Any current drained to foreign structures should be added to the current requirements. After the total current requirement is known, the ground bed is designed so that the circuit resistance is relatively low. Actual ground-bed design is dependent on soil resistivity. A number of empirical formulas are available to determine the number of parallel anodes required for a certain circuit resistance.

Cathodic protection criteria Criteria for determining adequate cathodic protection have been established by The National Association of Cor-

of cathodic protection current required. Care must be taken to avoid short-circuiting (bypassing) the insulation, or protection can be destroyed. Test stations are wires attached to the underground structure (pipeline or tank) to provide electrical contact for the purpose of determining protection effectiveness. Test stations are also used to make bonds or connections between structures when required to mitigate stray-current effects.

Costs of cathodic protection Corrosion of underground, ferrous metal structures can be economically controlled by cathodic protection. Cathodic protection costs are added to the initial investment since they are a capital expense. To be economically sound, the spending of the funds must yield a fair return over the expected life of the facility.

To protect a new facility requires an initial increase of perhaps 10% in capital investment. Payout time is usually 10 to 15 years; thereafter, appreciable savings accrue due to this investment, which prevents or reduces the frequency of leaks. Effective corrosion control through the application of cathodic protection reduces the leak frequency for a structure to the minimum with minimum cost.

Cathodic protection systems must be properly maintained. Rectifier outputs must be checked monthly. Changes or additions to the protected structure must be considered to see if changes or additions to the cathodic protection system are required. Annual inspections by a corrosion engineer are required to ensure that all malfunctions are corrected, and cathodic protection continues unhampered.

Inhibitors (Water Treatment)

Plant utility services such as boiler feed water, condensate, refrigerants, and cooling water require the addition of inhibitors or water treatment. Boiler feed water must be treated to maintain proper pH control, dissolved solid levels, and oxygen content. Condensate requires treatment to control corrosion by oxygen and carbon dioxide. Brine refrigerants and cooling water in closed-loop circulating systems require proper inhibitors to prevent corrosion.

Water treatment may consist of a simple adjustment of water hardness to produce naturally forming carbonate films. This carbonate film, if properly adjusted, will form to a controlled thickness just sufficient to prevent corrosion by keeping water from contacting the metal surface. In cooling water, where hardness control is not practical, inhibitors or film-forming compounds may be required.

Sodium silicate and sodium hexameta-phosphate are examples of film-forming additives in potable water treatment. A tight, thin, continuous film of silica (water glass) or phosphate adheres to the metal surface, preventing pipe contact with the water. (Phosphate additives to potable water are limited or prohibited in some jurisdictions.)

In closed-loop cooling systems, and systems involving heat-exchange surfaces, it may not be possible to use film-forming treatment because of detrimental effects on heat transfer. In these cases, inhibitors are used; these control corrosion by increasing polarization of anodic or cathodic surfaces and are called "anodic" or "cathodic inhibitors," respectively. The anodic or cathodic surfaces are covered, preventing completion of the corrosion cell by elimination of either the anode or cathode.

When water treatment or inhibitors are used, a testing program must be established to ensure that proper additive levels are maintained. In some cases, continuous monitoring is required. Also, environmental considerations in local areas must be determined before additives are used or before any treated water is discharged to the sanitary sewer or storm drainage system.

GLOSSARY

Active The state in which a metal is in the process of corroding.

Active potential The capability of a metal corroding based on a transfer of electrical current.

Aeration cell An oxygen concentration cell– an electrolytic cell resulting from differences in the quantity of dissolved oxygen at two points.

Amphoteric corrosion Corrosion usually caused by a chemical reaction resulting from a concentration of alkaline products formed by the electrochemical process. Amphoteric materials are those materials that are subject to attack from both acidic and alkaline environments. Aluminum and lead, commonly used in construction, are subject to amphoteric corrosion in highly alkaline environments. The use of cathodic protection in highly alkaline environments, therefore, intensifies the formation of alkaline byproducts.

Anaerobic Free of air or uncombined oxygen.

Anion A negatively charged ion of an electrolyte that migrates toward the anode under the influence of a potential gradient.

Anode Negative in relation to the electrochemical process. The electrode at which oxidation or corrosion occurs.

Anodic protection An appreciable reduction in corrosion by making a metal an anode and maintaining this highly polarized condition with very little current flow.

Cathode Positive in relation to the electrochemical process. The electrode where reduction (and practically no corrosion) occurs.

Cathodic corrosion An unusual condition in which corrosion is accelerated at the cathode because cathodic reaction creates an alkaline condition corrosive to certain metals, such as aluminum, zinc, and lead.

Cathodic protection Reduction or elimination of corrosion by making the metal a cathode by means of an impressed DC current or attachment to a sacrificial anode.

Cathodic The electrolyte of an electrolytic cell adjacent to the cathode.

Cation A positively charged ion of an electrolyte that migrates toward the cathode under the influence of a potential gradient.

Caustic embrittlement Weakening of a metal resulting from contact with an alkaline solution.

Cavitation Formation and sudden collapse of vapor bubbles in a liquid, usually resulting from local low pressures, such as on the trailing edge of an impeller. This condition develops momentary high local pressure which can mechanically destroy a portion of the surface on which the bubbles collapse.

Cavitation-corrosion Corrosion damage resulting from cavitation and corrosion: metal corrodes,

been adopted by the Electrochemical Society and the National Bureau of Standards; it is employed in this publication. The opposite convention of G. N. Lewis has been adopted by the American Chemical Society.)

Electronegative potential A potential corresponding in sign to those of the active or anodic members of the e.m.f. series. Because of the existing confusion of sign in the literature, it is suggested that "anodic potential" be used whenever "electronegative potential" is implied. (See "electromotive force series.")

Electropositive potential A potential corresponding in sign to potentials of the noble or cathodic members of the e.m.f. series. It is suggested that "cathodic potential" be used whenever "electropositive potential" is implied. (See "electromotive force series.")

Flash attack A heavily etched, dark surface resulting from contaminated passivating solutions with high chloride levels.

Forced drainage Drainage applied to underground metallic structures by means of an applied e.m.f. or sacrificial anode.

Galvanic cell A cell consisting of two dissimilar conductors in contact with an electrolyte, or two singular conductors in contact with dissimilar electrolytes. More generally, a galvanic cell converts energy liberated by a spontaneous chemical reaction directly into electrical energy.

Galvanic corrosion Corrosion that is increased because of the current caused by a galvanic cell (sometimes called "couple action").

Galvanic series A list of metals arranged according to their relative corrosion potential in some specific environment; sea water is often used.

General corrosion Corrosion in a uniform manner.

Graphitization (graphitic corrosion) Corrosion of gray cast iron in which the metallic constituents are converted to corrosion products, leaving the graphite flakes intact. Graphitization is also used in a metallurgical sense to mean the decomposition of iron carbide to form iron and graphite.

Hydrogen embrittlement Hydrogen embrittlement causes a weakening of the metal by the entrance of hydrogen into the metal through, for example, pickling or cathodic polarization.

Hydrogen overvoltage A higher than expected difference in potential associated with the liberation of hydrogen gas.

Impingement attack Localized erosion-corrosion caused by turbulence or impinging flow at certain points.

Inhibitor A substance that, when added in small amounts to water, acid, or other liquids, sharply reduces corrosion.

Ion An electrically charged atom or group of atoms

is reached, there will be little or no variation in the voltage.

Resistivity The specific opposition of a material. Measured in ohms (Ω) to the flow of electricity.

Rusting Corrosion of iron or an iron-base alloy to form a reddish-brown product that is primarily hydrated ferric oxide.

Stray current corrosion Corrosion that is caused by stray currents from some external source.

Stress corrosion/stress-accelerated corrosion Corrosion that is accelerated by stress.

Stress corrosion cracking Cracking that results from stress corrosion.

Tuberculation Localized corrosion at scattered locations resulting in knob-like mounds.

Under-film corrosion Corrosion that occurs under lacquers and similar organic films in the form of randomly distributed hairlines (most common) or spots.

Weld decay Corrosion, notably at specific zones away from a weld.

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9 Seismic Protection of Plumbing Equipment

INTRODUCTION

Every structure is designed for vertical, or gravity, loads. In the case of pipes, gravity loads include the weight of the pipe and its contents, and the direction of the loading is downward. Seismic loads are the horizontal forces exerted on a structure during an earthquake. Earthquake forces can be in any direction. The ordinary supports designed for gravity loads generally take care of the vertical loads during an earthquake. Therefore, the primary emphasis in seismic design is on lateral, or horizontal, forces.

Study of seismic risk maps, Figures 9-1 and 9-2, indicates that the potential for damaging earthquake motion is far more pervasive than is commonly known. Complete seismic design requirements, including construction of nonstructural elements (piping, ductwork, conduit, etc.), are in effect in only a small fraction of the areas that could be rated as having a high or moderate risk. Seismic design requirements for nonstructural elements, except for heavy cladding panels, are seldom enforced even in California, which is considered the innovator in state building code requirements related to seismic movement. However, the nonstructural damage resulting from recent small earthquakes and the large United States and Japanese shocks shows that the major advancements in building structural design, by themselves, may not have produced an acceptable level of overall seismic protection. Now that—at least for modern structures designed and built in accordance with current seismic codes—the potential for collapse or other direct, life-endangering structural behavior is quite small, attention has shifted to nonstructural life safety hazards, continued functionality, and economic issues. The cost of an interruption in a building's ability to function—which could cause a loss of rent,

disruption of normal business affairs, or curtailment of production—is coming more into focus.

The costs of seismic protection of plumbing components and equipment range from small—such as those to anchor small tanks—to a considerable percentage of installation costs—such as those for complete pipe bracing systems. Beyond protection of life, the purpose or cost-benefit relationship of seismic protection must be clearly understood before the appropriate response to the risk can be made. The design professional responsible for any given element or system in a building is in the best position to provide that response. Seldom, however, can rational seismic protection be supplied solely by a single discipline. Building systems are interdependent in both design and function, and good seismic protection, like good overall building design, is best provided by employing a cooperative, interdisciplinary approach.

This chapter is intended to provide a basic understanding of the mechanisms of seismic damage and the particular vulnerabilities of plumbing systems and equipment. It is desirable that the professional sufficiently understand the problem in order to select the appropriate seismic protection in any situation, based on a ranking of the damage susceptibility and a knowledge of the scope of mitigation techniques.

The seismic-protection techniques currently in use for buildings are described in general. Although specific seismic-protection details for some situations are discussed, it is suggested that structural-design assistance be obtained from a professional of that discipline. Care should be taken in the design of seismic control systems. Proper design may require assistance from an engineer experienced in these systems. In all cases, the current local building code requirements for seismic movement should be consulted and used as minimum standards.

The detailed analysis and design techniques used for nuclear power plants and other heavy industrial applications, while similar in nature to those discussed here, are considered inappropriate for most buildings and are beyond the scope of this chapter. References are given throughout the text for additional study in specific areas of interest.

CAUSES AND EFFECTS OF EARTHQUAKES

Plate Tectonics and Faults

All seismic activity on the earth's surface, including earthquakes and volcanoes, are now understood to be caused by the relative movement of pieces of the earth's crust. Ten of the largest pieces, called plates, and their prevailing motions, are shown in Figure 9-3. The edges of these plates make up the world's primary fault systems, along which 90% of all earthquakes occur. The balance of earthquakes occur on countless additional, smaller faults that lie within plate boundaries. The causes and exact mechanisms of these intraplate earthquakes, which affect much

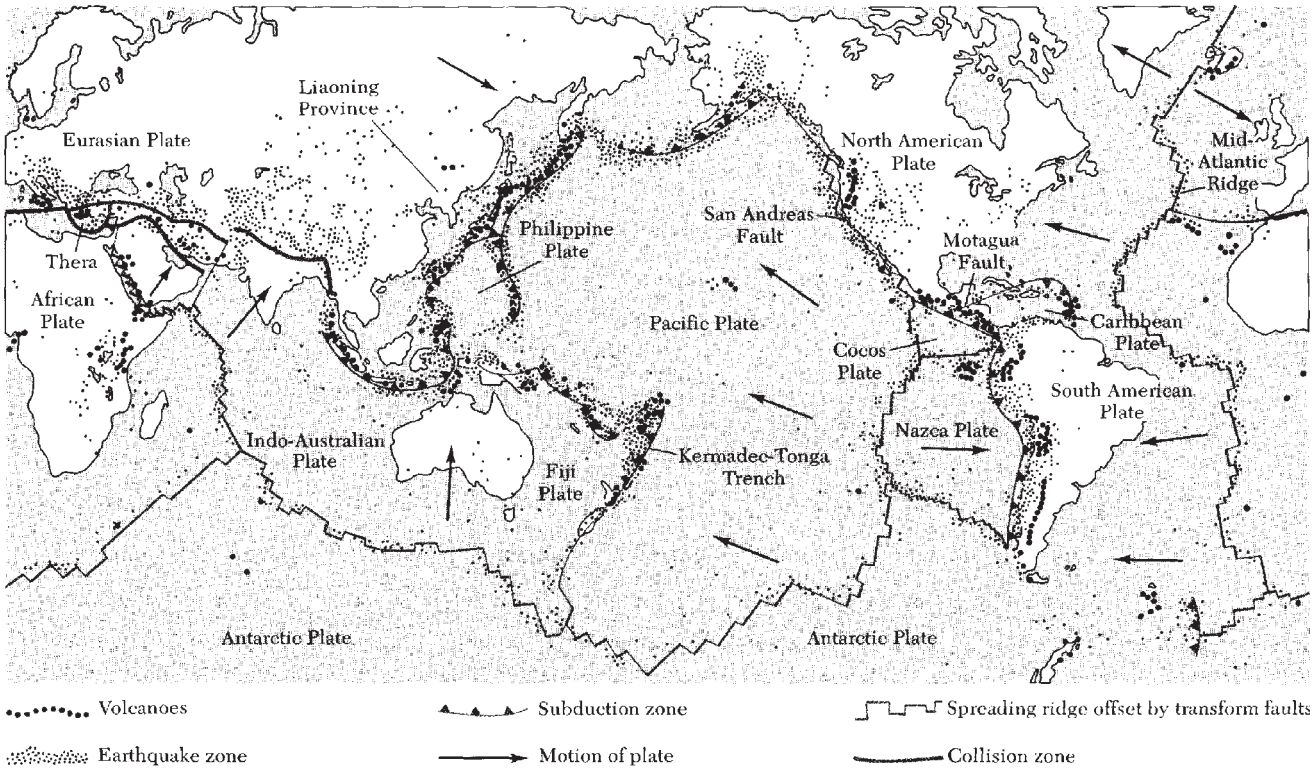
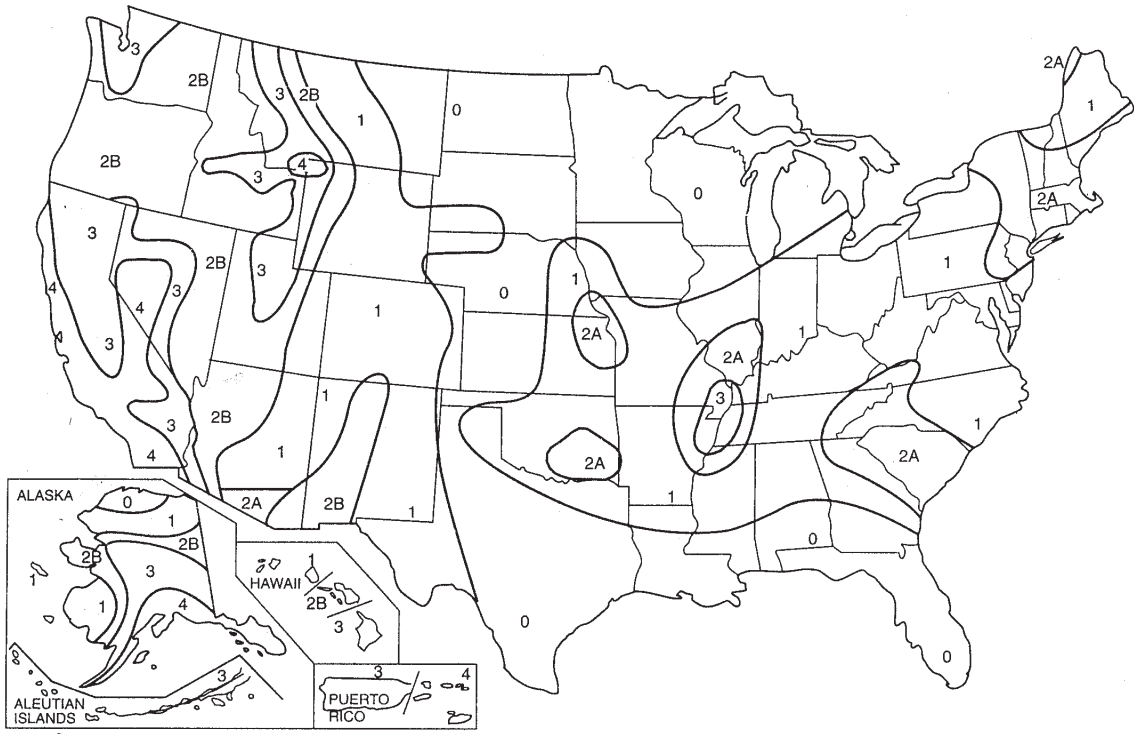
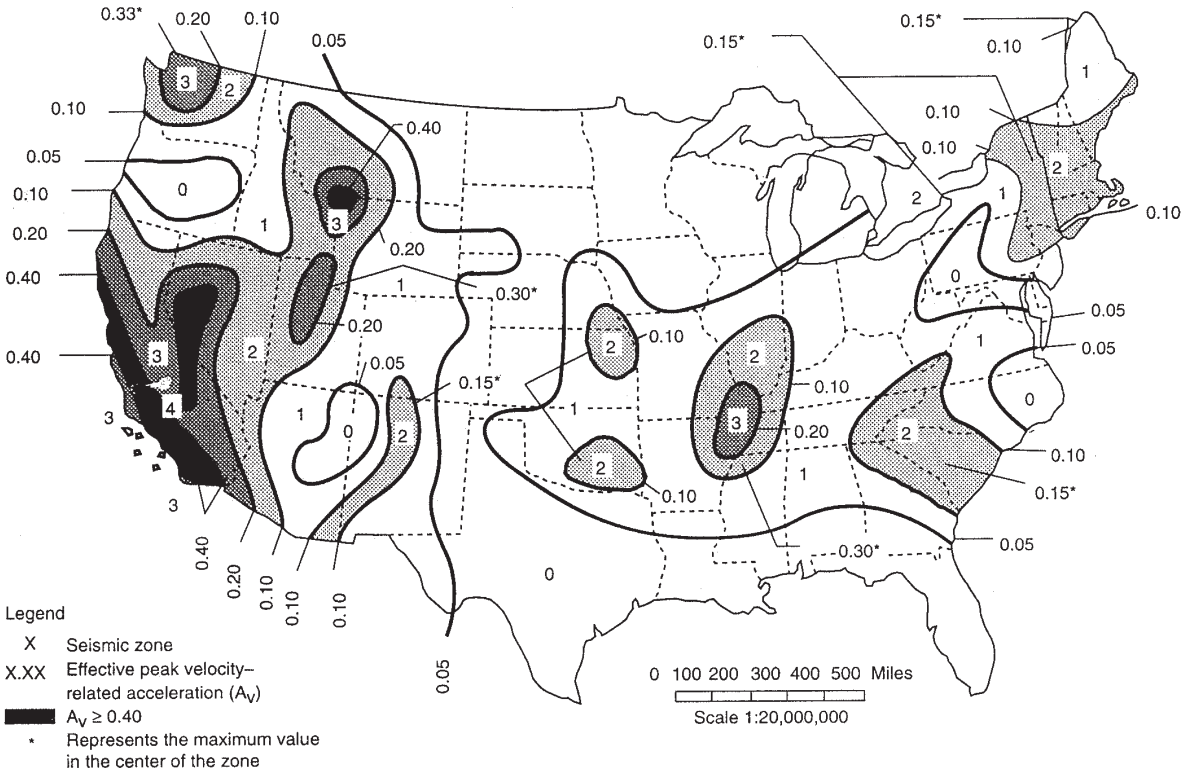


Figure 9-3 World Map Showing Relation Between the Major Tectonic Plates and Recent Earthquakes and Volcanoes.

Note: Earthquake epicenters are denoted by small dots, volcanoes by large dots.


ALASKA
HAWAII
PUERTO RICO
ALEUTIAN ISLANDS

(A)


Legend
X Seismic zone
X.XX Effective peak velocity–related acceleration (A_V)
$A_V \geq 0.40$
* Represents the maximum value in the center of the zone
0 100 200 300 400 500 Miles
Scale 1:20,000,000

of the middle and eastern United States, are not well understood.

The relative movement at plate boundaries is often a sliding action, such as occurs along the San Andreas Fault along the west coast of North America. The plates can also converge, when one plate slides beneath another, or diverge, when molten rock from below rises to fill the voids that gradually form. Although overall plate movement is extremely slow, properly measured only in a geologic time frame, the local relative movement directly at the fault plane can occur either gradually (creep) or suddenly, when tremendous energy is released into the surrounding mass.

The most common mechanism used to describe earthquakes is the "elastic rebound theory," wherein a length of fault that is locked together by friction is strained to its capacity by the continuing plate movement, and both sides spring back to their original positions (See Figure 9-4). Waves in a variety of patterns emanate from this fault movement and spread in every direction. These waves change throughout the duration of the earthquake, add to one another, and result in extremely complicated wave motions and vibrations. At any site away from the fault, the three-dimensional movement of the surface, which is caused by combinations of direct, reflected, and refracted waves, is known simply as "ground shaking." Energy content or intensity of the ground shaking decreases with distance from the causative fault, although because certain structures can be tuned into the motion, this is not always apparent. The horizontal, vertical, and rotational forces on structures are unpredictable in direction, strength, and duration. The structural load is proportional to the intensity of shaking and to the weight of the supported elements.

By combining knowledge of known fault locations with historical and instrumented ground motion records, seismologists can construct maps showing zones of varying expected ground motion. Figure 9-2 shows such maps, which were used to develop design criteria zoning for a national seismic code.

Damage from Earthquakes

Four separate phenomena created by earthquakes can cause damage:

1. Surface fault slip (ground rupture).
2. Wave action in water created by seismic movement (called tsunamis in open bodies of water, seiches in closed bodies of water).
3. Ground shaking.
4. Ground failure, such as a sudden change to liquid characteristics in certain sands caused by increased pore water pressure called "liquefaction" and "landslides."

It is accepted that buildings and their contents are not designed to withstand ground rupture caused by seismic events. Protection from this is obtained by avoiding potentially dangerous sites. Underground piping can be severely damaged by either fault rupture or ground failure, and frequently pipe lines must cross areas with these potential problems. Seismic design provisions for underground systems in these cases consist of special provisions for the considerable distortion expected in the ground or redundant systems and valving, such that local damage can be accepted without serious consequences.

EARTHQUAKE MEASUREMENT AND SEISMIC DESIGN

Ground Shaking and Dynamic Response

The primary thrust of seismic design, as it relates to buildings, is to protect against the effects of ground shaking. Although recently there has been concern that surface waves may damage structures by pure distortion, virtually all design is done assuming the entire ground surface beneath a structure moves as a unit, producing a shaking or random motion whose

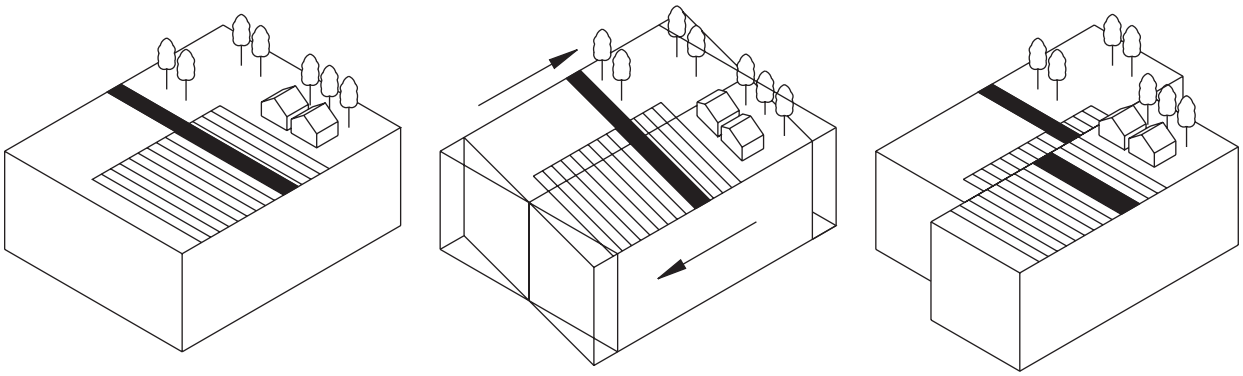


Figure 9-4 Elastic Rebound Theory of Earthquake Movement

According to the Elastic Rebound Theory, a fault is incapable of movement until strain has built up in the rocks on either side. As this strain accumulates, the earth's crust gradually shifts (at a rate of about 2 inches a year along the San Andreas Fault). Rocks become distorted but hold their original positions. When the accumulated stress finally overcomes the resistance of the rocks, the earth snaps back into an unrestrained position. The "fling" of the rocks past each other creates the shock waves we know as earthquakes.

unidirectional components can be studied mathematically and whose effects on structures can be analyzed using structural dynamics and modeling. The movement of the ground mass under a building during an earthquake is measured and recorded using the normal parameters of motion, displacement, velocity, and acceleration. Two orthogonal plan components and one vertical component are used to completely describe the motion. The effect of each orthogonal plan component on the structure under design is considered separately.

The amplitude of displacement, velocity, and acceleration at any moment are, of course, related, as each measures the change in the other over time. Given the record of how one parameter has changed over time (time history), the other two can be calculated. However, due to the direct relationship of force to acceleration (F-Ma) and also because acceleration is easiest to instrumentally measure, acceleration has become the standard measurement parameter. The characteristically spiked and jagged shape of the acceleration time history (accelergram, Figure 9-5) is universally recognized as being associated with earthquakes.

When any nonrigid structure, such as the pendulum or cart and spring of Figure 9-6(A) is subjected to a time history of base motion, the movement (D) of the mass (M) can be measured over time, and this record of motions becomes the dynamic response (K). The dynamic response will be different than the input motion because of the inertial lag of the mass behind the base and the resultant energy stored by distorting the connecting structure. The dynamic response to any input motion, then, will depend on the size of the mass and the stiffness of the supporting structure.

The Response Spectrum

Because of the difficulty of measuring all the variations of distortion in a normal structure at each moment of time, a shorthand measure of maximum response is often used. The maximum response of a

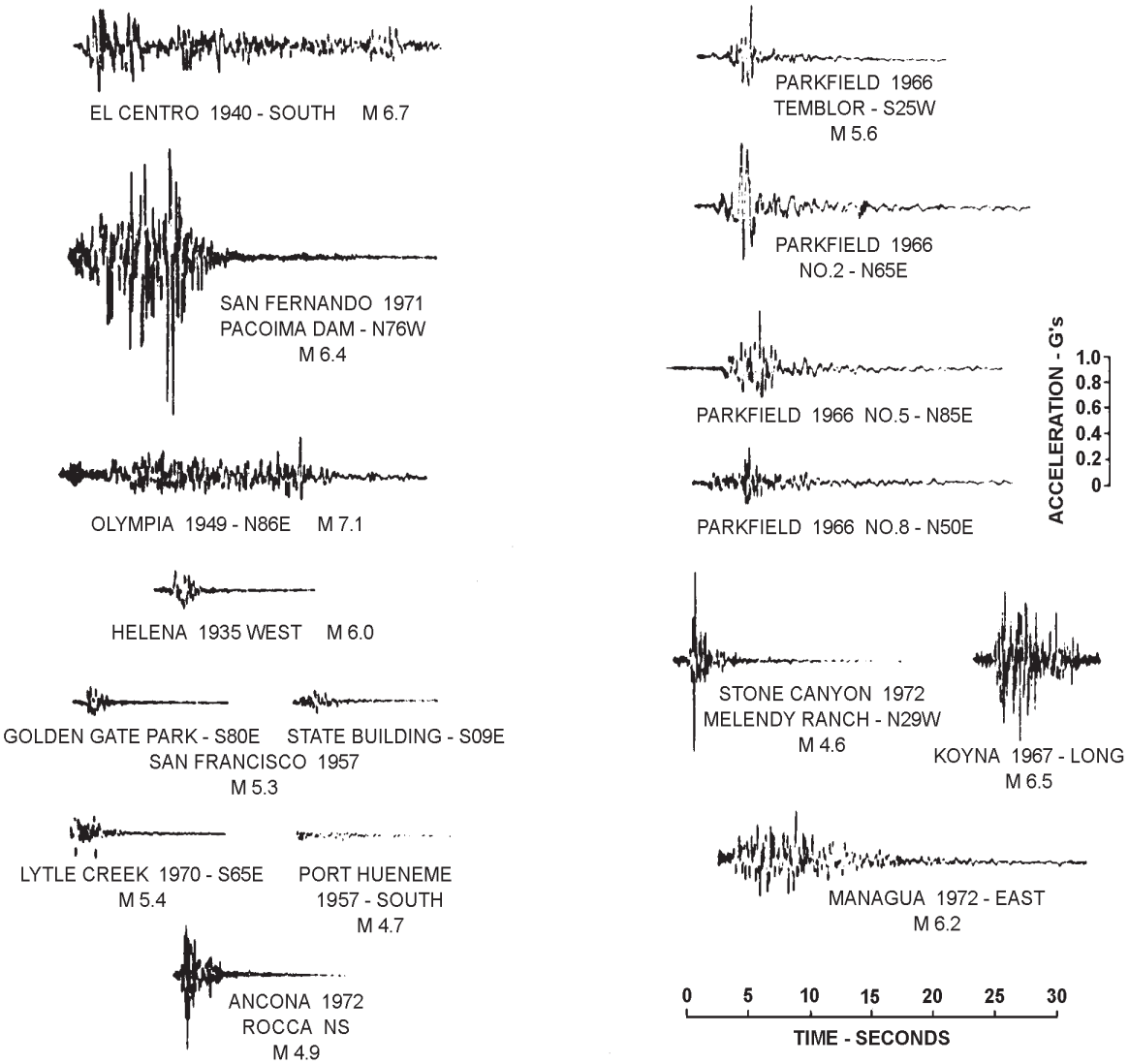


Figure 9-5 Earthquake Ground Accelerations in Epicentral Regions

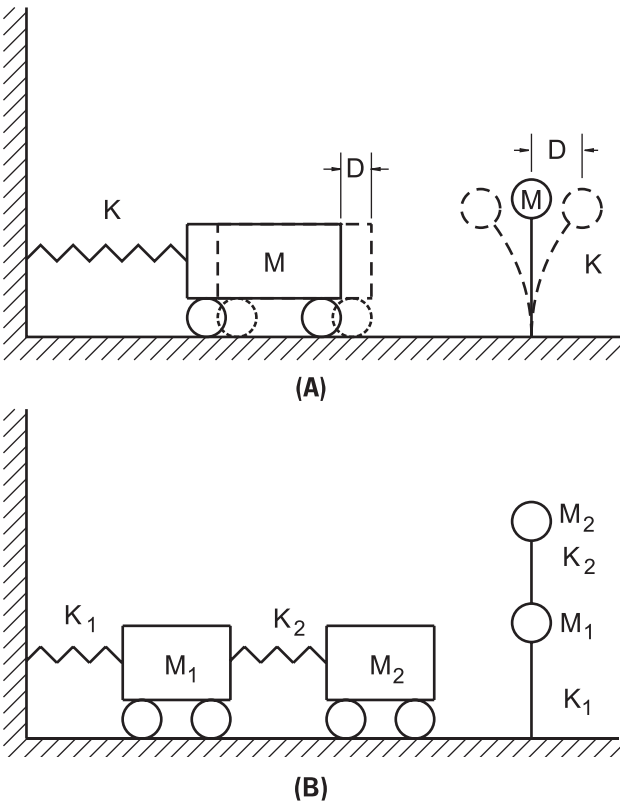


Figure 9-6 Undamped Mechanical Systems: (A) Single-Degree-of-Freedom Systems; (B) Multiple-Degree-of-Freedom Systems.

series of simple pendulums (single-degree-of-freedom system) to a given time history of motion is calculated, and the resulting set of maximums is known as a "response spectrum." (See Figure 9-7.) The response parameter could be displacement, velocity, or acceleration, although acceleration is most often used. The variation in dynamic characteristics of each pendulum in the infinite set is measured by the natural period of vibration. The natural period of any system is dependent on stiffness and mass and measures the length of one complete cycle of free (natural) vibration. Frequency, or the inverse of the period, is also often used in place of the period.

If the input motion (or forcing function) for a structure is of constant frequency and matches the natural frequency, resonance occurs, and the response is theoretically infinite. Damping that occurs to some degree in all real systems prevents infinite response, and the amplitude of the actual response will be proportional to the damping present. Damping is normally measured as a percentage of the amount of damping that would create zero response; that is, the pendulum when set in motion would simply return to its at-rest position. The damping in most structures is between 2 and 10 percent. For any input motion, the response would depend on the amount of damping present, and, therefore, responses (and response spectra) are often presented as families of similar curves, each corresponding to a different damping value. (Refer to Figure 9-7.)

By the response-spectrum technique, the maximum single response to a given base motion of a structure with a known period and damping can be predicted. It must be remembered that the response spectra eliminates the time element from consideration because the maximums plotted for each period are likely to have occurred at different times during the time history. Every ground motion will have its own distinct response spectrum, which will show on a gross basis which vibratory frequencies were predominant in motion. Since ground motions vary not only between earthquakes but between sites during the same earthquake, an infinite variety of response spectra must be considered possible. Fortunately, characteristics of wave transmission and physical properties of soil place upper bounds on spectral shapes. Using statistical analysis of many motions and curve fitting techniques, it is possible to create a design spectrum of energy stored by distorting the connecting structure. The spectrum that is theoretically most appropriate for a dynamic response to any input motion, then, will depend upon the region or even the given site.

With such a design spectrum for acceleration, measured in units of the acceleration of gravity (e.g., the maximum horizontal force in single degree of freedom), systems can be closely approximated using the ordinate as a percentage of the system.

Just as the response of a structure on the ground can be calculated by consideration of the ground motion time history, the response of a system on any floor of a building can similarly be calculated if the time history of the floor motion is known. Using computers, it is possible to calculate such floor motions in structures using base ground motion as input. Response spectra can then be calculated for each floor that would be appropriate for building contents or equipment. The vibratory response of the building is generally far more coherent than rock or soil, as the motion of floors is focused into the natural periods of the building. Floor response spectra are, therefore, often highly peaked around one or two frequencies, so responses nearer to theoretical resonance are more likely than they are on the ground. Responses 25 times greater than input acceleration can be calculated in such circumstances where response spectra for ground motion usually show response multiples of 25. (See US Department of Defense 1973.) These extreme responses are unlikely and are not considered in design, however, due to the many non-linearities in real structures and the low possibility of near-perfect resonance.

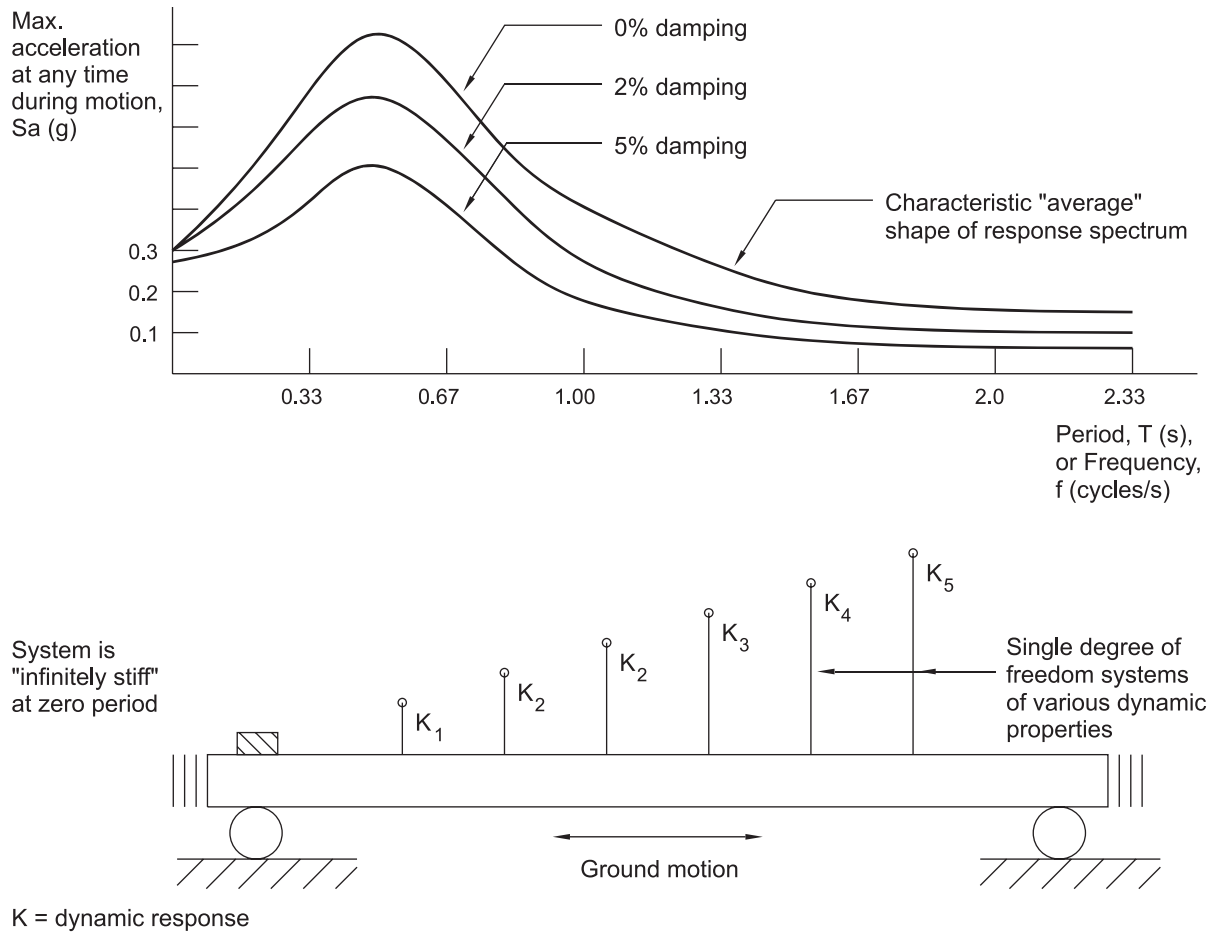


Figure 9-7 Response Spectrum

The response of multidegree-of-freedom systems [Figure 9-6(B)] cannot be simply calculated from a response spectrum, but spectra are often used to quickly approximate the upper limit of the total lateral force on the system. A "pseudo-dynamic elastic analysis" can be done on any system using response spectra to obtain a close approximation of maximum forces or distortions. These analyses are typically done by an experienced engineer using a computer, as they can be labor intensive if performed manually.

LEARNING FROM PAST EARTHQUAKES

Damage to Plumbing Equipment

Damage to plumbing equipment or systems in earthquakes occurs in two ways:

1. Failure due to forces on the element resulting from dynamic response to ground or floor shaking. The most common example is the sliding or overturning of tanks.
2. Failure due to forced distortions on the element caused by differential movement of two or more supports. This can occur at underground utility entrances to buildings, at building expansion or seismic joints, or, on rare occasions, even between floors at a structure due to interstory drift.

An obvious method of determining failure modes and isolation elements susceptible to damage is to study the experience of past earthquakes.

Particularly useful are the following summaries.[1] (Concerning piping, it should be pointed out that both reports indicate that damage was light on an overall basis; the scattered damage found was as described below.)

The 1964 Alaska Earthquake

Damage summary

1. Most pipe failures occurred at fittings. Most brazed or soldered joints were undamaged, many screwed joints failed, and a few caulked joints were pulled apart or twisted.
2. Failures in screwed joints often occurred where long unbraced horizontal runs of pipe joined short vertical risers or were connected to equipment. Small branch lines that were clamped tightly to the building were torn from large horizontal mains if these were unbraced and allowed to sway.

1. Ayres, Sun, et al. 1973 and Ayres and Sun 1973.

3. Joints were loosened or pulled apart in long horizontal runs of unbraced cast-iron pipe, and hangers were bent, shifted, or broken.
4. Pipes crossing seismic joints were damaged if provisions were not made for the relative movements between structural units of buildings.
5. Thermal expansion loops and joints were damaged when the pipes were not properly guided.
6. Fire-sprinkler piping was practically undamaged because it was provided with lateral bracing.
7. Sand filter, water softener, domestic hot water, heating-hot-water expansion and cold-water-storage tanks shifted, toppled, or rolled over when they were not firmly anchored to buildings.
8. Hundreds of small, gas-fired and electric domestic water heaters fell over. Many of the legs on which heaters stood collapsed, and vent connectors were damaged.
9. Some plumbing fixtures were damaged by falling debris.
10. Vertical plumbing stacks in tall buildings were practically undamaged.

The 1971 San Fernando Earthquake

Damage summary

1. Unanchored heavy equipment and tanks moved and damaged the connected piping.
2. Heavy equipment installed with vibration isolation mounts moved excessively, often destroyed the isolators, and damaged the connected piping.
3. Cast-iron supports for heavy cast-iron boilers failed.
4. Pipes failed at threaded connections to screwed fittings. Some cast-iron fittings were fractured.
5. Pipes were damaged when crossing separations between buildings.
6. Screwed pipe legs under heavy tanks failed, and angle iron legs were deformed.
7. Plumbing fixtures were loosened from mounts, and enamel was chipped.
8. Domestic water heater legs were bent or collapsed.

The overall recommendations applicable to plumbing equipment from the Alaska report, made primarily as a response to observed damage, are worth relating:

1. Pipelines should be tied to only one structural system. Where structural systems change, and relative deflections are anticipated, movable joints should be installed in the piping to allow for the same amount of movement.
2. Suspended piping systems should have consistent freedom throughout; for example, branch lines should not be anchored to structural elements if the main line is allowed to sway.
3. If the piping system is allowed to sway, movable joints should be installed at equipment connections.
4. Pipes leading to thermal expansion loops or flexible pipe connections should be guided to confine the degree of pipe movement.
5. Whenever possible, pipes should not cross seismic joints. Where they must cross seismic joints, appropriate allowance for differential movements must be provided. The crossing should be made at the lowest floor possible, and all pipe deflections and stresses induced by the deflections should be carefully evaluated. Standards of the National Fire Protection Association (NFPA) for earthquake protection to fire-sprinkler systems should be referred to for successful, field-tested, installation details that are applicable to any piping system. The latest revision to FM data sheet 2-8 for sprinkler systems is also valuable as a reference guide.
6. Supports for tanks and heavy equipment should be designed to withstand earthquake forces and should be anchored to the floor or otherwise secured.
7. Suspended tanks should be strapped to their hanger systems and provided with lateral bracing.
8. Pipe sleeves through walls or floors should be large enough to allow for the anticipated movement of the pipes and ducts.
9. Domestic water heaters should be provided with legs that can withstand earthquake forces, and the legs should be anchored to the floor and/or strapped to a structurally sound wall.
10. Earthquake-sensitive shut-off valves on gas-service lines should be provided where maximum protection from gas leaks is required.
11. Vibrating and noisy equipment should, if possible, be located far from critical occupancies, so that the equipment can be anchored to the structure, and vibration isolation is not required.

    Avoid mounting heavy mechanical equipment on the top or upper floors of tall buildings unless all vibration-isolation mounts and supports are carefully analyzed for earthquake-resistant design.

    When equipment and the attached piping must be isolated from the structure by vibration isolators, constraints should be used.

SEISMIC PROTECTION TECHNIQUES

General

Assuming that the building in which the piping systems are supported is designed to perform safely in response to earthquake forces, the piping systems must be designed to resist the seismic forces through the strength of the building attachments.

The design professional must consider local, state, and federal seismic requirements, as applicable, in the area of consideration. Only those engineers with seismic experience should design the supports required for seismic zones. Close coordination with the structural engineer is required to ensure the structural system properly supports the mechanical systems and equipment.

Equipment

Seismic protection of equipment in buildings, as controlled by the design professional, consists of preventing excessive movement that would either damage the equipment directly or break the connected services. Equipment certification is required in the International Building Code (IBC) 2000 for equipment with importance factor of 1.5. Also, piping systems with importance factor of 1.5 must be completely designed and detailed on the plans including supports and restraints. These are major issues.

Other than meeting the requirements set forth in IBC 2000, the ability of the equipment housing or working parts to withstand earthquake vibration is generally not formally considered for one or more of the following reasons:

1. Such failure would not endanger life.
2. Continued functioning is not always required.
3. Most equipment will experience transportation shocks or working vibrations that are similar to earthquake motions, and the housing and internal parts are therefore considered adequate.
4. The design professional has little control over the manufacturing process. Competitively priced equipment specially qualified to resist earthquake motion is not available.
5. Because of a lack of performance data for equipment that is anchored, the extent of the problem is unknown.

Movement to be prevented is essentially overturning and sliding, although these effects can take place with a variety of characteristics:

1. Overturning (moment).
   A. Overturn of equipment.
   B. Failure in tension or compression of perimeter legs, vibration isolators, hangers, or their supports.
   C. Excessive foundation rotation.
2. Sliding (shear).
   A. Sliding of floor-mounted equipment.
   B. Swinging of hung equipment.
   C. Excessive sideways failure of legs, stands, tank mounts, vibration isolators, or other supports. Although these failures are often described as local overturning of the support structure, they are categorized as a shear or sliding failure because they are caused by the straight lateral movement of the equipment rather than the tendency to overturn.

Prevention of overturning and sliding effects can best be discussed by considering the categories of mounting equipment, such as fixed or vibration-isolated, and floor-mounted or hung.

Fixed, floor-mounted equipment This group includes tanks, water heaters, boilers, and other equipment that can rest directly on the floor. Although anchoring the base of such equipment to the floor is obvious, simple, and inexpensive, it is commonly omitted. Universal base anchorage of equipment undoubtedly would be the single largest improvement and would yield the largest cost-benefit ratio in the entire field of seismic protection of plumbing equipment. This anchoring is almost always to concrete and is accomplished by cast-in-place anchor bolts or other inserts, or by drilled or shot-in concrete anchors. The connection to the equipment base is totally configuration dependent and may require angles or other hardware to supplement the manufactured base. For elements that have a high center of gravity, it may be most efficient to resist overturning by bracing at the top, either diagonally down to the floor, to the structure above, or to adjacent structural walls. Vertical steel beams, or "strongbacks," can also be added on either side of tall equipment to span from floor to floor; a vertical slip joint connection should be placed at the top of such beams to avoid unexpected interaction between the floor structures.

Tanks supported on cast-iron legs or threaded pipes have proven to be particularly susceptible to support failure. These types of legs should be avoided or have supplemental bracing.

The horizontal earthquake loads from equipment mounted on or within concrete stands or steel frames should be braced from the equipment through the support structure and out the base. Concrete tank saddles often are not attached to the tank, are of inadequate strength (particularly in the longitudinal direction), are not anchored to the floor foundation,

or have inadequate provisions for earthquake-generated forces in the floor or foundation. Steel equipment frames often have similar problems, some of which can be solved by diagonal bracing between legs.

Fixed, suspended equipment The most common element in this group is the suspended tank. Seldom are these heavy elements laterally braced. The best solution is to install the tank tightly against the structural member above, thus eliminating the need for bracing. However, even these tanks should be secured to the suspension system to prevent slipping. Where the element is suspended below the supporting member, cross-bracing should be installed in all directions to provide lateral stability. Where a tank is suspended near a structural wall, struts to the wall may prove to be simpler and more effective than diagonal bracing.

Vibration-isolated, floor-mounted equipment This group includes units containing internal moving parts, such as pumps, motors, compressors, and engines. The entire concept of vibratory isolation by flotation on a nontransmitting material (spring, neoprene, cork, etc.), although necessary for equipment-operating movement, is at cross-purposes with seismic anchorage. The isolation material generally has poor lateral, force-carrying capacity in itself, plus the housing devices are prone to overturning. It is, therefore, necessary to either supplement conventional isolators with separate snubbing devices (Figure 9-8), or to install specially designed isolators that have built-in restraints and overturning resistance (Figure 9-9). Isolators with minimal lateral-force resistance used in exterior applications to resist wind are usually inadequate for large seismic forces and are also commonly made of brittle cast iron. The possibility of complete isolator unloading and ensuing tension forces due to overturning or vertical acceleration also must be considered. Manufacturers' ratings of lateral loads for isolators should be carefully examined, for often the capacity is limited by the anchorage of the isolators themselves, which is normally unspecified.

The containment surfaces in these devices must be hard connections to the equipment or its base to avoid vibratory short circuits. Because this requirement for complete operational clearance allows a small, ¼-d" (6.4-9.5 mm), movement before restraint

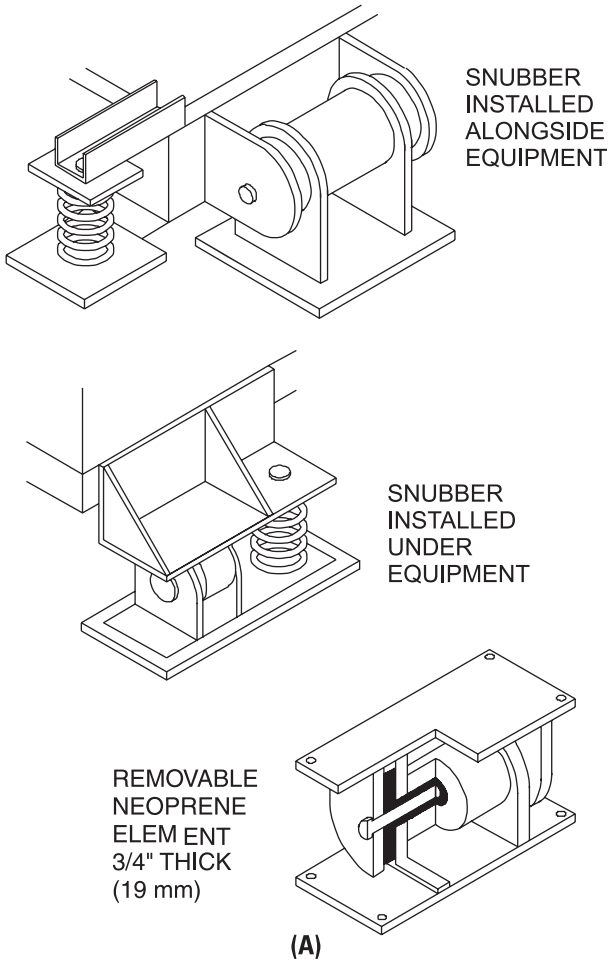


Figure 9-8 Snubbing Devices: (A) Three-Dimensional Cylinder Snubber

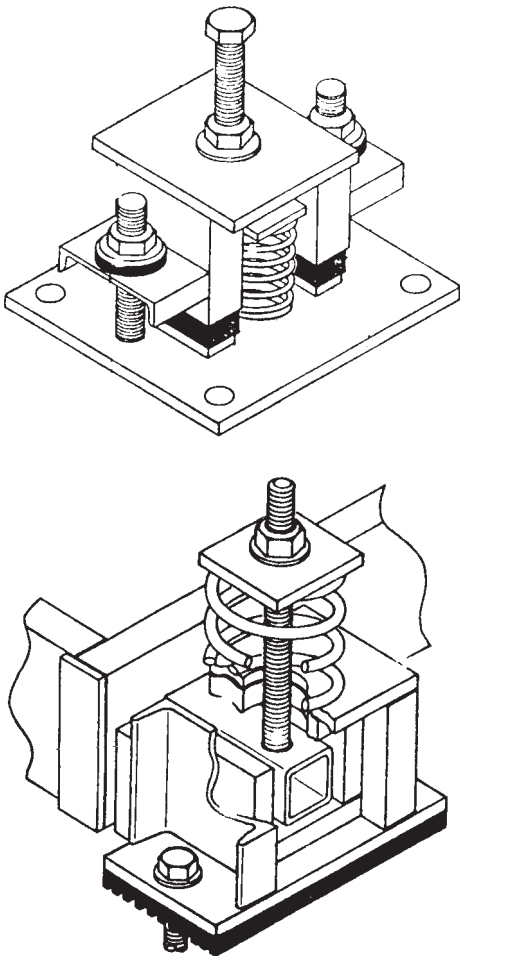
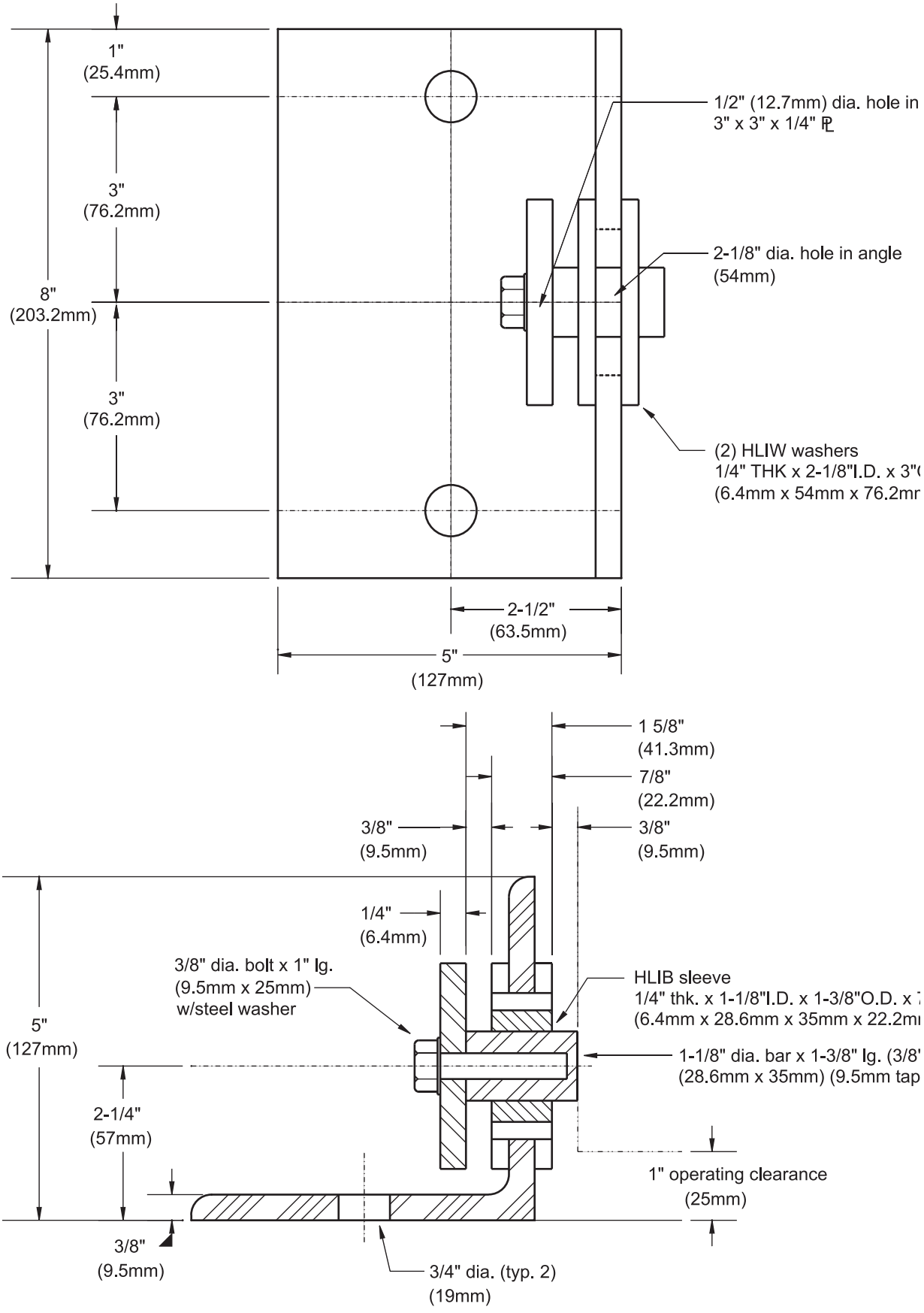


Figure 9-9 Isolators with Built-In Seismic Restraint



(B)

Figure 9-8 Snubbing Devices: (B) Three-Directional Angle Snubbers

begins, resilient pads are added to ease the shock load that could be caused by impact.

Because of the stored energy in isolation springs, it is more efficient to anchor the assembly, as restraint is built into the isolator rather than being a separate unit. In retrofit applications, or occasionally due to dimensional limitations, separate snubbers are preferable. Once snubbers are decided upon, those that restrain in three dimensions are preferred because that minimizes the number required. Although some unconfirmed rubber-in-shear isolators are intended to resist loads in several directions, there is little data to indicate adequacy to resist the concurrent large amplitude dynamic loading that could occur in an earthquake. Unless such isolators are considered for real earthquake loading (as opposed to code requirements) with a suitable safety factor, additional snubbing is recommended. Rubin-in-shear isolators with metal housing are more likely to have the overload capacity that may be needed to resist seismic loading, but unless they are specifically tested and rated for this loading, ultimate capacities should be compared with expected real seismic loads.

Vibration-isolated, suspended equipment This is by far the most difficult type of equipment to restrain, particularly if only a small movement can be tolerated. The best method is to place an independent, laterally stable frame around the equipment with proper operating gaps padded with resilient material, similar to a snubber. However, this frame and its support system can be elaborate and awkward. An alternate method is to provide a self-contained, laterally stable, suspended platform upon which conventional seismic isolators or snubbers can be mounted.

Smaller equipment bolted or welded directly to the structure doesn't need restraints, but the bolts or welds must be designed for seismic loads. However, equipment suspended close to the structure requires restraints. Isolators within hangers should always be installed tight against the supporting structural member. When hanger rods are used to lower the unit, cross bracing or diagonal bracing should be installed.

Cable that is installed taut, but allowed to sag under its own weight will allow vibration isolation to function. Additional slack is not required and should not be allowed. Use of neoprene grommets or bushings is not required. The cable sag and cable flexibility provide adequate cushioning.

Piping Systems

Normally, piping suspended by hangers less than 12 inches (305 mm) in length, as measured from the top of the pipe to the bottom of the support where the hanger is attached, do not require bracing. The following piping shall be braced:

1. Fuel oil, gas, medical gas, and compressed air piping 1-inch (25.4-mm) nominal diameter and larger.
2. Piping in boiler rooms, mechanical rooms, and refrigeration mechanical rooms 1¼-inch (31.8-mm) nominal diameter and larger.
3. All piping 2½-inches (63.5-mm) nominal diameter and larger.

Conventionally installed piping systems have survived earthquakes with minimal damage. Fitting failures generally occur at or near equipment connectors where equipment is allowed to move, or where a main is forced to move and small branches connected to the main are clamped to the structural elements. In theory, then, a few well-placed pipe restraints in the problem areas could provide adequate seismic protection. In practice, however, the exact configuration of piping is seldom known to the designer, and even if it was, the key brace locations are not easy to determine. Often, partial restraint in the wrong location is worse than no restraint at all. Correct practice is therefore to provide complete restraint when seismic protection of piping systems is advisable. This restraint can be applied throughout the system or in local, well-defined areas such as mechanical or service rooms.

Although there are many variables to consider when restraining pipe against seismic movement, the techniques to do so are simple and similar to those used for hanging equipment. Fixing pipe directly to structural slabs, beams, columns, or walls is, of course, the simplest method. Many codes and guidelines consider hangers of less than 12 inches (305 mm) as being equivalent to direct attachment. For pipes suspended more than 12 inches (305 mm), diagonal braces to the structure above or horizontal struts to an adjacent structure are normally installed at vertical hanger locations. Vertical suspension hardware is usually incorporated into braces, both for efficiency and because it is readily available.

Connection to the pipe at transverse braces is accomplished by bearing the pipe or insulation on the pipe clamp or hanger. Attachment to the pipe at longitudinal brace points is not as simple. For small loads, tight-fitting clamps (such as riser clamps) dependent on friction are often used. For larger loadings, details commonly used for anchor points in high-temperature systems with welded or brazed direct connections to the piping may be necessary. Welding should be done by certified welders in accordance with American Welding Society (AWS) D 1.1 and shall use either the shielded or submerged arc method.

Transverse bracing shall be at 40 feet (12.2 m) maximum spacing, except that fuel oil and gas piping shall be at 20 feet (6.1 m) maximum spacing. Longitudinal bracing shall be at 80 feet (24.4 m) maximum

spacing, except that fuel oil and gas piping shall be at 40 feet (12.2) maximum spacing.

The many parameters that must be considered before the exact details and layout of a pipe bracing system can be completed are shown schematically in Figure 9-10. These parameters are discussed in more detail below:

1. *Weight of pipe and contents* Since the motion being restrained is a dynamic response, the forces that must be resisted in each brace are proportional to the tributary weight.
2. *Location of pipe* The strength of structural members, particularly compression members, is sensitive to length, so a pipe that must run far from a structural support may require more or longer braces. In boiler service rooms, a horizontal grid of structural beams has sometimes been placed at an intermediate height to facilitate bracing of pipes.
3. *Type of structure* The connection of hangers and braces to the structure is an important factor in determining a bracing system, as demonstrated by the following considerations: Many light roof-deck systems cannot accept point loads except at beam locations; pipe locations and brace layout are thereby severely limited unless costly cross beams are placed at every brace. Other roof and floor systems have significant limitations on the magnitude of point loads, which limit brace spacing.

   It is often unacceptable to have anchors drilled or shot into the underneath of prestressed concrete floors. Limitations on depth and location also exist in the bottom flange of steel or reinforced concrete beams and in the bottom chord of joists.

   Many steel floor-deck styles have down flutes 1½ in. (38.1 mm) or less in width; the strength of drilled or shot-in anchors installed in these locations is questionable.

   The structures of buildings that employ interstitial space may have the capacity to brace pipe to either the top or the bottom of the space, which greatly increases bracing layout flexibility.
4. *Piping material* The strength and ductility of the material will affect brace spacing. The stiffness will affect dynamic response and therefore loading.
5. *Joint type* The joint has proven to be the element most likely to be damaged in piping systems; threaded and bell-and-spigot joints have been particularly susceptible. The joint type also determines, in conjunction with the pipe material, the length of the span between braces. Brazed and soldered joints perform acceptably. Most no-hub joints, however, have virtually no stiffness; effective bracing of such systems is nearly impossible. Mechanical joints exhibit the most complex behavior, with spring-like flexibility (when pressurized) within a certain rotation and then rigidity. In addition, the behavior of such systems under earthquake conditions, which cause axial loadings necessary to transmit forces to longitudinal braces, is unknown. As a minimum, cast iron and glass pipe, and any other pipe joined

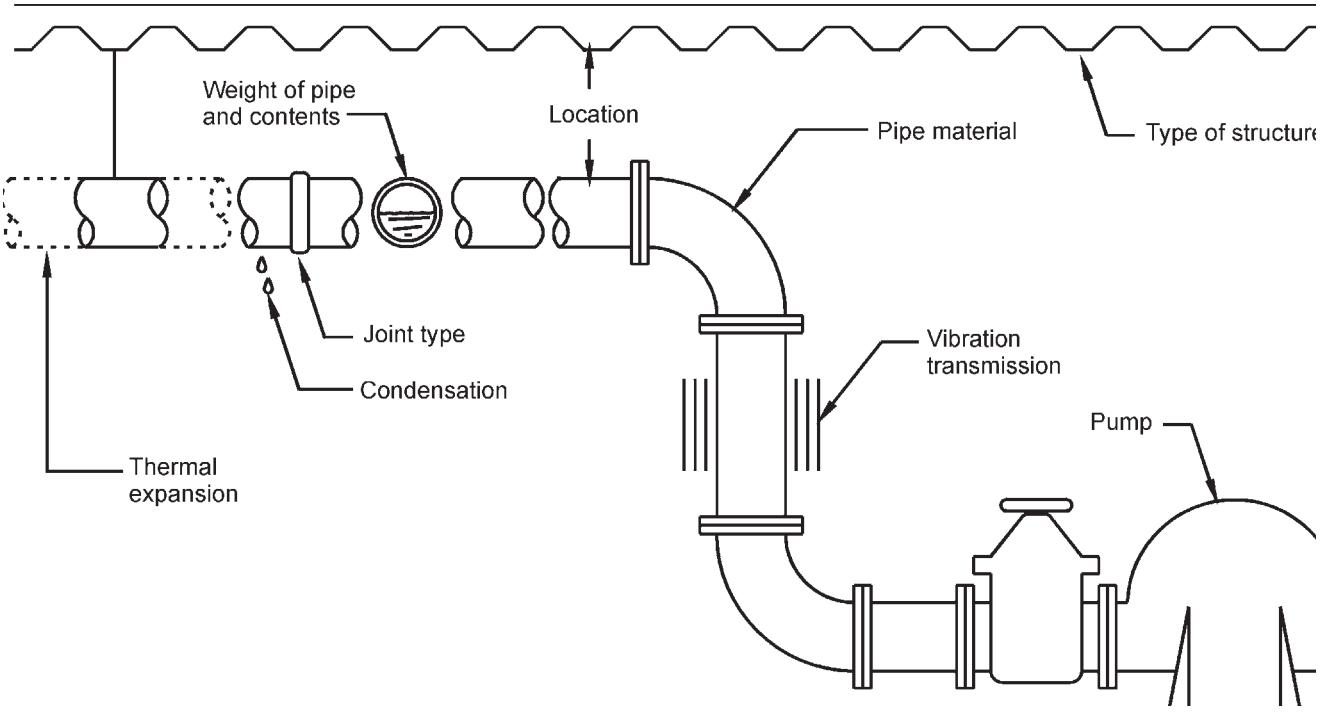


Figure 9-10 Parameters to be Considered for Pipe Bracing

with a shield-and-clamp assembly, where the top of the pipe exceeds 12 inches (305 mm) from the supporting structure, shall be braced on each side of a change of direction of 90 degrees or more. Riser joints shall be braced or stabilized between floors. For hubless, pipe-riser joints unsupported between floors, additional bracing is required. All pipe vertical risers shall be laterally supported with a riser clamp at each floor.

6. *Vibration* Traditionally, unbraced pipe systems seldom cause vibration transmission problems because of their inherent flexibility. Many engineers are concerned that completely braced "tight" piping systems could cause unpredictable sound and vibration problems.
7. *Temperature movement* Pipe anchors and guides used in high-temperature piping systems must be considered and integrated into a seismic bracing system. A misplaced longitudinal brace can become an unwanted anchor and cause severe damage. Thermal forces at anchor points, unless released after the system is operational, are additive to tributary seismic forces. Potential interference between seismic and thermal support systems is particularly high near pipe bends where a transverse brace can become an anchor for the perpendicular pipe run.
8. *Condensation* The need to thermally insulate high-temperature and chilled water lines from hanging hardware makes longitudinal brace attachment difficult. In some configurations of short runs with bends, transverse braces can be utilized near elbows to brace the system in both directions. Friction connections, using wax-impregnated oak or calcium-silicate sleeves as insulators, have been used.

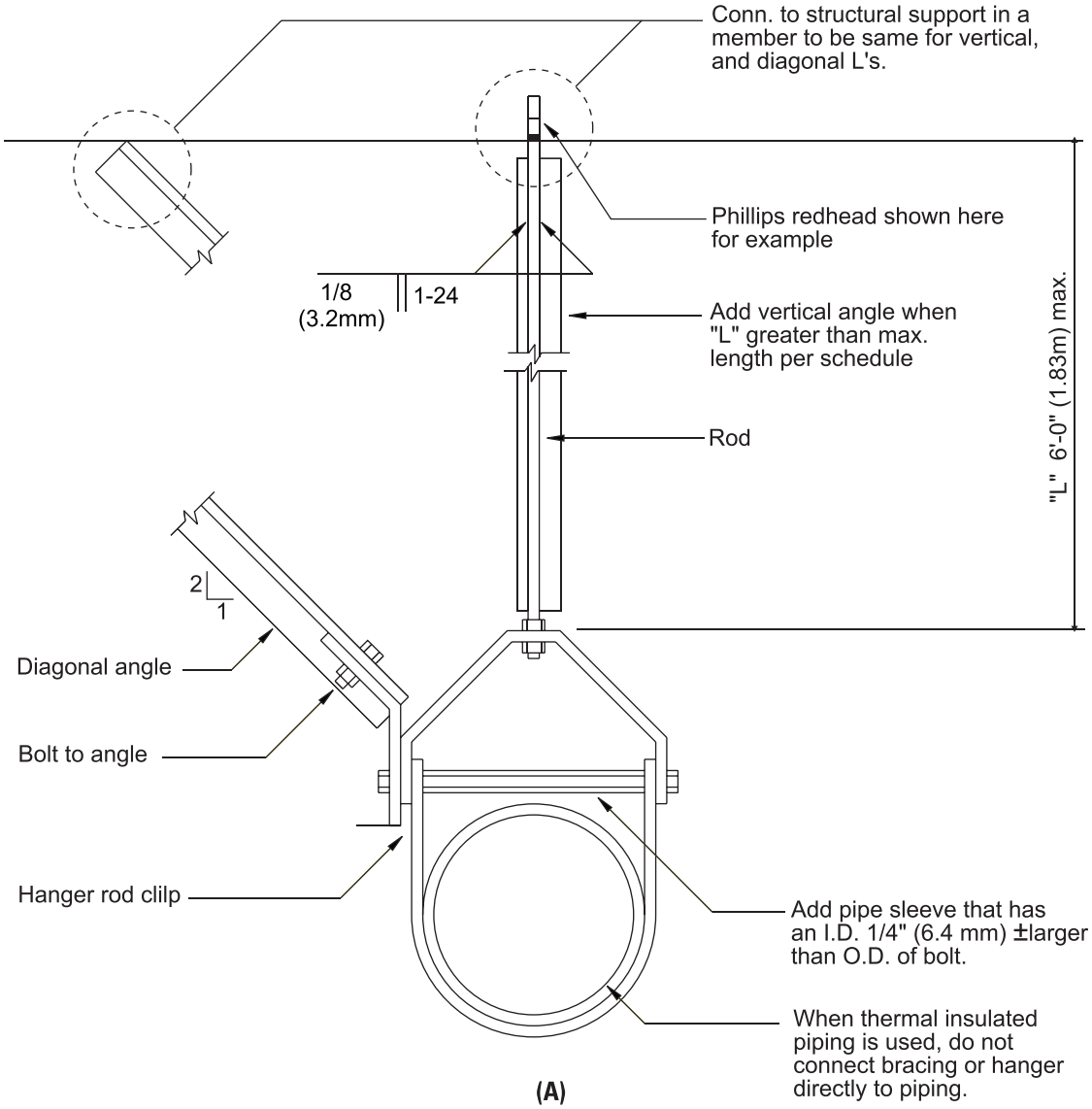
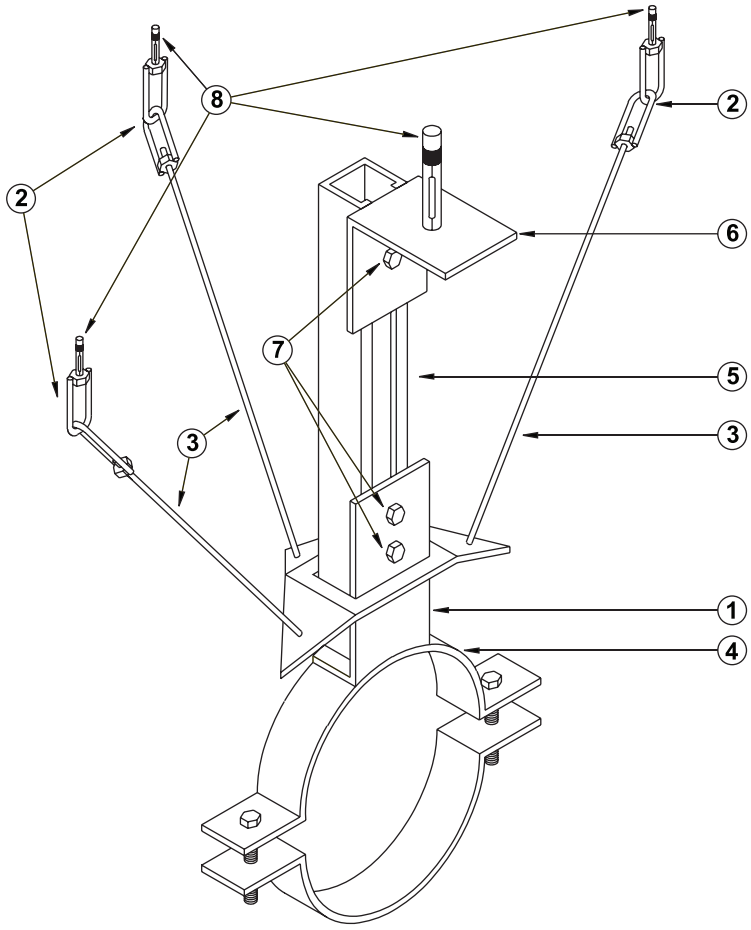
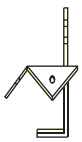
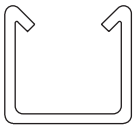
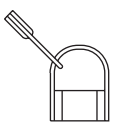
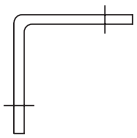
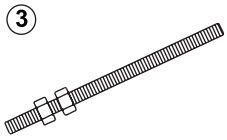
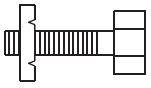
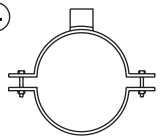
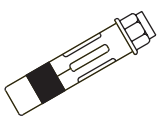


Figure 9-11 Pipe Bracing Systems: (A) Typical Pipe Bracing

Source: SMACNA



1 	Triangle Plate 1/4" Plate 1/4"X1-1/4" Flat Bar	5 	1-1/4"x1-1/4"x12 Ga. Channel Length Varies (Not Included)
2 	1/2" Flexible Connector	6 	1/4" Angle Clip
3 	1/2" All-Thread Rod (Not Included) Length Varies With Nylon Lock Nut	7 	1/4" Dia Mach. Bolt with Clamp Nut 30 Ft # Torque
4 	Pipe Hanger Size and Type Can Vary	8 	Phillips Sleeve Anchor

(B)

Figure 9-11 Pipe Bracing Systems: (B) Tension 360

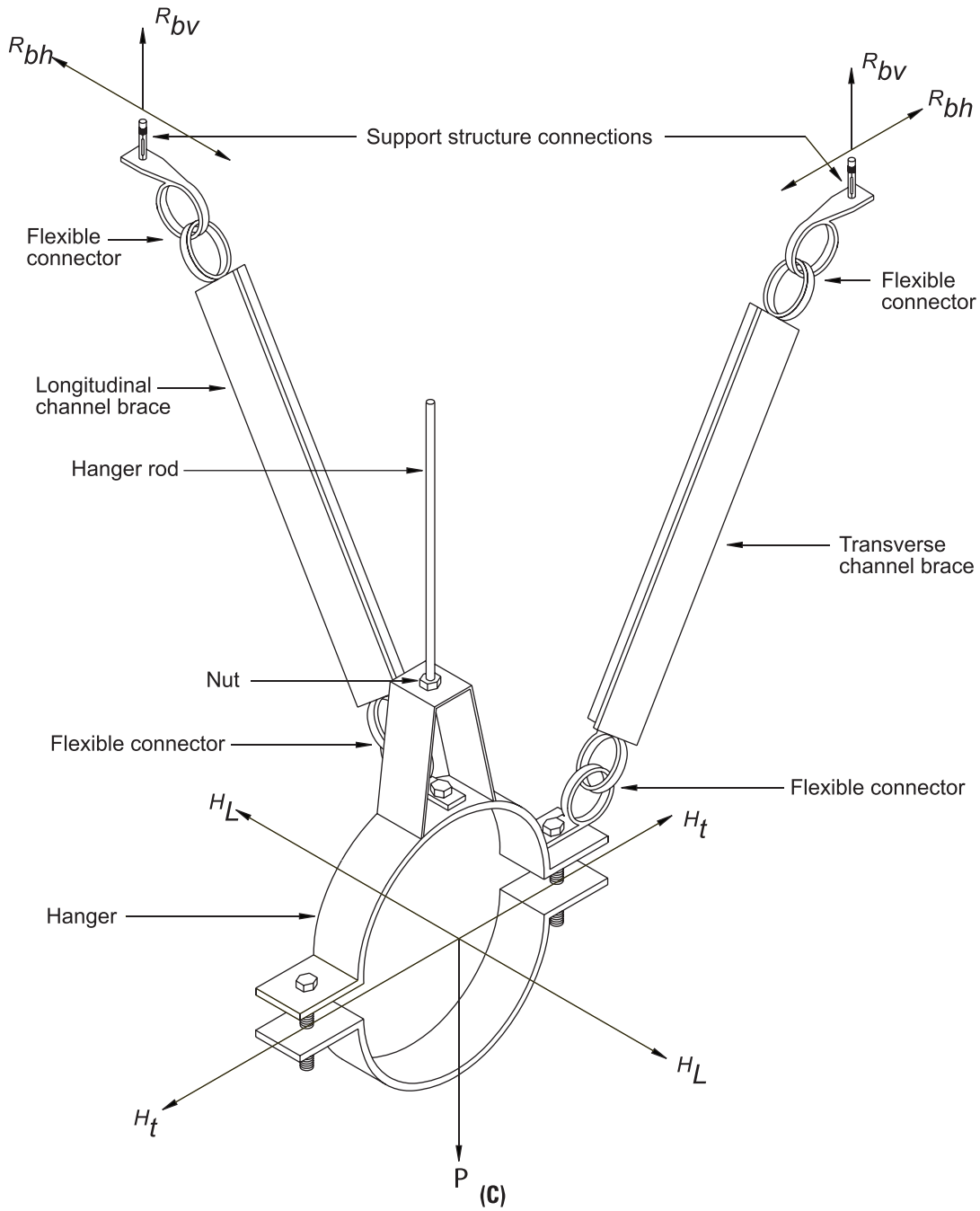


Figure 9-11 Pipe Bracing Systems: (C) Superstrut.

Several bracing systems have been developed that contain some realistic and safe details governing a wide range of loading conditions and configurations. For example, SMACNA (Sheet Metal and Air Conditioning Contractors' National Association) and PPIC (Plumbing and Piping Industry Council) have prepared some guidelines on bracing systems for use by engineers, architects, contractors, and approving authorities. Some of these details for construction of seismic restraints are seen in Figures 9-11 and 9-12.

The guidelines set forth by SMACNA and PPIC utilize three pipe-bracing methods:

1. The structural angle.
2. The structural channel.
3. The aircraft cable method. (See Figure 9-12.)

Several manufacturers have developed their own seismic bracing methods. (See Figures 9-13 and 9-14.)

Whatever method is used, one should determine the adequacy of the supporting structure by properly applying acceptable engineering procedures.

Pipe risers seldom pose a problem because they are normally clamped at each floor and movement due to temperature changes are routinely considered. Very large or stiff configurations, which could be affected by interstory drift, or situations where long, free-hanging horizontal runs could be inadvertently "braced" by a riser, are possible exceptions. The effect of mid-span couplings with less strength or rigidity than the pipe itself must also be considered.

The techniques for handling the possible differential movement at locations of utility entrances to buildings or at building expansion joints are well developed because of the similarity to nonseismic problems of settlement, temperature movement, and wind drift. Expansion loops or combinations of mechanically flexible joints are normally employed. For threaded piping, flexibility may be provided by the installation of swing joints. For manufactured ball joints, the length of piping offset should be calculated using seismic drift of 0.015 feet per foot (0.0046 meter per meter) of height above the base where seismic separation occurs. The primary consideration in seismic applications is to recognize the possibility of repeated, large differential movements.

CODES

Design Philosophy

The process of the seismic design for buildings has had a reasonably long time to mature. Beginning in the 1920s, after engineers observed heavy building damage from earthquakes, they began to consider lateral forces on buildings in this country and Japan. Today's procedures are based on analytical results as well as considerable design experience and observed performance in earthquakes of varying characteristics. Lateral forces for buildings specified in most codes are much lower than could be calculated from structural dynamics for a variety of reasons, including:

1. Observed acceptable performance at low design levels.
2. Expected ductile action of building systems (ability to continue to withstand force and distort after yielding). Redundancy of resisting elements in most systems.
3. High damping as distortions increase, which creates a self-limiting characteristic on response.

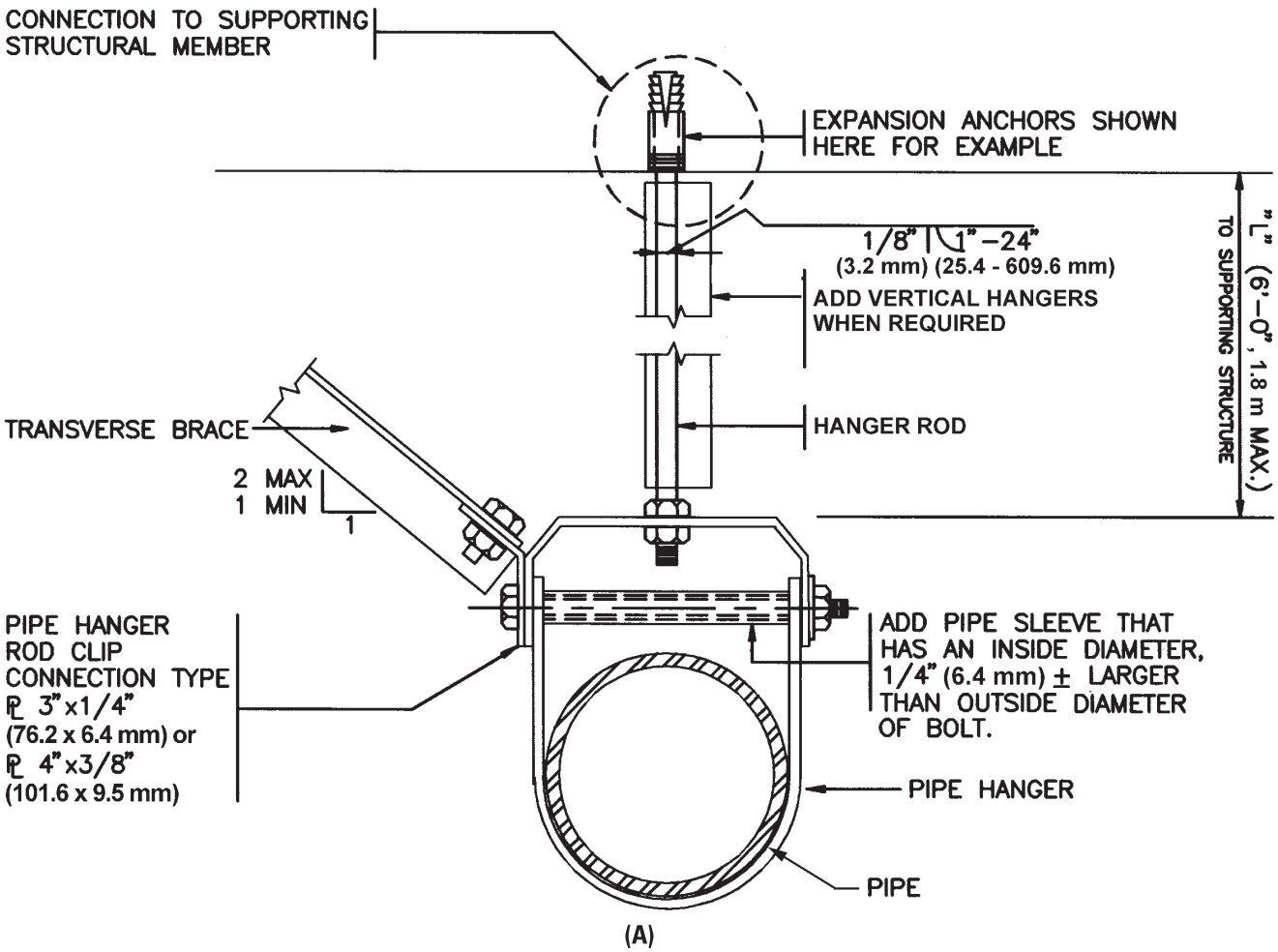
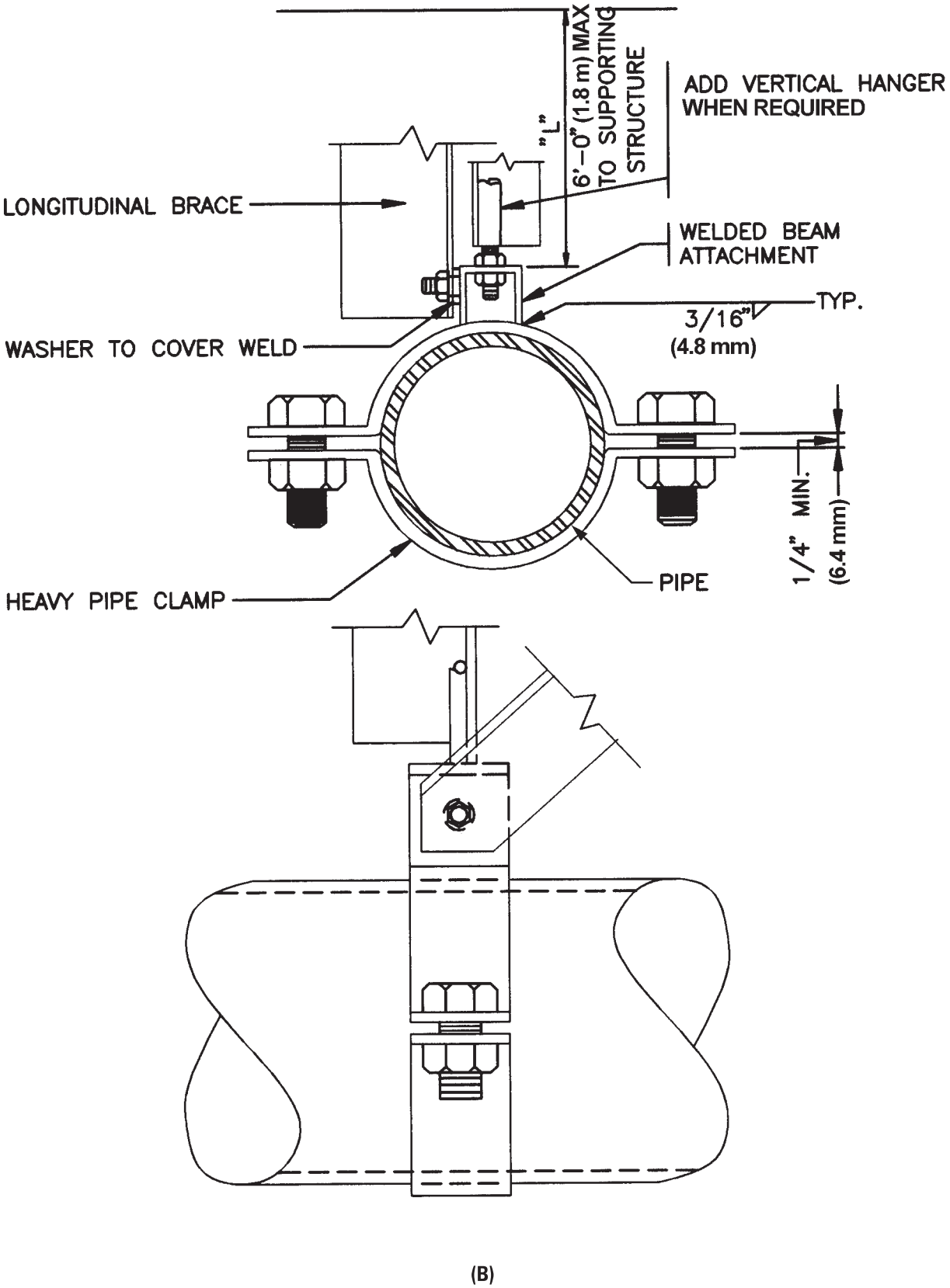


Figure 9-12 Construction Details of Seismic Protection for Pipes: (A) Transverse Bracing for Pipes

Source: SMACNA 1991. Note: For additional information, refer to SMACNA 1991.

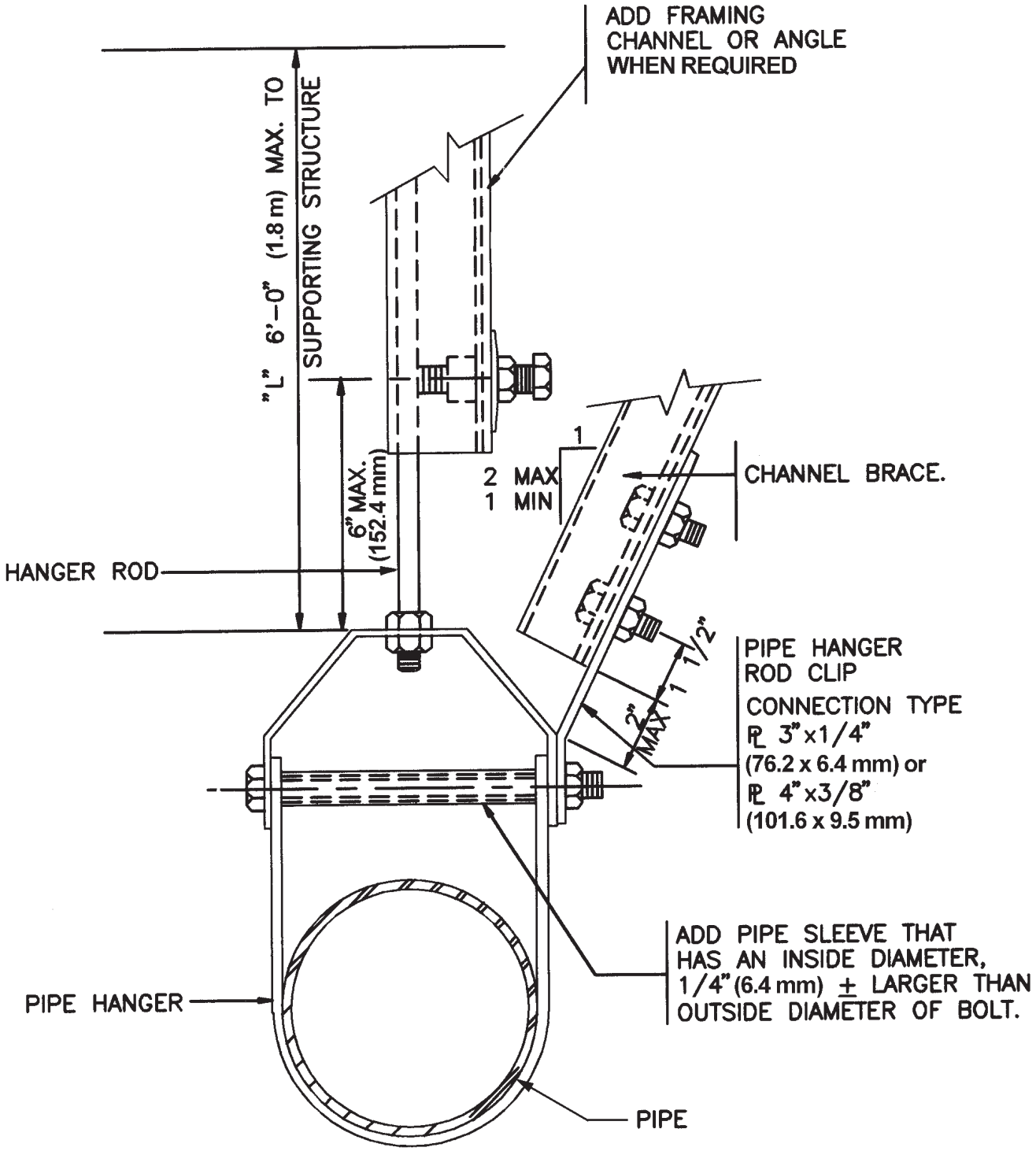


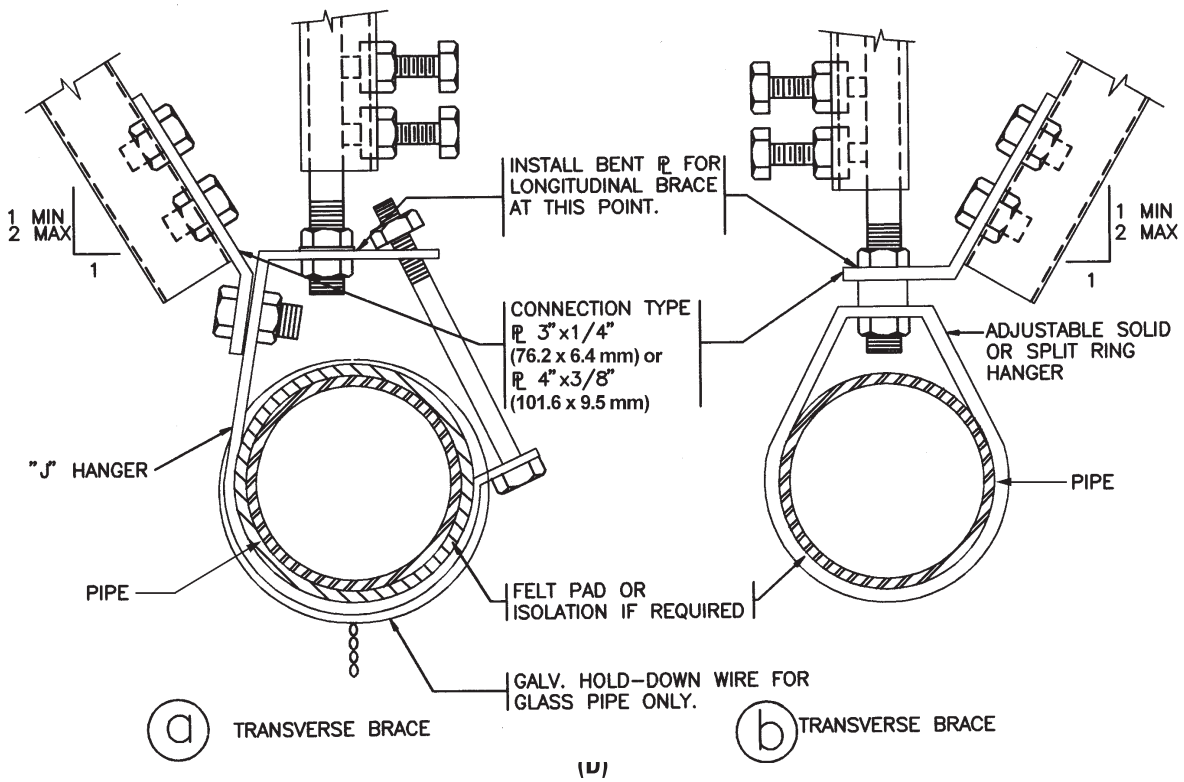
(B)

Figure 9-12 Construction Details of Seismic Protection for Pipes: (B) Longitudinal Bracing for Pipes

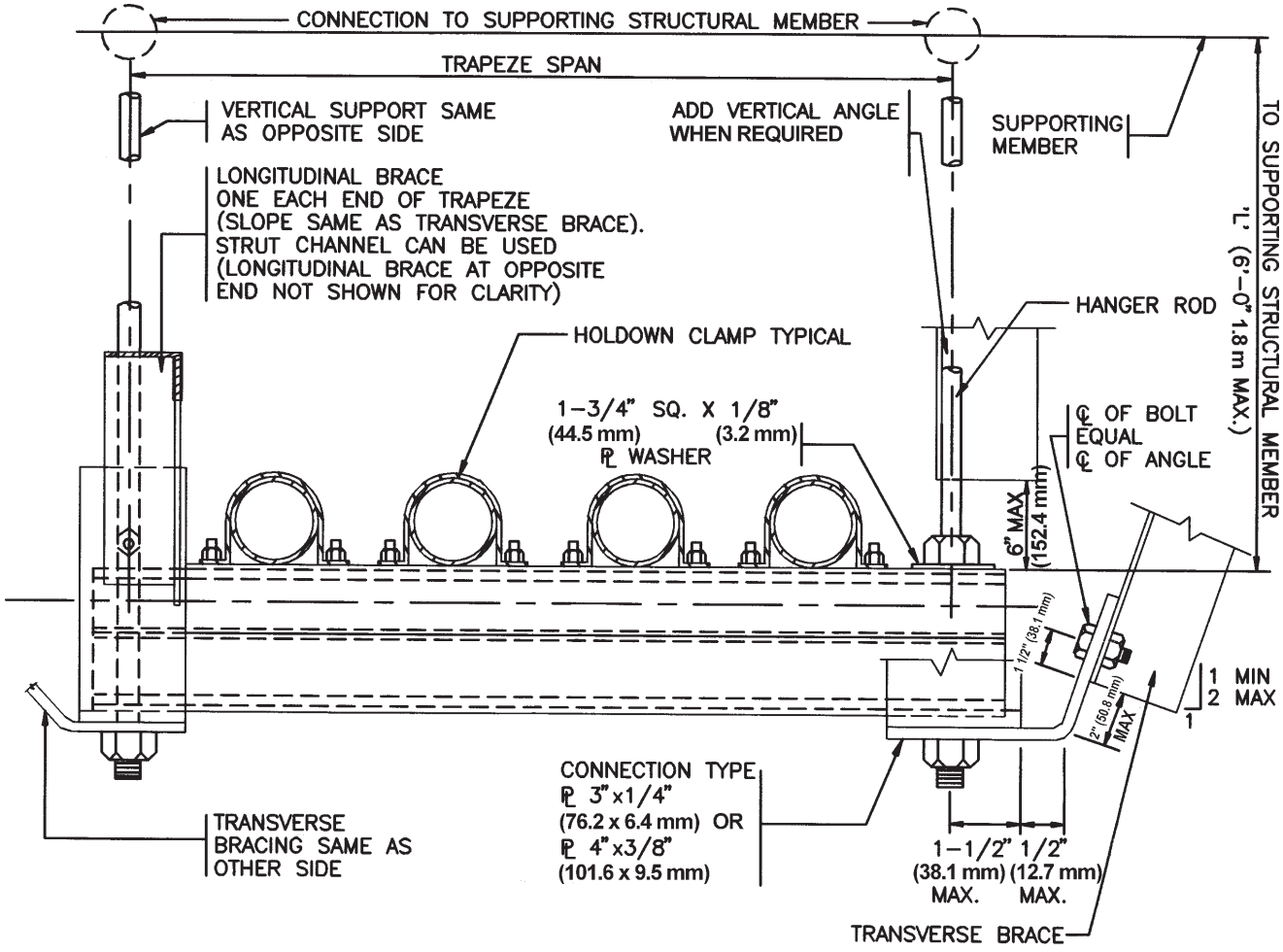
Note: Movement due to temperature has been neglected in this example.

Source: SMACNA 1991. Note: For additional information, refer to SMACNA 1991.


ADD FRAMING CHANNEL OR ANGLE WHEN REQUIRED
"L" 6'–0" (1.8 m) MAX. TO SUPPORTING STRUCTURE
6" MAX. (152.4 mm)
HANGER ROD
1
2 MAX
1 MIN
CHANNEL BRACE.
1 1/2"
2" MAX
PIPE HANGER ROD CLIP CONNECTION TYPE
PL 3"x1/4" (76.2 x 6.4 mm) or
PL 4"x3/8" (101.6 x 9.5 mm)
ADD PIPE SLEEVE THAT HAS AN INSIDE DIAMETER, 1/4" (6.4 mm) ± LARGER THAN OUTSIDE DIAMETER OF BOLT.
PIPE HANGER
PIPE


1 MIN
2 MAX
1
INSTALL BENT PL FOR
LONGITUDINAL BRACE
AT THIS POINT.
CONNECTION TYPE
PL 3"x1/4"
(76.2 x 6.4 mm) or
PL 4"x3/8"
(101.6 x 9.5 mm)
"J" HANGER
PIPE
FELT PAD OR
ISOLATION IF REQUIRED
GALV. HOLD-DOWN WIRE FOR
GLASS PIPE ONLY.
a TRANSVERSE BRACE
1 MIN
2 MAX
1
ADJUSTABLE SOLID
OR SPLIT RING
HANGER
PIPE
b TRANSVERSE BRACE

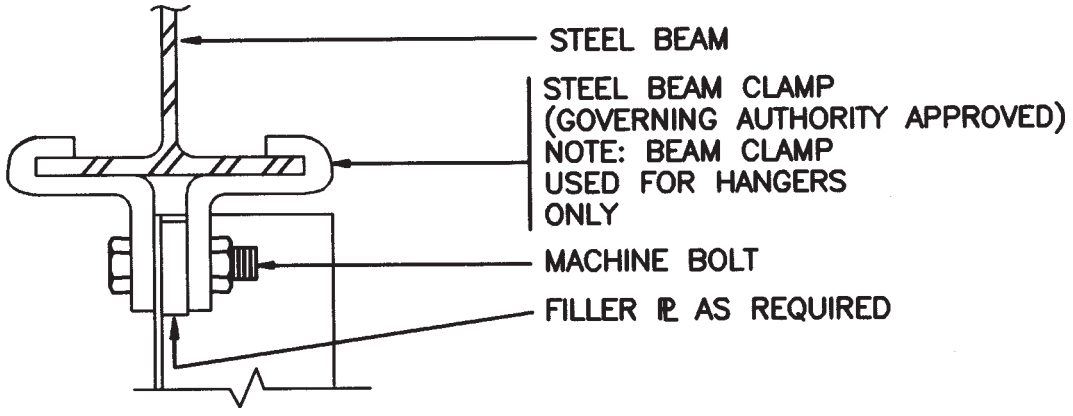
(b)



(F)

Figure 9-12 Construction Details of Seismic Protection for Pipes: (F) Strut Bracing for Pipe Trapeze

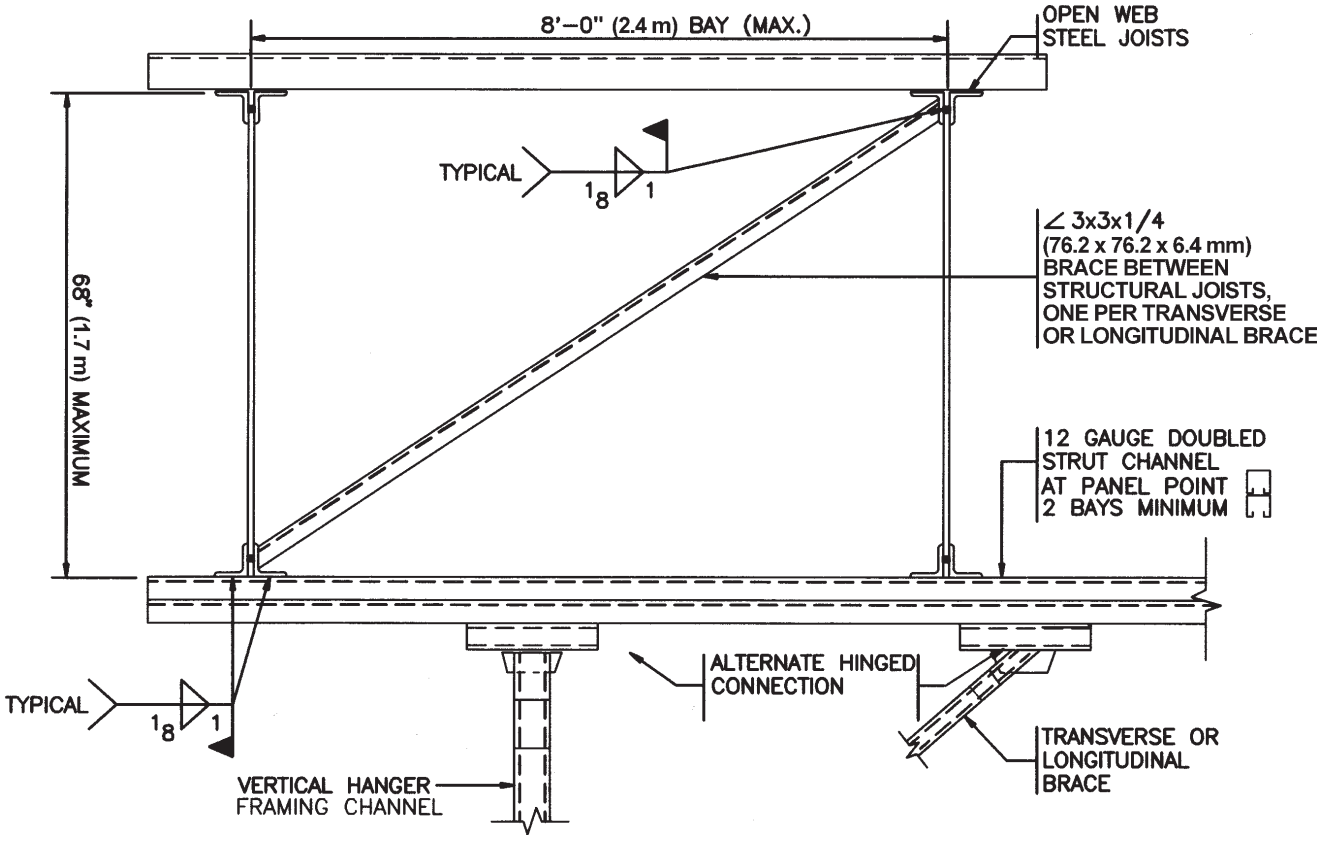
Source: SMACNA 1991. Note: For additional information, refer to SMACNA 1991.



(G)

Figure 9-12 Construction Details of Seismic Protection for Pipes: (G) Connections to Steel Beams

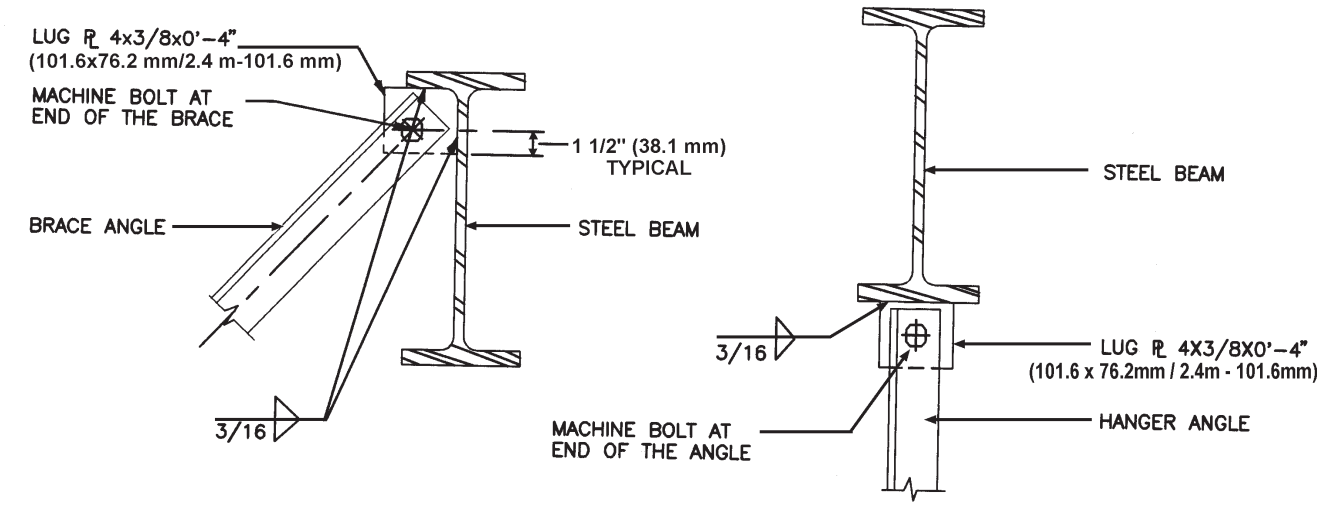
Source: SMACNA 1991. Note: For additional information, refer to SMACNA 1991.



(H)

Figure 9-12 Construction Details of Seismic Protection for Pipes: (H) Connections to Open-Web Steel Joists

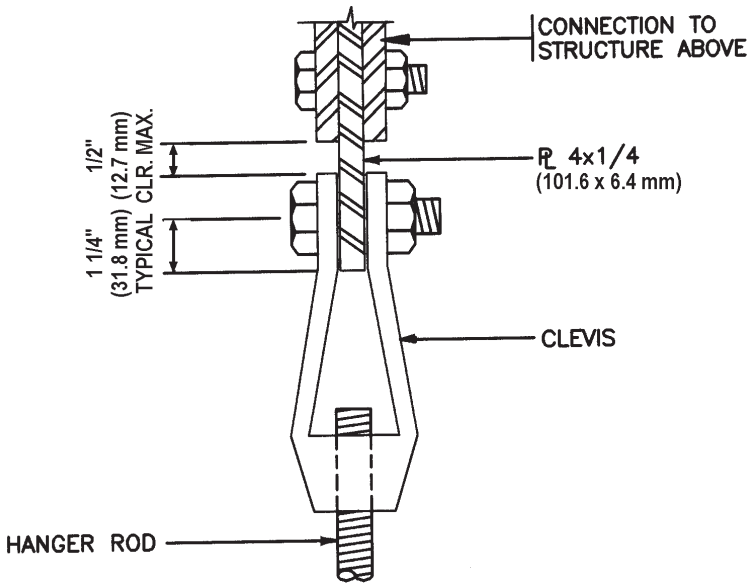
Source: SMACNA 1991. Note: For additional information, refer to SMACNA 1991.



(I)

Figure 9-12 Construction Details of Seismic Protection for Pipes: (I) Connections to Steel

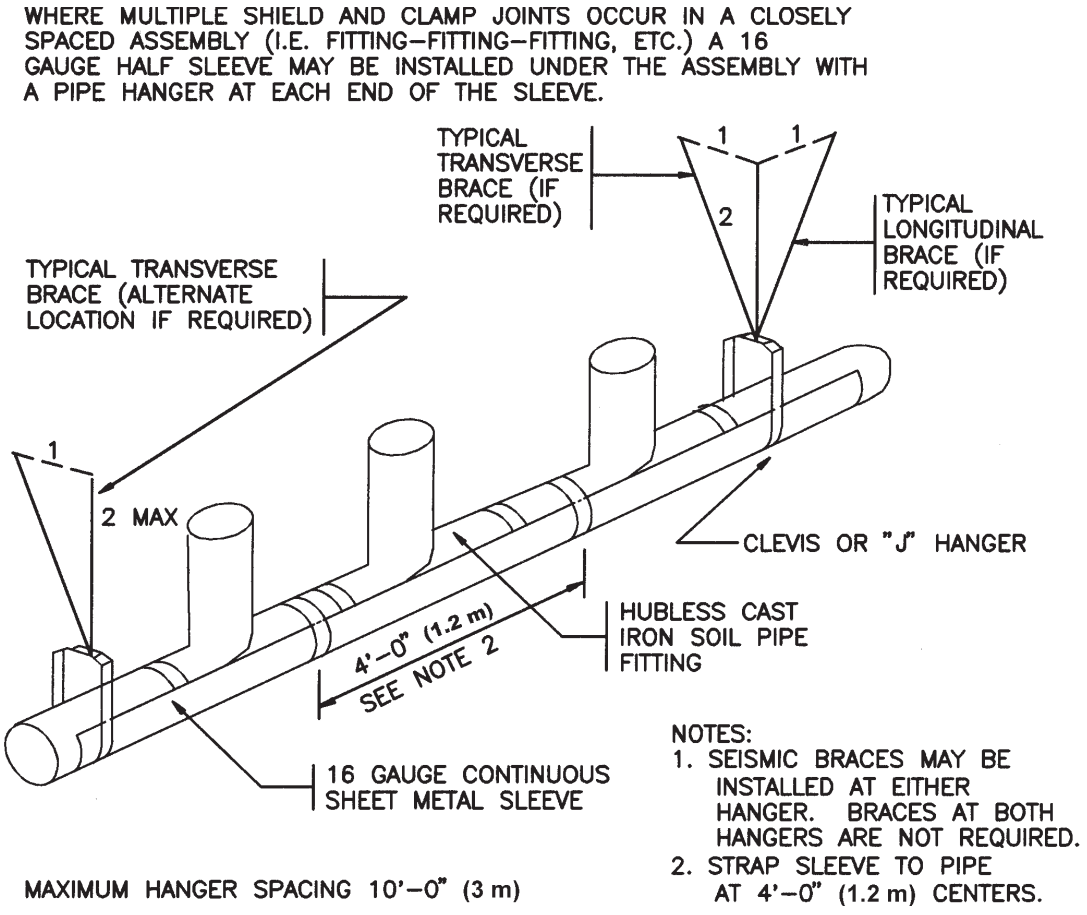
Source: SMACNA 1991. Note: For additional information, refer to SMACNA 1991.



(J)

Figure 9-12 Construction Details of Seismic Protection for Pipes: (J) Hanger Rod Connections

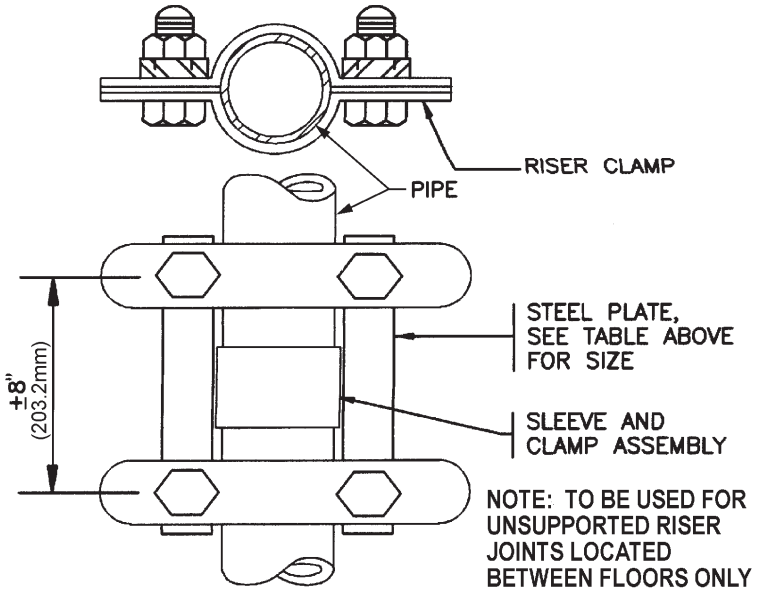
Source: SMACNA 1991. Note: For additional information, refer to SMACNA 1991.



(K)

Figure 9-12 Construction Details of Seismic Protection for Pipes: (K) Hubless Cast-Iron Pipe

Source: SMACNA 1991. Note: For additional information, refer to SMACNA 1991.

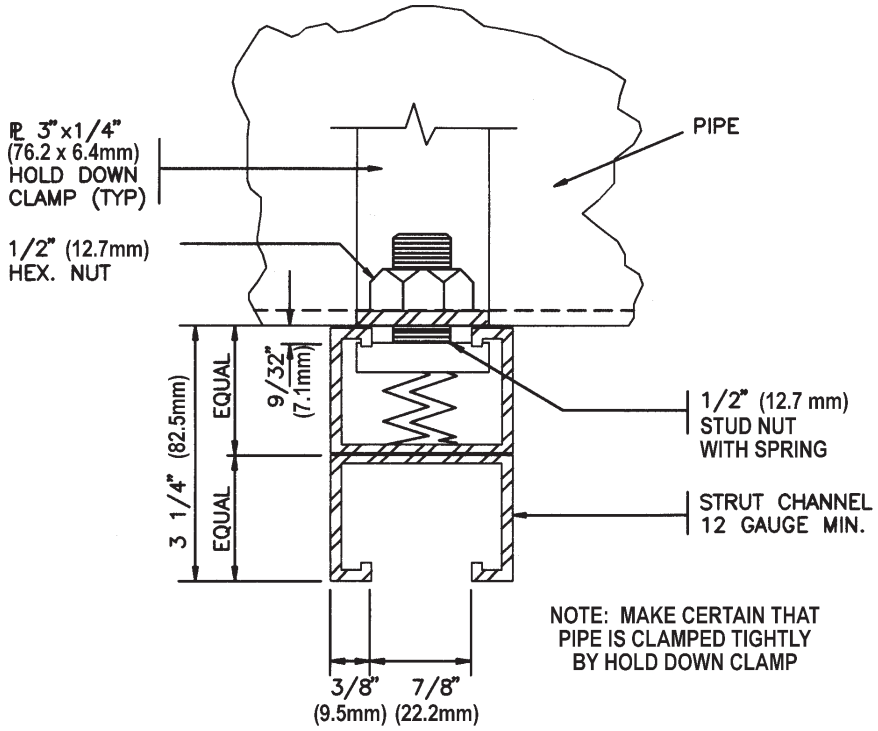


PIPE SIZE	PLATE SIZE	BOLT SIZE
Up To 2" (50.8mm)"	¼" x 1¼" (6.4 x 31.8mm)	¼" (6.4mm)
2½" to 3" (63.5 - 76.2mm)	¼" x 1¼" (6.4 x 31.8mm)	⅜" (9.5mm)
4" and 5" (101.6 & 127mm)	¼" x 1¼" (6.4 x 31.8mm)	½" (12.7mm)
6" (152.4mm)	⅜" x 1½" (9.5 x 38.1mm)	½" (12.7mm)
8" (203.2mm)	⅜" x 1½" (9.5 x 38.1mm)	⅝" (15.9mm)

(L)

Figure 9-12 Construction Details of Seismic Protection for Pipes: (L) Riser Bracing for Hubless Pipes

Source: SMACNA 1991. Note: For additional information, refer to SMACNA 1991.



(M)

Figure 9-12 Construction Details of Seismic Protection for Pipes: (M) Connections for Pipes on Trapeze.

Source: SMACNA 1991. Note: For additional information, refer to SMACNA 1991.

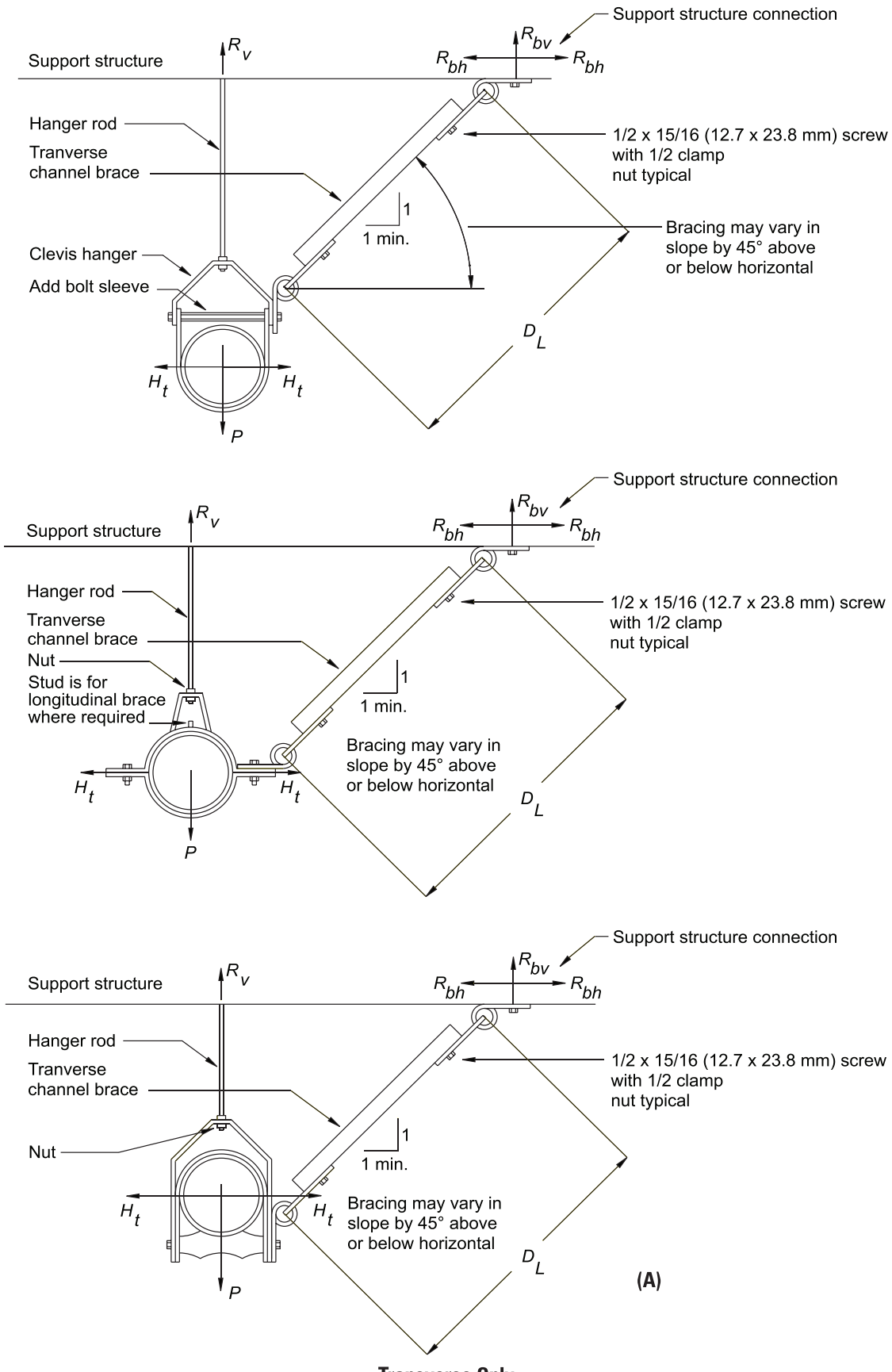


Figure 9-13 Sway Bracing, 0.5 G Force

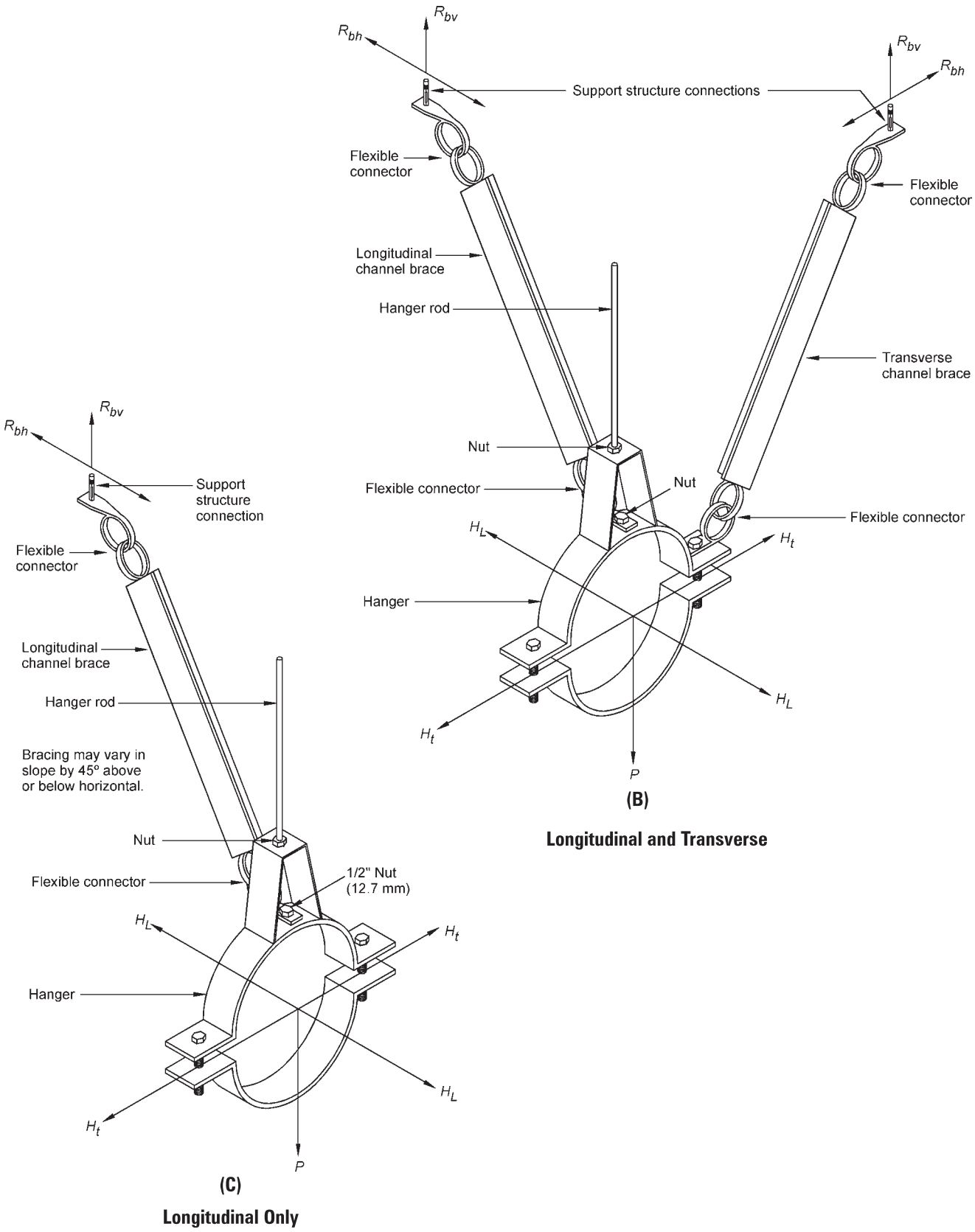
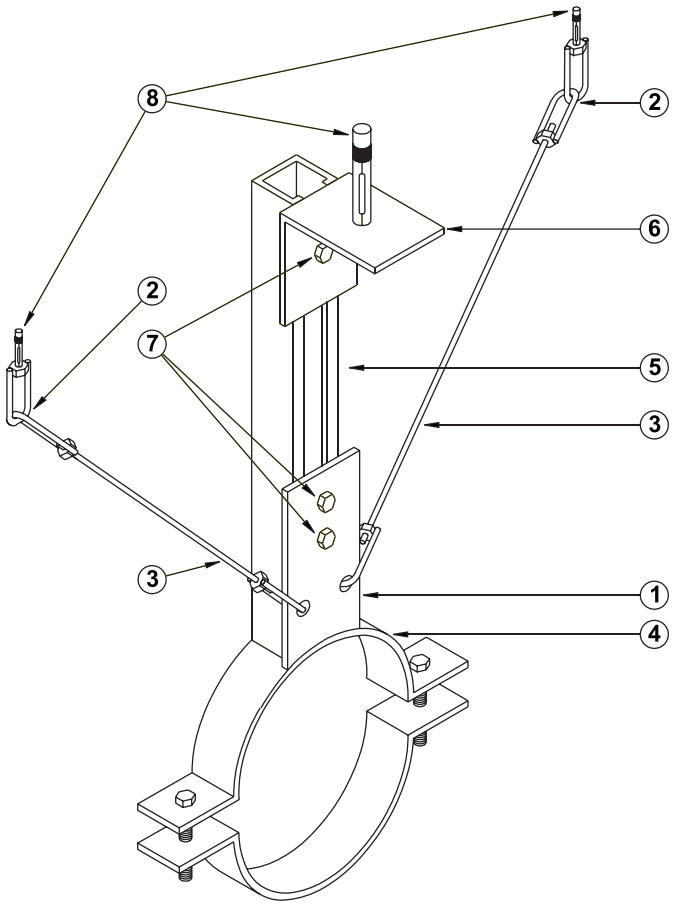
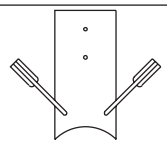
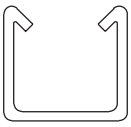
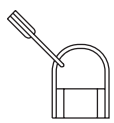
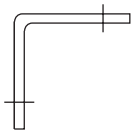
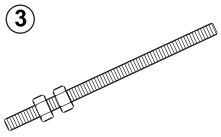
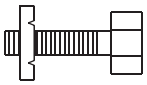
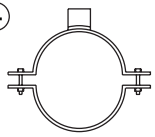
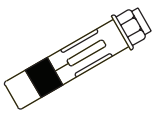


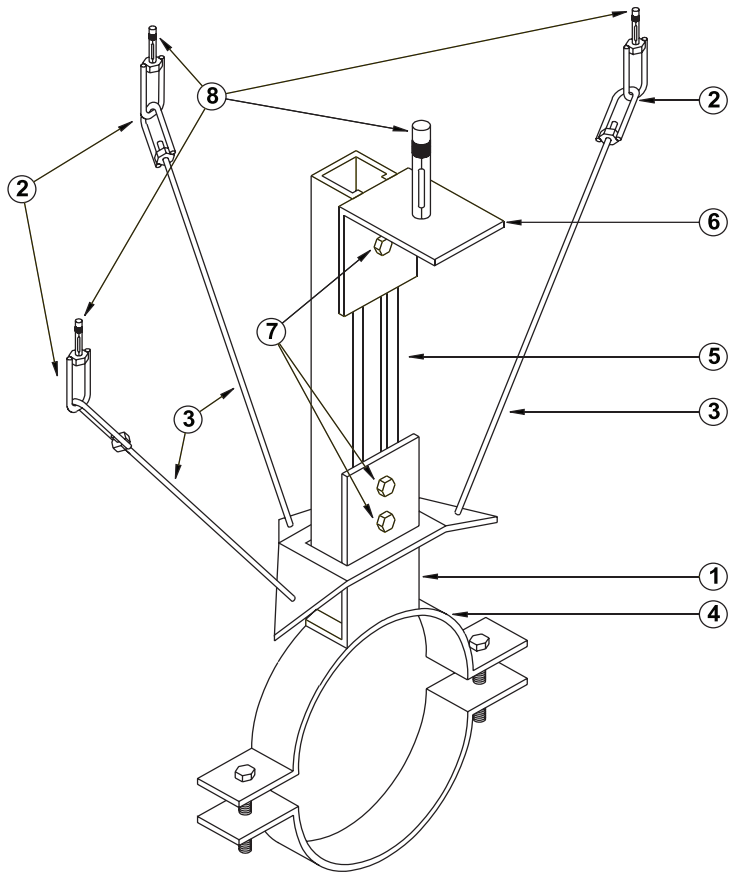
Figure 9-13 Sway Bracing, 0.5 G Force (continued)

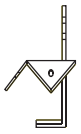
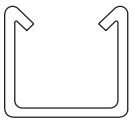
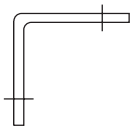
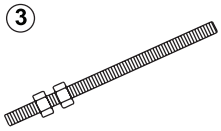
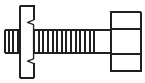
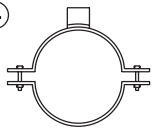
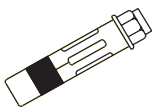


1 	Brace Plates Type Thickness Links 1 3/8" (9.5mm) 1/2" (12.7mm) 2 1/2" (12.7mm) 5/8" (15.8mm)	5 	Strut Type 1 1-5/8"(41.3mm)x1-5/8"(41.3mm)x12 Ga 2 1-5/8"(41.3mm)x1-5/8"(41.3mm)x12 Ga
2 	Connectors Type Diameter 1 1/2" (12.7mm) 2 5/8" (15.8mm)	6 	Angle Clip Type Thickness Hole Dia. 1 3/8" (9.5mm) 9/16" (14.3mm) 2 1/2" (12.7mm) 11/16" (17.5mm)
3 	All-Thread Rod & Nylock Nuts Type Diameter 1 1/2" (12.7mm) 2 5/8" (15.8mm) (4 Tension Rods Required)	7 	Bolts & Clamping Nut Type Diameter 1 1/2" (12.7mm) 2 5/8" (15.8mm)
4 	Pipe Clamp Model Selection per pipe Clamp & Accessory Detail	8 	Drilled Sleeve Anchor

(A)

Figure 9-14 A Seismic Bracing Method: (A) Lateral Sway Bracing



① 	Brace Plates Type Thickness 1 3/8" (9.5mm) 2 1/2" (12.7mm)	⑤ 	Strut 1-5/8"(41.3mm) x 1-5/8"(41.3mm) x 12 Ga Length Varies
② 	Connectors Type Diameter 1 1/2" (12.7mm) 2 5/8" (15.8mm)	⑥ 	Angle Clip Type Thickness Hole Dia. 1 3/8" (9.5mm) 9/16" (14.3mm) 2 1/2" (12.7mm) 11/16" (17.5mm)
③ 	All-Thread Rod & Nylock Nuts Type Diameter 1 1/2" (12.7mm) 2 5/8" (15.8mm)	⑦ 	Bolts & Clamping Nut Type Diameter 1 1/2" (12.7mm) 2 5/8" (15.8mm)
④ 	Pipe Clamp Model Selection per pipe Clamp & Accessory Detail	⑧ 	Drilled Sleeve Anchor

(B)

Figure 9-14 A Seismic Bracing Method: (B) Lateral and Longitudinal Sway Bracing.

4. Less-than-perfect compliance of the foundation to the ground motion.
5. Economic restraints on building codes.

The fact that the actual response of a building during an earthquake could be 3 or 4 times that represented by code forces must be understood and considered in good seismic design. Traditionally, this is done by rule of thumb and good judgment to ensure that structural yielding is not sudden or does not produce a collapsed mechanism. More recently, the response of many buildings to real earthquake input is being considered more specifically using computer analysis.

Design of seismic protection for nonstructural elements, including plumbing components and equipment, has neither the tradition nor a large number of in-place tests by actual earthquakes to enable much refinement of design force capability or design technique. Unfortunately, few of the effects listed above that mitigate the low force level for structures apply to plumbing or piping. Equipment and piping systems are generally simple and have low damping, and their lateral force resisting systems are usually nonredundant. It is imperative, therefore, when designing seismic protection for these elements, to recognize whether force levels being utilized are arbitrarily low for "design" or realistic predictions of actual response. Even when predictions of actual response are used, earthquake forces are considered sufficiently unpredictable when friction is not allowed as a means of "anchorage." Often, less-than-full dead load is used to both simulate vertical accelerations and to provide a further safety factor against overturning or swinging action.

Code Requirements

All current building codes require most structures and portions of structures to be designed for a horizontal force based on a certain percentage of its weight. Each code may vary in the method of determining this percentage, based on factors including the seismic zone, the importance of the structure, and the type of construction.

It is difficult to consider specific code requirements out of context. The code documents themselves should be consulted for specific usage. Most codes currently in use, or being developed, can generally be discussed by considering these four:

1. *Uniform Building Code 1997* (UBC).

For reference, the following three tables provide good information for the engineer. Table 9-1 provides weights of steel pipes filled with water for determining horizontal loads. Table 9-2 provides load information for the spacing of sway bracing, and Table 9-3 provides maximum horizontal loads for sway bracing.

ANALYSIS TECHNIQUES

Determination of Seismic Forces

As discussed in the previous section, the most common method of defining seismic forces is by use of code static equivalents of dynamic earthquake forces. Regardless of the parameters used, this procedure reduces to the following formula:

Equation 9-1

$$F_p = K_g$$

Table 9-3 Maximum Horizontal Loads for Sway Bracing

Shape and Size, in. (mm)		Least Radius of Gyration	Maximum Length for 1/r = 200		Maximum Horizontal Load, lb (kg)					
					30-44° Angle from Vertical		45-59° Angle from Vertical		60-90° Angle from Vertical	
Pipe (Schedule 40)		$= \frac{\sqrt{r_0^2 + r_1^2}}{2}$								
1	(25.4)	0.42	7 ft 0 in	(2.1 m)	1,767	(801.5)	2,500	(1134.0)	3,061	(1388.4)
1¼	(31.8)	0.54	9 ft 0 in	(2.7 m)	2,393	(1085.4)	3,385	(1535.4)	4,145	(1880.1)
1½	(38.1)	0.623	10 ft 4 in	(3.1 m)	2,858	(1296.4)	4,043	(1833.9)	4,955	(2241.5)
2	(50.8)	0.787	13 ft 1 in	(4 m)	3,828	(1736.3)	5,414	(2455.7)	6,630	(3007.3)
Pipe (Schedule 10)		$= \frac{\sqrt{r_0^2 + r_1^2}}{2}$								
1	(25.4)	0.43	7 ft 2 in	(2.2 m)	1,477	(670.0)	2,090	(948.0)	2,559	(1160.7)
1¼	(31.8)	0.55	9 ft 2 in	(2.8 m)	1,900	(861.8)	2,687	(1218.8)	3,291	(1492.8)
1½	(38.1)	0.634	10 ft 7 in	(3.2 m)	2,194	(995.2)	3,103	(1407.5)	3,800	(1723.6)
2	(50.8)	0.802	13 ft 4 in	(4.1 m)	2,771	(1256.9)	3,926	(1780.8)	4,803	(2178.6)
Angles										
1½ x 1½ x ¼	(38.1 x 38.1 x 6.4)	0.292	4 ft 10 in	(1.5 m)	2,461	(1116.3)	3,481	(1578.9)	4,263	(1933.7)
2 x 2 x ¼	(50.8 x 50.8 x 6.4)	0.391	6 ft 6 in	(2 m)	3,356	(1522.2)	4,746	(2152.7)	5,813	(2636.7)
2½ x 2 x ¼	(63.5 x 50.8 x 6.4)	0.424	7 ft 0 in	(2.1 m)	3,792	(1720.0)	5,363	(2432.6)	6,569	(2979.6)
2½ x 2½ x ¼	(63.5 x 63.5 x 6.4)	0.491	8 ft 2 in	(2.5 m)	4,257	(1930.9)	6,021	(2731.1)	7,374	(3344.8)
3 x 2½ x ¼	(76.2 x 63.5 x 6.4)	0.528	8 ft 10 in	(2.7 m)	4,687	(2126.0)	6,628	(3006.4)	8,118	(3682.2)
3 x 3 x ¼	(76.2 x 76.2 x 6.4)	0.592	9 ft 10 in	(3 m)	5,152	(2336.9)	7,286	(3304.9)	8,923	(4047.4)
Rods		$= \frac{r}{2}$								
3/										

Shape and Size, in. (mm)	Least Radius of Gyration	Maximum Length for 1/r = 200	Maximum Horizontal Load, lb (kg)		
			30-44° Angle from Vertical	45-59° Angle from Vertical	60-90° Angle from Vertical
Rods	$= \frac{r}{2}$				
3/					

In typical pipe braces [Figure 9-16(B)], it is important to note that R, the gravity force in the hanger rod, is significantly affected by the addition of the brace and is not equal to W, as indicated previously. Dealing with these loads is a huge problem. A tension rod hanger commonly goes into compression in such a situation. Cable restraints do not have this problem.

COMPUTER ANALYSIS OF PIPING SYSTEMS

Computers programs have been used to analyze piping systems for stress for some time. These programs were initially developed to consider thermal stresses and anchor point load, but software is now commonly available that can consider seismic and settlement loading, spring or damping supports, snubbers (similar to equipment snubbers), differing materials, and nonrigid couplings. The seismic loading normally can be figured by using a full-time history, as a response spectrum, or equivalent static forces. The time history has the inherent problem of requiring a search of each time increment for worst-case stresses and brace loadings. The computer time and man-hours required are seldom justified. In fact, for seismic loading alone, computer analysis is almost never performed because brace loadings can easily be determined by tributary length methods, and rule-of-thumb pipe spans (brace spacing) are contained in several publications (see National Fire Protection Association 1996; Hillman, Biddison, and Loevenguth; and U.S. Dept. of Defense 1973). Computer analysis may be appropriate, however, when it is necessary to combine seismic loading with several of the following considerations:

1. Temperature changes and anchorage.
2. Nonlinear support conditions (springs, snubbers, etc.).
3. Complex geometry.
4. Several loading conditions.
5. Piping materials other than steel or copper.
6. Joints or couplings that are significantly more flexible or weaker than the pipe itself.

Because of the variety of computer programs available and because many have proprietary restrictions, specific programs are not listed here. Piping analysis programs are available at most computer service bureaus, many universities, and national computer program clearinghouses.

DESIGN CONSIDERATIONS

Loads in Structures

It is always important to identify unusual equipment and piping loads during the first stages of project design to assure that the structural system being developed is adequate. Consideration of seismic effects makes this coordination even more important because seismic forces produce unusual reactions. During an earthquake, not only must horizontal forces be taken into the structure, but vertical load effects are intensified due to vertical accelerations and overturning movements. These reactions must be acceptable to the structure locally (at the point of connection) and globally (by the system as a whole).

If the structural system is properly designed for the appropriate weights of equipment and piping, seismic reactions will seldom cause problems to the overall system. However, local problems are not uncommon. Most floors are required by code to withstand a 2000-pound (908 kg) concentrated load, so this is a reasonable load to consider acceptable without special provisions. However, seismic reactions to structures can easily exceed this figure; for example:

1. A longitudinal brace carrying a tributary load of 80 feet (24.8-m) of 8-inch (203-mm) steel pipe filled with water will generate reactions of this magnitude.
2. Transverse or longitudinal braces on trapezes often have larger reactions.
3. A 4000-pound (1816-kg) tank on legs could also yield such a concentrated load. In addition, possible limitations on attachment methods due to structure type could reduce the effective maximum allowable concentration.

Roof structures have no code-specified concentrated load requirement and often are the source of

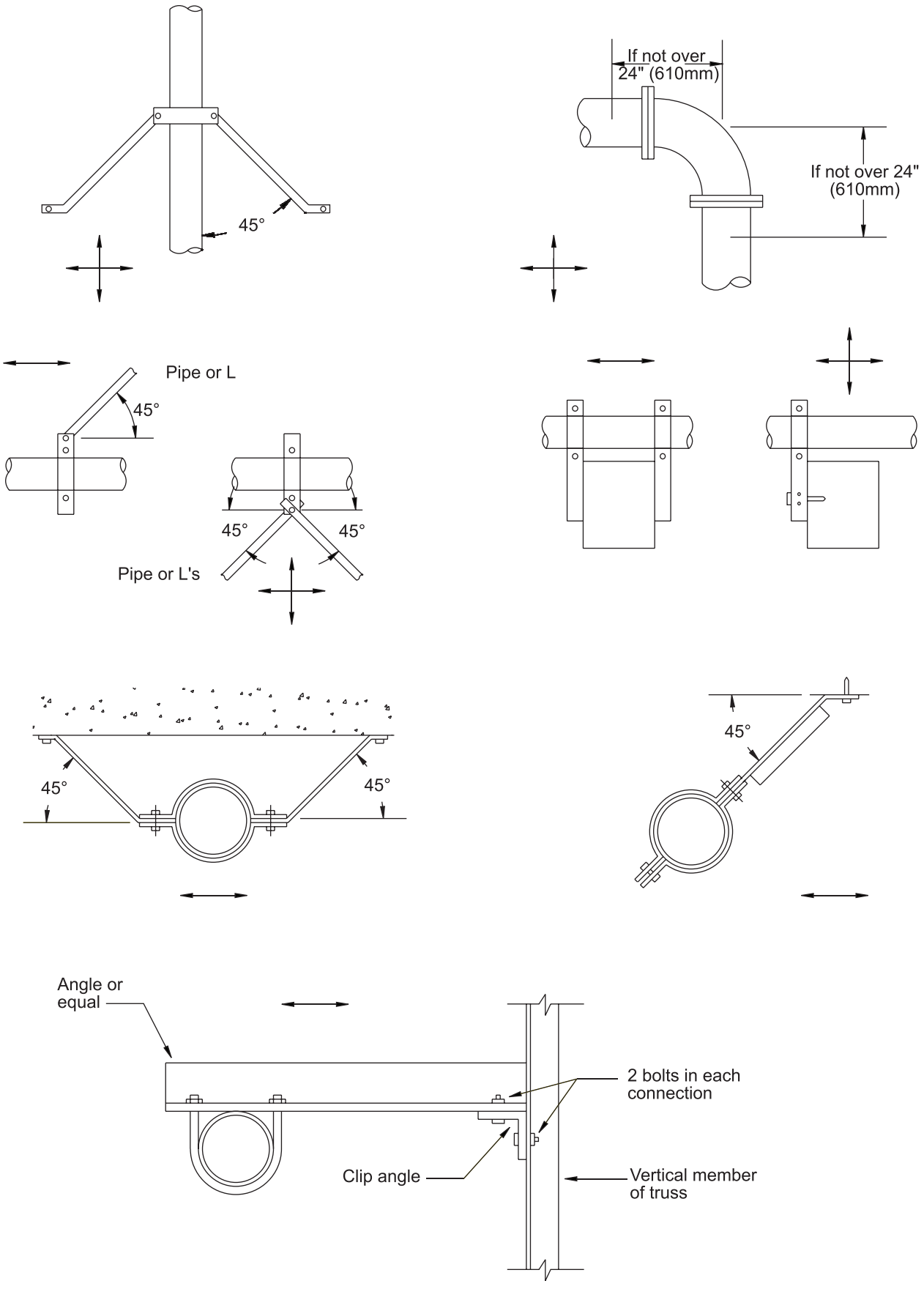


Figure 9-15 Acceptable Types of Sway Bracing

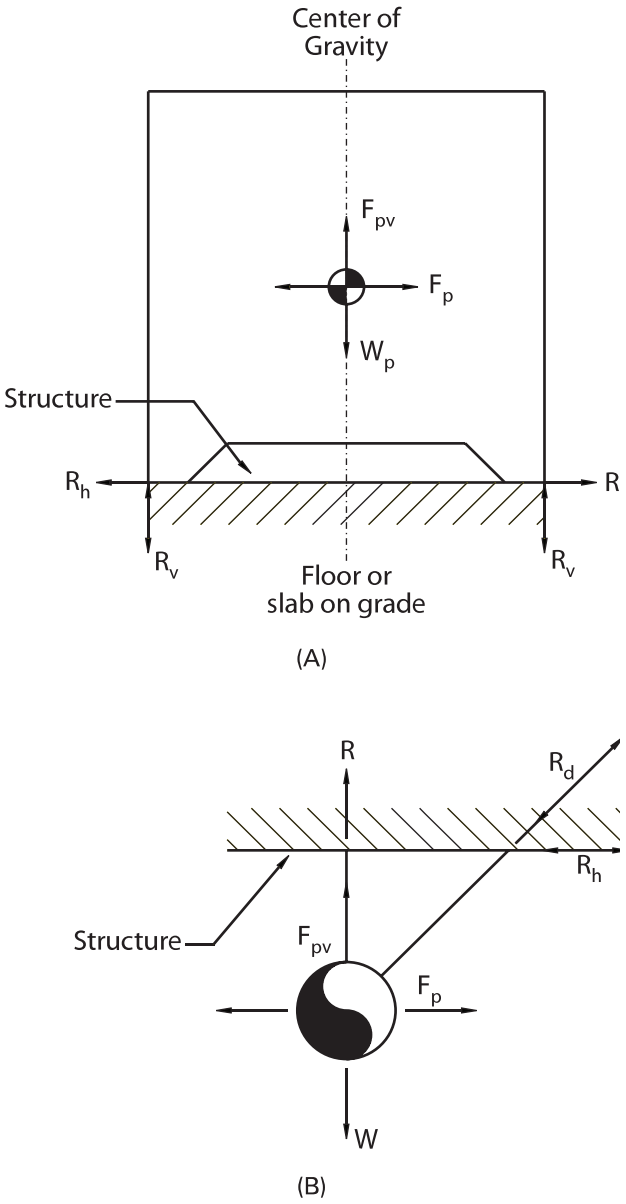


Figure 9-16 Forces for Seismic Design: (A) Equipment; (B) Piping.

problems, particularly concerning piping systems, because of the random nature of hanger-and-brace locations. Many roof-decking systems cannot accept concentrations greater than 50 pounds (22.7 kg) without spreaders or strengthening beams. Such limitations should be considered both in the selection of a structural system and in the equipment and piping layout.

If equipment anchorage or pipe bracing is specified to be contractor supplied, attachment load limitations or other structural criteria should be given. Compliance with such criteria should be checked to assure that the structure is not being damaged or overloaded.

POTENTIAL PROBLEMS

It would be impractical to cover the details of structural design for seismic anchorage and bracing in this chapter. The engineer can get design information and techniques from standard textbooks and design manuals or, preferably, obtain help from a professional experienced in seismic and/or structural design. Simple, typical details are seldom appropriate, and all-encompassing, seismic-protection "systems" quickly become complex. Certain common situations that have the potential to create problems can be identified, however; these are shown schematically in Figure 9-17 (see page 194) and discussed below.

Condition 1 in Figure 9-17 occurs frequently in making attachments to concrete. Often an angle is used, as indicated. The seismic force, P, enters the connector eccentric to the reaction, R, by the distance e; this is equivalent to a concentric force plus the moment P_e. In order for the connector to perform as designed, this moment must be resisted by the connection of the angle either to the machine or to the concrete. To use the machine to provide this moment, the machine base must be adequate, and the connection from angle to base must be greatly increased over that required merely for P. Taking this moment into the concrete significantly increases the tension in the anchorage, R, which is known as "prying action." The appropriate solution must be decided on a case-by-case basis, but eccentricities in connection should not be ignored.

Legs 18 inches (457 mm) or longer supporting tanks or machines clearly create a sideways problem and are commonly cross-braced. However, shorter legs or even rails often have no strength or stiffness in their weak direction, as shown in Condition 2, and should also be restrained against base failure.

Conditions 3 and 4 point out that spring isolators typically create a significant height, h, through which lateral forces must be transmitted. This height, in turn, creates conditions similar to the problems shown in 1 or 2 and must be treated in the same manner.

Condition 5 is meant to indicate that seldom can the bottom flange of a steel beam resist a horizontal force; diagonal braces, which are often connected to bottom flanges, create such a horizontal force. This condition can be rectified by attaching the diagonal brace near the top flange or adding a stabilizing element to the bottom flange.

Condition 6 depicts a typical beam connection device (beam clamp), which slips over one flange. Although this is often acceptable, significant stresses can be introduced into the beam if the load is large or the beam small. Considering the variability and potential overload characteristics of seismic forces, this condition should probably be avoided. Condi-

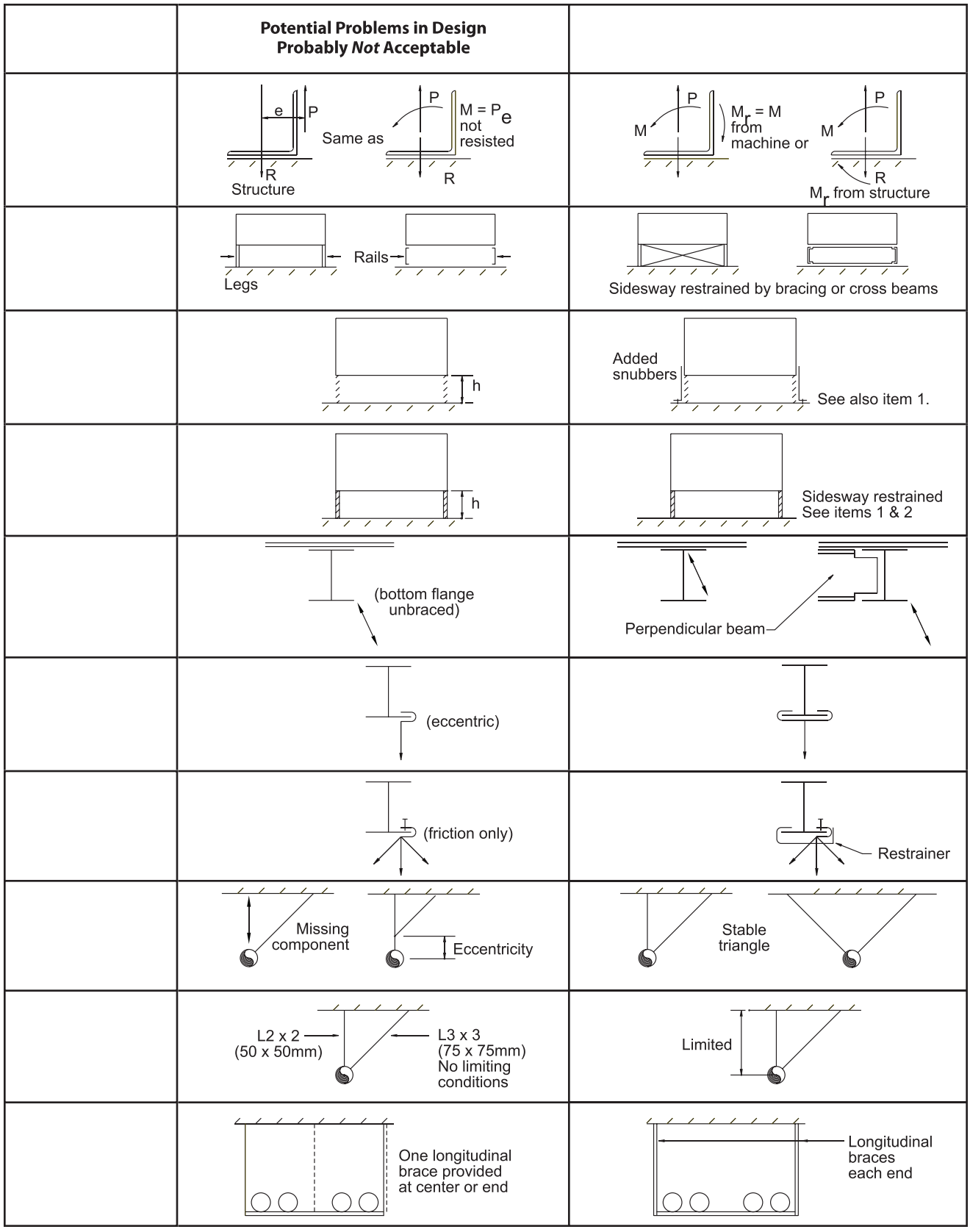


Figure 9-17 Potential Problems in Equipment Anchorage or Pipe Bracing

tion 7 also shows a connector in common use, which is probably acceptable in a nonseismic environment but which should be secured in place as shown under dynamic conditions.

Most pipe bracing systems utilize bracing members in pure tension or compression for stiffness and efficiency. This truss-type action is only possible when bracing configurations make up completed triangles, as shown on the right under condition 8. The brace configuration on the far left is technically unstable and the eccentric condition shown produces moment in the vertical support.

As previously indicated, "typical" details must be carefully designed and presented to prevent their misuse. Condition 9 shows the most common deficiency: A lack of limiting conditions.

Condition 10 shows a situation often seen in the field where interferences may prevent placement of longitudinal braces at the ends of a trapeze and either one is simply left out or two are replaced by one in the middle. Both of these "substitutions" can cause an undesirable twist of the trapeze and subsequent pipe damage. All field revisions to bracing schemes should be checked for adequacy.

Other potential problems that occur less frequently include incompatibility of piping systems with differential movement of the structure (drift) and inadvertent "self bracing" of piping through short, stiff service connections or branches that penetrate the structure. If the possibility of either is apparent, pipe stresses should be checked or the self-bracing restraint eliminated.

A few problems associated with making connection to a structure were discussed above, in relation to 9-17. When connecting to structural steel, in addition to manufactured clip devices, bolting and welding are also used. Holes for bolting should never be placed in structural steel without the approval of the structural engineer responsible for the design. Field welding should consider the effects of elevated temperatures on loaded structural members.

The preferred method of connecting to concrete is through embedments, but this is seldom practical. Since the location of required anchorages or braces is often not known when concrete is poured, the use of drilled-in or shot-in anchors is prevalent for this purpose. Although these anchors are extremely useful and practically necessary connecting devices, their adequacy has many sensitivities and they should be applied with thorough understanding and caution. The following items should be considered in the design or installation of drilled or shot-in anchors:

1. Manufacturers often list ultimate (failure) values in their literature. Normally, factors of safety of 4 or 5 are applied to these values for design.
2. Combined shear and tension should be considered in the design. A conservative approach commonly used is the following equation:

Equation 9-2

$$(T/T_a) + (V/V_a$$

the result of observations of damage to structures in actual earthquakes over 75 years.

The net result of current standards in seismic protection can only be positive. The fine-tuning of scope, force levels, and detailing techniques must wait for additional, full-scale testing in real earthquakes.

GLOSSARY

Anchor A device, such as an expansion bolt, for connecting pipe-bracing members into the structure of a building.

Attachment See "positive attachment."

Bracing Metal channels, cables, or hanger angles that prevent pipes from breaking away from the structure during an earthquake. See also "longitudinal bracing" and "transverse bracing." Together, these resist lateral loads from any direction.

Dynamic properties of piping The tendency of pipes to change in weight and size because of the movement and temperature of fluids in them. This does not refer to movement due to seismic forces.

Essential facilities Buildings that must remain safe and usable for emergency purposes after an earthquake in order to preserve the health and safety of the general public. Examples include hospitals, emergency shelters, and fire stations.

Equipment For the purposes of this chapter, "equipment" refers to the mechanical devices associated with pipes that have significant weight. Examples include pumps, tanks, and electric motors.

Gas pipe For the purposes of this chapter, "gas pipe" is any pipe that carries fuel gas, fuel oil, medical gas, vacuum, or compressed air.

Lateral force A force acting on a pipe in the horizontal plane. This force can be in any direction.

Longitudinal bracing Bracing that prevents a pipe from moving in the direction of its run.

Longitudinal force A lateral force that happens to be in the same direction as the pipe.

OSHPD Office of Statewide Health Planning and Development (California).

Positive attachment A mechanical device designed to resist seismic forces that connects a nonstructural element, such as a pipe, to a structural element, such as a beam. Bolts and screws are examples of positive attachments. Glue and friction due to gravity do not create positive attachments.

Seismic Related to an earthquake. Seismic loads on a structure are caused by wave movements in the earth during an earthquake.

Transverse bracing Bracing that prevents a pipe from moving from side to side.

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10 Acoustics in Plumbing Systems

ACOUSTICAL RATINGS OF PLUMBING FIXTURES AND APPLIANCES

The acoustical rating tests for fixtures are still in their infancy and have not yet been internationally standardized. While some countries, most notably Germany, do have useful standards, the United States has yet to formalize any plumbing acoustic tests. The problem of adequately defining the direct airborne and structure-borne components of vibration still constitutes a major problem in performing acoustic rating tests. Only the German standard DIN 52218, *Laboratory Testing on the Noise Emitted by Valves, Fittings and Appliances Used in Water Supply Installations (Part 1)*, has so far addressed this problem. Also, the International Organization for Standardization (ISO) has published standard 3822/1, *Laboratory Tests on Noise Emission by Appliances and Equipment Used in Water Supply Installations*, and the American Society for Testing and Materials (ASTM) has established a project E-33.08B, Plumbing Noise, to investigate this problem.[1]

The airborne sound radiated by showers, dishwashers, waste-disposal units, washing machines, water closets and bathtubs is specified by the fixture/appliance manufacturer. The sound ratings for fittings are normally expressed in terms of sound power or A-weighted and octave-band levels measured in a reverberant toilet room or kitchen-type environment at a distance of 3 feet (0.9 m). Because of the differences in the reverberations between one environment and another, the characteristics of the test environment should ideally have a reverberation time lying in the range of 1 to 2 seconds and be independent of the frequency.

Valves The sound levels from valves are dependent upon the size of the fitting, the mass flow rate, and the pressure differential across the fitting. Sound levels from taps and valves at a distance of 3 feet (0.9 m) may range between 30 and 50 dB(A) for well-designed and properly installed fittings, 50 and 70 dB(A) for adequately designed and adequately installed fittings, and 70 and 90 dB(A) for poorly designed and poorly installed fittings. Improvements in the performance of faucets are most notably achieved through the incorporation of aerators, which may result in reductions in noise levels of as much as 15 or more dB.

Water closets The noise from water closets can be subdivided into:

- The noise of the water flushing the closet bowl.
- The noise of the water refilling the tank.
- The noise of a flush-valve operation, including water discharge into the fixture and the ejection of materials from the closet bowl.

The noise of the water flushing the closet bowl is a function of the specific flow rate from the tank, the proximity of the tank to the closet bowl, and the method of mounting the tank itself. While sound levels as high as 90 dB(A) at 3 feet (0.9 m) are possible in older style fittings with the tank located as much as 6 feet (1.8 m) above the bowl, modern, close-coupled tanks, when properly installed (with bowl cover down), may be as low as 55 dB(A).

The noise of the tank refilling is a function of its design, which includes the type of construction of its envelope, the method of mounting to the wall (or closet bowl), the type of tank valve used, the water, and the time required for the refill cycle. There are many cases where the noise of the tank refilling is far more annoying than the noise produced by the toilet flushing. The noise of toilet tanks refilling may be as low as 40 dB(A) at 3 feet (0.9 m) in well-designed units incorporating quiet valves and silenced, tail-pipe assemblies. In poorly designed installations operating at the maximum flow rate, this noise may be as high as 95 dB. Flush-valve operation can be as high as 95 dB, while blowout-type fixtures have been recorded at as high as 120 dB.

Urinals The noise associated with urinals is a function of the wall-mounting method used to install the fixture and the flushing action of the urinal—water discharge into the fixture and the ejection of the materials. The flush-valve operation may be as high as 95 dB, with blowout units as high as 110 dB.

Bathtubs The noise from bathtubs is usually caused by the impact of a high-velocity water stream into a glazed metallic, fiberglass, or acrylic bathtub. While this noise varies during the filling cycle, it may also be significant during the drainage cycle.

In both cases, this noise is a function of the bathtub material and its structural design as well as its method of installation, particularly the extent of its structural decoupling from the walls and floor (in order to reduce the acoustical impact on adjacent rooms or other apartments). In many European countries, the building regulations specify stringent decoupling procedures to minimize the structure-borne noise propagation. Outside these countries, such procedures are relatively unknown and are not generally utilized. The noise of a bathtub filling typically lies in the range of 60 to 100 dB(A) at 3 feet (0.9 m), depending on the flow rate. The point of impact of the water stream with the side of the bathtub is generally reduced by using an aerator on the spout. Good design practice calls for the water spout to be installed so that the water stream is not directed to strike the bottom of the bathtub.

Showers Shower noise is mostly a function of the floor surface in the shower enclosure and the type of

[1]Copies of the DIN and ISO standards are available from the American National Standards Institute (ANSI), 1430 Broadway, New York, NY 10018.

shower head. The constant-temperature controller is only significant when the water-pressure drop across it is unusually high or the method of supporting the pipe from the walls results in the generation of resonant noise. Shower noise typically lies in the range of 60 to 90 dB(A) at 3 feet (0.9 m).

Dishwashers Dishwasher noise is a function of the basic design of the unit, the choice of the mounting procedures employed, and the extent to which the installer provides additional thermal and acoustical insulation. The noise from dishwashers can be minimized by mounting the units on rubber isolation devices or by providing layers of fiberglass or mineral wool insulation on their tops, rear and sides. Significant noise is created by the activation of solenoids and solenoid-activated valves that create water hammer and sound propagation through the piping.

The use of flexible connections and the incorporation of surge eliminators to minimize the water hammer are highly recommended. Typical noise levels from dishwashers are in the range of 65 to 85 dB(A) at 3 feet (0.9 m) with peaks as high as 105 dB(A) created by solenoid operation.

Waste-disposal units Sink or waste-disposal-unit noise is a function of the design of the unit as well as the design of the sink or basin to which it is attached. Lightly constructed, stainless-steel sinks or basins will tend to amplify the sound energy. The supporting cupboards or fixtures may also have a similar effect. The sinks and basins used to support such fittings should be designed to incorporate an effective dampening of the bowl through the application of damping materials or framework.

The plumbing connection to the waste-disposal units should be flexible at the inlet and the discharge. The noise levels produced by these units can vary widely and most manufacturers do not publish the noise-rating data. Noise levels can vary between 75 and 105 dB(A) at 3 feet (0.9 m), depending on the method of mounting and the extent to which the protective covers are used.

Washing machines Washing-machine noise is a function of the design of the unit and, to a lesser extent, the method of mounting or type of plumbing connections used. The airborne noise levels can be somewhat reduced through the application of dampening material on the inside surfaces of the enclosing panels.

The incorporation of isolation mounts does not normally reduce the direct airborne sound but may drastically reduce the structure-borne component audible in adjacent apartments or rooms and perceptible vibration in the floor during spin cycle. The noise levels produced by washing machines range between 65 and 90 dB(A) at 3 feet (0.9 m), and few manufacturers publish the sound-rating data.

An indirect discharge of the wastewater into a trough or hub drain may be very loud in the room but may have a reduced noise transmission through the piping system.

GENERAL ACOUSTICAL DESIGN

Water Pipes

Origin and spread of noise The causes of noise are the surge due to the sudden opening or closing of valves and flow where the cross sections of such valves are greatly restricted. In addition, because of the high velocity, cavitation and turbulence are also created by the sudden changes in direction. The higher the pressure head of the fittings, the louder the noise. Water hammer arrestors (shock absorbers) may be beneficial in eliminating sound noise generated by these problems.

Noises originate when a stream of water strikes the base of the bathtub, sink, or lavatory. In the emptying operation, gurgling noises often occur because of the whirlpool action. These noises are conducted partly along the pipe and partly by the column of water. The pipes induce the walls and ceilings to vibrate and radiate sound.

Reducing the noise at its origin Fittings of satisfactory design with a low noise level should be employed whenever possible.

Flush tanks, in particular, can be substantially quieter than pressure flush valves, especially when insulated. Low-flush, gravity-flush valve fixtures will operate more quietly than high-velocity (blowout) type fixtures.

The largest possible cross sections for the pipes should be used and the water supply pipes in all critical areas should be designed for a maximum velocity of 4 ft/s (1.2 m/s).

The emptying noise can be reduced by using waste fittings to ensure that the air is simultaneously and uninterruptedly sucked out of the stream of water and carried away with it.

The pressure in the pipes inside of the building can be reduced to the extent that the operating conditions allow closed-circuit pressure.

Reducing the spread of noise The designer must make a distinction among the pipes laid on a wall, those in a wall, and those in shafts.

In the case of pipes installed on a wall or in pipe shafts, structure-borne, sound-damping packing (e.g., cork, felt, profiled strips of rubber, or other elastic materials) should be inserted between the fastenings and the pipe. The packing should not be compressed by excessive tightening of the pipe clips. Instead of

packing for structure-borne sound control, vibration isolation mounts should be used.

Pipes in the wall should be wrapped with sound-damping materials (e.g., felt, bituminized felt, or viscoelastic damping materials) without leaving any gaps. The same effect may be achieved by having pipes elasticity mounted in a firm outer casing.

Several pipes running in the same direction in shafts can be fastened to a single common rack. This rack should not have any structural, noise-conducting connections with the walls. Common racks should be fastened to the wall with rubber/metal connections interposed.

When pipes pass through ceilings or walls, they should be taken through sound-control sleeves of fibrous damping materials and resilient sealant. This approach must not adversely affect the airborne sound control (for instance, through joints), in particular in the case of party ceilings and walls of separate tenants. In the case of ceilings and walls that have to be fire resistant, this approach must be complied with when deciding on the fire-rated sleeves that will generally be sealed with a fire-rated silicone foam.

In the case of apparatus and equipment, such as washing machines, spin dryers, bathtubs, and wash sinks that generate noise or in which noise occurs during filling and emptying, resilient sound-damping materials should be used at the places where they touch or are attached to the structure. In the case of bathtubs, a solid joint between the bathtub outlet and the waste pipe should be avoided. Rubber pads under the bathtub supports are recommended.

Bear in mind, in the case of water pipes and apparatus in or on walls that border occupied spaces, that the permissible loudness levels are not exceeded. In such cases, conventional water-closet flush valves should be avoided and quiet-acting siphon jet actions should be used.

Occupied Domestic Spaces

Keeping within the maximum allowable loudness levels in occupied rooms requires that steps be taken during the planning and construction stages of the building. The term "occupied domestic spaces" generally covers hotels, motels, dormitories, and other locations where, in addition to domestic appliances, the elevators, incinerators, ventilation equipment, switch gear, boilers, and refuse-disposal installations can cause unacceptable noise levels in habitable areas, particularly sleeping quarters. As early as the planning stage, the various points requiring consideration must be taken into account by the plumbing designer.

Because of the multiplicity of influences involved, no simple or standard rules can be given for keeping within the permissible loudness levels. For some groups of installations, the following criteria apply:

1. Apparatus and machines in which the noise is predominantly transmitted as structure-borne sound (e.g., motors, pumps, pressure-increasing installations, ventilation machinery, drives for elevators, gearing, and heavy switch gear) must be sound insulated/vibration isolated from the building.
2. In order to reduce the structure-borne sound transmission from the heating installations into occupied rooms,a concrete floating floor should be added in the rooms where the solid fuel is stored and where there is heating equipment. The boilers must be supported on vibration isolators and be separated from other components and from the floating floor. The pipes can be supported by collector blocks on the floating floor. Rigid fastening to ceilings, floors, or walls should be avoided.
3. Ceilings over rooms where there is heating equipment should be provided with a floating barrier consisting of plaster or gypsum board in order to increase the airborne soundproofing.
4. In the case of refuse-disposal installations, the inside shaft should be constructed in such a way that the building is insulated against structure-borne sounds. Whenever possible, low-noise materials should be used. Metal sheeting should be provided with a resilient impact-absorbing coating on the inside and/or covering. The roof of the shaft should be made of sound-absorbent material.
5. Refuse bins should stand on a floating concrete slab and be enclosed by walls and ceilings complying with the requirements for party walls and ceilings of apartments. If deflector plates are provided, these devices must be fixed in a flexible manner and with structure-borne sound insulation.

Pumps

Sources of noise The following items are some of the major sources of noise from pumps in plumbing systems:

1. Unbalanced motors.
2. Pulsation of the air mass flow from electric fans. (This is a major source of noise in 2-pole, fan-cooled, electric motors. The noise from the fan is usually so dominant that all other sources of noise in the electric motor can be neglected.)
3. Pulsation of the magnetic field in the electric motor.
4. Motor/gear/pump journal and thrust bearings.
5. Contacting of the components in parallel-shaft and epicyclic gears.
6. Imbalance of the pump impellers.

7. Pulsation in the pumps. (Hydrodynamic noise generation is inherent in all types of pumps; the fundamental frequency of noise, when the pump runs at the design point, is governed by the number of blades and their interaction with the volute cut-water or diffuser guide vane ring. The intensity of the noise generated and the relative strength of the various harmonics produced are determined by the velocity profile shape leaving the impeller passages, vortex wakes shed by vanes, and the impulsive effect as they pass under the volute cut-water. The impulse wave form, although very complex, can be resolved into a fundamental equal to the speed times the number of blades and a series of harmonics. Manufacturing errors, which produce angle or pitch variations between the blades, are instrumental in generating a less-prominent series of harmonics with fundamental frequency equal to the speed with the amplitude and/or the frequency modulation of the blade-passing frequency. At off-design operation, unsteady flow conditions can arise due to flow separation and rotating stall effects.)
8. Cavitation. (Air is entrained in the solution, which can damage the pump; impellers constructed with open-grain material, such as cast iron, may disintegrate because of the implosive effect of cavitation.)

Possible modifications Obviously, if the overall noise level of the pumping plant is considered to be too high to comply with the accepted specifications, identifying and reducing the noise output from the components and equipment in the plumbing system contributing the most noise will yield the most dramatic results.

Some possible modifications the plumbing engineer should consider in order to reduce the noise output from the system are as follows:

1. *Gearbox.* A silencing enclosure or cladding should be provided.
2. *Motor fan.* A silencer should be provided at the air inlet and outlet or, if possible, the design should be modified.
3. *Motor rotor.* The number of slots should be changed or, if possible, its design should be modified.
4. *Pump and pump bearings.* Sleeve types should be employed.
5. *Pump operation.* The pump should be operated near design flow conditions in order to achieve the correct system matching. (Modifying the characteristics of the system or altering the diameter of the impeller, resulting in operation at lower speeds, will make the pump operate more quietly.)
6. *Pump impeller blades.* The clearance between the tip of the impeller and cut-water should be increased (a maximum of 85% impeller diameter to volute diameter is recommended).
7. *Impeller and guide-vane tips.* Should be dressed in order to reduce the thickness and intensity of the trailing wakes.
8. *Out of balance.* Should be balanced to fine limits. Impeller, motor, blades, and rotor should be balanced at all rpms to eliminate—or minimize—vibrations.
9. *Cavitation.* The suction characteristics of the installation/system should be improved. (Ideally, the pump should always be under positive head at the pump suction.)

Plant noise The resulting noise output of the plant, as installed on the site, is dependent upon all of the above factors coupled with the induced resonance of the adjacent parts (such as pipes, bedplates, fabricated stools, tanks, and panels). These factors form part of the final environment of the pump and are discussed under the section "Noise and Vibration Control," which follows. The effects are best investigated by determining the natural frequency of these parts, by separate excitation, or by operating the pump through its service-speed range. The natural frequency of the part can be modified by a simple trial-and-error stiffening or damping.

Other effects are also likely to appear for the first time on the site. One of them is the interaction of the pump with the intake sump. Testing a model of the sump intake before installation can prevent air-entraining vortices, eddies, and distorted flow distributions, which cause a mismatch at the impeller leading edges. Vortex formations generated entirely below the water level can be particularly troublesome in actual practice, since these formations are caused by water spinning at high velocities, which causes submerged cavitating vapor cores to be generated and drawn into the sump intake. These vortices cannot be observed on the site; however, they can be prevented at the outset by testing the sump model with observation windows fitted below the surface level.

Associated venturi-meters, valves, and pipes, in the final installation, contribute to raising the general noise level of the station. Water at high velocities passing through partially closed valves, particularly in high-pressure systems, can produce severe cavitation noise, which is generated by the rapid collapse of the vapor bubbles against the walls of the valve and downstream pipe. Sound-pressure levels of 110 dB have been recorded.

These high sound-pressure levels can be greatly reduced by using multistage pressure breakdown systems and by paying special attention to the valve's

port design. Thick-walled pipe and external acoustic installation are only effective for localized noise reduction; they do not reduce the noise in the fluid stream but shroud it where treatment is used. Much of the noise is still carried downstream and, at times, upstream as well, depending on the system. Poor pipe design, involving many sharp bends and sudden expansions and contractions, can induce considerable turbulence and noise.

Estimating the noise level of a pump Small, motor-driven pump sets, which are commonly employed in plumbing systems, can be conveniently tested in an anechoic chamber with accurate results. However, the most important sources of sounds in large pumping stations are usually associated with custom-built units.

Pump noise levels are measured by the near-field technique 3 feet (0.9 m) from the unit in order to minimize the sound transmissions from pipe coupled to the pump. The sound-pressure level, at 3 feet (0.9 m) from the pump, can be estimated by using the following equation (presented in the International System of Units, or SI units, which is the best means for available test data):

Equation 10-1

$$\text{Pump sound-pressure level} = 163.9 + 8.5 \log \frac{(\text{volume flow rate} \cdot \text{head})}{(\text{rpm} \cdot \text{specific speed} \cdot \text{impeller diam.} \cdot \text{impeller width})}$$

7. Supervision of the plumbing installation in order to ensure adherence to the acoustic details.

Specific acoustic performance guarantees for plumbing installations should be avoided where sufficient research has not been carried out. On any critical projects, the retention of an acoustical consultant may be essential. In the end, the final results are as much dependent on the quality of the workmanship and supervision as they are on the design details. Many well-designed projects fail to achieve the required performance because of inadequate supervision, which is necessary in order to pinpoint and correct substandard details.

Noise and Vibration Control

All noise-control problems can be reduced to three basic elements: source, path, and receiver.

Noise-control problems frequently involve consideration of several sources of noise, several paths for the transmission of noise, and several different receivers. The relationship among these elements defines the seriousness of the problem. In order to solve a noise problem, the source strength can be reduced, the path can be made less effective in transmitting sound, or the receiver can be made more tolerant of disturbance. However, most practical solutions involve a trade-off, so concentration on only a single aspect of the problem may result in over-design or an unsatisfactory solution.

For sources that not only produce noise and vibration problems but also have the potential to lead to damage or decrease the useful channel space for liquids, it is desirable to reduce the source strength. Cavitation is a typical example of this kind of problem. The solution to this problem hinges on the pump suction (i.e., net positive suction head, NPSH). One may consider placing the pump at a lower elevation, if practical, or one may improve the suction piping and raise or pressurize the supply tank. In recent years, efficient suction-assisting devices (such as booster pumps) have become commonly used where low NPSH must be handled at low cost. Several manufacturers supply add-on or built-in inducers for end-suction pumps.

For noise and vibration sources that do not influence systems operating conditions or reliability, control of noise transmission (i.e., the path) from the source to the noise-sensitive area may be the most economical solution. Noise may be transmitted through structure-borne, airborne, and fluid-borne paths. Structure-borne noise travels in the form of high-frequency structural vibrations; airborne noise travels in the form of sound waves; and fluid-borne noise travels in the form of pressure fluctuations. The structure-borne path usually plays an important role because the noise source within the pump, or piping , often can communicate with the surroundings only by setting the enclosure into vibration. These vibrations may radiate sound directly or may be transmitted through the supporting structure, to be converted to airborne sound elsewhere.

Vibration isolators, such as resilient mounts and resilient pipe hangers, are commonly used to reduce structure-borne vibrations. Theoretically, in order to design an adequate isolation system, the engineer must realize how much vibratory force is generated by the equipment and the maximum permissible force transmission to the building. Since these design parameters cannot readily be obtained, some practical guidelines have been formulated to provide effective isolation at a reasonable cost. These are generally adequate for all but the most critical or special applications (such as very light or flexible structures or equipment installed above adjoining very quiet spaces).

To ensure that the desired noise isolation is achieved, a detailed vibration-control specification and its stringent enforcement are required. With increased public awareness of noise, government agencies such as the General Services Administration (GSA Guide Specification Number 4-1515-71, *Public Building Service*) and Federal Housing Administration (FHA *A Guide to Airborne, Impact and Structure-Borne Noise Control in Multifamily Dwellings*) have established recommended guidelines on noise and vibration control.

However, it is not enough merely to have noise-control specifications. Adequate detailing techniques are most essential for communications between the design engineers and the contractors. For most situations, acoustical details are well developed and are available for most applications. From a practical point of view, most plumbing fixtures cannot be effectively isolated, although they can be installed to minimize vibration.

When pipes are connected to vibrating equipment installed on vibration isolators, sufficient flexibility must be built into the piping systems to match the equipment vibration isolators. In addition, adequate flexibility is required in order to protect the equipment from any strains imposed by misalignment and by thermal movement of the piping. Piping flexibility can be achieved by the inherent resilience of the pipe in simple bend-and-loop configurations (if there is sufficient length) or by the use of flexible pipe connectors, which also attenuate the transmission of noise and vibration along the piping system. However, their use as vibration-isolation devices should be considered very carefully for the following reasons:

- They are the weakest component in the piping system. (Without proper specification of the mate-

rial, installation, and maintenance, they may fail and cause severe water damage.)

- In many instances, sound energy may flank the flexible pipe connectors so that pipe-wall noise is exited downstream of the resilient break. Indeed, the various restraints added by the manufacturers to reduce the possibility of failure make the flexible pipe connectors almost as rigid as the pipe itself.

Studies have found that flexible pipe connectors are most effective in the case of cavitation. Flexible pipe connectors have also been found to be effective in the attenuation of the tonal components at the impeller passage frequency of a pump.

Equipment design Quiet operation of pumps begins with proper design. Although today's state-of-the-art design and development of pumps and plumbing fixtures has a long heritage, noise is still seldom considered by the manufacturer. This is perhaps because of the designer's lack of awareness and experience, but even knowledgeable designers yield to economic pressures for cost reduction.

It is obvious that the primary purpose of a pump or plumbing fixture is to move liquids and to perform the necessary plumbing functions. These considerations must come first. However, noise and vibration controls should be integrated in the design and may then be expected to lead to improved performance with little or no cost penalty. Quite often, the cost of modification is negligible. The key to effective noise control is a complete understanding of the noise-generating mechanisms.

By simply changing the cut-water clearance of a pump, a major reduction in the blade-passage-frequency noise is achieved. Similarly, water faucets can easily be designed for quiet operation. For a particular value of pressure drop, a valve can be designed to minimize cavitation and its resulting noise within the water-pressure design range.

Some water-closet manufacturers indicate that, like dishwashers and food-waste disposers, economy models are noisier than more expensive ones. Nevertheless, quietness in water closets is a marketable attribute. One of the problems with flush-valve-operated water closets is the high initial noise impulse that is associated with the opening of the flush valve. However, if the valve discharges against a properly selected resistance, the noise impulse can be substantially reduced. There is no doubt that a cost-saving, quiet fixture could be achieved with more research.

SYSTEM DESIGN

Equipment selection To select a quiet unit, the engineer must have an understanding of the noise characteristics of plumbing fixtures and appliances. Good matching between machine characteristics and system requirements is essential for performance, as well as for noise control. For example, in a system operating over a narrow load range, a pump of single-volume design (selected for near-peak efficiency operation) is acceptable because the unbalanced radial load on the impeller is the least at optimum delivery.

Adequate criteria should be established for equipment vibration to ensure that there are no excessive forces that must be isolated or will adversely affect the performance or the life of the equipment. There are many ways to develop equipment-vibration criteria. A simple but satisfactory approach would be to use the criteria that have been developed on the basis of the experience of persons and firms involved with vibration testing of mechanical equipment in the building construction industry.

Pressure Most model plumbing codes have established the rate of flow desirable for many common types of fixtures as well as the average pressure necessary to provide this rate of flow. Although the pressure varies with the design of the fixture, a pressure of 5 to 8 psi (34.5 to 55.2 kPa) at the entrance to the fixture is generally the minimum required for good service at lavatory faucets and tank-type water closets. A pressure of 15 psi (103.4 kPa) may be ample for most of the manufacturer's requirements. Some fixtures, especially wall-hung water closets, require a pressure up to 25 psi (172.4 kPa).

Water pressure in many mains is typically 50 to 80 psi (334.7 to 551.6 k Pa). As the water flows through a pipe, the pressure continually decreases along the pipe, due to the loss of energy from friction and the difference in elevation between the water main and the fixture.

From a noise-control point of view, it is desirable to keep the fixture inlet water pressure as low as possible. This condition usually can be achieved by installing pressure-regulating devices in order to balance the pressure gradient in the water system. Many cities experience large pressure fluctuations in the hydraulic gradient of their water systems due to demand changes (such as after working hours). The inlet water pressure must be kept higher than the required minimum pressure to ensure good service. The alternative, if it were practical, would be to have continuous adjustments of the system's inlet pressure as the demand changes. The system pressure also has a great effect on the occurrence of cavitation. The plumbing system must be operated at a pressure level high enough to prevent cavitation.

Speed Changes in the operating conditions of the pump have a significant effect upon the level of pressure fluctuations, particularly for plumbing systems

in which resonance exists. It is possible that a 5% change in the pump speed may result in a 70% change in the pressure fluctuations. Also, a valve's pressure-flow characteristics and structural elasticity may be such that, at some operation point, it will oscillate (perhaps in resonance with parts of the piping system) so as to produce excessive noise or even physical damage. A change in the operating conditions or details of the valve geometry may then result in significant noise reduction.

Pipe sleeves One very important consideration for piping-system noise control that seldom receives any attention is the detailing of the piping sleeves at the wall and floor penetrations. Each type of piping sleeve has a specific application, and its acoustical treatment cannot easily be generalized. For example, the acoustical requirements for a piping sleeve used on water piping that passes through a foundation wall will be different than those for a piping sleeve used for sprinkler pipes that pass through a double-wall construction enclosing a concert hall. However, each case should be treated so that the pipe penetration will match the acoustical value of the wall and provide the proper separation between the piping and the building construction. This requirement must be made clear to the contractor, and entails showing the construction details on the contract drawings.

Most plumbing systems contain many points at which the piping must penetrate floors, walls, and ceilings. If such penetrations are not properly treated, they provide a path for noise transmission that can destroy the acoustical integrity of the occupied space. Accepted practice is to seal the openings with fibrous material and caulking in a manner similar to that illustrated in Figures 10-1 and 10-2. Some penetration seals, as shown in Figure 10-3, are also available commercially.

Water hammer A common method of controlling water hammer noise is to install a shock absorber or air chamber where the water hammer is most likely to originate, such as at a faucet or a control valve. In many residential systems, it is common to install one similar to that shown in Figure 10-4.

Pipe wrapping The noise from a pipe may be reduced by applying a wrapping (lagging) to the pipe. Such a wrapping normally consists of a layer of porous insulation material placed between the pipe surface and an external, impervious cover. The insulation should be glass or mineral fiber; do not use closed-cell sponge rubber or rigid blown cellular glass or calcium cilicate. The cover must be supported by the blanket with no structural ties between the outer cover and the pipe. Structural connections reduce the effectiveness of the pipe wrapping. The porous insulating material serves three purposes:

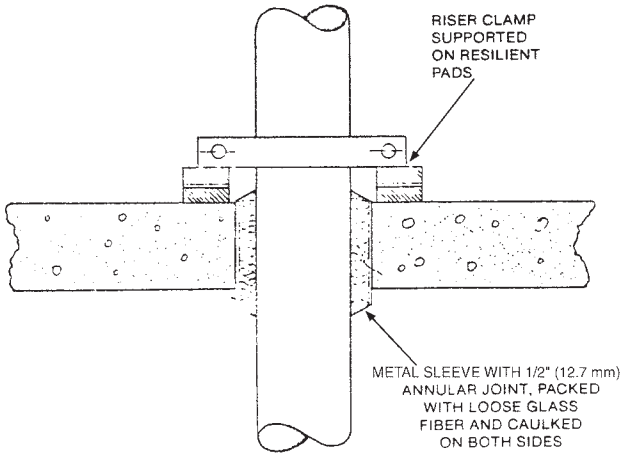


Figure 10-1 Pipe-Sleeve Floor Penetration

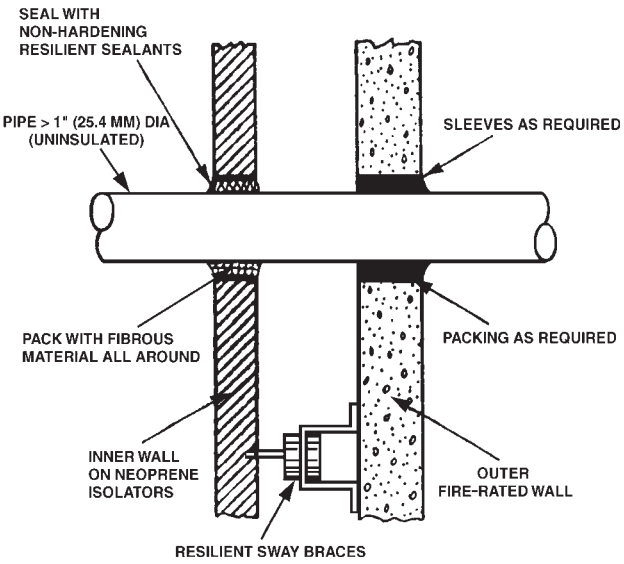


Figure 10-2 Acoustical Treatment for Pipe-Sleeve Penetration at Spaces with Inner Wall on Neoprene Isolators

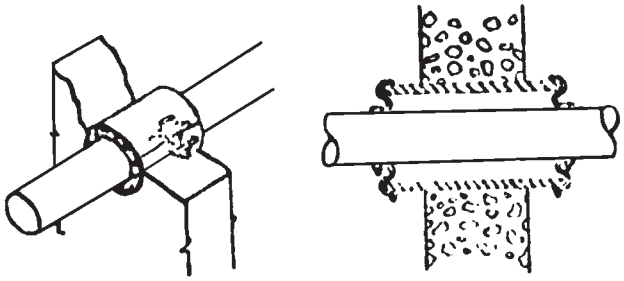


Figure 10-3 Acoustical Pipe-Penetration Seals

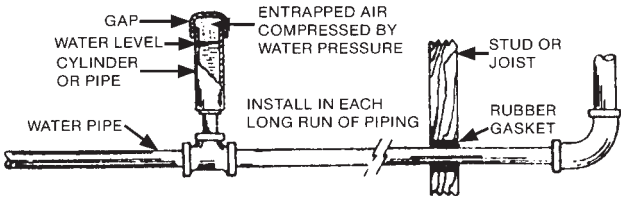


Figure 10-4 Installation of an Air Lock in a Residential Plumbing System

- It keeps the external, impervious cover separated from the surface.
- It attenuates sound (particularly, at high frequencies).
- It reduces the amplitude at the resonant frequency defined by the mass of the cover and the stiffness of the layer of porous material.

The typical noise reduction from a pipe wrapping is in the range of 0 to 5 dB at low frequency and 15 to 25 dB at high frequency.

System layout A system that is undersized (or that contains a section of undersized piping) will usually generate excessive noise. It is good engineering practice to use simple-design pipe layout (i.e., long straight runs with a minimum of elbows and tees) and long radius elbows and connectors. The straight run can be estimated as being 12 times the diameter of the pipe. Piping layout near pumps and valves is also of great importance. Figure 10-5 illustrates some examples of suction-piping installations.

Vibration isolation The sources most commonly responsible for the generation of noise in plumbing systems are discussed in this section. However, most plumbing noise problems are not caused directly by the noise radiated to the air from these sources. Usually, the plumbing system transmits the sounds so that the mechanical vibration follows its support system to the surface and is eventually radiated as noise.

A complete discussion of vibration-isolation theory is beyond the scope of this chapter. Only the methods of vibration control that are readily applied and broadly useful in practical problems are considered here. This chapter does not address the various, specific, vibration-control techniques that are useful only in the hands of a specialist or that require detailed measurements and analyses.

Selection criteria A vibration-isolating device should be selected using the following criteria:

1. It must be soft enough to provide the desired isolation effect and have a stiffness that is less than the local stiffness of each of the items it connects.
2. It must provide a natural frequency that is considerably lower than the lowest excitation frequency of concern.

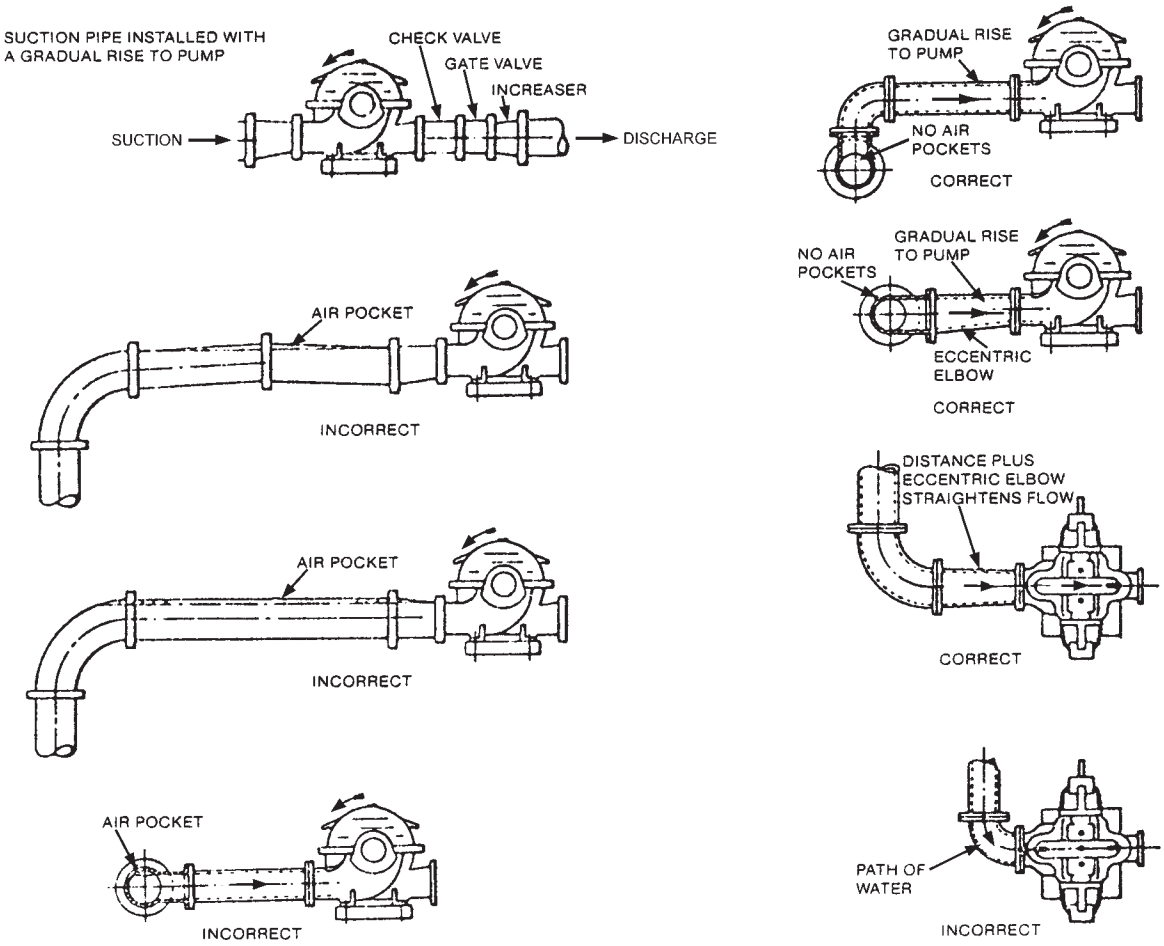


Figure 10-5 Examples of Suction-Piping Installations

3. It must be capable of carrying the loads imposed on it.
4. It must be able to withstand the environment to which it will be exposed.

Vibration-control devices In plumbing systems, vibration-control devices generally consist of steel springs, air springs, rubber isolators, pads or slabs of fibrous (or other resilient) materials, isolation hangers, flexible pipe connectors, concrete bases, or any combination of these items. Some of the most common vibration-isolation devices are illustrated in Figures 10-6 and 10-7. Additionally, refer to Table 10-1 for the recommended static deflection for pump vibration-isolation devices.

Steel springs Steel springs are available for almost any desired deflection. These devices are generally used as vibration isolators that must carry heavy loads where more isolation performance is desired than rubber or glass fiber provides or where the environmental conditions make other materials unsuitable. They are generally available for deflection only up through 4

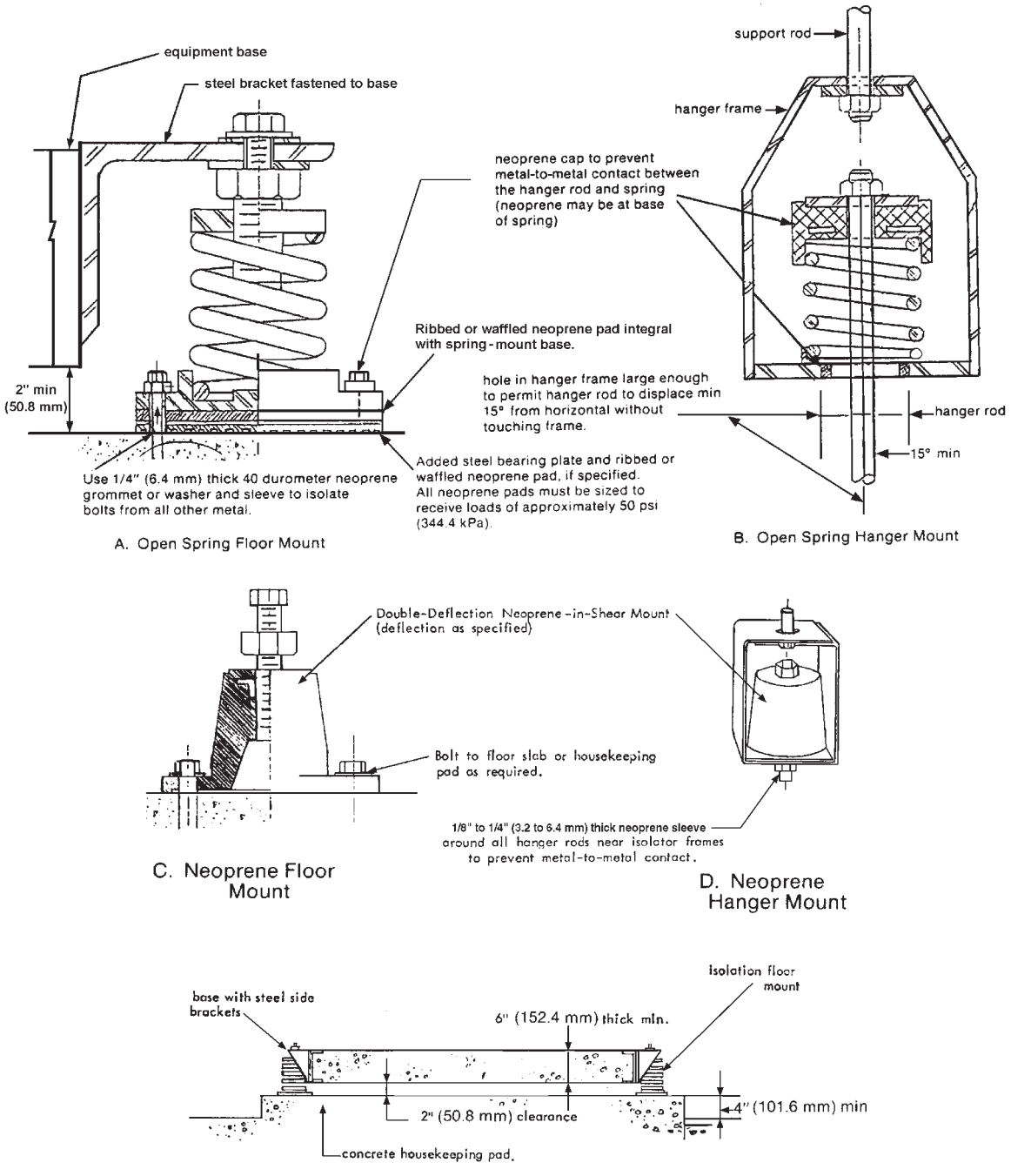
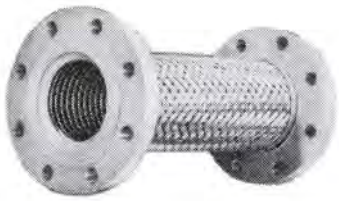
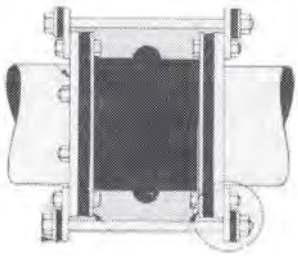
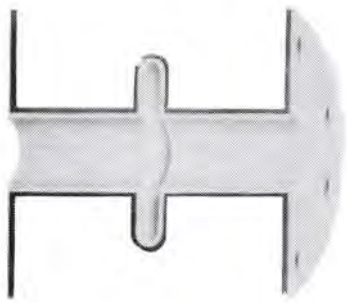


Figure 10-6 Typical Vibration-Isolation Devices

inches. The basic types of steel spring mountings are as follows:

1. Housed-spring mountings.
2. Open-spring mountings.
3. Restrained-spring mountings.

Because steel springs have little inherent damping and can increase their resonance in the audio-frequency range, all steel-spring mountings should be used in series with pads of rubber, fibrous or other resilient materials to interrupt any possible vibration-transmission paths.

Air springs Air springs, as steel springs, are available for almost any desired deflection where 6 inches. (152.4 mm) or more is required. By varying the air pressure in the bladder, air springs are capable of carrying a wide range of loads. The shape, rather than the pressure, determine the spring frequency. Air springs have the advantage of virtually no transmission of high-frequency noise. They have the disadvantage of higher cost, higher maintenance, failure rates and low damping.

Rubber isolators (neoprene mounts and hangers) Rubber isolators are generally used where deflections of 0.3 inches (7.6 mm) or less are required. These devices can be molded in a wide variety of forms designed for several combinations of stiffness in the various directions. The stiffness of a rubber isolator depends on many factors, including the elastic modules of the material used. The elastic modules of the material vary with the temperature and frequency and are usually a characteristic of a durometer number, measured at room temperature. Materials in excess of 70 durometers are usually ineffective as vibration isolators. Rubber isolating devices can be relatively light, strong, and inexpensive; however, their stiffness can vary considerably with the temperature. They are effective primarily against high-frequency disturbances with very limited performance at low frequencies.

Precompressed, glass-fiber pads These devices are generally used where deflections of 0.25 inch (6.4 mm) or less are required. Precompressed, glass-fiber pads are available in a variety of densities and fiber diameters. Although glass-fiber pads are usually specified in terms of their densities, the stiffness of the pads supplied by different manufacturers may differ greatly, even for pads of the same density.

Sponge rubber Sponge-rubber vibration-isolation materials are commercially available in many variations and degrees of stiffness. The stiffness of such a material usually increases rapidly with increasing load and increasing frequency. This material is rarely used in manufactured isolators but is often used in job-site fabricated installations.

Concrete base Concrete-base devices are usually masses of concrete, poured with steel channel, weld-in reinforcing bars and other inserts for equipment hold-down and vibration-isolator brackets. These devices perform the following functions:

1. Maintain the alignment of the component parts.
2. Minimize the effects of unequal weight distribution.
3. Reduce the effects of the reaction forces, such as when a vibration-isolating device is applied to a pump.
4. Lower the center of gravity of the isolated system, thereby increasing its stability.

Table 10-1 Recommended Static Deflection for Pump Vibration-Isolation Devices

Equipment Location	Power Range, HP (kW)	Speed, RPM	Indicated Floor Span, in. (mm)		
			30 ft (9.1 m)	40 ft (12.2 m)	50 ft (15.2 m)
Slab on grade	Up to 7.5 (5.6)	1800	¾ (19.1)	¾ (19.1)	¾ (19.1)
		3600	¼ (6.4)	¼ (6.4)	¼ (6.4)
	Over 7.5 (5.6)	1800	1 (25.4)	1 (25.4)	1 (25.4)
		3600	¾ (19.1)	¾ (19.1)	¾ (19.1)
	50-125 (37.3-93.2)	1800	1½ (38.1)	1½ (38.1)	1½ (38.1)
		3600	1 (25.4)	1 (25.4)	1 (25.4)
Upper floor above noncritical areas	Up to 7.5 (5.6)	1800	¾ (19.1)	¾ (19.1)	1½ (38.1)
		3600	¾ (19.1)	¾ (19.1)	1 (25.4)
	Over 7.5 (5.6)	1800	1 (25.4)	1½ (38.1)	2 (50.8)
		3600	¾ (19.1)	1 (25.4)	1½ (38.1)
	50-125 (37.3-93.2)	1800	1½ (38.1)	2 (50.8)	2½ (63.5)
		3600	1 (25.4)	1½ (38.1)	2 (50.8)
Upper floor above critical areas	Up to 7.5 (5.6)	1800	1 (25.4)	1½ (38.1)	2 (50.8)
		3600	¾ (19.1)	1 (25.4)	1½ (38.1)
	Over 7.5 (5.6)	1800	1½ (38.1)	2 (50.8)	3 (76.2)
		3600	1 (25.4)	1½ (38.1)	2 (50.8)
	50-125 (37.3-93.2)	1800	2 (50.8)	3 (76.2)	4 (101.6)
		3600	1½ (38.1)	2 (50.8)	3 (76.2)

5. Reduce motion.

Concrete bases can be employed with spring isolators, rubber vibration isolators, and neoprene pads. Usually, industrial practice is to make the base in a rectangular configuration approximately 6 inches (152.4 mm) larger in each dimension than the equipment being supported. The base depth needs not to exceed 12 inches (0.3 m) unless specifically required for mass, rigidity, or component alignment. A concrete base should weigh at least as much as the items being isolated (preferably, the base should weigh twice as much as the items). The plumbing designer should utilize the services of a structural engineer when designing the concrete base.

Flexible connectors When providing vibration isolation for any plumbing system or component, the engineer must consider and treat all possible vibration-transmission paths that may bypass (short-circuit or bridge) the primary vibration isolator. Flexible connectors are commonly used in pipe connecting between isolated and unisolated plumbing components. Flexible pipe connectors are usually used for the following reasons:

1. To provide flexibility of the pipe and permit the vibration isolators to function properly.
2. To protect the plumbing equipment from strains due to the misalignment and expansion or contraction of the piping.
3. To attenuate the transmission of the noise and vibration along the piping system.

For plumbing systems, the flexible pipe connectors usually consist of hose connectors and expansion joints.

Most commercially available flexible pipe connectors are designed for objectives (1) and (2) denoted above and not primarily for noise reduction. For noise control, resilient pipe isolators should be utilized.

Vibration isolation of plumbing fixtures From a practical point of view, most plumbing fixtures cannot be effectively isolated, although these components can be installed in a manner to minimize vibration transmission. Figures 10-8, 10-9, 10-10 and 10-15 illustrate some examples of resiliently mounted plumbing fixtures.

Vibration isolation of pumps Concrete bases with spring isolators or neoprene pads are preferred for all floor-mounted pumps. It is common practice to isolate a pump in a manner similar to that illustrated in Figure 10-11. Figure 10-12 shows some of the most common errors found in pump-isolation systems. Table 10-1 contains the recommended static deflection for the selection of pump vibration-isolation devices.

For critical system applications, sump pumps and roof drains should also be isolated. See Figure 10-13 for a typical installation.

Vibration isolation of piping All chilled, condenser, domestic, and hot-water piping, including the heat exchanger and the hot-water storage tank, should be isolated in addition to the following:

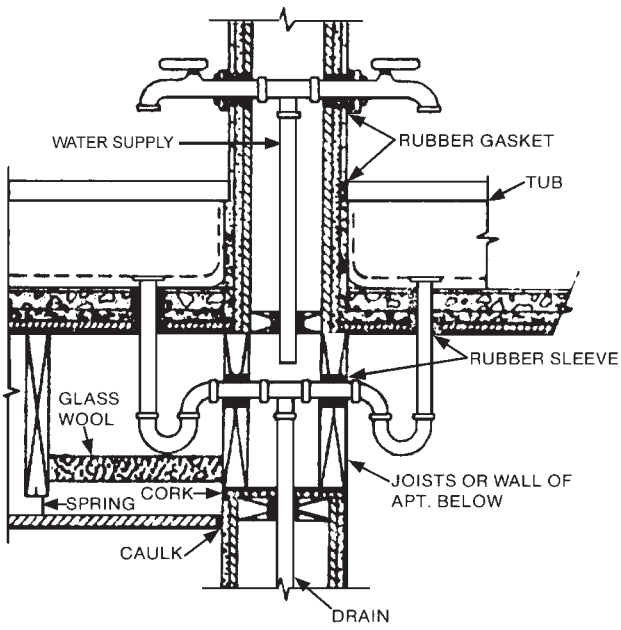


Figure 10-8 Bathtub and/or Shower Installation

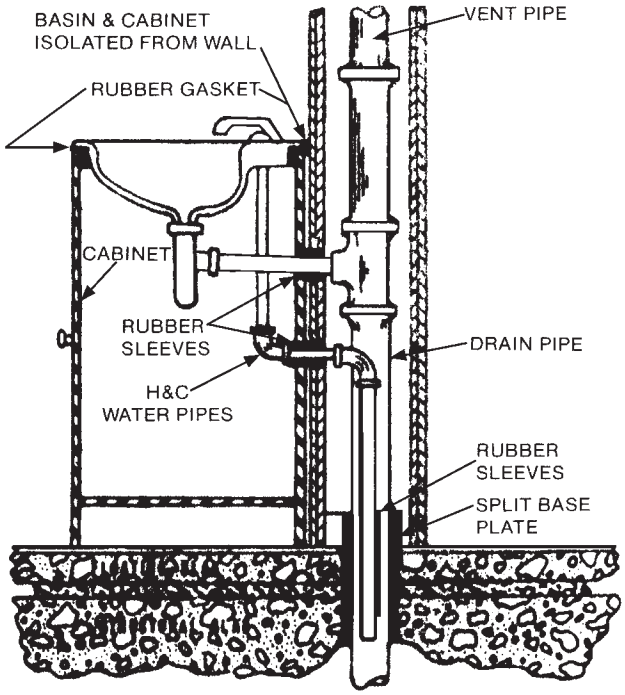


Figure 10-9 Suggested Mounting of Piping and Plumbing Fixture

1. All piping in the equipment room.
2. All piping outside of the equipment room, within 50 feet (15.2 m) of the connected pump.
3. All piping over 2 inches in diameter (nominal size) and any piping suspended below or near a noise-sensitive area.
4. The first three (3) supports provide the same deflection as the pump vibration isolators. They should be a precompressed type in order to prevent a load transfer to the equipment when the piping systems are filled.
5. The remaining vibration isolators should provide one-half (½) the deflection of the pump isolators or 0.75 inch (19.1 mm) deflection, whichever is larger.

All piping connected to plumbing equipment should be resiliently supported or connected. See Figures 10-14 and 10-15 for typical installations.

Seismic protection The seismic protection of resiliently mounted systems presents a unique problem for vibration-isolation selection and application. Since resiliently mounted systems are much more susceptible to earthquake damage (due to resonances inherent in the vibration isolators), a seismic specialist should be consulted if seismic protection of such a system is desired. (Refer to the *Plumbing Engineering Design Handbook* chapter "Seismic Protection of Plumbing Equipment" for more information on this topic.)

GLOSSARY

Acoustics The study of airborne sound and structural vibration propagation over the frequency range 2 to 20 kHz.

Decibel The unit used to qualify the level of sound (or loudness) relative to an arbitrary reference point [zero is equal to 20 Pa (20×10^{-6} pascals)]. These units are also employed to quantify sound power. This unit is the smallest increment of change in sound intensity that a normal human being can detect, while a 10-decibel change of increasing or decreasing sound is commonly regarded as a subjective doubling or halving of loudness, respectively. Abbreviated "dB."

Decibel (A) scale A frequency-modified sound level in which low-frequency and high-frequency sounds are attenuated in a similar manner to that in which the human ear responds to wide-range sounds. It is the most common unit used for sound measurement to relate sound intensity to normalized subjective loudness. Abbreviated "dB(A)."

Hertz The unit of frequency internationally accepted to be equivalent to cycles per second of sound. 1 Hertz is equal to 1 cycle/second. Abbreviated "Hz."

Net positive suction head (NPSH) Actual fluid energy available or required at the inlet of a pump.

Noise criteria (NC) curves Employed to assess loudness or annoyance on an octave band basis. These noise criteria (NC) curves have been partially superseded by the "preferred noise criteria (PNC) curves."

Octave A doubling of the frequency. Also used as the most common frequency division for the specification

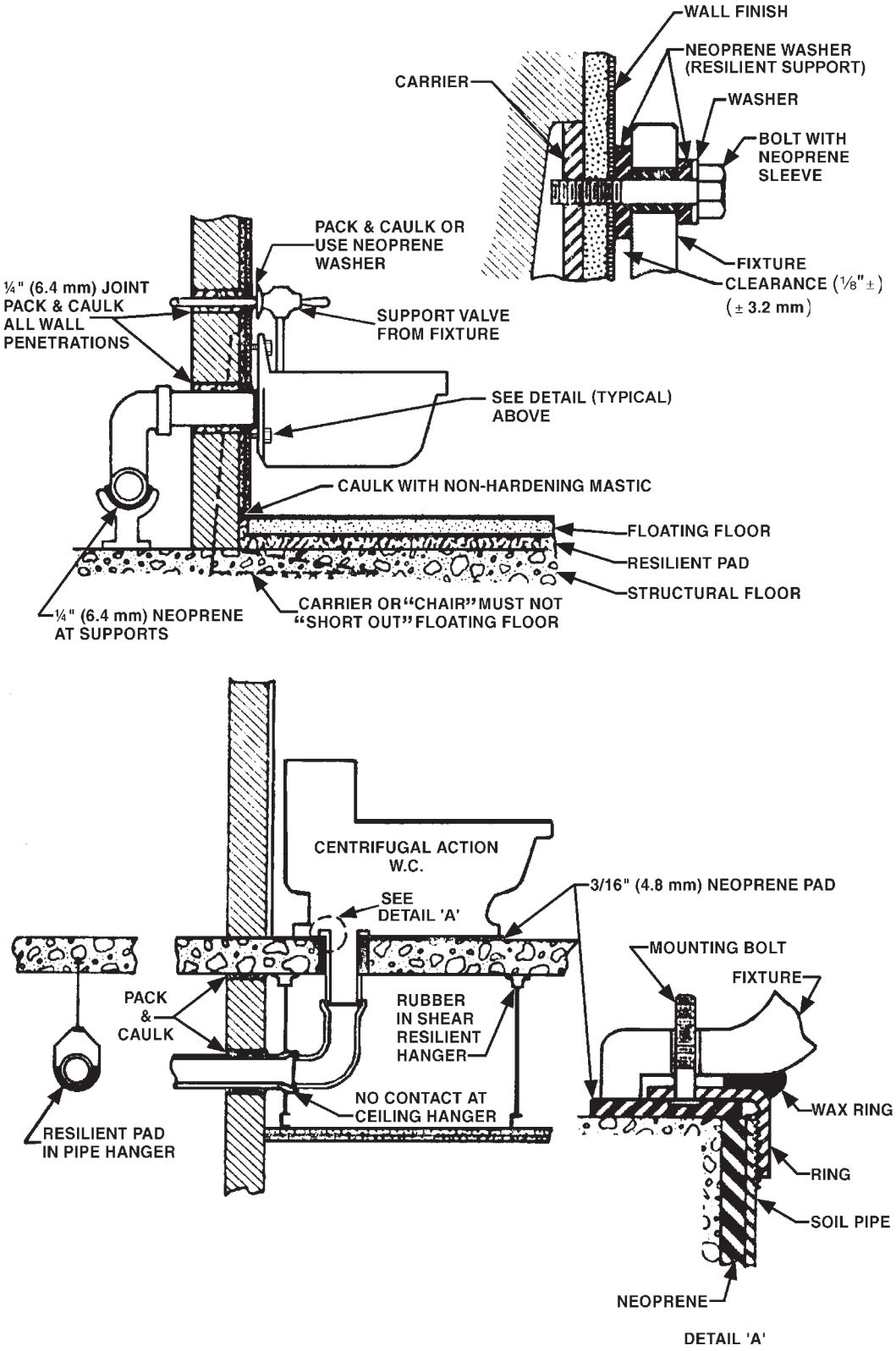


Figure 10-10 Suggested Installation of Plumbing Fixtures

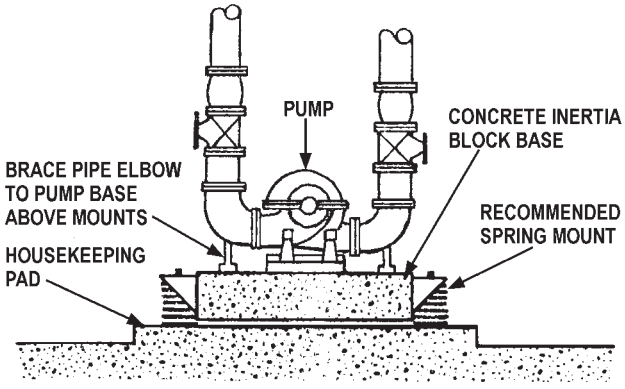


Figure 10-11 Vibration Isolation of Flexible-Coupled, Horizontally Split, Centrifugal Pumps

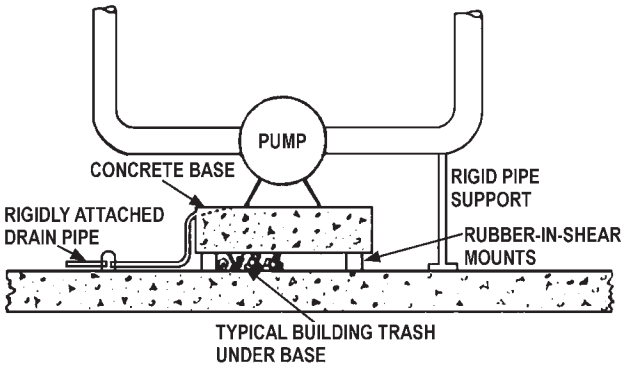


Figure 10-12 Common Errors Found in Installation of Vibration-Isolated Pumps

of filters employed for acoustical analyses.

Pure tones Detectable and generally audible frequency components with characteristics similar to whistles or shrieks generally regarded as being more obtrusive and more likely to give rise to annoyance than other broadband sounds devoid of such components.

Sound power The total acoustical energy radiated by a device or fitting operating under normal working conditions.

Sound-power level The acoustical output, in decibels, radiated by a device or fitting with reference to a sound power of watts and normally determined in octave bands and, typically, at octave bands center frequencies in the range between 63 Hz and 8 kHz.

Sound pressure The oscillation in pressure that gives rise to a sound field in a gas or a liquid.

Sound-pressure level The logarithmic value of sound pressure referenced to a point of absolute zero (usually 20 μPa) in order to provide a convenient numerical value, in decibels, typically occurring within the range 0 to 120 dB. Typical sound levels are denoted in Table 10-2.

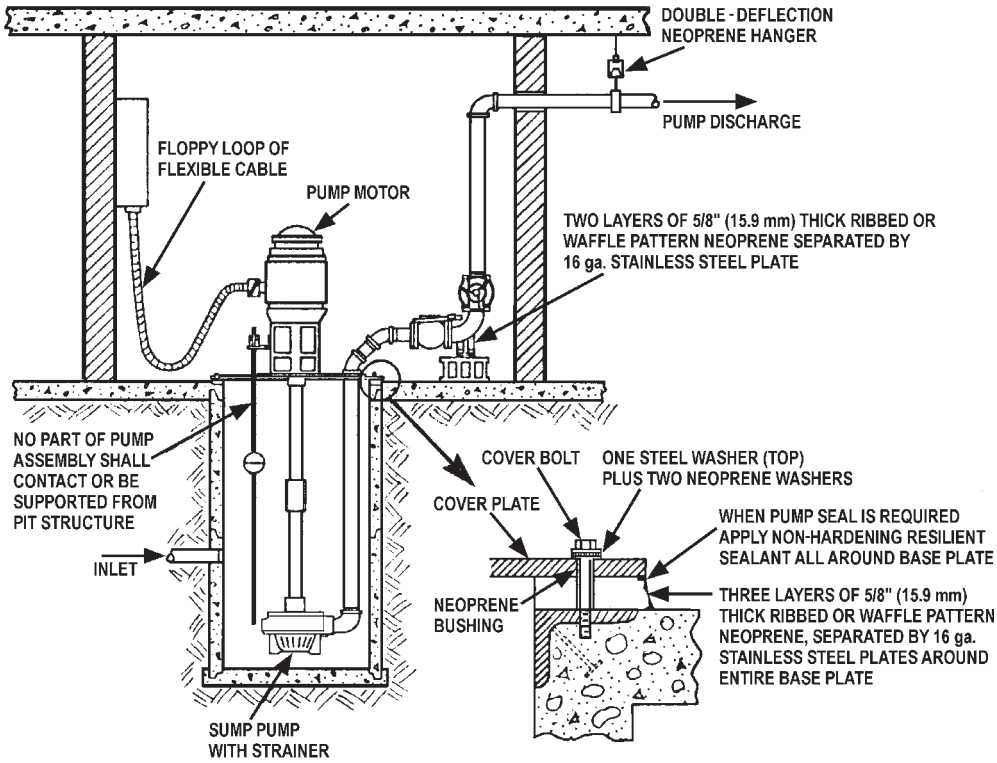


Figure 10-13 Vibration Isolation of a Sump Pump

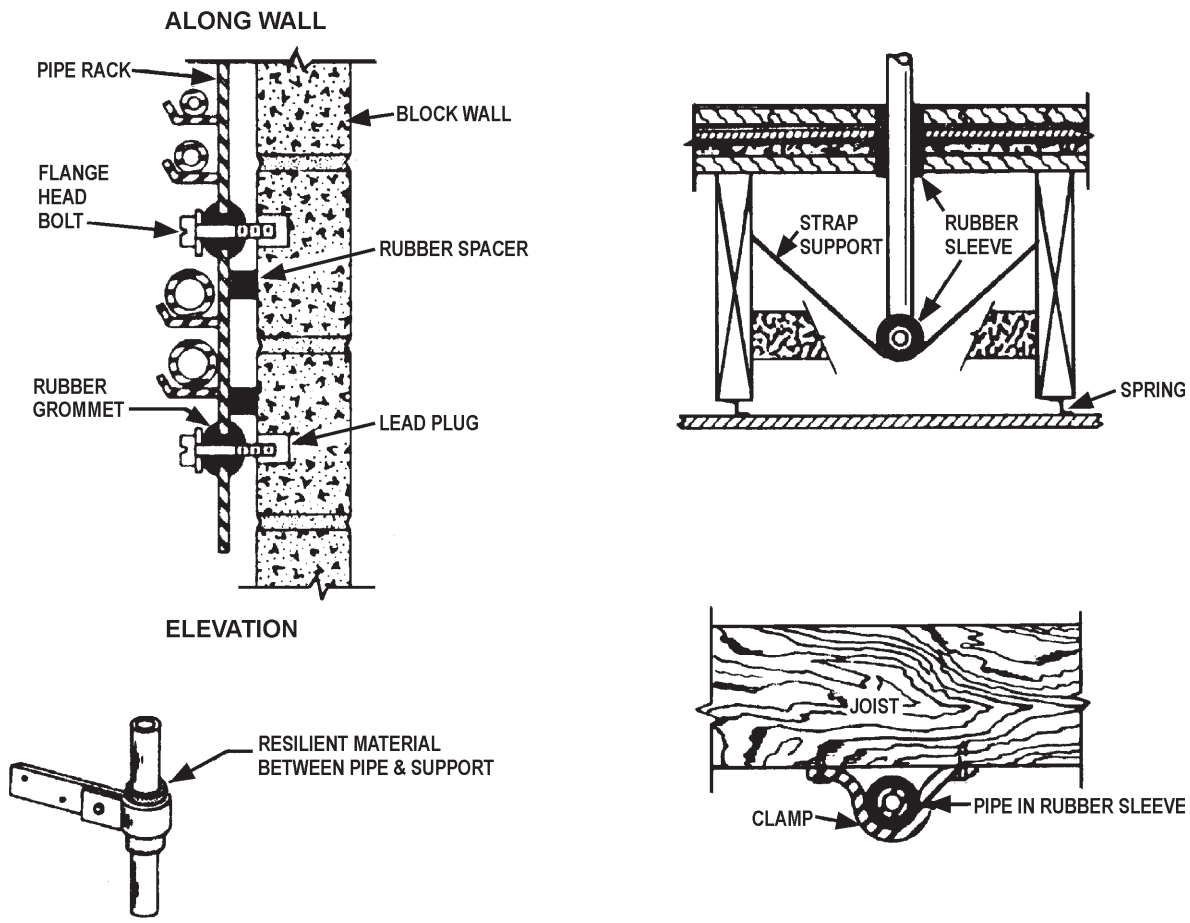


Figure 10-14 Typical Pipe Run Installations

Table 10-2 Typical Sound Levels

Sound Level (dB)	Type of Operation
100	Hammering on pipes
70	Normal speech levels
50	Background sound in office
30	Background sound in urban bedroom
10	Threshold of hearing for normal adult

Transmission loss A measure of the sound insulation of a partition or wall, in decibels. It is equal to the number of decibels by which the sound energy passing through it is reduced. The value of the transmission loss is independent of the acoustical properties of the two spaces separated by the partition.

Vibration The generation of cylic or pulsating forces through a physical medium other than air that converts to sound energy at the boundary between a solid and a gaseous medium. Sound energy may be converted to vibration at the interface between a gaseous medium and a solid medium.

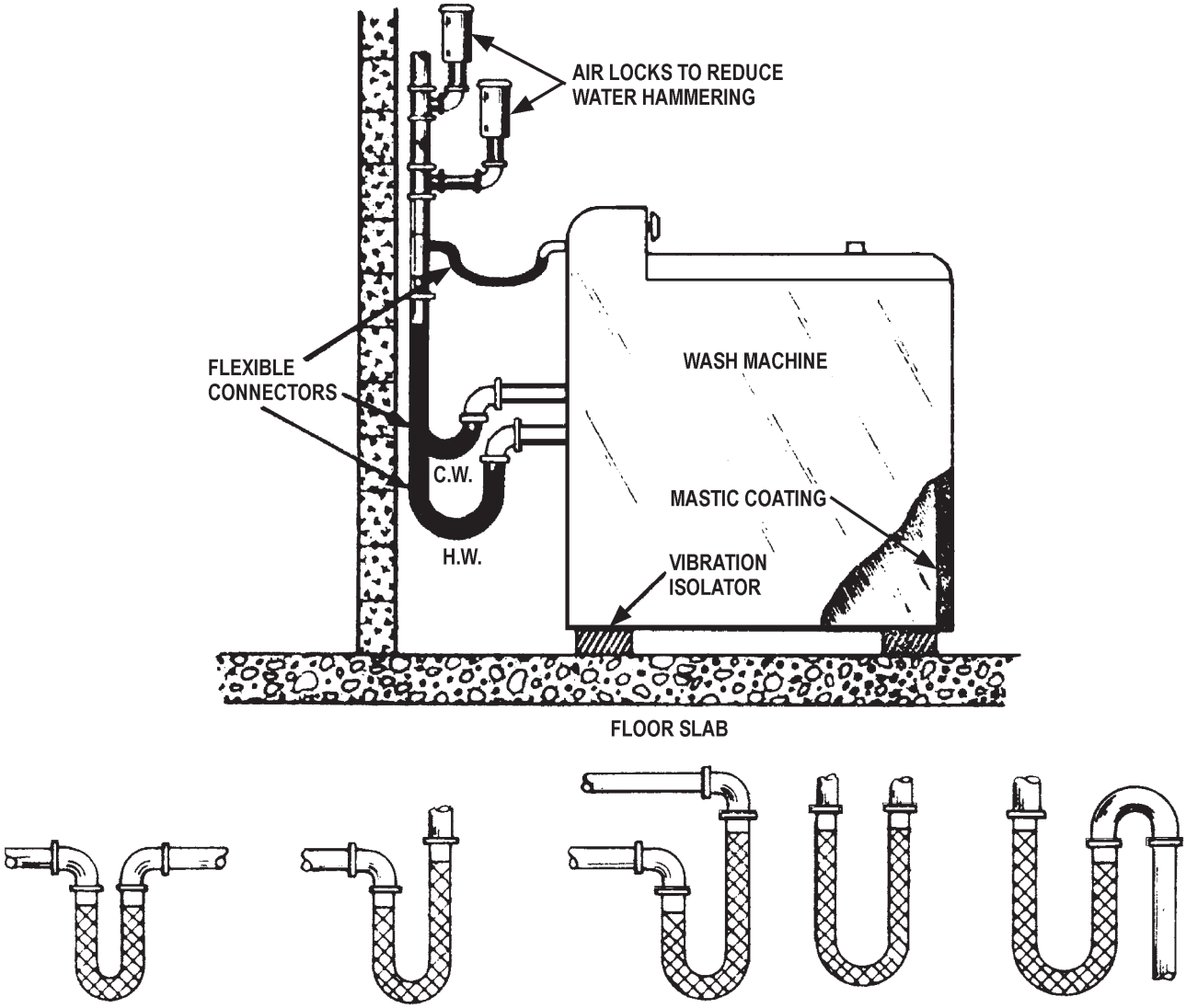


Figure 10-15 Typical Flexible Pipe-Connector Installations

11 Basics of Value Engineering

worth and its cost. For a facilities construction project, "best value" is a finished project that will consistently perform its required basic function and has the lowest total cost. Therefore, construction of a facility can yield maximum value when value engineering is incorporated into the project. This is accomplished by providing and developing alternatives that produce the desired results and maintain the quality and reliability of the project utilizing the most efficient and effective mix of resources at the least cost.

It would seem that implementing value engineering would be fairly simple; all you need to do is control and/or reduce costs. First, however, we need to have some perspective about where, how and why value engineering will be applied. For the plumbing engineer and designer, the most typical application is the creation of a building. In this regard, there are at least three major aspects of costs that will be of concern to the overall development/engineering/construction "team": The development costs, the engineering and design costs, and the construction costs. Within these three areas all related costs associated with the creation of a building will be lumped, such as property acquisition, inspections, licenses and permits, build-out, finishing, etc.

In the end, there is one "person" or organization concerned with the total picture in the creation of a building—the owner or developer. And, as noted earlier, value engineering can be introduced at any point in the construction or life-cycle of the project. Therefore, for maximum efficiency and to assure maximum value, value engineering needs to be integrated from the beginning and continue throughout a project's life-cycle. In this regard, it is important that the concept of a "team" be immediately integrated into all aspects and phases of the project. For it is this "team" that needs to ultimately be responsible for the finished project and its final total cost.

As with any project, there are three major components that comprise the cost cycle: Material costs, labor costs, and administrative and operation cost (which is typically described as overhead). It is up to the "team" to constantly monitor and evaluate all aspects of the project, including any changes and modifications that may affect the quality, life-expectancy or life-cycle, maintenance cycles, and reliability of each aspect of the project; from development through engineering, design, and construction. Interestingly, although labor is a major component for each area of a building's creation, it is not often subject to any in-depth analysis in value engineering. Instead, the main effort of value engineering is directed at the cost and value of "things" — the cost of the elements of construction, the functionality of each element, and the materials and products being utilized.

The Intent of Value Engineering

In 1965, the U.S. Department of Defense conducted a study to evaluate cost-saving opportunities that could accrue from the use of value engineering. The study examined a number of projects and analyzed 415 project changes that were considered successful "value changes." The result of the study was that only a limited number of factors could achieve over 95 percent of cost savings. These factors were: Excessive cost, additional design effort, advances in technology, and the questioning of specifications.

Reason for Change	Percent Total Savings Achieved	Change Definitions
Advances in technology	23	Incorporation of new materials, components, techniques or processes not available a the time of the previous design effort.
Additional design effort	15	Application of additional skills, ideas and information available but not utilized during previous design effort.
Change in user's needs	12	User's modification or redefinition of mission, function or application of item.
Feedback from test/use	4	Design modifications based on user tests or field experience suggesting that specified parameters governing previous design were unrealistic or exaggerated.
Questioning specifications	18	User's specifications were examined, questioned, determined to be inappropriate, out-of-date or over specified.
Design deficiencies	4	Prior design proved inadequate in use (e.g., was characterized by inadequate performance, excessive failure rates or technical deficiency.
Excessive cost	22	Prior design proved technically adequate, but subsequent cost analysis revealed excessive cost.
Other	2	

Source: Directorate of Value Engineering, Office of the Assistant Director of Defense as taken from "Value Engineering Theory & Practice in Industry," Thomas R. King, 2000, Lawrence D. Miles Foundation, Washington, DC.

Figure 11-1 Qualitative Results From the Implementation of Value Engineering

The study (see Figure 11-1) revealed: no single factor was ever dominant in the implementation of value engineering. It was rare for the implementation of the change the result of a "bad" design; trying to "second-guess" a design looking for deficiencies provided little value, because the majority of designs perform as expected. What was discovered is that many designs did not always provide maximum value due to excessive costs, over specifying and the lack of value for the project.

What is Value?

"Value" means different things to different people. Thus, there is no one perfect definition of value. For purposes of value engineering, value does not simply equate to "cost reduction." There are all kinds of "values" — economic, moral, social, political, etc. In terms of value engineering, it is the economic value that most conforms to what is being measured or evaluated. Value, then, is:

> *The lowest cost to provide the necessary and required products, functions, or services at the chosen time to its needed place with the requisite quality.*

For engineering purposes, value can be best defined by the following formula:

$$\text{Value} = \frac{\text{Worth}}{\text{Cost}}$$

In this formula, when value is equal to or greater than 1 (V=1), it is understood that there is equality of value. As an example, consider the specification of a vacuum pump. The pump is vital to the function of the design. If the pump costs $1,000 and it is indeed worth $1,000, then there is equality of value ("good value"). If the pump is only worth $800 and cost $1,000, then there is imperfect value ("poor value"). If the pump is worth $1,200 and cost $1,000, then there is increased value ("outstanding value").

Which then brings up the whole concept of cost and worth. Cost seems pretty straight forward. It's what you pay for the product or service. But, what is worth? For value engineering purposes, worth is the concept of the value of a function, product, system, etc. Or, alternately stated, worth is the least cost to provide the function, product, or service. Still confused? It's no wonder. The concept of value and worth are amorphous; they are not easily measured or defined. A number of basic questions were developed as part of the concept of value engineering. To help determine "value" and "worth," it is important to note that these questions relate to the general nature of value engineering, and are relevant for all types of engineering, from construction to manufacturing. They have been modified below to be more construction specific.)

1. Are the products, systems, and materials necessary for the functionality of the project, and do they contribute value to the project?
2. Are the costs of the products, systems, or materials in proportion to their usefulness within the project?
3. Do the designed or specified products, systems, or materials need all the designated features?
4. Are there other products, systems, or materials available that will accomplish the intended use or purpose and provide better performance?
5. Are the exact products, systems, or materials available for less?
6. Are there other products, systems, or materials available that will accomplish the intended use or purpose at a lower cost?
7. Are there other products, systems or materials available that will accomplish the intended use and purpose with an equal performance?
8. Is there another dependable supplier that can provide the products, systems, or materials for less?
9. Does the total cost of the products, systems, or materials include all materials, reasonable labor, and overhead?
10. Are the products, systems, or materials the proper ones considering the quantity available or manu-

Job Plan Phases Noted Practitioners Name SAVE*					
Miles	**Fowler**	**King**	**Parker**	**Mudge**	**International**
Information Analysis Creativity Judgement Development Development Presentation Follow-up	Preparation Information Analysis Creativity Synthesis	Information Function Analysis Creative Evaluation Implementation Presentation Implementation Follow-up	Information Function Creative Judicial Development Investigation Recommendation	General Information Function Creation Evaluation Presentation	Information Function Analysis Creative Evaluation Development

Figure 11-2 Value Engineering Job Plan Examples

* SAVE International, Society of American Value Engineers, International.

factured, or the quantity that is needed and will be used?

ELEMENTS OF VALUE ENGINEERING

In the world and vernacular of value engineering, a value engineering analysis incorporates a VEJP (Value Engineering Job Plan). Because this analysis is in itself an engineering project, the job plan is divided into "phases." The number of phases can vary (see Figure 11-2). It all depends on what "expert" you have learned from, what books you've read and what direct experience you have had in conducting value engineering projects.

It doesn't really matter how many phases there are in a VEJP. What is vital is that the engineer be comfortable with all the phases of his/her plan, understand the various techniques for each phase's evaluation and analysis, and that the plan provide a systematic and consistent approach for implementation of the project. This introduction to value engineering integrates the six general phases as listed by Society of American Value Engineers (SAVE) with the five phases from Lawrence E. Mills (considered the "father" of value engineering) and incorporates the various techniques of implementation within each.

Phase One: Information

This phase addresses three questions: "What is it?" "What does it do?" and "What does it cost." In practice this phase describes the project and collects the necessary information, both critical components for the remainder of the value engineering project. Actually, gathering information is pretty simple and straightforward. The really hard part is making sure the information gathered is factual, accurate, unbiased, untainted by opinion, and contains no assumptions.

As every plumbing engineer knows, the hardest part of the project is collecting accurate and factual information. A project can only be engineered and designed according to the quality of information used. Likewise, value engineering is only as good and accurate as the quality and accuracy of the data and information collected and used throughout the process.

The information phase of value engineering is the heart of the overall process. It is also undoubtedly the hardest to explain and understand as the collection of the data that will be vital to a successful value engineered result is often colored by layers of subjectiveness, biases and lack of objectivity.

The key to successful information gathering is being prepared. The value engineer, like the plumbing engineer, depends on organization and structure and design standards. The value engineer collects the key information in a standardized format. The use of forms or checklists is helpful in this endeavor. The value engineer's job is compounded by having to collect information from many individuals and disciplines. For this reason, it is best to integrate value engineering throughout each phase of the project: Conception, design, engineering, bidding, construction, commissioning, and occupancy.

For the plumbing design portion of a facility, the value engineer must follow the engineer's thinking and collect and assemble the same information used by the engineer (see figure 11-3). This means detailing every product and design element.

ABC Project — Plumbing Design

Project Description Documents
Original Client Directions/Specifications
Architectural Drawings
Engineering Drawings
Detail Drawings
Materials List
Details of Materials Examined/Considered
Material Line Information
Product List
Details of Products Examined/Considered
Product Line Information
Vendor Information

Figure 11-3 Information Gathering

There are many variations of VE worksheets, but typically they include the basic information form that describes the project and related data such as in Figure 11-4A. Additional information forms such as Figure 11-4B, allow each detail of the project or design.

The next phase of the information collection process is to understand the background and purpose of the complete project and each of its elements. This requires developing the right questions or checklist of items that need to be collected, understood, and used for the remainder of the engineering process. Figure 11-5 is a sample of such a checklist.

As the VE collects all this information, he/she needs to keep a detailed record of information sources and types of actions needed or taken. This record provides the forensic trail that will backup the final conclusions. It is a way to track each stage of the information collection process and provides a reference record and a source record for the analysis and recommendations. A sample of a source record form is shown in Figure 11-6.

With all the information and data that has been collected, the engineer must still make a qualitative determination of its value. The following can help make that determination of questions:

1. Does the information/data support the definition/specifications/requirements of the project?
2. Does the information/data seem to be factual and valid for the project/detail being analyzed?

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Project Information

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Project Information

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Project Information

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Value Engineering Consultants
Project Information — Continued

Contractors:

Structural:
Address:
City: State: Zip:
Telephone: Fax: E-mail:

Electrical:
Address:
City: State: Zip:
Telephone: Fax: E-mail:

Plumbing:
Address:
City: State: Zip:
Telephone: Fax: E-mail:

HVAC:
Address:
City: State: Zip:
Telephone: Fax: E-mail:

Communications:
Address:
City: State: Zip:
Telephone: Fax: E-mail:

Other:
Address:
City: State: Zip:
Telephone: Fax: E-mail:

Suppliers:

Structural:
Address:
City: State: Zip:
Telephone: Fax: E-mail:

Electrical:
Address:
City: State: Zip:
Telephone: Fax: E-mail:

Plumbing:
Address:
City: State: Zip:
Telephone: Fax: E-mail:

HVAC:
Address:
City: State: Zip:
Telephone: Fax: E-mail:

Communications:
Address:
City: State: Zip:
Telephone: Fax: E-mail:

Other:
Address:
City: State: Zip:
Telephone: Fax: E-mail:

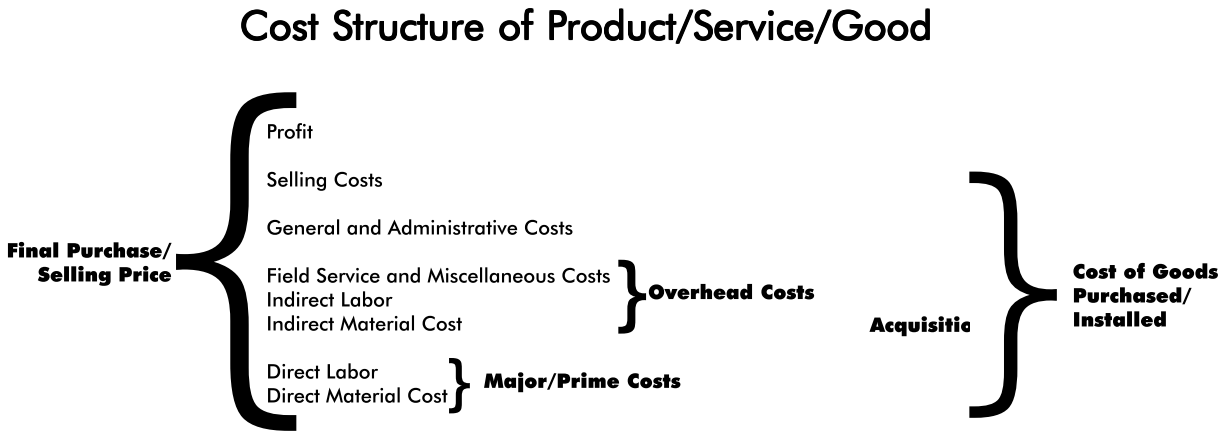
Value Engineering Consultants
Project Information Checklist

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Value Engineering Consultants
Project Information Checklist

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Value Engineering Consultants
Project Information & Data Sources


Cost Structure of Product/Service/Good
Final Purchase/
Selling Price
Profit
Selling Costs
General and Administrative Costs
Field Service and Miscellaneous Costs
Indirect Labor
Indirect Material Cost
Overhead Costs
Direct Labor
Direct Material Cost
Major/Prime Costs
Acquisitio
Cost of Goods
Purchased/
Installed

In the facility "business" there may be myriad levels of purchasers—from the owner to the developer to the architect to the engineer/designer to the contractor. Therefore, the cost structure actually becomes a pyramid of costs and prices with different "users" along each link in the project chain. Figure 11-8 gives a generalization of the cost makeup for each "user" at the different stages of the facility project process.

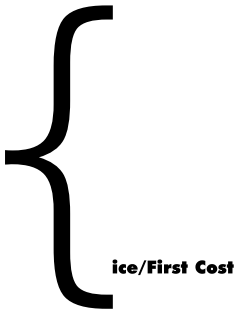


Figure 11-8 Generalized Total Cost to Each User

A wide variety of costs go into each element and aspect of a facility. These costs are divided into ongoing costs and one-time costs. Ongoing costs are those that will occur throughout the life of the project. The owner has one set of ongoing costs, while each product/service/material provider has its own ongoing cost structure. Likewise, there are one-time costs for all of these providers. Figure 11-9 offers an example of the differing cost elements that will not only comprise the cost of a total project but also be considered at each stage of the project process.

With all the costs collected and detailed, the analysis can proceed. The next step is to relate all of the costs to each other, define relationships, and establish which of the costs are related to specifications for the project/design and which are imposed requirements. Costs associated with specifications are those imposed by the owner/developer/user of the facility. These costs can be connected to the land, construction limitations, or user-defined needs.

Required costs are those that different vendors, project managers, and contractors impose on the project due to his/her experience and knowledge. They are the "expert" costs that form the basis for the creation of the facility.

It is the value engineer's job to discover and understand all these different potential costs. Then, as part of his/her analysis, the engineer must differentiate between costs that are "real"— based on specifications, available information, and conditions—and those that are "imaginary" (skewed by bias, attitudes, habits, lack of information, old technology, lack of ideas and creativity, and temporary conditions).

Value engineering has come about because users will inevitably overestimate their needs and have unrealistic expectations. This will be compounded by those involved in a facility project who often over-engineer and over-design at the beginning of a project due to the unrealistic expectations and overestimates of the owner/user. It is the value engineer who must bring expectations, estimates, and reality into focus.

The Pareto Principle: Vilfredo Pareto developed an economic theory regarding the distribution of wealth. This principle has found its way into many disciplines of engineering, and especially value engineering, where the principle is better known as the 80/20 Rule. In its original form, Pareto stated that 80 percent of all wealth is held by just 20 percent of all people. This 80/20 principle has been applied to everything from manufacturing to construction to engineering principles. In this chapter's context, it states that 80 percent of a facility's costs will be associated with just 20 percent of its components.

Is it true? The principle is stated as the theory of the Law of Inverse Proportions and is actually a concept. It is very useful when examining the resources available for a project and focusing on those that will provide the largest economic benefit and result in the highest levels of return for the expended effort.

Phase Two: Analysis/Function Analysis

The questions "What does it do?" and "What is it supposed to do?" continue to be addressed in this phase and concisely sum up this concept. In this phase the engineer needs to identify the functions of the project. The Analysis/Function phase is often considered the "heart" of value engineering because it is in this phase that the engineer has a methodology to reestablish the original project/element needs into simply workable expressions.

For example, value engineering, the accepted definitions for "Function" are:

> *That which makes a product work or sell; that which satisfies the needs or requirements of the user.*

If it were only that simple. The difficulty in this phase is the translation and giving of substance to the words used for project/element specifications and requirements. An engineering discipline has taken these words, brought them to life, and provided a vi-

Active Verbs (Desirable)

Apply	Amplify
Attract	Change
Collect	Conduct
Control	Create
Emit	Enclose
Establish	Filter
Hold	Induce
Impede	Insulate
Interrupt	Modulate
Prevent	Protect
Rectify	Reduce
Repel	Shield
Support	Transmit

(Less Desirable)

Provide

Passive Verbs (Desirable)

Create	Decrease
Establish	Improve
Increase	

Measurable Nouns (Desirable)

Contamination	Current
Density	Energy
Flow	Fluid
Force	Friction
Heat	Insulation
Light	Liquid
Load	Oxidation
Protection	Radiation
Torque	Voltage
Weight	

(Less Desirable)

Article	Component
Damage	Device
Circuit	Part
Repair	Table
Wire	

Nonmeasurable Nouns (Desirable)

Appearance	Beauty
Convenience	Costs
Exchange	Features
Style	

(Less Desirable)

Effect	Form
Loops	Symmetry

Figure 11-10 Function Definition Verbs and Nouns

sual interpretation. The value engineer must now also examine those same words and provide a structured evaluation and analysis to them — which results in a functional analysis and/or definitions.

RULES OF FUNCTION ANALYSIS

There are three generally accepted rules for conducting functional analysis or creating functional definitions.

Rule 1: The expression of all functions must be accomplished using two words; one must be an active verb, the other a descriptive or measurable noun. Figure 11-10 offers a sample listing of verbs and nouns typically used in value engineering functional definitions.

Rule 1 is based on the adage that less is more. The concept is if you cannot provide a definition of a function in two words, either you do not have enough information about the project/element, or the item has not yet been defined in its simplest form. By being limited to two words, you will be able to describe the simplest element of the project in a manner that reduces the potential for mis-communication or misunderstanding.

Rule 2: All functional definitions can be divided into one of two levels of importance: Work or appearance (or selling). Work functions are expressed in action verbs and descriptive or measurable nouns that establish a quantitative statement for the item. Appearance or Sell functions are expressed in passive verbs and in general or nonmeasurable nouns that describe a qualitative statement for the item.

Rule 2 provides meaning to the descriptive terms or rule 1. The definitions here are designed to amplify the meanings of the function under consideration. If the function cannot be described with action or active verb, the functionality of the element is questionable. If there is no action, then nothing is being accomplished and, thus, there is no end result or usefulness to the function.

By using measurable nouns, the evaluating engineer will establish a cost-to-function relationship. These nouns provide a quantitative measure to the function, and, therefore, provide a measurable level of usefulness for the function.

Why, then, have appearance or sell factors, if they do not provide any quantifiable or measurable attribute? First, having appearance or sell factors involved in the function that can be separated out, will help in the assignment of some proportionate amount of the elements cost. Second, by identifying these function descriptors, the engineer will be providing a further description of the specifications and requirements of the function. This will help the owner in the final decision process regarding the function. While the value engineer may well find an equal element at lower cost, it may be that the nonquantifiable part of the requirements is an overriding consideration. (E.g, color; while a basic white porcelain bowl may be less expensive, the use of a special color porcelain bowl may be an important and overriding appearance/selling requirement.)

Rule 3: All functional definitions can also be divided, into one of two descriptive uses: Basic or secondary. A basic function is one that describes the primary purpose for a product, system, or material. Secondary functions are all other functions of the product, system, or material that do not directly accomplish the primary purpose but support the primary purpose or are the result of a specific engineering or design approach. In functional analysis, the secondary functions are the ones that can be combined, modified, or eliminated.

This rule further enhances the ability to assign a relative importance to the function. For a majority of projects/products/materials, there is only one basic function to be derived. In those rare cases when more than one basic function is stated, usually it is just a restatement of the original basic function. When there are secondary functions, they tend to fall into two categories: Specific and dependent.

Specific functionality requires a specific action to be accomplished. Dependent functionality are those functions that require some prior action before it can be performed. Secondary functions can exist because they are part of the specifications or requirements, or because they are inherent to the engineering or design approach used.

Function Definitions

With all the rules in place and understood, the value engineer begins the function analysis. Figure 11-11 shows a sample of the type of form that helps in this phase. The form is straightforward, and, given all the definitions and explanations supplied, should be self-evident. The most important part of this phase is to define the function or the element under analysis and create its functional definitions.

Example 3 in Figure 11-11 is considered one of the quintessential examples in value engineering analysis for explaining the use of two-word definitions. The pencil is an everyday object that requires a successive and seemingly unnecessary number of items to define it and all of its elements. However, this remains the crux of the value engineering definition phase. Example 4 in Figure 11 provides an example that could well be used to evaluate a product used in plumbing engineering. However, as should be obvious, in both these examples, the emphasis of the value engineering would be in the manufacture of the item and is not related to its role in a construction project.

Only a portion of the form in Figure 11-11 is filled out at this early stage of the analysis process. At a

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Functional Definiton and Analysis

Example 1: Expansion Chamber

Qty	Item Descrp.	FUNCTIONS* VERB	NOUN	B	S	W	AP SL	Cost per Function (Estimate)	Label Function V= vital E = Essential N = Nice to Have	Notes/ Comments
1	Expansion Tank	Contain	Liquid	X						
		Provide	Pressure	X						

Example 2: Wall Box

Qty	Item Descrp.	FUNCTIONS* VERB	NOUN	B	S	W	AP SL	Cost per Function (Estimate)	Label Function V= vital E = Essential N = Nice to Have	Notes/ Comments
1	Wall Box	Confine	Material	X						
		Store	Material		X					
		Protect	Inside		X					
		Protect	Material	X						
		Prevent	Loss		X					
		Enhance	Appearance		X					
		Establish	Privacy		X					

Figure 11-11 Function Analysis/Definition Form (Continued)

minimum, the function is defined, and, if necessary, its elements. At this stage, only basic and secondary indicators are marked. The remaining portion of the form will become part of the evaluation phase.

FAST

There is a second approach that is an adjunct to, and works in tandem with, function definitional analysis. This approach is known as FAST, which stands for Functional Analysis System Technique. The FAST process is essentially a diagraming process. With diagraming, a visual representation is created that highlights the functions of a product/system/material and the interrelations between them.

A basic FAST model diagram is shown in Figure 11-12. The FAST model is a building process that will:

- Help to avoid a random listing of functions. The requirement of functional analysis requires the use of verb–noun definitions. The FAST diagram will help sort out the functions and show interrelationships.
- Help to find any missing functions.
- Aid in the identification of the basic function and understanding the secondary functions.
- Provide a visualization and better understanding of the product/system/material under study.
- Result in a team consensus in defining the product/system/material under study.
- Provide a test of the functions utilizing system analysis and determinate logic.
- Demonstrate the team approach has fully analyzed the elements.

The parts of FAST shown in Figure 11-12 are:

1. Scope Lines: The two vertical dotted lines provide a boundary to the function under study. It is that part of the function which is of concern.
2. Highest Order Function: The object or output side of the basic function under study is referred to as the highest order function. Additional functions to the left of another on the critical path is a “higher” order function.

Example 3: Pencil

Value Engineering Consultants
Functional Definiton and Analysis

Reference Number: _____ **Date:** _____

Detail/Product/Material Specification: PENCIL
Function: MAKE MARKS
Description (e.g., part number): _____

Qty	Item Descrp.	FUNCTIONS* VERB	NOUN	B	S	W	AP SL	Cost per Function (Estimate)	Label Function V= vital E = Essential N = Nice to Have	Notes/ Comments
1	ERASER	REMOVE	MARKS		X	X				
1	BAND	SECURE	ERASER		X					
		IMPROVE	APPEARANCE		X					
1	BODY	SUPPORT	LEAD	X						
		TANSMIT	FORCE	X						
		ACCOMODATE	GRIP							
		DISPLAY	INFO							
1	PAINT	PROTECT	WOOD							
		IMPROVE	APPEARANCE		X					
1	LEAD	MAKE	MARKS	X						

Note: **B — Basic**
S — Secondary
W — Work
AP/SL — Appearance/Sell

Figure 11-11 Function Analysis/Definition Form (Continued)

Figure 11-12 Function Analysis Systems Technique (FAST) Model

11. Activity: The method selected to perform a function.

For engineers familiar with systems-type diagraming, it would appear that the FAST diagram is backwards. As an example, consider the position of the WHY part of the function. For systems analysis, it is on the left. But for FAST the HOW function is in the left position and dominates the analysis. In this position, all the functions/activities to the right are dependent on the basic function or moving toward the WHY of the function.

Figure 11-13 diagrams the how, why, and when relationship, relates it to the FAST diagram, and shows a simple how functional relationship.

Purpose of the Model

As it turns out, in the team environment the FAST model, while a means to an end, is not the vital part of this process. The vital part is the dialogue and discussions between the team members as the model is formulated and built. It is the process of identification — functions, questions, justifications, relationships — that is the key to the structure of the function analysis and provides the team with a methodology to produce a desired result. In fact, once the model is created its only purpose remains as an explanatory, rationale, and communication to the decision makers and other engineering disciplines.

It would seem to be intuitive that the next step should be evaluation and cost determination. But in value engineering the next phase is creativy.

Creativity

The creative process evaluates the project with an emphasis on, "What else will do the job?" The creative part of the value engineering process is best summed by the trite expression, "start with a clean sheet of paper." Again, this phase requires a team approach to engineering disciplines. In the creativity phase the team needs to unstructure itself and separate itself from all of the previous phases. The team needs to leave the drawings, information, forms, and models behind and find a fresh environment in which to reassemble. In this creativity environment the only information permitted are the two-word, verb-noun functions that describe a single product/system/material being analyzed.

It is up to the team to now develop creative ideas. Creativity is not an exact science; but it is teachable and thus learnable. The creative phase is to be the act of putting together unconnected or seemingly unrelated factors or ideas to "create" a single new idea. Creativity is the art of bringing something new into existence. It is an original concept not an imitation of something else. The important element of creativity is perception: If the creative thought or idea is "new" to us, it is a creative act regardless of whether it may have existed somewhere else at some other time. Creativity is also the mother of innovation, and both are important elements of the value engineering process. If creativity is something "new", then innovation is a "creative" or imaginative use or application of the concept. Innovation is adaptive of creativity.

Creativity is conceptualizing a pipe structure; basically a hollowed or formed material that can be connected, bent, twisted, buried, hung or laid flat or vertical. The innovation is to use the creative idea to carry liquids or gases from point A to point B.

Creativity is divergent thinking. It is overcoming perceptions, preconceived notions, emotional blocks, cultural divides, and habits. To be successful it is imperative to avoid the path of least resistance: "Follow the past." After all if it worked before it must still be a workable solution today. No sense "reinventing the wheel."

Creative Thinking Personified

Positive creative thinking can be described by the invention of the cotton gin. Eli Whitney was trying to find a way to remove seed from raw cotton. One afternoon, on a walk, he noticed a cat trying to catch a chicken through a wire fence. The cat's claw would stick through the fence whenever a chicken came close, but all that came through the fence on the cat's claw was feathers. This was the observation that provided the creative incentive. Whitney conceived the concept of pulling the cotton (feathers) though a comb (fence). It was a subtle difference to all the thinking that went before. Instead of trying to remove seeds from the cotton by pulling on the seeds, Whitney's solution was to pull the cotton away from the seeds.

Inflexibility: An illustration of just the opposite inflexible thinking is of an innovation made to an invention that to this day remains a world-wide standard despite its outmoded purpose. It is the computer keyboard configured in the QWERTY style. This style was an innovation of Christopher Sholes who, invented the typewriter. Because of the mechanics of the typewriter, and that gravity was the engine to move the keys back into position, Sholes found that fast typists would quickly create key jambs as they stroked faster than the keys could clear each other and return to rest. Through persistence and experimentation, he developed a keyboard layout that separated the most often used letter keys and thereby SLOWED down the typing process. Today, that same "slow down" mentality continues with the modern computer keyboard. This despite the Dvorak and American Standard system of keyboard layout that produces a faster result. Ingrained habit is hard to overcome.

Roadblocks to Creativity: Creativity takes work. Hard work. Of course, as an alternative to providing the creativity phase in value engineering,

the engineer can fall back on, and use one of the top ten reasons for why value engineering should not be used at this time:

1. It isn't in the budget.
2 We don't have the time.
3. Let's form a committee.
4. Has anyone else tried it on this type of project?
5. Why change it? It's always worked perfectly before?
6. We tried that before.
7. The developers will never buy into it.
8. You're years ahead of your time.
9. Let's shelve it for the time being.
10. It's against company policy.

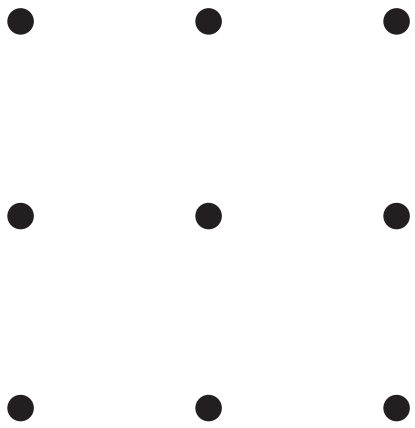
(Adapted form *Value Management*, General Services Administration, Washington, DC.)

Divergent Thinking

Creativity in value engineering is best described as speculation and brainstorming. An all too often overused and "trite" phrase, "Thinking Outside the Box" is an attempt to describe divergent thinking.

Outside the Box: What is outside the box thinking? One much used example is the Nine Dots:

Nine Dots



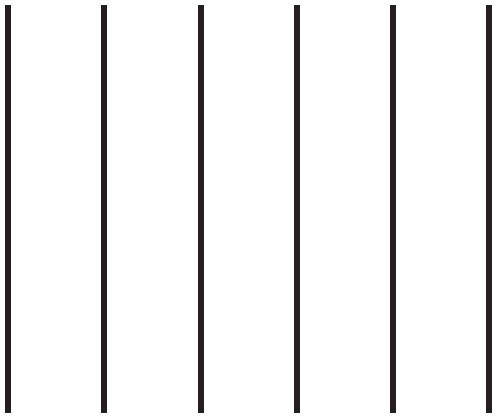
First draw nine dots in the form of a square on a piece of paper as shown.

Next, without lifting you pencil from the paper, draw four straight connected lines that will go through all nine dots. You may not backtrack on a line and each line must go through each dot only once.

See the end of this chapter for the solution.

Another often used example is the six sticks. You are given six "sticks" (use toothpicks, straightened paperclips or matchsticks) of equal length as shown below.

Equilateral Triangles



Arrange the sticks to make four equilateral triangles. All of the ends of each "stick" must touch each other. (And, as engineers, we all know that an equilateral triangle has three sides of the same length.)

See the end of this chapter for the solution.

Finding Solutions: In this phase the team is not trying to find solutions, only ideas. To help this process the "leader" has some help; a simple paper and pencil — and of course, a form can be created from this idea (see Figure 11-14). The brainstorming or speculative process consists of two techniques: unassisted creativity and assisted creativity.

With unassisted creativity, one team member takes the creativity worksheet and is assigned one two-word definition for one of the functions. The individual lists every possible idea he/she has regarding that function, such as "create seal." Once the individual has put down whatever ideas he/she has, the worksheet is moved on to another team member who then adds his/her own ideas. The sheet is passed to each team member in turn.

The second step, assisted creativity, is nothing more than a group exercise where each participant "hitchhikes" on each other's ideas in order to create yet another "new" idea. To get started the team splits into 3 parts: one group has the worksheet for one of the two-word function definitions, one group has a set of "idea generators" or checklists to help the thinking, and the third group has reference sources such as a dictionary and thesaurus. As one sub-team reads the list, the second could find new words and ideas using the alphabet concept (take a word and think of another word with a different starting letter of the alphabet) and the dictionary, while the third worked the checklists continually questioning all the thought processes. Two sample checklists are shown in Figure 11-15A and Figure 11-15B.

There are a couple of important elements to using this process. The first is that the strong individual's habit of being judgmental must be abated. To do this, the group should decide beforehand how to indicate

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Creativity Worksheet

Reference Number: _____ **Date:** _____

Function: _____

1.	31.	61.
2.	32.	62.
3.	33.	63.
4.	34.	64.
5.	35.	65.
6.	36.	66.
7.	37.	67.
8.	38.	68.
9.	39.	69.
10.	40.	70.
11.	41.	71.
12.	42.	72.
13.	43.	73.
14.	44.	74.
15.	45.	75.
16.	46.	76.
17.	47.	77.
18.	48.	78.
19.	49.	79.
20.	50.	80.
21.	51.	81.
22.	52.	82.
23.	53.	83.
24.	54.	84.
25.	55.	85.
26.	56.	86.
27.	57.	87.
28.	58.	88.
29.	59.	89.
30.	60.	90.

Figure 11-14 Creativity Worksheet

How much of this is the result of custom, tradition, or opinions?
Why does it have this shape?
How would I design it if I had to build it in my home workshop?
What if this were turned inside out? Reversed? Upside down?
What if this were larger? Higher? Wider? Thicker? Lower? Longer?
What else can it be made to do? Suppose this were left out?
How can it be done piecemeal?
How can it appeal to the senses?
How about extra value?
Can this be multiplied?
What if this were blown up?
What if this were carried to extremes?
How can this be made more compact?
Would this be better symmetrical or asymmetrical?
In what form could this be-liquid, powder, paste, or solid? Rod, tube, triangle, cube, or sphere?
Can motion be added to it?
Will it be better standing still?
What other layout might be better?
Can cause and effect be reversed?
Is one possibly the other?
Should it be put on the other end or in the middle?
Should it slide instead of rotate?
Demonstrate or describe it by what it isn't.
Has a search been made of the patent literature? Trade journals?
Could a vendor supply this for less?
How could this be made easier to use?
Can it be made safer?
How could this be changed for quicker assembly?
What other materials would do this job?
What is similar to this but costs less? Why?
What if it were made lighter or faster?
What motion or power is wasted?
Could the package be used for something afterwards?
If all specifications could be forgotten, how else could the basic function be accomplished?
Could these be made to meet specifications?
How do competitors solve problems similar to this?

Figure 11-15A Creativity Checklist

1. Can the dimensions be changed?
Border
Converge
Deeper
Delineate
Encircle
Intervene
Invert (reverse)
Larger
Longer
Make slanted or parallel
More shallow
Place horizontally
Shorter
Smaller
Stand vertically
Stratify
Thicker
Thinner
Use crosswise

2. Can the quantity be changed?
Add something
Combine with something
Complete
Fractionate
Join something
Less
More

3. Can the order be changed?
Arrangement
Assembly or disassembly
Beginning
Focus
Precedence

4. Can the time element be changed?
Alternated
Anticipated
Chronologized
Faster
Longer
Perpetuated
Recurrence
Renewed
Shorter
Slower
Synchronized

5. Can the cause or effect be changed?
Altered
Counteracted
Destroyed
Energized
Influenced
Louder
Softer
Strengthened
Stimulated

6. Can there be a change in character?
Add color
Altered
Change color
Cheaper
Interchanged
More expensive
Resilient
Reversed
Stabilized
Stronger
Substituted
Weaker
Uniformity

7. Can the form be changed?
Accidents avoided
Conformation
Curved
Damage avoided
Delays avoided
Harder
Irregular
Notched
Regular
Rougher
Smoother
Something added
Softer
Straight
Symmetrical
Theft avoided

8. Can the motion be changed?
Admitted
Animated
Agitated
Attracted
Barred
Deviated
Directed
Lifted
Lowered
Oscillated
Repelled
Rotated
Slowed
Speeded
Stilled

9. Can the state or condition be changed?
Abraded
Coagulated
Colder
Disposable
Drier
Effervesced
Elasticized
Harden
Heavier
Hotter
Incorporated
Insulated
Lighter automatic electric blanket
Liquefied
Lubricated
Open or closed
Parted
Preformed
Pulverized
Resistant
Soften
Solidified
Vaporized
Wetter

10. Can the use be adapted to a new market?
Children
Elderly
Foreigners
Men
Physically Challenged
Women

Figure 11-15B Creativity Checklist

someone is being judgmental and thus can modify the behavior (e.g., slapping the table with a palm).

The two sub-teams switch roles from time-to-time until they reach the point of stagnation and agree that they are finished. The team will by now have created a unique creative list of "new' and "old" ideas for each function under study. After the creative process, it becomes time for the evaluation phase. A possible result of this team effort for the two-word definition create-seal is shown in Figure 11-16.

Evaluation

The evaluation phase is a continuation of the creativity phase. It deals with a combination of appraisal, judgement, and selection to the qualitative and quantitative criteria and ideas developed for each function. In this phase, we go from divergent thinking to convergent thinking. Where, divergent thinking is problem identification and fact finding, convergent thinking is a mixing of appraisal, evaluation, judgement, selection, development, and implementation.

It is this phase that will create the final development of workable and meritorious alternatives. The introduction of appraisal, evaluation, and judgement will eliminate or reduce unnecessary costs and create a preferred recommendation or course of action.

Yet also in this phase it is all too easy to impart a cost-reduction spiral that does not result in value engineering, but simple cost reductions for budgetary reasons. It is in this phase that it is all too easy to degrade the product/system/material by reducing its quality, reliability, or maintainability.

Finally, in this phase ideas developed in the function and creativity phases will be refined and combined and evaluated by comparison. All of the costs of each function or idea will be established, and the team will continue to develop function alternatives. To do this will require a couple of new forms, an evaluation technique, and continuing the completion of the functional definition and analysis form.

In Concert With

Although this Evaluation Phase is shown as distinct from the Develpment/Investigation Phase, in reality in many cases, the two phases often overlap and there is really only one. It is up to the value engineering team to decide how many phases will be needed and what will be done when.

Refining, Combining, Evaluating by Comparison

Idea generation is a dynamic process that doesn't ever really stop. The creative thought process is an ongoing series of judgements and evaluations. In the evaluation phase ideas that seem unusable may well be combined with other ideas to create a better solution. Some ideas will stand out as preferred solutions, while others may be found to be lacking information. It is important, however, that no idea be discarded out-of-hand, for whatever reason. All ideas have some merit, which is not always immediately obvious.

To get started, the team should use a worksheet to list the advantages and disadvantages of each function or idea that is an offshoot of a function. Figure 11-17A shows a sample of such a worksheet. The essence of this step is to be sure that no good ideas are overlooked, and that no efforts are misdirected. As the functions and ideas are refined, combined, and evaluated, it is important to be evaluating the time required to develop alternatives versus any potential gain. The gain is, of course, improvements in quality, maintainability, and reliability, as well as cost advantages. Similarly, any immediately perceived disadvantages may, with a little thought and creativity, be turned into advantages. Figure 11-17B shows the information included.

At this stage, the form is fairly self-explanatory: In the first column is a simplified and short statement of an idea from the functional development; in the second and third columns, every advantage and disadvantage, no matter how large, how important, or how small or insignificant is identified.

If all this sounds a bit simplistic, it is. But, at the same time, it is an important step. Although we make evaluations, simple and complex on a daily basis, we often do so intuitively. With this structured methodology, the evaluation process will be seen to be more complex and exacting than simple intuition.

This worksheet is carried through the Development/Investigation Phase. In practice, this worksheet will be analyzed and evaluated twice — first in the evaluation phase by the value engineering team, and then in the Development/Investigation Phase, when similar forms will be used with other team components.

Cost Analysis and Evaluation

This step is also integrated into the development and investigation phase. In this initial evaluation step, a new worksheet is used to first draw a sketch of the function item being evaluated and then prepare a basic cost basis. Figure 11-18A shows the basic worksheets, and Figure 11-18B shows the same sheets with the information included.

In the sketch step, all that is needed is a freehand drawing that incorporates the essential items. With the parameters clearly defined and set there will be fewer tangential discussions and considerations.

Using the simple concept of the wall box, in this phase the requirement may be for an off-shelf-unit supplied out of a catalogue. It will be in the next phase, the Development/Investigation, when the team is expanded and a second review and evaluation made that advantages/disadvantages and cost savings can be integrated with each other.

Value Engineering Consultants
Creativity Worksheet

Reference Number: _____ **Date:** _____

Function: CREATE SEAL

1. PAINT	31. SPIGOT	61.
2. RUBBER	32. LABYRINTH	62.
3. RNG	33. WATER	63.
4. PLUG	34. DOVETAIL	64.
5. DRIED BLOOD	35. CORK	65.
6. VARNISH	36. FLANGE	66.
7. GLUE	37. PAPER	67.
8. PLASTIC	38. ROD	68.
9. EPOXUY	39. FOAM PLASTIC	69.
10. WAX	40. STOPPER	70.
11. PITCH	41.	71.
12. CHROME	42.	72.
13. WELD	43.	73.
14. RIVET	44.	74.
15. FIT	45.	75.
16. WASHER	46.	76.
17. SOAP	47.	77.
18. GASKET	48.	78.
19. LEATHER	49.	79.
20. GREASE	50.	80.
21. AIR	51.	81.
22. HEAT	52.	82.
23. FREEZE	53.	83.
24. COMPRESS	54.	84.
25. EXPAND	55.	85.
26. BRAZE	56.	86.
27. PLATE	57.	87.
28. SOLDER	58.	88.
29. GLASS	59.	89.
30. VACUUM	60.	90.

Figure 11-16 Creativity Worksheet

Value Engineering Consultants
Idea and Function Evaluation

--

Value Engineering Consultants
Idea and Function Evaluation

Reference Number: _____ **Date:** _____
Team: _____
Detail/Product/Material Specification: _____
Function: Wall Box; Confine and Secure Material
Description (e.g., part number): _____

IDEA FROM FUNCTIONAL DEVELOPMENT	ADVANTAGES	DISADVANTAGES
Provide 2' by 2' 10 gauge polished aluminum wall box to confine and secure on/off regulator valve for hot water for each fixture in each bathroom	1. Secures and Hides valve	1. Hides valve
	2. Provides protection of material	2. Not easily visible in emergency
	3. Gives better appearance than plain valve	3. Requires identification on outside of box
	4. Quality Look and Finish	4. Requires secure latching mechanism
		5. Requires access to latch key or opening mechanism
		6. Additional Cost to Install
Plan(s)/Action(s) on Idea(s)		

Figure 11-17B Initial Example — Idea Evaluation Worksheet

Value Engineering Consultants

Functional Development

Sketch

--

Value Engineering Consultants

Functional Development

Sketch

--

Value Engineering Consultants

Functional Development

Idea Development and Estimated Cost

--

Value Engineering Consultants

Functional Development

Idea Development and Estimated Cost

In this evaluation phase, everything from quantity purchases to custom designed and manufactured items should be taken into account. The value engineering team is: Establishing the first benchmarks of the functional and cost analysis; examining any secondary functions that should or can be considered; and ensuring that all of the project parameters have been met. The team must answer many questions: Are all the specifications and requirements met? Are all the two-word function definitions accounted for? Are all functions and needs being met? Is there duplication of effort or definitions that can be eliminated and, thus, reduce costs?

Incorporating the Functional Definitions

In the information phase, the Functional Definitions Worksheet was initialized. The evaluation phase provides the information necessary to complete the final four sections of the worksheet: the Work versus Appearance evaluation, the estimated cost, the importance valuation of each element, and any notes or comments. The first step is to evaluate and compare the functional relationships and create a numerical weighting of the functions. This numerical weighting will provide a basis for determining value or levels of importance of the functions, as well as the magnitude of importance. To create a numerical evaluation, a Functional Evaluation Worksheet will be utilized as shown in Figure 11-19.

To start, use the function definition and analysis worksheet for detail/product/material. Continuing the Wall Box example, the worksheet identified eight functions for the wall box and listed them in order in the Functional Evaluation Worksheet—Part 1. This simply provides a list order for the items with appropriate alphabetic identification. See Figure 11-20A.

Comparison of Functions: The value engineering team must know and compare each function with every other function. Starting with the function delineated as "A" or *Confine Material*, it is compared to function "B," *Store Material*. *Confine Materials* is determined to be more important than *Store Materials,* and is thus accorded a listing of "A" in the "A" line under the "B" listing in the Functional Evaluation Worksheet — Part 2.

At the same time that the relative importance is being determined, the magnitude of the importance must also be established. The numerical weights provided in Part 2 are then used to establish this importance difference. As seen, the *Confine Materials* is rated to be of major importance when compared to *Store Materials*.

Each of the remaining functions are evaluated and analyzed in a similar manner in relationship to all of the functions below it, as shown in Figure 11-20B.

With the evaluation and analysis complete, Figure 11-20B shows that the functions in importance as follows:

Prevent Loss	15
Protect Inside	10
Confine Material	9
Protect Material	9
Establish Privacy	5
Enhance Appearance	1
Store Material	0

From this analysis, the value engineering team would declare the Prevent Loss function to be the basic function. The final weighted list shows the relative importance of each of the functions to each other and to the project.

With this information, the Function Definition and Analysis Worksheet can now be completed as shown in Figure 11-21. Note that the basic and secondary functions have now been redefined based on the evaluation, and it can now be determined which of the elements are vital, essential, or would just be nice to have.

This analysis would continue to examine each of the system functions in relationship to the others and would, in turn, create a weighted evaluation of each of the separate products/systems/materials for the overall project being examined.

The Pencil: Another Look

An alternative evaluation and analysis could also be constructed by establishing idea criteria using a qualitative approach. In this method, each of the items of the function can be evaluated in the reverse of the function definitions and uses perscriptive connotations for expressing value. In this instance, the listing order might look like Figure 11-22A, the evaluation worksheet part 2 like Figure 11-22B, and the completed Evaluation worksheet part 1 like Figure 11-22C.

This alternate analysis can be conducted by the value engineering team or can wait until the next phase, Development/Investigation, and be conducted with an expanded value engineering team.

DEVELOPMENT/ INVESTIGATION

Consultation and Evaluation

The evaluation phase is continued here in the Development/Investigation phases as the value engineering team brings in other team members to provide additional creativity and energy to the process. All of the functional development worksheets are prepared for review by the advanced team. In Figure 11-23, the Idea Evaluation Worksheet is recreated with only the ideas of the function development filled in. As

Value Engineering Consultants
Functional Evaluation — Part 1

Value Engineering Consultants
Functional Evaluation — Part 2

Value Engineering Consultants
Functional Evaluation — Part 1

Value Engineering Consultants
Functional Evaluation — Part 2

Value Engineering Consultants
Functional Evaluation — Part 1

Value Engineering Consultants
Functional Definiton and Analysis

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Value Engineering Consultants
Functional Evaluation — Part 1

Value Engineering Consultants
Functional Evaluation — Part 2

Figure 11-22B Functional Evaluation, Part 2

Value Engineering Consultants
Functional Evaluation — Part 1

Figure 11-22C Functional Evaluation, Part 1, Step 2

Value Engineering Consultants
Idea and Function Evaluation

Reference Number: _____ **Date:** _____
Team: _____
Detail/Product/Material Specification: _____
Function: Wall Box; Confine and Secure Material
Description (e.g., part number): _____

IDEA FROM FUNCTIONAL DEVELOPMENT	ADVANTAGES	DISADVANTAGES
Plan(s)/Action(s) on Idea(s)		

Figure 11-23 Completed Idea Evaluation Form

before, a Sketch is provided, as is the ideas development sheet.

Once again, the team sets down rules to follow similar to those that went before. In this phase additional team members might include the manufacturer, contractor, and owner representative. This phase can provide an intense critique of the function/idea under discussion. It is this value-added group that reestablished advantages and disadvantages, with the initial value engineering team providing input based on their initial worksheet.

Second Creativity, Evaluation, Cost Anaylsis

In this phase, the larger team will again do creativity and evaluation. As seen in Figure 11-24A and 11-24B, the sketch can be significantly modified, and a new, secondary approach to the idea development phase can result in a different evaluation that could result in significant cost savings.

As seen in Figure 11-24, in this development/investigative phase the emphasis was on alternatives to a catalogue box and a "new" brainstorming session with different expertises and viewpoints.

Final Alternatives

With additional idea evaluation and cost estimates worksheets and possible sketches, the expanded value engineering team is ready to redevelop the idea. The team would again establish advantages and disadvantages using Figure 11-23 worksheet. At this stage, all of the engineering diciplines, contractors, and even the owners would help in the final development and investigation to determine the best outcome.

With a workable and best-cost idea developed, the final step is to use construction supplies and industry standards to confirm the ability to meet the final engineering and design.

The Gut Feel Index

The Gut Feel Index is what engineers have developed from the original Delphia method of evaluation. The Delphia method attempts to achieve a consensus of opinion within a group using questionnaires regarding future events and technical expertise.

The Gut Feel Index is similar, but uses the intuitive qualification of each developed idea using the technical expertise of the individuals. Each team member scores each idea on a scale of 1 to 10 based on its technical merits and the economic expectations. Low technical requirements, low costs, and low risks get the highest mark.

High rankings by any individual are further explained to the other goup members so all understand the rationale behind the rankings. The average of the scores are then computed.

Finally, a Risk Guide is used to make the final determination as to each idea. Figure 11-25 defines a sample Risk Guide.

In this approach, the Risk 1 level can be implemented or accepted without much concern. All the other categories will require further investigation.

Cost Analysis, More

One of the major elements of value engineering is the final cost analysis that is done for the recommendations and alternatives. Cost considerations are an important element of the value engineering process. Up to this point, the process has relied on creative techniques, brainstorming, functional analysis, and comparitive analysis. The concentration has been on the technical side of the equation.

The result for value analysis must also incorporate the cost analysis side of value engineering. Interestingly, in many value engineering projects, a comparative-cost analysis is not often conducted. A cost analys will look at life-cycle costing, break-even analysis, and comparitive-cost analysis. For purposes of this basic overview, the details and in-depth review of the various cost-analysis methodologies are not included.

Are We There Yet?

The evaluation phase was intended to provide visibility to all ideas and flush out any constraints while offering alternative solutions. This phase, while seeming to repeat some of the evaluation phase, is the final organization and analysis phase. It is in this phase that the value engineering team prepares their final recommendations prior to presentation to the owners/clients.

The value engineering process reviewed here has used, depended and recommended the use of standardized worksheets. One major disadvange to this approach is the attempt to find a standardized process that is all encompassing for all situations and projects. Alas, that is not the case. So why then have worksheets?

The primary purpose is use as a tool, to help provide structure to the process and offer a presentation format. All of the worksheets help form a "picture" of the value engineering process and provide illustrative detail for support of the final recommendations. It is important that the end result show that there was depth to the engineering and analysis; that what is proposed is not "just" a suggestion or best guess but is based on engineering discipline.

Perhaps the best final step for the value enginering team is to have yet one more checklist; this one of questions that support the value engineering process.

Value Engineering Consultants
Functional Development
Sketch

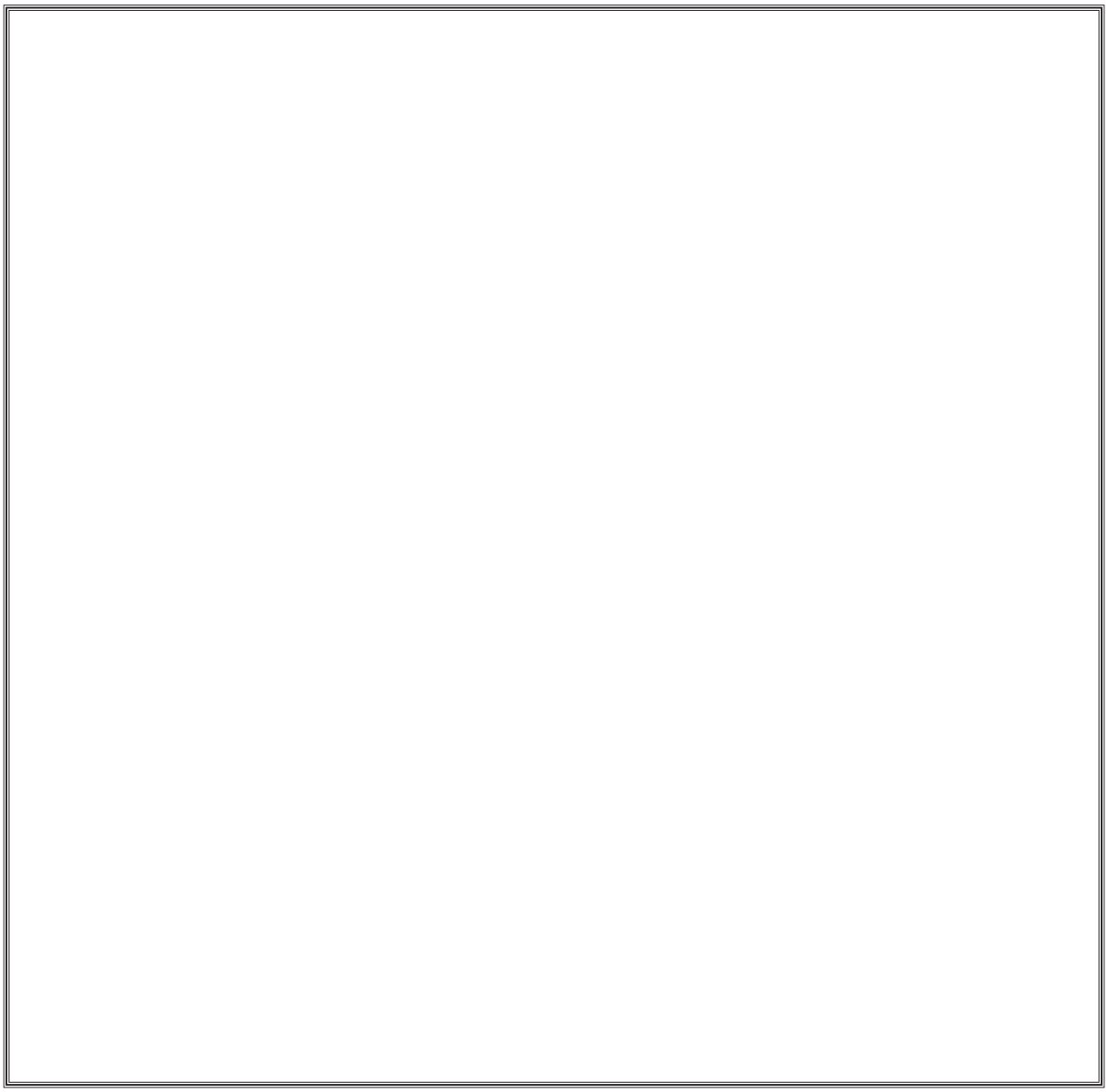
Reference Number: _____ **Date:** _____

Team: _____

Detail/Product/Material Specification: _____

Function: _____

Description (e.g., part number): Standard Wall Box:
ABC Manufacturer
Model Number 123456-A



Value Engineering Consultants

Functional Development

Idea Development and Estimated Cost

Rank	Risk Description	GFI Range
1	Recommendation/idea has low risk, good payback, minimal cost or investment risk, and change will not be owner/client sensitive.	7.5-10
2	Recommendation/idea has some technical risk, payback and/or cost/investment is not fully defined, and change will not be sensitive to the owner/client.	6-7.4
3	Recommendation/idea is a new approach, needs some additional technical engineering/design work, cost/investment is not expected to be excessive, but change is a new approach to owner/client.	4.5-5.9
4	Recommendation/idea is whole different technical concept with attendant risks, unknown cost/investment requirements, and will be unknown to owner/client.	2-4.4

A Gut Feel Index of less than 2.0 would automatically be excluded.

Figure 11-25 Risk Guide

1. Does the proposed solution or alternative satisfy all of the original requirements and specifications?
2. Are there any issues or idea that remain unresolved prior to final recommendations?
3. Are all reliability requirements and specifications met by the alternative?
4. Are all of the recommendations and alternatives compatible with all other systems, processes and materials?
5. Do the recommendations or alternatives create any health or safety concerns?
6. Do the recommendations and alternatives meet the operational and maintainability requirements of the project/system?
7. Are the recommendations or alternatives able to be implemented within the guidelines of codes and regulations, and offer no additional delays or costs over the original engineering and design?
8. Do the recommendations and alternatives support the owners/clients requirements, specifications, and goals?

Everything is now in place and ready for the final step — the presentation of the results.

Recommendation/Presentation

The presentation and recommendation phase is the culmination of all the previous phases. Will the value-engineering-team reccommendations and alternatives be accepted or rejected?

In the end, it all boils down to "salesmanship." The recommendations and alternatives, no matter how they are couched, will be seen as an attack, repudiation, or rejection of another engineer's work. People react in different ways, but in the engineering/design profession a couple of things can be counted on occuring.

First, because it is human nature, change, no matter how slight or how right, will be resisted. Overcoming resistance will require patience and "proof." This requires that the value engineering team have all their worksheets for all aspects and phases of the process available for critical review.

Second, all recommendations and alternatives must be based on the same technical basis as the original specification. Not everyone will require exquisite detail to be convinced while, others will never be satisfied with whatever is provided.

To prevail, the value engineering team need only present two items: the facts and the truth. The presentation of the facts must be accomplished in the same deliberate manner that was followed throughout the value engineering process. Prepared with the worksheets and a written analysis, the presentation will be able to account for every requirement and specification, and be able to trace the path of the analysis from beginning to end with a clear understanding of the final recommendations/alternatives.

The worksheets used throughout the value enginering process will prove invaluable. They paint a picture for all to see and will provide a concise and complete visual explanation of the end result, along with compelling and unrefutable conclusion.

Present Costs

The whole exercise for value engineering is to provide cost savings on the total project. It is the presentation of exacting support details that will result in a

successful and fully accepted modification. Because value engineering is a "team" approach and depends on a "Team Recommendation," an agreed-to consuensus result is the one most sought after by everyone involved.

Present Recommendation

The final step is to present a team recommendation. A recommendation worksheet is shown in Figure 11-26. This worksheet will be a summary of all the support worksheets and will spell out the findings and recommendations.

Making the Presentation

The final presentation should be both a written report of findings and a verbal description. Both need to be clear and concise, and the presentation confident and positive. The basic strategies for successful presentations are:

1. Expain the Whys: Provide the facts, detail the modification/changes, and describe and acknowledge any risks.
2. List the Benefits: It's important to concentrate on the benefits that will accrue because of the value engineering process. However, be sure not to exaggerate or oversell the results.
3. Make it a Participatory Presentation: Be sure to involve the audience in the discussion and presentation. Incorporate audience suggestions. Involvement is ownership.
4. Answer Questions Before They Are Asked: Be ready for the negativity that will be present by some individuals.
5. Be Prepared: Avoid surprises by being prepared, and don't let emotions interfere with the presentation.
6. Acknowledge Difficulties or Unknowns: Don't gloss over an obvious problem or a void in the presentation. Acknowledge the unknown and provide an interpretation or at least some alternative response.
7. Repeat, Repeat, Repeat: Repetition is the road to understanding. However, in repeating, be sure you are prepared with alternative road directions and maps. Repeating the same words over and over will not make the material understood any easier to be embraced.

Is It Value Engineering?

In the construction industry, the emphasis is constantly on the cost side of the equation. All too often the quality of the engineering and design are "attacked" under the rubric of "value engineering." As should be clear by this point, "true" value engineering can be an expensive undertaking. It is why value engineering invokes the Pareto principle: Only 20 percent of the product/project/system will produce 80 percent of the savings. It is for this 20 percent that a value engineering analysis is of value.

Unfortunately, most so-called "value engineering" it is simly the misappropriation of a term that connotes structured and scientific analysis to the evaluation of a product/system/material. In reality, it is nothing more than simple cost cutting or cost reductions for the sake of savings alone. This process is not value engineering, no matter what you may wish to call it. It is more appropriate to use the proper term for what all too often passes for "value engineering" — cost reductions. Or, if a analytical name needs to be used, **Cost Fitting** is appropriate.

Cost Fitting

Cost fitting is where engineers, designers, and the like are often left out of the process and the designs and mechanicals are turned over to a "value engineer," often nothing more than a contractor seeking the bid for the project. "The budget is the budget," as developers and owners like to say.

In this iteration of cost fitting, the Pseudo Value Engineer (PVE) will offer replacement products or designs that can be installed for less money or "To meet the budgetary needs of the project." There is no concern in cost fitting for the quality of the engineering or design. One problem with cost fitting is that there is always an alternative to anyone's choice of a product or design element. The PVE, knowing this, can offer cost savings over the design engineer's original work. All too often, the cost savings result in increased profits for the PVE as he/she garners the business with an on-budget bid—only to use inferior or less-desirable products/systems/materials with greater markups for the supplier.

Level the Playing Field

One option open to engineers is to have included in their contracts a series of clauses that would provide or require "true" value engineering to be performed on their designs. The role of the engineer is not to inhibit good value engineering of a project. As already shown, value engineering is a discipline that, when properly applied, will result in cost savings without any sacrifice in quality of design. The following example in Figure 11-27 is not intended to be exact legal language or offered as a instant contract addition. Rather, it is provided as a concept for insuring that proper value engineering is implemented on the engineers design and mechanicals.

The Déja Vu of the "Science" of Value Engineering

Does the "science" of value engineering seem very familiar? It should, because it contains many of the same elements followed in plumbing engineering and design. As you read about value engineering, you

Value Engineering Consultants
Team Cost/Improvement Recommendation

Reference Number: _____ **Date:** _____

Detail/Product/Material Specification: _____
Function: _____
Description (e.g., part number): _____

_____

_____

Team Members: _____

_____

Original Design/Sketch	Recommended Design/Sketch

Expected Savings: _____
Life Cycle Costs: _____
Explanation of Savings or Cost Reduction(s) _____

_____

_____

FINDINGS AND RECOMMENDATIONS:

_____

_____

_____

_____

_____

_____

_____

_____

_____

EXPLANATION FOR:
❑ **APPROVAL** ❑ **REJECTION:**

_____

_____

_____

_____

_____

_____

_____

_____

_____

1. INTENT AND OBJECTIVES-This clause applies to any cost reduction proposal (hereafter referred to as a Value Engineering Change Proposal or VECP) initiated and developed by the Contractor for the purpose of changing any requirement of this contract. This clause does not, however, apply to any such proposal unless it is identified by the Contractor, at the time of its submission to the Owner, as a proposal submitted pursuant to this clause.

1.1 VECPs contemplated are those that would result in net savings to the Owner by providing either: (1) a decrease in the cost of performance of this contract, or; (2) a reduction in the cost of ownership (hereafter referred to as collateral costs) of the work provided by this contract, regardless of acquisition costs. VECPs must result in savings without impairing any required functions and characteristics such as service life, reliability, economy of operation, ease of maintenance, standardized features, esthetics, fire protection features, and safety features presently required by this contract. However, nothing herein precludes the submittal of VECPs where the Contractor considers that the required functions and characteristics could be combined, reduced, or eliminated as being nonessential or excessive for the function served by the work involved.

2. SUBCONTRACTOR INCLUSION—The Contractor shall include the provisions of this clause, with the pre-determined sharing arrangements contained herein, in all subcontracts in excess of $25,000, and any other sub-contracts which, in the judgment of the Contractor, is of such nature as to offer reasonable likelihood of value engineering cost reductions. At the option of the first-tier Subcontractor, this clause may be included in lower tier subcontracts. The Contractor shall encourage submission of VECPs from Sub-contractors; however, it is not mandatory that VECPs be submitted, nor is it mandatory that the Contractor accept and/or transmit to the Owner VECPs proposed by his Subcontractors.

3. DATA REQUIREMENTS—As a minimum, the following information shall be submitted by the Contractor with each VECP:

3.1 A description of the difference between the existing contract requirement and the proposed change, and the comparative advantages and disadvantages of each; including justification where function or characteristic of a work item is being reduced;

3.2 Separate detailed cost estimates for both the existing contract requirement and the proposed change, and an estimate of the change in contract price, including consideration of the costs of development and implementation of the VECP and the sharing arrangement set forth in this clause;

3.3 An estimate of the effects the VECP would have on collateral costs to the Owner, including an estimate of the sharing that the Contractor requests be paid by the Owner upon approval of the VECP;

3.4 Architectural, engineering, or other analysis in sufficient detail to identify and describe each requirement of the contract, which must be changed if the VECP is accepted, with recommendation as to how to accomplish each such change and its effect on unchanged work.

Figure 11-27 Example of Value Engineering Change Proposal Contract Clause

should have been aware that this discipline is very much like that of plumbing engineering and design. In fact, the elements described could just as easily be transported to, and applied to a plumbing design project. The elements techniques of value engineering are similar to most other engineering disciplines, and almost exactly the same as used by many other disciplines. Well then, if the plumbing engineer is already doing all this, why does it need to be done again?

For the project's owner, developer, or manager it becomes an issue of perception. Each of the engineering and design disciplines used throughout the creation of a facility's project are always open to suspect and suspicion. Engineers and designers are often seen not just as "engineers" doing their necessary and important work, but as "engineering artists." The engineering artist is suspect as creating an enduring engineering work of art under the guise of "quality of design." A forever lasting engineered product that may well include redundancies will most likely include the most up-to-date and state-of-the-art products and materials available on the market — and therefore, by inference, the most expensive products and materials. The perception is of the engineering artist over-engineering a project. The engineer is suspect of using materials and products that have a longer life-cycle cost than may actually be necessary in order to provide an extra measure of safety, longevity, and quality of design.

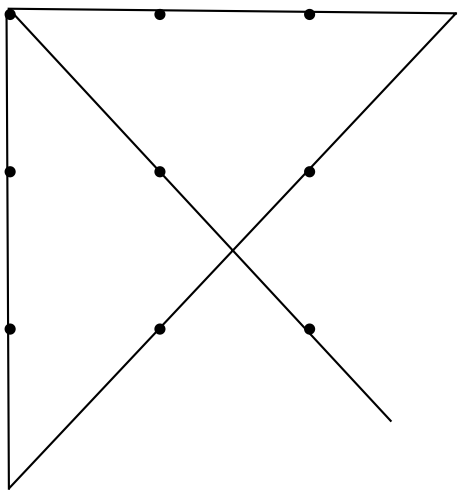
It is this "quality of design" that is perceived by those financing the project to result in a more costly enterprise than is necessary, while still providing the safety and longevity desired. Enter the discipline of value engineering. This engineering step at each stage of a project is perceived to be nothing more than an oversight function protecting the economic interests of the owner and insuring quality of design at the best possible cost. It is not intended to be cost reductions simply for the sake of cost reduction.

What the engineer often "sees" as being the end result of value engineering, and why many object to its use, is the misconception that lower costs equate

directly with reduced quality. The plumbing engineer, like all other engineers and designers, needs to remain flexible and open to the integration of other discipline's ideas and concepts. Value engineering is not a methodology designed to undermine the engineering, design, or specifications of a project. Nor is it intended to "outsmart" or "out-think" the engineers. Value engineering is not intended or designed to reduce quality, safety, professionalism or creativity. *It is an analysis to identify and stop waste, thus lowering costs while maintaining quality.*

Value engineering, when performed properly, will not affect performance and will not result in tradeoffs to reliability, quality, or maintainability. And this may well be the crux of the conundrum inherent in the discipline. Value engineering is only as good as the process followed, the experience of the engineers, and like any project, subject to various obvious and hidden agendas by numerous parties involved. Moreover, it is not unheard of for many "value engineered changes" to be nothing more than an owner-mandated cost reduction disguised under the rubric of "value engineered." Which is not much different than having a carefully engineered and specified product substituted by a contractor as something deemed "equal," often for nothing more than increased profit potential and no real savings for the owner. Despite the negative connotation often is improperly designated with the value engineering label, the concept needs to be looked at as an adjunct to a project's engineering, and each other engineering discipline needs to embrace the concept and use it effectively within his/her discipline.

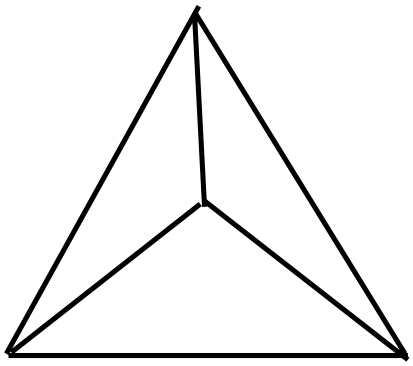
Solution to Nine Dots



The solution calls for thinking "Outside the box."

Solution to Equilateral Triangle

The solution calls for thinking off the two-dimensional surface of a table and into three dimensions. The solution shown is as viewed from above. It's a Pyramid shape. The base is, of course, one of the equilateral triangles.



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12

INTRODUCTION

An important part of a sustainable design plumbing system is the conservation of water. Seventy percent of the earth's surface is covered with water, but only 0.5percent of that water is fresh water that is available for drinking water and is relatively easily obtainable. Of that 0.5percent, only 2percent is potable without some form of treatment. With such a limited resource, it only makes sense that we should be trying to limit the consumption of water.

Sustainable design is gaining popularity in the building community, offering new and innovative ways to improve the built environment. The basic premise of sustainability is to reduce the use of non-renewable resources, and the amount of waste discarded, and provide a healthier environment to live and work in. Sustainability is gaining acceptance from a wide variety of places and is a required design philosophy by many governmental agencies such as the General Services Administration (GSA). The GSA requires all of the new buildings they are involved with to meet certain sustainable requirements defined by the U.S. Green Building Council.

The U.S. Green Building Council was formed in 1993 and is the nation's foremost coalition of leaders from across the building industry working to promote buildings that are environmentally responsible, profitable and healthy places to live and work. The U.S. Green Building Council (USGBC) is leading a national consensus for producing a new generation of buildings that deliver high performance inside and out. As the leading organization representing the entire industry on environmental building matters, USGBC's unique perspective and collective power provides its members with enormous opportunity to effect change in the way buildings are designed, built, and maintained.

One of the methods the USGBC has developed for maintaining consistency in sustainable guidelines is through the development of a certification program for buildings known as Leadership in Energy & Environmental Design (LEED™).

LEADERSHIP IN ENERGY AND ENVIRONMENTAL DESIGN

The LEED (Leadership in Energy and Environmental Design) Green Building Rating System™ is a voluntary, consensus-based national standard for developing high-performance, sustainable buildings. LEED provides a complete framework for assessing building performance and meeting sustainability goals. Based on well-founded scientific standards, LEED emphasizes state-of-the-art strategies for sustainable site development, water savings, energy efficiency, materials selection, and indoor environmental quality. LEED recognizes achievements and promotes expertise in green building through a comprehensive system offering project certification, professional accreditation, training, and practical resources.

The LEED program is based on a rating system that is divided into six main areas of design. These areas are Sustainable Sites, Water Efficiency, Energy & Atmosphere, Materials & Resources, Environmental Quality, and Innovation & Design Process. Each of the areas has specific requirements and prerequisites that must be met in order to qualify for any certification levels. The certification levels and minimum points for each level in the LEED program are as follows:

Certified	26-32 points
Silver Level	33-38 points
Gold Level	39-51 points
Platinum Level	52+ points with a possible 69 points available.

A complete listing of the LEED Rating system and other requirements of the certification system are available from the USGBC at www.usgbc.org.

One of the listed areas in the LEED program is Water Efficiency. The area is broken down into three sub areas that allow points to be earned by achieving certain criteria established to reduce water consumption. The first credit available is for utilizing water-efficient landscaping to reduce the amount of

potable water used for irrigation by 50 percent. This is typically accomplished by using a highly efficient irrigation system, capturing rainwater, or using recycled site water to reduce the consumption of potable water. Additionally another credit is available for the elimination of the use of potable water for irrigation purposes.

WASTEWATER TECHNOLOGIES

For water efficiency, the area of credit is Innovative Wastewater Technologies. Reduction of the use of municipally provided potable water for building sewage conveyance by a minimum of 50 percent or treating 100 percent of the wastewater on-site to tertiary standards is required. This is typically accomplished by the use of storm water or grey water for the conveyance of sewage in the building drainage system. Additionally, the use of high-efficiency plumbing fixtures or dry fixtures can reduce the amount of potable water used in the plumbing system.

Ideas for ways to accomplish this point:

1. Automate the operation of equipment.
2. Connect cooling water for equipment to a closed-loop chilled water system instead of using potable water.
3. Monitor the water consumption of the equipment.
4. Use ultra-low-flow fixtures in the plumbing system.

WATER-USE REDUCTION CREDIT

Closely related to the reduction in wastewater through Innovative Wastewater Technologies is the Water-Use Reduction Credit. There are two of these credits available, one for reducing the use of potable water by 20 percent over and above the requirements of the Energy Policy Act of 1992 (EPACT), and another credit for reducing the potable water usage by an additional 10 percent for a total reduction in potable water usage of 30 percent.

Ideas for ways to accomplish this point:

1. Select equipment that provides for maximum water efficiency.
2. Provide ultra-low-consumption plumbing fixtures.
3. Use metering or infrared faucets.
4. Use infrared flush valves.
5. Eliminate one-pass cooling for equipment.
6. Reduce cooling-tower drift losses and other equipment losses to save on the amount of makeup water.

CAUTIONS

Many factors should be considered when sustainable designs are required or even contemplated. For example, the reduction in the amount of water used in the system needs to be verified, and the effects on the system need to be considered. Reduction in the amount of wastewater generated can have another impact on the sizing of the water and drainage piping in the building. Waste piping, in particular, needs to be sized based on a flow velocity of two feet per second; reducing the flow rate of the fixtures changes the tables and information commonly used by the plumbing designer and code officials. The model plumbing codes have been modified to reduce the number of fixture units attributed to the plumbing fixtures in the pipe-sizing calculations based on the reduction in water mandated by EPAC. Communication between the code official and designer is imperative to minimize potential problems in the plumbing system.

EPACT requires all manufacturers of plumbing products in the United States to meet or exceed water-usage requirements for plumbing fixtures as follows:

Faucets:	2.5 gallons per minute (9.5 liters per minute, lpm)
Metered Faucets:	0.25 gallons per cycle (0.9 liters per cycle, lpc)
Shower Heads:	2.5 gallons per minute (9.5 liters per minute, lpm)
Water Closets:	1.6 gallons per flush (6.1 liters per flush, lpf)
Urinals:	1.0 gallons per flush (3.8 liters per flush, lpf)

It should be noted there are millions of plumbing fixtures installed in existing buildings that have not been modified to meet the requirements of EPACT and represent a significant opportunity to reduce the amount of water used by the plumbing system.

PLUMBING PRODUCTS

Reductions in water usage beyond what is required by EPACT can be obtained by using products such as lavatory faucets with flow rates of 0.5 gallons per minute (1.9 lpm), showerheads with flow rates of 1.5 gallons per minute (5.7 lpm), and water closets that use dual-flush technology. Use of these ultra-low consumption fixtures should be cautioned without taking appropriate measures in the sanitary drainage system to accommodate the lower volume of water in the piping system. Usually, reducing the pipe size or increasing the slope of the pipe—thereby increasing the velocity of the water flowing through the piping system–accomplishes this.

The use of infrared faucets and flush valves in the plumbing systems can reduce the amount of water

consumed. The exact amount of reduction in water usage varies depending on the type of building and occupancy, but can be a significant amount upwards of 75 percent over conventional faucets.

Waterless urinals have been developed to use a biodegradable, immiscible fluid that is less dense than normal liquid waste and allows the waste to pass through a special trap and then to the drainage system. These products do not connect to the building water supply and do not use water. There is quite a bit of controversy about the use of these products and their potential for increased maintenance costs. Some areas have provisions in the plumbing code that would prohibit the use of these fixtures and require special permissions or variances in order for the fixtures to be used. Care should be taken by the designer to fully understand the advantages and disadvantages and discuss these items with the building owner prior to using this type of fixture.

Composting water closet systems use little or no water, are not connected to a conventional plumbing system, and convert wastes into compost by means of an aerobic decomposition process carried out by micro and macro organisms. Another type of fixture that does not use water is an incinerating water closet, which utilizes a combustion chamber in order to incinerate wastes. Use of these units is typically limited to remote locations or locations where water availability is limited. Again, the limitations of code should be investigated prior to using these units.

Dual-flush water closets are available with controls to provide a reduced volume of water when a full flush is not required. These fixtures are becoming more common in the United States. Several manufacturers currently have units available.

ADDITIONAL LEED POINTS—ENERGY SAVERS

Another area where LEED points are available is energy efficiency and energy-use reduction. There are many ways energy consumption can be reduced in a plumbing system. While the most common ways to conserve energy have to do with heating, ventilating, and air-conditioning systems in a building, there are still ways to conserve energy in the plumbing system.

Using high-efficiency water heaters to heat domestic water is one of the first steps in saving energy in a plumbing system. Using solar water heating systems or photovoltaic technology and generating electricity to heat water can also be an option in some cases; capture an alternative energy source and reduce the amount of other types of energy used. Many of the alternatives for heating water will depend on the type of building being designed and the quantity of hot water your system requires. The use of a solar water-heating system may be an option for some buildings. However, if there is a high demand and you require a quick recovery on the water heating system, then a solar water-heating system may not be advisable. The use of photovoltaic receptors to generate electricity to heat water can also be a viable option if your situation only requires a limited amount of hot water.

The use of small electric or natural gas-fired instantaneous water heaters, which only use energy when the water is flowing, is very much a viable option--especially when the fixture is remotely located from the rest of the building, or the hot water demand is only needed for a short period of time. Understanding how the building uses hot water and accurately determining the demand of the building are prerequisites to providing a water heater that is not oversized, and, therefore, an energy-wasting device.

Reducing the amount of standby heat loss from the water heater or storage tank is all part of saving energy. Not storing quantities of hot water and using an instantaneous water heater may provide a great solution—if you have the right circumstances. However, other types of facilities may need to have a large quantity of water stored for use during high-demand periods. It is important to have conversations with the client and understand the constraints the design will need to conform to.

Opportunities for the application of different water heating technologies are endless. Depending on the type of building you are designing, there may be multiple solutions for providing hot water to the building fixtures.

Hot-water recirculation systems conforming to ASHRAE 90.1 should also be provided. These systems require that the piping system be insulated with a minimum insulation thickness and the circulating pump be controlled by a temperature-sensing device or a time clock. This standard should be consulted prior to the design of a recirculation system. Another consideration to limit the energy lost in a hot-water recirculation system is the routing of the supply and return piping. Using the shortest route for the distribution system will provide a more-efficient piping system, thereby saving energy from the heat loss of the system. These systems should also be balanced to provide uniform heat loss throughout the system and limit the temperature drop in the system.

In certain building types and installations, consideration may be given to using a central-chilled drinking-water system for energy conservation. The amount of energy consumed by electric water coolers spaced throughout a facility may actually be greater than the amount of energy consumed by a central chiller with a looped piping system to the drinking fountains and the recirculation pump—keeping the

water in the system moving and cool. As with a hot-water recirculation system, a chilled drinking-water system should also have the piping insulated to prevent heat gain and also prevent condensation on the piping system. Of course, using drinking fountains instead of electric water coolers would also save energy, piping, and insulation costs associated with the system. The building owner should be consulted prior to providing a non-chilled drinking-water solution for their building.

The possibilities are numerous for energy conservation, and taking the time to stop and review the building being designed can provide some interesting ways to save energy. The use of a waste-heat-recovery system to preheat the inlet water to domestic water heaters can to limit the amount of energy used to heat the domestic water. If a building system is connected to a central steam system where the condensate is not returned, using the heat remaining in the condensate is advisable. It is common to provide heat-recovery systems on large laundry and car-wash facilities, but common to apply them to other types of buildings.

Recovering the heat from dishwashers, glass washers, showers, and other devices that use hot water has not been utilized on a wide basis. One technology that allows heat recovery from these types of uses is the gravity-film heat exchanger. This device utilizes a vertical counter-flow heat exchanger that extracts heat from waste water and uses it to preheat the cold water to the water heater. The heat exchanger consists of a copper drainage pipe with small-diameter copper piping coiled around the drainage piping over a given length. The heat is transferred from the drainage piping to smaller coils on the outside of the piping. The unit is installed in the vertical position so waste water in a vertical stack flows down the entire perimeter of the waste piping with a center core of air in the middle. This type of configuration would not be as efficient installed in the horizontal position, as water in the drainage piping would only be in contact with the coiled piping over half of the piping system perimeter.

INNOVATIVE IDEAS

When thinking about sustainable design and portions of the plumbing system that could be modified to provide a more ecological solution to the installation of plumbing systems, there are several things that could be investigated.

Considering the use of mechanical joints or press joints with o-ring gaskets to limit the use of flux and solder and reduce the potential negative health effects of the byproducts of making soldered joints could be shown to be sustainable. While the use of lead pipe has declined to almost nothing, the retrofit of any system containing lead would be considered sustainable—even to the point of not using lead and oakum for joining cast-iron hub and spigot piping. Not many areas still use this method of joining piping, but there are some areas where lead and oakum are still prevalent today.

GREEN ROOFS

One portion of some sustainable designs is the use of green roofs or roofs that have a thin layer of soil, which contains vegetation and helps provide additional insulation and a thermal break for the building occupants. There are several types of these systems available, each with its own specific criteria and method of installation. Common to many of the different types of green roofs is the requirement to be able to provide some type of irrigation water for the plants.

Typically, the preferred solution in sustainable design would be to use some type of water other than the potable water supply to the building. Many of the potential solutions for how much water will be needed for the irrigation systems, as well as the type of irrigation system to be used, should be verified with the architect or landscape designer. It is recommended the plantings used in this type of situation be more drought resistant than conventional types of plants. This assists with the premise to save as much water as possible. Whether rainwater or clear water wastes from the building is collected to water the plants, there are several options available. The use of other types of water, not drinking water, will assist in the reduction of water use for the building.

It is common for the irrigation system of a green-roof installation to be a drip-type irrigation system. Other types of systems exist to limit the amount of run-off water into the roof-drainage system. The designer of the landscape portion of the green roofing system should be consulted on the type of irrigation system to be provided. The type of irrigation system used may depend on the type of vegetation planted on the roof, and whether or not water must be in a specific area for a predetermined length of time, or if another type of system is recommended.

The roof-drainage system used in a green roof setting is designed as a conventional roof drainage system would be. The plumbing code should be consulted regarding the amount of rainwater anticipated and the requirements of storm durations. Pipe sizing for the storm-drainage system remains the same as it would for a conventional system. If a secondary drainage system is required for a conventional roof, and the green roof being designed contains the same attributes, (such as parapets) then a secondary drainage system with overflow drains or scuppers would also be required on the green roof. Green roofs are designed in many shapes and sizes, and each will be

different depending on the designer and the area with which they are working.

To help keep soil and other plants away from the roof drains, usually a small area around the drain is separated from the remainder of the green roof. Care should be taken when designing these systems to keep debris and other portions of the plantings from getting into the roof-drainage system and potentially creating a problem. Additional screening of the roof-drain strainers may be necessary.

GREY WATER SYSTEMS

One of the technologies becoming more prevalent in the design of sustainable plumbing systems is the use of grey water systems. The systems reuse previously used water for another. Typically, grey water systems are used to flush water closets and urinals and should not come into any human contact. The collection of rainwater for use in this type of system is also gaining acceptance and can reduce the amount of potable water used for things other than drinking.

Typically these systems gather water from various uses (allowing the water to be classified as grey water) and bring that water back to a central location. Once the water is gathered into a tank, it can then be sent back to the system to be used again. The water must be filtered prior to distribution to water closets and urinals to remove substances from the water that may cause the flush valves or other components to fail. For example, small particles of sand or other matter can clog the diaphragms of flush valves so they run continuously. Distribution pumps are required to pressurize the system and allow it to function properly.

Grey water systems are commonly found in laundry facilities, car washes, and other such facilities. Treatment of the waste water from these systems is usually required before the water can be used again. Various manufacturers of these systems are available and should be consulted regarding the specific requirements of their systems.

Another potential resource for grey water usage is condensate gathered from high-efficiency condensing-type water heaters, and boilers, and from fan-coil units, air-handling units, etc. That water can be used to provide makeup water to the boiler or chiller makeup water systems. Condensate gathered from high-efficiency water heaters and boilers should be tested and potentially treated to reduce corrosive properties that may restrict it from being reused for another purpose. The condensate gathered from cooling coils or fan-coil units is generally water relatively free of impurities and can also reduce the amount of chemical treatment of the makeup water required for the other systems.

Rainwater-collection systems are becoming more prevalent for use in irrigation systems. These collection systems require the storage of the rainwater, usually in underground storage tanks that can be quite large. The amount of storage depends on the requirement for irrigation water, as well as the amount of rainwater anticipated. Some amount of water treatment and filtration should be anticipated to keep the sprinkler heads from fouling and becoming clogged with debris, but not to the same extent as the water used to flush water closets and urinals.

If rainwater collection is being considered, the designer needs to investigate its potential impacts. Certain areas of the country prohibit the collection of rainwater because the rainwater serves other areas of the country as their primary water supply. Thus, rainwater collection in one area could create a significant shortfall in another water supply if the rainwater is not allowed to flow downstream.

Δ (delta), 2004 V1: 14

vapor recovery, 2000 V3:168
venting, 2000 V3:167
abrasion, 2004 V1: 146, 1999 V2: 18, 276
ABS. *See* acrylonitrile-butadiene-styrene (ABS)
abs, ABS (absolute), 2004 V1: 14
absolute (abs, ABS), 2004 V1: 14
absolute pressure, 2000 V3: 200
defined, 2004 V1: 17
in vacuums, 1999 V2: 254
absolute temperature, 2004 V1: 17
absolute zero, 2004 V1: 17
absorphan (carbon filtration). *See* activated carbon filtration (absorphan)
absorption
air drying, 2000 V3: 204
defined, 2004 V1: 17
rates for soils, 1999 V2: 217–220, 2000 V3: 99
surfaces in seepage beds, 1999 V2: 224
trenches. *See* leaching trenches (leach fields)
absorptive silencers, 2000 V3: 202
ac, AC (alternating current), 2004 V1: 14
AC (air chambers). *See* air chambers (AC)
AC-DC rectifiers, 2004 V1: 150, 2004 V1:151
acc (accumulate or accumulators), 2004 V1: 14, 17
acceleration
earthquakes, 2004 V1: 159, 160
linear, 2004 V1: 33, 35
measurements, 2004 V1: 33
accelerators (dry-pipe systems), 2000 V3: 11, 12–13
accelergrams, 2004 V1: 159
access
aboveground tank systems, 2000 V3: 166
clean agent gas fire containers, 2000 V3: 23
to equipment, piping and, 2003 V4: 25
underground liquid fuel tanks, 2000 V3: 156–157
access doors, 2004 V1: 17
accessibility, 2004 V1: 17. *See also* people with disabilities
Accessibility Guidelines for Buildings and Facilities, 2004 V1: 105
Accessible and Usable Buildings and Facilities, 2004 V1: 105, 123, 2003 V4: 2
accessories section in specifications, 2004 V1: 91
accreditation of health-care facilities, 2000 V3: 50
accumulate (acc, ACCUM), 2004 V1: 14
accumulators (acc, ACCUM), 2004 V1: 14, 17
accuracy
in measurements, 2004 V1: 32
of pressure-regulating valves, 1999 V2: 152
ACEC (American Consulting Engineers Council), 2004 V1: 62
acfh (actual cfh), 1999 V2: 180
acfm (actual cubic feet per minute), 1999 V2: 255–256, 257
defined, 2000 V3: 83, 200
medical air compressors, 2000 V3: 65, 66
medical vacuum systems, 2000 V3: 69
acid-containing inhibitors, 1999 V2: 305
acid fumes, 2000 V3: 42
acid neutralization, 2000 V3: 40–41, 91
acid-neutralization tanks, 2000 V3: 40–41, 42
acid radicals, 1999 V2: 281
acid regenerants, 1999 V2: 295, 302, 305
acid resins, 1999 V2: 295
acid-resistant fixtures, 2003 V4: 1–2
acid-resistant floor drains, 1999 V2: 16
acid-resistant piping, 1999 V2: 14, 341
acid-resistant sinks, 2000 V3: 37
acid vents (AV), 2004 V1: 8, 17
acid-waste systems
acid-waste treatment, 1999 V2: 334–337
continuous systems, 1999 V2: 338
health and safety concerns, 1999 V2: 332
health-care facilities, 2000 V3: 39–40
introduction, 1999 V2: 329, 332–334
large facilities, 1999 V2: 336
metering, 2000 V3: 41–42
piping and joint material, 1999 V2: 334
solids interceptors, 2000 V3: 41, 43
system design considerations, 1999 V2: 334
types of acid, 1999 V2: 332–334
acid wastes (AW), 2004 V1: 8, 17, 2000 V3: 42
acidity
in corrosion rates, 2004 V1: 145
pH control, 2000 V3: 91–92
swimming pool water, 2000 V3: 146–147
in water, 1999 V2: 244, 281, 285
acids, defined, 1999 V2: 280
acme threads, 2004 V1: 17
acoustics in plumbing systems
acceptable levels in buildings, 2004 V1: 193
acoustics, defined, 2004 V1: 206
building material acoustic insulation, 2004 V1: 193
cold-water systems, 1999 V2: 115
design procedures, 2004 V1: 198–200
equipment selection, 2004 V1: 200
flow velocity, 2004 V1: 198
glossary, 2004 V1: 206–210
gurgling noises in pipes, 1999 V2: 35
introduction, 2004 V1: 193
noise and vibration control, 2004 V1: 199–200
occupied domestic spaces, 2004 V1: 196
pipe sleeves and, 2004 V1: 201
pressure and, 2004 V1: 200
pumps, 2004 V1: 196–198, 201–202
ratings for fixtures and appliances, 2004 V1: 194–195, 198
silencers on vacuum systems, 1999 V2: 268
sound power levels, 2004 V1: 194
system design, 2004 V1: 200–206
system layout, 2004 V1: 202
transmission in pipes, 1999 V2: 15, 121
vacuum systems, 1999 V2: 263
vibration isolation, 2004 V1: 202–206
water hammer, 2004 V1: 198, 201, 1999 V2: 132
water piping design, 2004 V1: 195–196
acoustics in swimming pools, 2000 V3: 129
acquisition costs
acquisition prices defined, 2004 V1: 222
base acquisition costs, 2004 V1: 223
ACR/MED pipes, 2003 V4: 36
ACR piping, 2003 V4: 36
acres, converting to SI units, 2004 V1: 39
acrylic fixtures, 2003 V4: 2
acrylonitrile butadiene rubber (ABR), 2000 V3: 169
acrylonitrile-butadiene-styrene (ABS)

defined, 2004 V1: 17
fixtures, 2003 V4: 2
pipe characteristics, 2003 V4: 59–60
piping, 1999 V2: 14, 15, 68, 2000 V3: 48
plastic underdrains, 2000 V3: 131
weirs, 2000 V3: 146
activated alumina air dryers, 2000 V3: 204
activated alumina water treatment, 1999 V2: 318
activated carbon filtration (absorphan)
in gray-water systems, 1999 V2: 27, 28
in gray-water treatment, 1999 V2: 29
illustrated, 1999 V2: 301
overview, 1999 V2: 300
pure-water systems, 1999 V2: 323
small water systems, 1999 V2: 318
well water, 1999 V2: 244, 245
Activated Carbon Process for Treatment of Wastewater Containing Hexavalent Chromium (EPA 600/2-79-130), 2000 V3: 96
activated sludge systems, 2000 V3: 95
active, defined, 2004 V1: 151
active potential, defined, 2004 V1: 151
active sludge, 2004 V1: 17
active verbs in function analysis, 2004 V1: 224, 225
activities in FAST approach, 2004 V1: 231
actual cfh (acfh), 1999 V2: 180
actual cubic feet per minute. *See* acfm (actual cubic feet per minute)
actual flow rates, 2000 V3: 5, 217
actual liters per minute (aL/min), 2000 V3: 69, 200
actual pressure. *See* static pressure (SP)
actuator-control valves, 2000 V3: 119
ACU (air-conditioning units), 2004 V1: 14
ADA. *See* Americans with Disabilities Act
ADAAG *(Americans with Disabilities Act Accessibility Guidelines),* 2004 V1: 105, 106
ADAAG Review Federal Advisory Committee, 2004 V1: 123
adapter fittings, 2004 V1: 17
addenda in contract documents, 2004 V1: 62–63
addresses of organizations and associations, 2004 V1: 58–59
adiabatic processes, 2000 V3: 200
adjustment section in specifications, 2004 V1: 71, 92
administrative and operation costs in value engineering. *See* overhead
administrative authorities, 2004 V1: 17
admiralty brass, 2004 V1: 144
adp, ADP (apparatus dew points), 2004 V1: 14
adsorption, 2000 V3: 204
adult-sized wheelchairs, dimensions, 2004 V1: 108. *See also* wheelchairs
advanced oxidation water treatment, 1999 V2: 318
aerated lagoons, 2000 V3: 95
aerating fountain nozzles, 2000 V3: 108, 119–120
aeration, 2004 V1: 17
aeration cells, 2004 V1: 151
aerators
aeration treatment, 1999 V2: 292–294, 318
lavatories and sinks, 2000 V3: 33
sovent aerators, 1999 V2: 19, 46, 54–56, 60, 62
aerobic, defined, 2004 V1: 17
aerobic wastewater treatment plants, 1999 V2: 232–233
AFF (above-finished floor), 2004 V1: 14
AFFF foam concentrates, 2000 V3: 21
after-coolers
air compressors, 2000 V3: 202–203
air dryers and, 2000 V3: 207
medical air compressors, 2000 V3: 66
after-filters, 2000 V3: 203
AGA (American Gas Association)
appliance venting standards, 1999 V2: 178
defined, 2004 V1: 17
gas-train vent standards, 1999 V2: 177
relief valve standards, 1999 V2: 166
water heating standards, 1999 V2: 170
age of water mains, 2000 V3: 8
age-related disabilities, 2004 V1: 107
aggregation in soil structure, 1999 V2: 218
aggressiveness index, 1999 V2: 292
aging disabilities, 2004 V1: 107
aging water mains, 2000 V3: 8
agitators in kill tanks, 1999 V2: 344
agreement documents, 2004 V1: 62
agreement states, 1999 V2: 340
agricultural drain tile, 1999 V2: 221
AHJ. *See* authorities having jurisdiction
ahp, AHP (air horsepower), 2004 V1: 14
AHU (air-handling units), 2004 V1: 14
AI (aggressiveness index), 1999 V2: 292
AIA (American Institute of Architects). *See* American Institute of Architects
air
free, 2004 V1: 17, 2000 V3: 199, 200–201
oil-free, 2000 V3: 83
in pipes, 1999 V2: 2
properties, 2000 V3: 199
standard, 2004 V1: 17–18
water vapor in, 2000 V3: 200–201
air, compressed. *See* compressed air (A, X#, X#A)
air, free, 2004 V1: 17, 2000 V3: 199, 200–201
air, oil-free, 2000 V3: 83
air, standard, 2004 V1: 17
air-admittance valves, 2004 V1: 43, 1999 V2: 64
air binding, 2000 V3: 178, 180
air-bleed vacuum controls, 1999 V2: 268–269
air breaks, 2004 V1: 17. *See also* air gaps
air chambers (AC)
defined, 2004 V1: 17
self-priming pumps, 2000 V3: 142
symbols for, 2004 V1: 10
water hammer arresters, 2004 V1: 198, 201, 1999 V2: 132, 143
air circuits in instrumentation, 2000 V3: 199
air compressors
accessories, 2000 V3: 202–203
compressed air systems, 2000 V3: 201–202
dry-pipe systems, 2000 V3: 12
medical systems, 2000 V3: 65
pulsation, 2000 V3: 205
selection factors, 2000 V3: 213
sizing, 2000 V3: 210–213
types of, 2000 V3: 201–202
vacuum pumps, 1999 V2: 259

AIR COND (air conditioning). *See* air-conditioning systems
Air-Conditioning and Refrigeration Institute (ARI), 2004 V1: 46–47, 58
air-conditioning cooling towers. *See* cooling-tower water
air-conditioning engineers, 2000 V3: 27–28
air-conditioning systems (AIR COND)
  fixture-unit values, 1999 V2: 9
  pipes, 2003 V4: 36
  symbols, 2004 V1: 14
  waste heat usage, 2004 V1: 131
  water demand, 1999 V2: 243
air-conditioning units (ACU), 2004 V1: 14
air-consuming devices, 2000 V3: 206
air-cooled after-coolers, 2000 V3: 203
air densities, calculating, 2004 V1: 5
air dryers
  compressed air systems, 2000 V3: 203–204
  deliquescent dryers, 2000 V3: 207
  desiccant dryers, 2000 V3: 207
  medical air compressors, 2000 V3: 66
  refrigerated air dryers, 2000 V3: 207
  selection, 2000 V3: 204
air ducts, 2000 V3: 23
air flow rates, 2004 V1: 14
air gaps. *See also* air breaks; effective openings
  as cross-connection control devices, 1999 V2: 144, 145, 148
  defined, 2004 V1: 17
air-gate valves, 1999 V2: 268
air-handling units (AHU), 2004 V1: 14, 267
air horsepower (ahp, AHP), 2004 V1: 14
air intakes, 2000 V3: 211
air locks, 2004 V1: 201
air pressure, 1999 V2: 255–256, 2000 V3: 12
air receivers, 2000 V3: 205–206
air-separation chambers, 1999 V2: 56
air springs, 2004 V1: 203, 210
air temperatures
  pool heating and, 2000 V3: 121
  swimming pools and, 2000 V3: 129
air tests
  in cold-water systems, 1999 V2: 154
  defined, 2004 V1: 18
air velocity in vacuum cleaning systems, 1999 V2: 270
air vessels (chambers), 2004 V1: 198
aircraft cable bracing method, 2004 V1: 171
aircraft fuel, 1999 V2: 13
airport runways, piping underneath, 1999 V2: 250
aL/min (actual liters per minute), 2000 V3: 69, 200
ALARA (as low as reasonably achievable), 1999 V2: 341
alarm check valves, 2004 V1: 13, 18, 2000 V3: 9
alarm lines on sprinklers, 2000 V3: 9
alarm relays, 2000 V3: 24
alarms
  aboveground tank leakage, 2000 V3: 168
  defined, 2004 V1: 18, 2000 V3: 83
  on bulk oxygen supply, 2000 V3: 62
  on corrosive-waste systems, 2000 V3: 40
  on hazardous waste systems, 2000 V3: 90
  on kill tanks, 1999 V2: 345
  on medical gas systems
    area alarms, 2000 V3: 72
    master alarms, 2000 V3: 72
    testing, 2000 V3: 81
  on vacuum systems, 1999 V2: 259, 262
  on water tanks, 1999 V2: 151
  overfill prevention, 2000 V3: 158, 167
  pressurized fuel delivery systems, 2000 V3: 162
Alaska Earthquake, 2004 V1: 161–162
Albern, W.F., 1999 V2: 277
alcohol-resistant AFFF foam concentrates, 2000 V3: 21
algae, 1999 V2: 282, 289, 2000 V3: 148
algaecides, 2000 V3: 150
alkalinity
  alkaline solutions in corrosion rates, 2004 V1: 145
  boiler feed water, 1999 V2: 314
  dealkalizing treatment, 1999 V2: 295
  measuring, 1999 V2: 282–283, 2000 V3: 123
  pH and, 1999 V2: 285, 329, 2000 V3: 91
  predicting scale and corrosion, 1999 V2: 290
  swimming pool water, 2000 V3: 147
  water saturation, 1999 V2: 293
allowable leakage in compressed air systems, 2000 V3: 209
allowable radiation levels, 1999 V2: 339
allowable vacuum system pressure loss, 1999 V2: 263
alloy pipes, 2004 V1: 18
alloys, 2004 V1: 18
alpha ray radiation, 1999 V2: 337
alt, ALT (altitude), 2004 V1: 14
alteration (altrn, ALTRN), 2004 V1: 14
alternate bracing attachments for pipes, 2004 V1: 174
alternating current (ac, AC), 2004 V1: 14
alternative collection and treatment of waste water, 1999 V2: 232
alternative energy solutions, 2004 V1: 263–267
alternative energy sources, 2004 V1: 130–131
alternative sketches in value engineering, 2004 V1: 254, 255
alternative treatment of waste water, 1999 V2: 226–227
Alternatives for Small Wastewater Treatment Systems: Cost-effectiveness Analysis", 1999 V2: 238
Alternatives for Small Wastewater Treatment Systems: On-site Disposal/Seepage Treatment and Disposal, 1999 V2: 238
Alternatives for Small Wastewater Treatment Systems: Pressure Sewers/Vacuum Sewers, 1999 V2: 238
alternators
  medical air compressors, 2000 V3: 67
  vacuum systems, 2000 V3: 70
altitude (alt, ALT), 2004 V1: 14. *See also* elevation
altitude valves, 1999 V2: 249
altrn, ALTRN (alteration), 2004 V1: 14
alum, 1999 V2: 294, 2000 V3: 147, 150
aluminates, 2000 V3: 147
aluminosilicates, 2000 V3: 204
aluminum, 2004 V1: 139, 144, 1999 V2: 281, 2000 V3: 20, 145
aluminum 1100, 2004 V1: 141
aluminum 2017 and 2024, 2004 V1: 141
aluminum check valves, 1999 V2: 177
aluminum hydroxide, 1999 V2: 281, 2000 V3: 149–150
aluminum piping, 1999 V2: 68, 176, 196, 2000 V3: 47, 210
aluminum silicates, 1999 V2: 301–302, 2000 V3: 134

aluminum sulfate, 1999 V2: 294, 2000 V3: 149–150
Amateur Athletic Union (AAU), 2000 V3: 151
amb, AMB (ambient), 2004 V1: 14
ambient (amb, AMB), 2004 V1: 14
ambient temperature, 2004 V1: 18
ambulatory accessible stalls, 2004 V1: 114
American Chemical Society, 2004 V1: 153
American Concrete Institute, 1999 V2: 102, 114
American Consulting Engineers Council (ACEC), 2004 V1: 62
American Gas Association (AGA)
  appliance venting standards, 1999 V2: 178
  defined, 2004 V1: 17
  gas-train vent standards, 1999 V2: 177
  relief valve standards, 1999 V2: 166
  water heating standards, 1999 V2: 170
American Institute of Architects (AIA)
  General Conditions of the Contract for Construction, 2004 V1: 62
  Masterspec, 2004 V1: 71
  medical-gas guidelines, 2000 V3: 50
  specifications format, 2004 V1: 63
American National Standards Institute (ANSI)
  abbreviation for, 2004 V1: 14, 18
  address, 2004 V1: 58, 2000 V3: 97
  consensus process, 2004 V1: 41
  gas piping standards, 1999 V2: 194
  list of standards, 2004 V1: 46
  publications, 2004 V1: 41
    ANSI A112.6.1, 2003 V4: 6
    ANSI A112.18.3, 2003 V4: 14
    ANSI A112.19.6, 2003 V4: 5, 9
    ANSI A117.1-1980, 2004 V1: 105
    ANSI A117.1-1986, 2004 V1: 105
    ANSI A117.1-1998, 2004 V1: 105, 106, 109–123, 2003 V4: 2, 14
    ANSI/ASME B16.15 Cast Bronze Threaded Fittings, 2003 V4: 34
    ANSI/ASME B16.24 Cast Copper Alloy Pipe Flanges and Flanged Fittings, 2003 V4: 34
    ANSI-ASSI: Building Code Requirements for Minimum Design Loads in Buildings and Other Structures, 2004 V1: 191
    ANSI/AWWA C104/A21.4 Cement Mortar Lining, 2003 V4: 32
    ANSI/AWWA C105/A21.5 Polyethylene Encasement, 2003 V4: 32
    ANSI/AWWA C110/A21.10 Fitting, 2003 V4: 32
    ANSI/AWWA C111/A21.11 Rubber-Gasket Joints, 2003 V4: 32
    ANSI/AWWA C115/A21.15 Flanged Pipe, 2003 V4: 32
    ANSI/AWWA C116/A21.16 Fusion-Bonded Epoxy Coating, 2003 V4: 32
    ANSI/AWWA C150/A21.50 Thickness Design, 2003 V4: 32
    ANSI/AWWA C151/A21.51 Manufacturing, 2003 V4: 32
    ANSI/AWWA C153/A21.53 Compact Fittings, 2003 V4: 32
    ANSI/AWWA C600 Installation, 2003 V4: 32
    ANSI B3.13: Chemical Plant and Petroleum Refinery Piping, 2000 V3: 95
    ANSI/NFPA Standard no. 54: National Fuel Gas Code, 2000 V3: 248, 254
    ANSI/NSPI-1: Standard for Public Swimming Pools, 2000 V3: 125, 151
    ANSI/NSPI-5: Standard for Residential, In-ground Swimming Pools, 2000 V3: 151
    ANSI Z358.1, 2003 V4: 18
    ANSI ZE 86.1: Commodity Specification for Air, 2000 V3: 65, 86
    ASME/ANSI B16.22 Wrought Copper and Copper Alloy Solder-Joint Pressure Fittings, 2003 V4: 37
    ASME/ANSI B16.23 Cast Copper Alloy Solder-Joint Drainage Fittings, 2003 V4: 45
    ASME/ANSI B16.26 Cast Copper Alloy Fittings for Flared Copper Tube, 2003 V4: 37
    ASME/ANSI B16.29 Wrought Copper and Wrought Copper Alloy Solder-Joint Drainage Fittings, 2003 V4: 45
    B16.15 Cast Bronze Threaded Fittings, 2003 V4: 27
    B16.24 Cast Copper Alloy Pipe Flanges and Flanged Fittings, 2003 V4: 27
    B36.1 standard, 2003 V4: 48
  standard air definition, 2000 V3: 200
  water quality standards, 1999 V2: 319
American Petroleum Institute
  address, 2000 V3: 97, 173
  emergency vent standards, 2000 V3: 167
  publications
    AOIRP 1004: Bottom Loading and Vapor Recovery for MC-306 Tank Motor Vehicles, 2000 V3: 173
    API Bulletin no. 1611: Service Station Tankage Guide, 2000 V3: 173
    API Bulletin no. 1615: Installation of Underground Gasoline Tanks and Piping at Service Stations, 2000 V3: 173
    API Specification 12D: Large Welded Petroleum Tanks, 2000 V3: 95
    API Specification 12F: Small Welded Petroleum Tanks, 2000 V3: 95
    API Standard 250: Steel Tanks for Oil Storage, 2000 V3: 95
  removal of globules standards, 1999 V2: 348
  separators, 2000 V3: 93
American Public Health Service, 1999 V2: 287
American Society for Testing and Materials (ASTM)
  abbreviation for, 2004 V1: 18
  address, 2004 V1: 58
  ASTM B819 tubing, 2000 V3: 77
  consensus process, 2004 V1: 41
  electronics-grade water standards, 1999 V2: 320
  high-purity water standards, 1999 V2: 317
  list of standards, 2004 V1: 41, 49–52
  membrane filters, 1999 V2: 289
  publications
    A-53 standard, 2003 V4: 48
    A-74 standard, 2003 V4: 28
    A-106 standard, 2003 V4: 48
    A-135 standard, 2003 V4: 48
    A-716 Culvert Pipe, 2003 V4: 32

A-746 Gravity Sewer Pipe, 2003 V4: 32
A-888 standard, 2003 V4: 28
ASME/ANSI B16.23 Cast Copper Alloy Solder-Joint Drainage Fittings, 2003 V4: 45
ASTM D2863: Method for Measuring the Minimum Oxygen Concentration to Support Candle-like Combustion of Plastics, 2000 V3: 85
B-16.9 standard, 2003 V4: 48
B-16.11 standard, 2003 V4: 48
B-16.28 standard, 2003 V4: 48
B-16.50 Wrought Copper Braze Fittings, 2003 V4: 45
B-29 standard, 2003 V4: 49
B-42 Standard Specification for Seamless Copper Pipe, Standard Sizes, 2003 V4: 34
B-43 Standard Specification for Seamless Red Brass Standard Sizes, 2003 V4: 27
B-88 Specification for Seamless Copper Water Tube, 2003 V4: 35
B-306 Specification for Copper Drainage Tube (DWV), 2003 V4: 35
B-306 Standard Specification for Copper Drainage Tube (DWV), 2003 V4: 45
B-813 Standard Specification for Liquid and Paste Fluxes for Soldering Applications of Copper and Copper Alloy Tube, 2003 V4: 37
B-819 Specification for Seamless Copper Tube for Medical Gas Systems, 2003 V4: 35
B-819 Standard Specification for Seamless Copper Tube for Medical Gas Systems, 2003 V4: 45
B-828 Standard Practice for Making Capillary Joints by Soldering of Copper and Copper Alloy Tube and Fittings, 2003 V4: 37
C-4 standard, 2003 V4: 49
C-12 standard, 2003 V4: 49
C-14 Standard Specification for Concrete Sewer, Storm Drain, and Culvert Pipe for Non-reinforced Concrete, 2003 V4: 32
C-76 Standard Specification for Reinforced Concrete Culverts, Storm Drain, and Sewer Pipe, 2003 V4: 32
C-296 standard, 2003 V4: 26
C-301 standard, 2003 V4: 49
C-425 standard, 2003 V4: 49
C-428 standard, 2003 V4: 26
C-443 Standard Specification for Joints for Circular Concrete Sewer and Culvert Pipe, Using Rubber Gaskets, 2003 V4: 32
C-599-77 standard, 2003 V4: 48
C-655 Standard Specification for Reinforced Concrete D-Load Culvert Storm Drain and Sewer Pipe for Reinforced Concrete Pipe, 2003 V4: 32
C-700 standard, 2003 V4: 49
C-828 standard, 2003 V4: 49
C-896 standard, 2003 V4: 49
D-1148 standard, 2003 V4: 61
D-1784 standard, 2003 V4: 62
D-1785 standard, 2003 V4: 62
D-2239 standard, 2003 V4: 61
D-2241 standard, 2003 V4: 62
D-2464 standard, 2003 V4: 62
D-2466 standard, 2003 V4: 62
D-2467 standard, 2003 V4: 62
D-2609 standard, 2003 V4: 61
D-2662 standard, 2003 V4: 58
D-2665 standard, 2003 V4: 62
D-2666 standard, 2003 V4: 58
D-2672 standard, 2003 V4: 62
D-2737 standard, 2003 V4: 61
D-3139 standard, 2003 V4: 62
E-33.08b Plumbing Noise, 2004 V1: 194
F-477 standard, 2003 V4: 62
F-876 standard, 2003 V4: 61
F-877 standard, 2003 V4: 61
F-1281 standard, 2003 V4: 62
F-1282 standard, 2003 V4: 62
reagent-grade water standards, 1999 V2: 279, 319
American Society of Civil Engineers (ASCE)
contract publications, 2004 V1: 62
sewer publications, 1999 V2: 95, 114
American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (ASHRAE)
address, 2004 V1: 58
defined, 2004 V1: 18
hot-water recirculation systems, 2004 V1: 265
list of standards, 2004 V1: 47
publications
Handbook of Fundamentals, 2004 V1: 2, 5, 6, 40, 2000 V3: 197
Handbooks, 1999 V2: 214
water heating codes and standards, 1999 V2: 170
American Society of Mechanical Engineers (ASME)
address, 2004 V1: 58, 2000 V3: 97
air receivers, 2000 V3: 205
defined, 2004 V1: 18
fired and unfired pressure vessel standards, 1999 V2: 170
list of standards, 2004 V1: 47–48
publications
ANSI/ASME A112.6.1, 2003 V4: 6
ANSI/ASME A112.18.1, 2003 V4: 14
ANSI/ASME A112.19.6, 2003 V4: 5, 9
ANSI/ASME B16.15 Cast Bronze Threaded Fittings, 2003 V4: 34
ANSI/ASME B16.24 Cast Copper Alloy Pipe Flanges and Flanged Fittings, 2003 V4: 34
ASME A17.1 Safety Code for Elevators and Escalators, 2000 V3: 25
ASME/ANSI B16.22 Wrought Copper and Copper Alloy Solder-Joint Pressure Fittings, 2003 V4: 37
ASME/ANSI B16.24 Cast Copper Alloy Pipe Flanges and Flanged Fittings, 2003 V4: 37
ASME/ANSI B16.26 Cast Copper Alloy Fittings for Flared Copper Tube, 2003 V4: 37
ASME/ANSI B16.29 Wrought Copper and Wrought Copper Alloy Solder-Joint Drainage Fittings, 2003 V4: 45
ASME Boiler and Pressure Vessel Code, 2000 V3: 95
B16.15 Cast Bronze Threaded Fittings, 2003 V4: 27
Fuel-Gas Piping, 1999 V2: 214
relief valve standards, 1999 V2: 166
American Society of Plumbing Engineers (ASPE)

ASPE Solar Energy System Design Handbook, 2004 V1: 130
defined, 2004 V1: 18
Domestic Water Heating Design Manual, 2000 V3: 45
medical gas station guidelines, 2000 V3: 50, 51–52
publications, 1999 V2: 65
American Society of Plumbing Engineers Research Foundation (ASPERF), 2004 V1: 18
American Society of Safety Engineers (ASSE), 2004 V1: 18
American Society of Sanitary Engineering (ASSE), 2004 V1: 18
address, 2004 V1: 58
ASSE 1002, 2003 V4: 8
ASSE 6000 Professional Qualifications Standard for Medical Gas Systems Installers, Inspectors, Verifiers, Maintenance Personnel and Instructors, 2003 V4: 45
list of standards, 2004 V1: 48–49
American standard pipe threads, 2004 V1: 18
American Standards Association. *See* American National Standards Institute (ANSI)
American Water Works Association (AWWA)
address, 2004 V1: 58
defined, 2004 V1: 18
list of standards, 2004 V1: 52
publications
ANSI/AWWA C104/A21.4 Cement Mortar Lining, 2003 V4: 32
ANSI/AWWA C105/A21.5 Polyethylene Encasement, 2003 V4: 32
ANSI/AWWA C110/A21.10 Fitting, 2003 V4: 32
ANSI/AWWA C111/A21.11 Rubber-Gasket Joints, 2003 V4: 32
ANSI/AWWA C115/A21.15 Flanged Pipe, 2003 V4: 32
ANSI/AWWA C116/A21.16 Fusion-Bonded Epoxy Coating, 2003 V4: 32
ANSI/AWWA C150/A21.50 Thickness Design, 2003 V4: 32
ANSI/AWWA C151/A21.51 Manufacturing, 2003 V4: 32
ANSI/AWWA C153/A21.53 Compact Fittings, 2003 V4: 32
ANSI/AWWA C600 Installation, 2003 V4: 32
AWWA Cross Connection Control Manual, 1999 V2: 155
AWWA Standard for Disinfecting Water Mains, 1999 V2: 155
AWWA Standard for Disinfection of Water Storage Facilities, 1999 V2: 155
C-400 standard, 2003 V4: 26
C651 Disinfecting, 2003 V4: 32
American Welding Society (AWS), 2004 V1: 52, 58, 167
American wire gage (AWG), 2004 V1: 14
Americans with Disabilities Act Accessibility Guidelines (ADAAG), 2004 V1: 106
Americans with Disabilities Act (ADA)
ADAAG Review Federal Advisory Committee, 2004 V1: 123
faucet flow rates, 2004 V1: 135
fixture standards, 2003 V4: 2
history, 2004 V1: 106
overview, 2004 V1: 105
Amin, P., 1999 V2: 325
ammonia, 1999 V2: 282, 294
amp, AMP, AMPS (ampere). *See* amperes
ampacity, 2000 V3: 83
amperes (A, amp, AMP, AMPS)
ampere-hours, 2004 V1: 139
amperes per meter, 2004 V1: 33
measurement conversions, 2004 V1: 33
symbols for, 2004 V1: 14
amphoteric corrosion, defined, 2004 V1: 151
amphoteric materials, 2004 V1: 145
amusement parks, numbers of fixtures for, 2003 V4: 19
anaerobic bacteria in septic tanks, 1999 V2: 227
anaerobic wastewater treatment, 2000 V3: 95
anaerobic, defined, 2004 V1: 18, 151
Analysis phase of value engineering, 2004 V1: 213, 224. *See also* Function Analysis phase in value engineering
analytical grade water, 1999 V2: 317
anchoring equipment
anchorage forces in earthquakes, 2004 V1: 186
anchors, defined, 2004 V1: 191
fire-protection equipment, 2000 V3: 23
illustrations of potential problems, 2004 V1: 189
seismic protection, 2004 V1: 163
anchoring pipes, 1999 V2: 18, 85
anchors, defined, 2004 V1: 18, 12004 V1: 191
anechoic chambers, 2004 V1: 198
anesthesia workrooms
fixtures, 2000 V3: 36
health-care facilities, 2000 V3: 32
medical air, 2000 V3: 53
medical gas stations, 2000 V3: 51
anesthetic gas management, 2000 V3: 70–71
anesthetics, 2000 V3: 83
anesthetizing locations, 2000 V3: 83
ANG (angle). *See* angles (ANG)
ANGI (angles of incidence), 2004 V1: 14
angle grates in school shower rooms, 1999 V2: 11
angle snubbers, 2004 V1: 165
angle stops, 2004 V1: 18
angle valves (AV), 2004 V1: 9, 18
angles (ANG)
measurements, 2004 V1: 33
symbols, 2004 V1: 14
angles of bend, 2004 V1: 18
angles of incidence (ANGI), 2004 V1: 14
angular acceleration measurements, 2004 V1: 33
angular velocity measurements, 2004 V1: 33
animal research centers, 1999 V2: 147, 344, 2000 V3: 51
animal shelters, 1999 V2: 16
animal treatment rooms, 2000 V3: 45
anions
anion resins, 1999 V2: 284, 305
defined, 2004 V1: 151, 1999 V2: 280
in electromotive force series, 2004 V1: 144
in ion exchange, 1999 V2: 300, 301, 302
in pH values, 1999 V2: 329
annealed temper (soft), 2003 V4: 37
annual costs. *See* costs and economic concerns
annular chambers in dry-pipe systems, 2000 V3: 11

annular spaces in wells, 1999 V2: 240, 243
anodes
  anode expected life, 2004 V1: 148
  anodic protection, 2004 V1: 151–152
  defined, 2004 V1: 139, 151
  galvanic series of metals, 2004 V1: 141
  sacrificial anodes, 2004 V1: 147
anodic inhibitors, 2004 V1: 151
anodic potential (electronegative potential), 2004 V1: 153
anodic protection, defined, 2004 V1: 151–152
ANSI. *See* American National Standards Institute (ANSI)
anthracite coal filters, 1999 V2: 244, 300, 2000 V3: 132, 134
anthropometrics for wheelchairs, 2004 V1: 109
anti-cross-connection precautions, 1999 V2: 32
anti-siphon ballcocks, 2003 V4: 8
anti-vortex drains, 2000 V3: 117
anti-vortex grating, 2000 V3: 110
apartment buildings
  firefighting demand flow rates, 2000 V3: 232
  numbers of fixtures for, 2003 V4: 20, 21
apparatus dew points (adp, ADP), 2004 V1: 14
appearance functions
  defined, 2004 V1: 225
  in value engineering, 2004 V1: 243
appliances. *See also* fixtures
  acoustic ratings, 2004 V1: 194–195, 198
  appliance connectors, 1999 V2: 176
  codes and standards, 2004 V1: 43–44
  defined, 1999 V2: 213
  draft hoods on appliances, 1999 V2: 178, 213
  gas regulators, 2000 V3: 251
  gravity vents for gas appliances, 1999 V2: 178
  natural gas, 1999 V2: 175, 177–178
  oxygen depletion and gas appliances, 1999 V2: 178
Applied Technology Council (ATC), 2004 V1: 183, 191
approaches to toilet compartments, 2004 V1: 114
approvals
  for radioactive materials systems, 1999 V2: 340
  for special-waste drainage systems, 1999 V2: 328
approved, defined, 2004 V1: 18
approved testing agencies, 2004 V1: 18
approximate (approx., APPROX)
  approximate values, 2004 V1: 32
  defined, 2004 V1: 14
appurtenances, in plumbing cost estimation, 2004 V1: 93, 97
aquastats, 2004 V1: 10, 2000 V3: 112, 125
Aqueous Film-Forming Foam (AFFF), 2000 V3: 21
aquifers
  defined, 1999 V2: 240
  potentiometric surfaces, 1999 V2: 241
  in private water systems, 1999 V2: 239
  unconsolidated aquifers, 1999 V2: 241
arabic numerals, 2004 V1: 32
arcades, numbers of fixtures for, 2003 V4: 19
Architect-engineers Turf Sprinkler Manual, 2000 V3: 105
architect's supplemental instructions (ASI), 2004 V1: 63
Architectural Barriers Act (90-480), 2004 V1: 106
area (A)
  calculating, 2004 V1: 3–5
  conversion factors, 2004 V1: 35
  measurements, 2004 V1: 33
  non-SI units, 2004 V1: 34
  symbols, 2004 V1: 14
area alarms, 2000 V3: 49, 72, 81
area drains, 2004 V1: 18
areas of sprinkler operation, 2000 V3: 16
areaways, 1999 V2: 67, 69
arenas, numbers of fixtures for, 2003 V4: 19
ARI (Air Conditioning and Refrigeration Institute), 2004 V1: 46–47, 58
arm baths, 2000 V3: 32, 35, 38
Army Corps of Engineers, 2004 V1: 63
arresters for water hammer. *See* water hammer arresters
arterial vents, 2004 V1: 18, 1999 V2: 52
articulated-ceiling medical gas systems, 2000 V3: 59
"as low as reasonably achievable" (ALARA), 1999 V2: 341
ASA A117.1-1961, 2004 V1: 105
asbestos cement piping, 1999 V2: 122, 2000 V3: 245
asbestos concrete piping, 2003 V4: 26
ASCE. *See* American Society of Civil Engineers (ASCE)
ASHRAE. *See* American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (ASHRAE)
ASI (architect's supplemental instructions), 2004 V1: 63
ASME. *See* American Society of Mechanical Engineers (ASME)
ASPE. *See* American Society of Plumbing Engineers (ASPE)
ASPERF (American Society of Plumbing Engineers Research Foundation), 2004 V1: 18
aspirating nozzles on foam extinguishers, 2000 V3: 21
aspirators, 2004 V1: 18, 2000 V3: 38
ASSE. *See* American Society of Safety Engineers (ASSE); American Society of Sanitary Engineering (ASSE)
assembly costs, 2004 V1: 222
assembly halls
  numbers of fixtures for, 2003 V4: 19, 21
  single-occupant toilet rooms, 2003 V4: 23
assisted creativity, 2004 V1: 232
assisted living facilities, numbers of fixtures for, 2003 V4: 20
Association for the Advancement of Medical Instrumentation (AAMI), 1999 V2: 279, 317, 319
ASTM. *See* American Society for Testing and Materials (ASTM)
ASTM A53 piping, 2000 V3: 254
ASTM A106 piping, 2000 V3: 254
ASTs (aboveground storage tanks). *See* aboveground tank systems
ATBCB (U.S. Architectural and Transportation Barriers Compliance Board), 2004 V1: 106, 107
ATC-3 (Tentative Provisions for the Development of Seismic Regulations for Buildings), 2004 V1: 183, 191
Atienze, J., 1999 V2: 34
atm, ATM (atmospheres). *See* atmospheres
atmospheres (atm, ATM)
  converting to SI units, 2004 V1: 39
  symbols, 2004 V1: 14
  vacuum units, 1999 V2: 254
atmospheric pressure in vacuum, 1999 V2: 254
atmospheric regulators, 2000 V3: 251
atmospheric tanks

defined, 2000 V3: 153
foam, 2000 V3: 21
venting, 2000 V3: 157–158
atmospheric vacuum breakers (AVB)
cross-connection control, 1999 V2: 144
defined, 2004 V1: 18
faucets, 2003 V4: 14
hazard levels and, 1999 V2: 145
irrigation sprinklers, 2000 V3: 103, 104
spillage, 1999 V2: 148
atmospheric vaporizers, 2000 V3: 61
atmospheric vents (steam or hot vapor) (ATV), 2004 V1: 9
attachments, 2004 V1: 191
"atto" prefix, 2004 V1: 34
ATV (atmospheric vents), 2004 V1: 9
Auciello, Eugene P., 1999 V2: 114
auditoriums, numbers of fixtures for, 2003 V4: 19, 21
authorities having jurisdiction
defined, 2004 V1: 17, 18, 2000 V3: 83
fire hazard evaluations, 2000 V3: 2
fire-protection system design, 2000 V3: 1
gaseous fire-suppression systems, 2000 V3: 22
manholes, 2000 V3: 234
medical gas stations, 2000 V3: 56
public sewer availability, 2000 V3: 234
swimming pools, 2000 V3: 127
automatic air vents (AAV), 2004 V1: 10
automatic alternators, 2000 V3: 70
automatic drain valves, 2000 V3: 103
automatic drains in vacuum systems, 2000 V3: 70
automatic fill lines makeup-water systems, 2000 V3: 124
automatic fire-detection devices, 2000 V3: 13
automatic fire-protection systems, 2000 V3: 1–18
history and objectives, 2000 V3: 1–2
pipes and hangers, 2000 V3: 15
automatic flushometer valves, 2003 V4: 8
automatic heat-up, 2000 V3: 191, 195, 196
automatic overfill prevention, 2000 V3: 167
automatic overrides for irrigation controllers, 2000 V3: 104
automatic skimmers, 2000 V3: 146
Automatic Sprinkler and Standpipe Systems, 2000 V3: 29
automatic sprinkler systems
combined dry-pipe and pre-action, 2000 V3: 15
design density, 2000 V3: 15
effectiveness statistics, 2000 V3: 2
elevator shafts, 2000 V3: 25
fire hazard evaluation, 2000 V3: 2–3
fire pumps for, 2000 V3: 25
gaseous fire-suppression systems and, 2000 V3: 22
history, 2000 V3: 1–2
hydraulic design, 2000 V3: 15–18
materials, 2000 V3: 12
numbers of sprinklers in operation, 2000 V3: 16
pipes and hangers, 2000 V3: 12, 15
pre-action systems, 2000 V3: 13
system design, 2000 V3: 2–18
types, 2004 V1: 29, 2000 V3: 8–15
water supplies, 2000 V3: 3–8
Automatic Sprinkler Systems Handbook, 2004 V1: 191
automatic storage water heaters, 1999 V2: 160
automatic tank gauging, 2000 V3: 159–160
automatic trap primers, 1999 V2: 10, 14
automotive traffic, 1999 V2: 11, 223
autopsy rooms
fixtures, 2000 V3: 35, 38
health-care facilities, 2000 V3: 32
medical gas stations, 2000 V3: 51, 58
medical vacuum, 2000 V3: 54
non-potable water, 2000 V3: 45
AV (acid vents), 2004 V1: 8, 17
AV (angle valves), 2004 V1: 9, 18
availability. *See* demand
available vacuum, safety factors and, 1999 V2: 276
AVB. *See* atmospheric vacuum breakers (AVB)
average (avg, AVG), defined, 2004 V1: 14
average pressure drops in water systems, 1999 V2: 125, 126, 127
avg, AVG (average), 2004 V1: 14
AW (acid wastes), 2004 V1: 8, 17, 2000 V3: 42
AWG (American wire gage), 2004 V1: 14
AWS. *See* American Welding Society (AWS)
AWWA. *See* American Water Works Association (AWWA)
Ayres, J.M., 2004 V1: 191
az, AZ (azimuth). *See* azimuth (az, AZ)
azimuth (az, AZ)
solar (SAZ), 2004 V1: 14
symbols for, 2004 V1: 14
wall (WAZ), 2004 V1: 14

B

B-16.9 standard, 2003 V4: 48
B-16.11 standard, 2003 V4: 48
B-16.15 Cast Bronze Threaded Fittings, 2003 V4: 27
B-16.24 Cast Copper Alloy Pipe Flanges and Flanged Fittings, 2003 V4: 27
B-16.28 standard, 2003 V4: 48
B-29 standard, 2003 V4: 49
B-36.1 standard, 2003 V4: 48
B-43 Standard Specification for Seamless Red Brass Standard Sizes, 2003 V4: 27
b/m (bills of material), 2004 V1: 14
back pressure tests, 2003 V4: 5
back pressures in pipes, 1999 V2: 2, 4, 35, 2000 V3: 251
back-siphonage, 2004 V1: 18, 1999 V2: 144, 145, 2000 V3: 103. *See also* backflow
back-spud water closets, 2003 V4: 3
back-to-back water closets, 2003 V4: 6–7
back venting, 1999 V2: 43, 47
backfilling
around septic tanks, 1999 V2: 228
around subsurface drainage pipes, 1999 V2: 102
around water system pipes, 1999 V2: 250
backfill defined, 2004 V1: 18
building sewers and, 1999 V2: 15
fountain piping systems, 2000 V3: 116
labor productivity rates, 2004 V1: 96
in plumbing cost estimation, 2004 V1: 93
storage tanks, 2000 V3: 155, 172
backflow. *See also* back-siphonage
backflow connections, defined, 2004 V1: 18
defined, 2004 V1: 18
backflow preventers
codes, 2004 V1: 42

cold-water pressure losses and, 1999 V2: 125
cold-water systems, 1999 V2: 144–149
cross-connection control devices, 1999 V2: 144–145
defined, 2004 V1: 18
domestic water supply, 2000 V3: 221–224
faucets, 2003 V4: 13–14
fire-protection connections, 2000 V3: 225, 226
fixtures in health-care facilities, 2000 V3: 33
hazard assessment, 1999 V2: 145
installation, 1999 V2: 148–149
isolating premises, 1999 V2: 145–147
makeup water in fountains, 2000 V3: 124
pressure loss, 2000 V3: 224
reduced pressure zones, 2000 V3: 223
roof drains, 1999 V2: 84
thermal expansion compensation and, 1999 V2: 167
vacuum breakers, 1999 V2: 144, 149, 2000 V3: 33, 45
background levels of radiation, 1999 V2: 339
backing rings, 2004 V1: 18
backup, defined, 2004 V1: 18
backup demineralizers, 2000 V3: 46
backup storm-drainage systems, 1999 V2: 70, 79
backwash from pool filtration, 2000 V3: 112, 113, 137
backwash from water softeners, 1999 V2: 244, 307
backwash pits, 2000 V3: 137, 140, 143
backwashing
diatomaceous earth filters, 2000 V3: 139
filters, 1999 V2: 300
in regeneration cycle, 1999 V2: 304–305
sand filters, 2000 V3: 132
vacuum diatomaceous earth filtration, 2000 V3: 135
backwater valves, 2004 V1: 19, 43, 1999 V2: 12, 13
bacteria
biological fouling, 1999 V2: 289, 316–317
chemical control, 1999 V2: 311–313
demineralizer systems, 2000 V3: 46
distilled water and, 2000 V3: 46
in drinking water, 1999 V2: 244
in feed water, 1999 V2: 282
in filters, 1999 V2: 300
in hot water, 2000 V3: 45
in septic tanks, 1999 V2: 227
in swimming pools, 2000 V3: 148
in water-heating systems, 1999 V2: 169
in wells, 1999 V2: 243
baffle systems, 2000 V3: 46
baffleplates, 2004 V1: 18
baffles in septic tanks, 1999 V2: 228
bag-filter gross filtration, 1999 V2: 300
Bahamas, gray-water systems in, 1999 V2: 33
bailers, 2000 V3: 162
balancing pumps, 2004 V1: 197
balancing valves (BLV), 2004 V1: 9, 2000 V3: 115
balcony drains, 1999 V2: 69
ball-and-globe valves, 2000 V3: 118
ball check valves, 2004 V1: 18
ball joints, bracing and, 2004 V1: 171
ball removal tests, 2003 V4: 5
ball valves (BV), 2004 V1: 9, 18, 1999 V2: 332, 2000 V3: 72
Ballanco, Julius, 1999 V2: 114
ballast pads, 2000 V3: 172
ballcocks, 2003 V4: 8
Baltimore Dept. of Public Works, 1999 V2: 34
banned practices in asbestos concrete piping, 2003 V4: 26
banquet halls, numbers of fixtures for, 2003 V4: 19
bare pipe, 2004 V1:150, 2004 V1: 150
barium, 1999 V2: 281
baro, BARO (barometric), 2004 V1: 14
baro pr, BARO PR (barometric pressure). *See* barometric pressure
barometers (baro, BARO)
symbols for, 2004 V1: 14
vacuums and, 1999 V2: 254
barometric (baro, BARO), defined, 2004 V1: 14
barometric loops, 1999 V2: 144
barometric pressure (baro pr, BARO PR, BP), 2000 V3: 200
altitude adjustments, 1999 V2: 257
barometric, defined, 2004 V1: 14
barometric pressure, defined, 2004 V1: 15
in vacuums, 1999 V2: 254, 275
barrels
converting to SI units, 2004 V1: 39
dimensions, 2003 V4: 29–31
barrier free, 2004 V1: 18. *See also* people with disabilities
barriers
around tanks, 2000 V3: 169
in sound insulation, 2004 V1: 193
bars, converting to SI units, 2004 V1: 39
bars, numbers of fixtures for, 2003 V4: 19
base acquisition costs, 2004 V1: 223
base materials
base defined, 2004 V1: 18
compounds in water, 1999 V2: 280
pH control, 2000 V3: 91–92
base units, 2004 V1: 33
basic functions in value engineering, 2004 V1: 225, 227, 230
basic material standards, 2004 V1: 66
Basic Plumbing Code (BOCA), 2000 V3: 154
basket strainers
fountain pumps, 2000 V3: 116
head loss and, 2000 V3: 115
maintenance, 2000 V3: 110
materials, 2000 V3: 146
pre-manufactured skimmers, 2000 V3: 137
pumps, 2000 V3: 115
swimming pool pumps, 2000 V3: 140
bathhouses, 1999 V2: 235, 2000 V3: 129, 130
bathing rooms, 2004 V1: 112–113
bathroom groups, 1999 V2: 43, 62, 63, 2000 V3: 217
bathtub fill valves, 2003 V4: 16
bathtubs
accessibility design, 2004 V1: 117–119
acoustic ratings of, 2004 V1: 194
bathtub enclosures, 2004 V1: 118–119
estimated water flows from, 1999 V2: 25
fixture-unit loads, 1999 V2: 3
grab bars, 2004 V1: 116, 117
gray-water systems and, 2004 V1: 135, 1999 V2: 22
health-care facilities, 2000 V3: 32
infant bathtubs, 2000 V3: 34
minimum numbers of, 2003 V4: 18–22
overflows, 2003 V4: 16

patient rooms, 2000 V3: 34
resilient-mounting design, 2004 V1: 206
seats, 2004 V1: 122
sound-damping materials, 2004 V1: 196
standards, 2003 V4: 2
temperatures, 2000 V3: 45
types and requirements, 2003 V4: 16
water fixture unit values, 2000 V3: 217
batteries
corrosion cells in sacrificial anodes, 2004 V1: 148
of fixtures, 2004 V1: 18, 1999 V2: 64
battery-controlled valves, 2004 V1: 135
Baumeister, Theodore, 2004 V1: 1, 2, 3, 5, 40
BCMC (Board for Coordination of Model Codes), 2004 V1: 106
BCuP brazing, 2003 V4: 45
beach components in pools, 2000 V3: 128
bead-to-bead joints, 2003 V4: 47
bead-to-cut-glass end joints, 2003 V4: 47
beam clamps, 2004 V1: 190
Beausoliel, R.W., 1999 V2: 65
bed locator units, 2000 V3: 57
bedding and settlement
around septic tanks, 1999 V2: 228
building sewers and, 1999 V2: 15
defined, 2000 V3: 234
illustrated, 2000 V3: 235
pipe supports and, 1999 V2: 14
protecting against settlement, 1999 V2: 19
settlement loads, 2004 V1: 186
subsurface drainage pipes, 1999 V2: 102
water system piping, 1999 V2: 250, 251
bedpan washers, 2000 V3: 32, 34, 36, 38
bell-and-spigot joints and piping. *See also* hub-and-spigot piping and joints
defined, 2004 V1: 18
earthquake protection and, 2004 V1: 167
underground, 1999 V2: 88
bell holes, 1999 V2: 88
bell hub depressions, 1999 V2: 15
bells, defined, 2004 V1: 18
below-slab drainage, 1999 V2: 103
bend-and-loop pipe configurations, 2004 V1: 199
bending movements, conversion factors, 2004 V1: 35
benefits in value engineering presentations, 2004 V1: 258
Bennett, E.R., 1999 V2: 238
bentonite clay, 1999 V2: 302
bentonite grout, 1999 V2: 243
Bernoulli's equation, 2004 V1: 5–6
beta ray radiation, 1999 V2: 337
beverage-processing plants, 1999 V2: 147
BFP (backflow preventers). *See* backflow preventers
BFV (butterfly valves), 2004 V1: 9, 20
bhp, BHP (brake horsepower), 2004 V1: 6, 14
bicarbonates, 1999 V2: 281, 282, 290, 295
bid bonds, 2004 V1: 62
bid by invitation, 2004 V1: 62
bid shopping, 2004 V1: 68
bidders
defined, 2004 V1: 61
information in project manuals, 2004 V1: 61
bidding documents, 2004 V1: 61
bidding requirements, 2004 V1: 61
Biddison, 2004 V1: 191
bidets, 2000 V3: 217, 2003 V4: 2, 16–17
bills of material (b/m, BOM), 2004 V1: 14
bimetallic traps, 2000 V3: 182
binding, preventing in cleanouts, 1999 V2: 9
biochemical measurements of microorganisms, 1999 V2: 282
biocides, 1999 V2: 311, 316, 317, 323
biodegradable foam extinguishers, 2000 V3: 21
biofouling, 1999 V2: 289, 316
biohazardous materials. *See* infectious and biological waste systems
biological and biomedical laboratories. *See* laboratories
biological characteristics of drinking water, 1999 V2: 316, 318
biological control in pure water systems, 1999 V2: 323. *See also* microbial growth and control
biological fouling, 1999 V2: 289, 316
biological oxygen demand (BOD), 2000 V3: 21, 93
biological treatment
in gray-water treatment, 1999 V2: 27
of oil spills, 1999 V2: 347
of sewage in septic tanks, 1999 V2: 227
wastewater treatment plants, 2000 V3: 93
biological waste systems. *See* infectious and biological waste systems
bio-pure water, 2000 V3: 46
biosafety cabinets, 1999 V2: 344
biosafety levels (BL1-BL4), 1999 V2: 343–344
biostats, 1999 V2: 311, 317
birthing rooms, 2000 V3: 36, 52, 58
bitumastic-enamel-lined piping, 1999 V2: 122
bituminized felt, 2004 V1: 196
bituminous pipe joint compound, 1999 V2: 223
BL1-4 levels, 1999 V2: 343–344
black iron coated pipe, 2003 V4: 48
black pipes, 2004 V1: 18
black steel piping, 1999 V2: 68, 176, 196, 197–211, 2000 V3: 165, 254
black-water systems
amount of generated black water, 1999 V2: 23
compared to gray water, 1999 V2: 21, 23
estimating sewage quantities, 1999 V2: 233–238
bladder bags, 2004 V1: 116
bladder tanks, 2000 V3: 21
blades in pumps, 2004 V1: 197
Blake, Richard T., 1999 V2: 325
blank flanges, 2004 V1: 18
blast gates, 1999 V2: 268
bleachers, numbers of fixtures for, 2003 V4: 19
bleaches, 1999 V2: 230
bleed cocks, 2000 V3: 4
block-like soils, 1999 V2: 218
block-method irrigation, 2000 V3: 100
blocking creativity, 2004 V1: 231–232
blocking water system pipes, 1999 V2: 250
blood analyzers, 1999 V2: 14
blood or other objectionable materials, 1999 V2: 16. *See also* infectious and biological waste systems
blood-type floor drains, 2000 V3: 35
blow-backs, reduced-size venting and, 1999 V2: 49

blow-off in air compressors, 2000 V3: 205
blowdown
boiler blowdown, 1999 V2: 314, 315
cooling towers, 1999 V2: 316
removing sludge, 1999 V2: 289
steam traps, 2000 V3: 195
blowout fixtures, acoustic design and, 2004 V1: 195
blowout urinals, 2003 V4: 8–9, 9
blowout water closets, 2003 V4: 3
blue dyes in gray water, 1999 V2: 22, 33
blue water in pools, 2000 V3: 148
BLV (balancing valves), 2004 V1: 9, 2000 V3: 115
Board for Coordination of Model Codes (BCMC), 2004 V1: 106
boarding houses, numbers of fixtures for, 2003 V4: 20
bobbin-wound fiberglass filters, 2000 V3: 131
BOCA. *See* Building Officials and Code Administrators International, Inc. (BOCA)
BOD (biological oxygen demand), 2000 V3: 21, 93
body sprays, 2003 V4: 16
Boegly, W.J., 1999 V2: 238
Boiler and Pressure Vessel Code, 2000 V3: 95
boiler blow-off tanks, 2004 V1: 18
boiler blow-offs, 2004 V1: 18
boiler feed lines, 2003 V4: 34
boiler room earthquake protection, 2004 V1: 166
Boiler Water Treatment, 1999 V2: 325
boilers
cast-iron supports for, 2004 V1: 162
codes and standards, 2004 V1: 42
condensation, 2004 V1: 267
earthquake protection, 2004 V1: 163
feed lines, 2003 V4: 34
feed pumps, 2000 V3: 188–189
feed receivers, 2000 V3: 188
feed water corrosion inhibitors, 2004 V1: 151
feed water treatments, 1999 V2: 314–315
gas train arrangements, 2000 V3: 251
natural gas systems and, 1999 V2: 174
scaling, 1999 V2: 289
sediment buckets in drains, 1999 V2: 12
short cycling, 2000 V3: 180
steam heating systems, 2000 V3: 178
swimming pool heaters, 2000 V3: 138
boiling points (bp, BP)
defined, 1999 V2: 213
liquid fuels, 2000 V3: 153
liquid oxygen, 2000 V3: 61
symbols for, 2004 V1: 14
bollards, 2000 V3: 169, 172
bolting problems in seismic protection, 2004 V1: 190
bolts for water closets, 2003 V4: 6
BOM (bills of material), 2004 V1: 14
bonded joints, 2004 V1:150
bonds and certificates, 2004 V1: 62
bonnets, 2004 V1: 18
booster-pump systems
connections, 2000 V3: 225
constant pressure and, 1999 V2: 152
constant use and, 1999 V2: 121
domestic water service, 2000 V3: 216
fire-protection systems, 2000 V3: 8
in health-care facilities, 2000 V3: 44
low-pressure fire pumps, 2000 V3: 25
noise control, 2004 V1: 199
booster water heaters, 2004 V1: 126, 129, 1999 V2: 160
boosting water pressure, 1999 V2: 149–152
borate, 1999 V2: 282
bore holes for wells, 1999 V2: 240
bored wells, 1999 V2: 241
borings
subsurface site drainage, 1999 V2: 100
wells, 1999 V2: 240
borosilicate glass piping, 1999 V2: 14, 15, 122, 2000 V3: 40, 2003 V4: 47
Bosich, Joseph F., 2004 V1: 154
bottled gas, 1999 V2: 174
bottled water, 2003 V4: 14
Bottom Loading and Vapor Recovery for MC-306 Tank Motor Vehicles (AOIRP 1004), 2000 V3: 173
Bourdon gauges, 1999 V2: 260
bowl depth of sinks, 2004 V1: 117
Boyle, W.C., 1999 V2: 34
BP (barometric pressure). *See* barometric pressure
bp, BP (boiling points). *See* boiling points (bp, BP)
braces (walking aids), 2004 V1: 107
bracing
aircraft cable method, 2004 V1: 171
alternate attachments for pipes, 2004 V1: 174
avoiding potential earthquake problems, 2004 V1: 189
defined, 2004 V1: 191
hanger rod connections, 2004 V1: 177
hanger rods, 2004 V1: 166
hubless cast-iron pipe, 2004 V1: 177
lateral sway bracing, 2004 V1: 181–182
longitudinal and transverse bracing, 2004 V1: 180
longitudinal-only bracing, 2004 V1: 172, 180
open-web steel joists, 2004 V1: 176
pipes on trapeze and, 2004 V1: 175, 178
piping systems for seismic protection, 2004 V1: 166–182
riser bracing for hubless pipes, 2004 V1: 178
self bracing, 2004 V1: 190
spacing of, 2004 V1: 184
steel beam connections, 2004 V1: 175
structural angle bracing, 2004 V1: 171
structural channel bracing, 2004 V1: 171
strut bracing, 2004 V1: 173, 175
superstrut, 2004 V1: 170
sway bracing, 2004 V1: 179, 180, 181–182, 185–186, 187
Tension 360 bracing, 2004 V1: 169
transverse bracing, 2004 V1: 171, 179
truss-type actions, 2004 V1: 190
typical earthquake bracing, 2004 V1: 168
brainstorming in creativity, 2004 V1: 232
brake horsepower (bhp, BHP)
fire pumps, 2000 V3: 25
pumps, 2004 V1: 6
symbols for, 2004 V1: 14
branch-bottom connections, 2004 V1: 11
branch intervals, 2004 V1: 18, 1999 V2: 64
branch lines, 2000 V3: 85
branch sewers (submain sewers), 2004 V1: 30

branch tees, 2004 V1: 18
branch-top connections, 2004 V1: 11
branch vents, 2004 V1: 18
branches, defined, 2004 V1: 18
brand names in specifications, 2004 V1: 66, 67
brass
  dezincification, 2004 V1: 141
  in electromotive force series, 2004 V1: 144
  in galvanic series, 2004 V1: 141
brass (copper alloy) pipe, 1999 V2: 14, 2003 V4: 27
brass fittings, 1999 V2: 196
brass floor drains, 1999 V2: 15, 16
brass pipes, 1999 V2: 68, 122, 176, 196, 2000 V3: 116
brass pool lighting, 2000 V3: 145
brazed joints
  earthquake protection and, 2004 V1: 167
  inspection, 2000 V3: 80
  medical gas tubing, 2000 V3: 77, 2003 V4: 45
brazing alloys on gas piping, 1999 V2: 196
brazing ends, 2004 V1: 18
Brazing Joints for Copper and Copper Alloy Pressure Fittings, 2003 V4: 45
break points (chlorination), 2000 V3: 149
breakdown chlorination, 2000 V3: 149
breathing apparatus
  chlorine gas, 2000 V3: 148
  diatomaceous earth and, 2000 V3: 134
  for emergencies, 1999 V2: 332, 333
brick dome covers on seepage pits, 1999 V2: 225
brines
  hydrostatic monitoring systems, 2000 V3: 160
  refrigerants, 2004 V1: 151
  in water softening, 1999 V2: 307
British thermal units (Btu, BTU)
  British thermal units per hour (Btu/h), 2004 V1: 18, 2000 V3: 122
  Btu (J) (fire loads), 2000 V3: 3
  calculating hot water savings, 2004 V1: 127
  converting to SI units, 2004 V1: 39
  defined, 2004 V1: 18, 136, 1999 V2: 213
  natural gas services, 2000 V3: 249
  symbols for, 2004 V1: 14
bromine, 2000 V3: 123, 149
bromtrifluoro-methane CBrF3 (halon 1301), 2004 V1: 25
bronze filtration tanks, 2000 V3: 131
Bronze Fittings for Brazed Joints, 2003 V4: 27, 34
bronze floor drains, 1999 V2: 15
bronze-mounted, defined, 2004 V1: 18
bronze pumps, 2000 V3: 115, 145
bronze sediment buckets, 1999 V2: 14
bronze trim, 2004 V1: 18
bronze valves, 2000 V3: 145
bronze, in electromotive force series, 2004 V1: 141
Brown & Sharpe wire gage (B&S), 2004 V1: 14
Brown, F.R., 2004 V1: 191
Brown, J., 1999 V2: 325
brown water, 2000 V3: 147
Brownstein, E., 1999 V2: 65
brushes for swimming pool cleaning, 2000 V3: 146
Bryan, John L., 2000 V3: 29
B&S (Brown & Sharpe wire gage), 2004 V1: 14
Btu, BTU (British Thermal units). *See* British Thermal units
Btu/h (British thermal units per hour), 2004 V1: 18, 2000 V3: 122
Btu (J) (fire loads), 2000 V3: 3
bubble aerators, 1999 V2: 293
bubbler irrigation heads, 2000 V3: 103
bubbles, 1999 V2: 38, 2000 V3: 21. *See also* detergents; soaps; suds
buffing finishes on grates, 1999 V2: 11
building code list of agencies, 2004 V1: 42
Building Code Requirements for Minimum Design Loads in Buildings and Other Structures, 2004 V1: 191
building drains
  combined, 2004 V1: 19
  cross-sections of, 1999 V2: 2
  defined, 2004 V1: 19, 1999 V2: 64
  flow in, 1999 V2: 2
  inspection checklist, 2004 V1: 102–103
  installation, 1999 V2: 15
  pneumatic pressure in, 1999 V2: 2
  sanitary. *See* sanitary drainage systems
  sovent system connections, 1999 V2: 60–61
  storm. *See* storm-drainage systems
building inspectors, 2000 V3: 2
Building Officials and Code Administrators International, Inc. (BOCA), 1999 V2: 114, 2000 V3: 154
  BOCA Basic Plumbing Code, 1999 V2: 114, 2000 V3: 154
building sewers (house drains), 2004 V1: 19, 1999 V2: 15
building sites. *See* site utilities; sites
building storm-sewer pipe codes, 2004 V1: 42
building subdrains, 2004 V1: 19
Building Systems Design, 1999 V2: 277
building traps, 2004 V1: 19
buildings
  acceptable plumbing noise levels, 2004 V1: 193
  building material acoustic insulation, 2004 V1: 193
  construction and fire hazards, 2000 V3: 2
  defined, 2004 V1: 18
  essential facilities, 2004 V1: 191
  expansion, 2000 V3: 49
  isolating premises with backflow hazards, 1999 V2: 145–147
  minimum numbers of fixtures, 2003 V4: 18–22
  standard fire tests, 2000 V3: 3
  storm-drainage systems. *See* storm-drainage systems
  subdrains, 2004 V1: 19
  traps, 2004 V1: 19
  type of structure and earthquake protection, 2004 V1: 167
  utilities. *See* site utilities
built-in continuous pool gutters, 2000 V3: 137
built-in showers, 2003 V4: 15
bulk media tests, 2003 V4: 6
bulk oxygen systems, 2000 V3: 59, 61–62, 63
bulkhead fittings, 2000 V3: 163
bull head tees, 2004 V1: 20
bumpers, 2000 V3: 228, 229
Buna-N (nitrile butadiene), 2000 V3: 169
Bunsen burners, 1999 V2: 176
buried piping. *See* underground piping

burners, defined, 1999 V2: 213
burning methane, 2004 V1: 130–131
burning rates of plastic pipe, 2003 V4: 59–60
burst pressure, 2004 V1: 20
Burton, Franklin L., 2000 V3: 125
bushels, converting to SI units, 2004 V1: 39
bushings, 2004 V1: 20
businesses, numbers of fixtures for, 2003 V4: 19
butane, 1999 V2: 194, 213. *See also* fuel-gas piping systems
butt caps on fire hydrants, 2000 V3: 4
butt-welded standard weight pipe, 2003 V4: 48
butt welding
  butt-weld end connections, 2004 V1: 23
  butt weld joints, 2004 V1: 20
  butt weld pipes, 2004 V1: 20
  radioactive drainage systems, 1999 V2: 341
butterfly valves (BFV), 2004 V1: 9, 20, 2000 V3: 118
BV (ball valves), 2004 V1: 9, 18, 1999 V2: 332
bypass systems for pools, 2000 V3: 122, 144
bypass valves, 2004 V1: 20, 2003 V4: 18
bypasses, 2004 V1: 20

C

C, °C (celsius), 2004 V1: 14, 34
c (centi) prefix, 2004 V1: 34
C (conductance), 2004 V1: 14, 33
C (coulombs), 2004 V1: 33, 139
c (curies), 1999 V2: 339
C (specific heat). *See* specific heat
c to c, C TO C (center to center), 2004 V1: 14
C-4 standard, 2003 V4: 49
C-12 standard, 2003 V4: 49
C-296 standard, 2003 V4: 26

color coding, 2000 V3: 56
decarbonation, 1999 V2: 295
extinguishing systems, 2000 V3: 20–21
medical gas system tests, 2000 V3: 83
portable fire extinguishers, 2000 V3: 27
in steam systems, 2000 V3: 190
symbols for, 2004 V1: 9
in water, 1999 V2: 281, 284, 294
Carbon Dioxide Extinguishing Systems (NFPA 12), 2000 V3: 20, 29
carbon filtration (absorphan). *See* activated carbon filtration (absorphan)
carbon monoxide, 2000 V3: 83
carbon steel, 2004 V1: 144, 2000 V3: 91, 92, 116, 210
carbon steel casings, 1999 V2: 179
carbonate films, 2004 V1: 151
carbonates, 1999 V2: 281, 282, 283, 290, 2000 V3: 147
carbonic acid, 1999 V2: 281
carpets, vacuum calculations for, 1999 V2: 269
cartridge filtration, 1999 V2: 300, 305–306, 312, 323, 2000 V3: 112, 113
Cartwright, Peter, 1999 V2: 325
cascade waterfall aerators, 1999 V2: 293
casings
driven wells, 1999 V2: 241
gas boosters, 1999 V2: 179
jetted wells, 1999 V2: 241
well casings, 1999 V2: 240
Cassidy, Victor M., 2004 V1: 137
cast-aluminum floor drains, 1999 V2: 15
cast bronze solder-joint fittings, 2003 V4: 38
cast bronze threaded fittings, 2003 V4: 27
Cast Bronze Threaded Fittings, 2003 V4: 27, 34
Cast Copper Alloy Fittings for Flared Copper Tube, 2003 V4: 37
Cast Copper Alloy Pipe Flanges and Flanged Fittings, 2003 V4: 27, 34, 37
Cast Copper Alloy Solder-Joint Drainage Fittings, 2003 V4: 45
cast-filled acrylic fixtures, 2003 V4: 2
cast-filled fiberglass fixtures, 2003 V4: 2
cast glands, 2000 V3: 229
cast-in-place anchor bolts, 2004 V1: 163
cast iron
in electromotive series, 2004 V1: 144
fountain pumps, 2000 V3: 115
in galvanic series, 2004 V1: 141
graphitization, 2004 V1: 141
radiators, 2000 V3: 179, 180
swimming pool main drains, 2000 V3: 143
cast-iron boiler supports, 2004 V1: 162
cast-iron fittings, 1999 V2: 196
cast-iron fixtures
enameled, 2003 V4: 1–2
in health-care facilities, 2000 V3: 33
standards, 2003 V4: 2
cast-iron floor drains, 1999 V2: 16, 17
cast-iron piping
blocking, 1999 V2: 250
bracing, 2004 V1: 177
corrosion and, 2004 V1: 150
laboratories, 2000 V3: 40
liquefied petroleum gas, 1999 V2: 196
Manning formula and, 2000 V3: 245
natural gas, 2000 V3: 254
radioactive materials systems and, 1999 V2: 341
roughness, 1999 V2: 122
sanitary drainage systems, 1999 V2: 14
storm-drainage systems, 1999 V2: 89–92
tree roots and, 1999 V2: 223
underground piping, 1999 V2: 68
cast-iron soil pipe
dimensions of hubs, spigots and barrels, 2003 V4: 29–31
telescoping and laying lengths, 2003 V4: 28
types, 2003 V4: 27–31
Cast-iron Soil Pipe and Fittings Engineering Manual, 1999 V2: 114
Cast Iron Soil Pipe Institute (CISPI), 2004 V1: 20, 53, 58, 1999 V2: 114
CISPI 301 standard, 2003 V4: 28
CISPI 310 standard, 2003 V4: 28
cast-iron tank legs, 2004 V1: 163
catch basins, 2000 V3: 157
piping size, 1999 V2: 69
in site storm systems, 1999 V2: 98
Category II, III, or IV vent systems, 2004 V1: 43
cathodes
defined, 2004 V1: 139, 152
galvanic series of metals, 2004 V1: 141
cathodic corrosion, 2004 V1: 152
cathodic inhibitors, 2004 V1: 151
cathodic potential (electropositive potential), 2004 V1: 153
cathodic protection
criteria, 2004 V1: 150–151
defined, 2004 V1: 20, 152
introduction, 2004 V1: 139
liquid fuel tanks, 2000 V3: 155
methods, 2004 V1: 147–151
sand filtration tanks, 2000 V3: 131
cathodic, defined, 2004 V1: 152
cations
cation resins, 1999 V2: 284, 305
defined, 2004 V1: 152, 1999 V2: 280
in ion exchange, 1999 V2: 300, 301, 302
in pH values, 1999 V2: 329
caulking
caulked joints on floor drains, 1999 V2: 16
defined, 2004 V1: 20
causes and effects
in creativity checklist, 2004 V1: 234
of earthquakes, 2004 V1: 156–158
caustic embrittlement, 2004 V1: 152
caustic soda, 1999 V2: 333, 337, 2000 V3: 93
caustic waste from regeneration cycle, 1999 V2: 304
cavitation
anti-vortex drains, 2000 V3: 117
cavitation corrosion, 2004 V1: 152
defined, 2004 V1: 20, 152
flexible pipe connectors and, 2004 V1: 200
fountain pumps, 2000 V3: 108
modifications to pump plants, 2004 V1: 197
pressure levels and, 2004 V1: 200
reducing noise source strength, 2004 V1: 199

water level in pools and, 2000 V3: 112
cavitation corrosion, 2004 V1: 152
CCS (Certified Construction Specifier), 2004 V1: 72
ccw, CCW (counterclockwise), 2004 V1: 14
CD. *See* construction contract documents (CD)
cd (candelas), 2004 V1: 33
CD (condensate drains), 2004 V1: 8, 1999 V2: 13
cd/m^2, 2004 V1: 33
CDA (Copper Development Association), 2004 V1: 20
CDI (continuous deionization), 1999 V2: 306–307
ceiling-mounted medical gas systems, 2000 V3: 57–59, 58–59
ceiling-with-gas-stacks systems, 2000 V3: 58
ceilings, piping in, 2004 V1: 195, 201
cell pairs, 1999 V2: 306
cells, defined, 2004 V1: 152
cellulose acetate membranes, 1999 V2: 310, 311
cellulose gas filters, 2000 V3: 250
cellulose tricetate membranes, 1999 V2: 310, 311
celsius (°C), 2004 V1: 14
cement grout, 1999 V2: 243
cement joints, 2004 V1: 20
cement-lined piping
Manning formula and, 2000 V3: 245
roughness, 1999 V2: 122
in sprinkler hydraulic calculations, 2000 V3: 17
water pipes, 2003 V4: 32
Cement Mortar Lining, 2003 V4: 32
cement plaster joints, 2003 V4: 32
center to center (c to c, C TO C), 2004 V1: 14
centerline spacing of gas outlets, 2000 V3: 56
centersets for faucets, 2003 V4: 10
"centi" prefix, 2004 V1: 34
Centigrade conversion factors, 2004 V1: 38
centipoise, 2004 V1: 39, 2000 V3: 154
central chilled drinking water systems, 2004 V1: 265
central heating boilers, 2000 V3: 138
central-supply rooms, 2000 V3: 46
central-water purification equipment, 1999 V2: 323–325
centrally-located vacuum cleaning systems. *See* vacuum cleaning systems
centrifugal air compressors, 2000 V3: 65, 202, 205
centrifugal drum traps, 2000 V3: 42
centrifugal pumps
acid wastes and, 1999 V2: 332
defined, 2004 V1: 24
fountains, 2000 V3: 115
shallow well discharge, 1999 V2: 247
vacuum pumps, 1999 V2: 259
centrifugal separators
centrifugal-type vacuum separators, 1999 V2: 268
for oil spills, 1999 V2: 348
centrifugal vacuum cleaning systems, 1999 V2: 276
centrifugation of oil, 1999 V2: 347
ceramic fixtures
standards, 2003 V4: 2
types of, 2003 V4: 1–2
ceramic wool, 2004 V1: 193
CERCLA (Comprehensive Environmental Response Compensation and Liability Act), 2000 V3:88, 2000 V3: 89–90
certificates of insurance, 2004 V1: 62
certification
certification of performance, 1999 V2: 155
LEED program, 2004 V1: 263–264
medical gas systems, 2000 V3: 77–83
medical gas zones, 2000 V3: 72
storage tanks, 2000 V3: 171
Certified Construction Specifier (CCS), 2004 V1: 72
Certified Plumbing Designer (CPD), 2004 V1: 72
cesspools
defined, 2004 V1: 20
irrigation systems and, 1999 V2: 27
CF (contact factors), 2004 V1: 14
CFAC, CFACT (correction factors), 2004 V1: 14
CFCs (chlorofluorocarbons), 2000 V3: 22
cfh (cubic feet per hour), 2000 V3: 200, 248
cfm (cubic feet per minute). *See* cubic feet per minute
CFR (Code of Federal Regulations), 2000 V3:88
CFT (cubic feet), 2004 V1: 14
cfus (colony forming units), 1999 V2: 282
CGA. *See* Compressed Gas Association, Inc.
cGMP (current good manufacturing practices), 1999 V2: 325, 328
CGPM (General Conference of Weights and Measures), 2004 V1: 32
chainwheel-operated valves, 2004 V1: 20
chambers (air chambers). *See* air chambers (AC)
Chan, Wen-Yung W., 2004 V1: 40
change orders, 2004 V1: 63
changed standpipes, 2004 V1: 13
channels, 2004 V1: 20
character in creativity checklist, 2004 V1: 234
Characteristics and Safe Handling of Medical Gases (CGA P-2), 2000 V3: 86
Characteristics of Rural Household Waste Water, 1999 V2: 34
chart recorders, 2000 V3: 142
chases, 2004 V1: 20
check valves (CV)
aluminum check valves, 1999 V2: 177
defined, 2004 V1: 20
dry-pipe systems, 2000 V3: 11
fountains, 2000 V3: 118–119
irrigation systems, 2000 V3: 103
multilevel pools, 2000 V3: 108
swimming pool pumps, 2000 V3: 142
symbols for, 2004 V1: 9
thermal expansion compensation and, 1999 V2: 167
vacuum systems, 1999 V2: 262, 268
with vent ports, 1999 V2: 145, 149
checklists and forms
creativity worksheets, 2004 V1: 233–234, 236
designs and drawings, 2004 V1: 100–102
detail/product/material specification checklist, 2004 V1: 220
evaluation checklists, 2004 V1: 237–238
field checklists, 2004 V1: 102–103
final checklist, 2004 V1: 103
forms of agreement, 2004 V1: 62
fuel systems, 2000 V3: 171
function definitions, 2004 V1: 225–227
functional evaluation worksheets, 2004 V1: 243–251
general checklists for jobs, 2004 V1: 99

health-care facility medical gas and vacuum systems, 2000 V3: 49–50
idea development and estimated cost forms, 2004 V1: 241–242
idea evaluation worksheet, 2004 V1: 243, 253
project information checklists, 2004 V1: 215–220
project information sources checklists, 2004 V1: 221
recommendations worksheets, 2004 V1: 258, 259
storage tanks, 2000 V3: 173
storm-drainage calculations, 1999 V2: 109–113
using in presentations, 2004 V1: 257
value engineering checklists, 2004 V1: 214
chemical cleaning connections, 2000 V3: 47
chemical feed pumps for pools, 2000 V3: 148, 150–151
chemical filtration, 2000 V3: 112
Chemical Plant and Petroleum Refinery Piping (ANSI B3.13), 2000 V3: 95
chemical plants, 1999 V2: 147, 2000 V3:87
chemical pretreatment of oils, 2000 V3: 93
chemical regeneration in demineralizers, 2000 V3: 46
chemical-resistance testing, 2003 V4: 2
chemical spill emergency fixtures, 2003 V4: 17
chemical-waste drains
glass pipe, 2003 V4: 47
plastic pipes, 2003 V4: 58
chemical-waste systems
codes and standards, 1999 V2: 345
defined, 2004 V1: 20
design considerations, 1999 V2: 346
pipe and joint selection, 1999 V2: 345–346
chemically-stabilized emulsions, 1999 V2: 347
chemicals
analysis of swimming pool water, 2000 V3: 131
chemical characteristics of drinking water, 1999 V2: 316, 318
chemical control of microbes in water, 1999 V2: 311
chemical treatment of oil spills, 1999 V2: 347, 348
emulsions, 2000 V3: 93
feed pumps for pools, 2000 V3: 148, 150–151
filtration, 2000 V3: 112
laboratory vacuum systems, 1999 V2: 262
material safety data sheets, 2000 V3: 90
in septic tanks, 1999 V2: 230–231
in special-waste effluent, 1999 V2: 328
chemistry of water. *See* water chemistry
children, fixtures and
fixture heights, 2004 V1: 107
water closets, 2003 V4: 4–5
water coolers, 2003 V4: 14
chilled drinking water recirculating (DWR), 2004 V1: 8
chilled drinking water supply (DWS), 2004 V1: 8, 265, 2000 V3: 34
chilled water returns (CWR), 2004 V1: 8
chilled water supply (CWS), 2004 V1: 8
chimneys
codes, 2004 V1: 43
defined, 1999 V2: 213
heights, 1999 V2: 178
china fixtures, 2003 V4: 1–2
chips in acid-neutralization tanks, 2000 V3: 40, 41
chloramines, 2000 V3: 149
chlorides, 2004 V1: 147, 1999 V2: 281, 283, 302
chlorimine, 1999 V2: 300
chlorinated polyethylene sheet shower pans, 2003 V4: 15
chlorinated polyvinyl-chloride (CPVC)
defined, 2004 V1: 21
industrial waste usage, 2000 V3: 93
pipe characteristics, 2000 V3: 48, 2003 V4: 59–60
pipes, 1999 V2: 284, 2003 V4: 62
VOCs and, 1999 V2: 284
chlorination
disinfecting water systems, 1999 V2: 252
domestic water systems, 1999 V2: 154
drinking water, 1999 V2: 245
gray water, 1999 V2: 27, 28, 29
wells, 1999 V2: 243
chlorine
as disinfectant in pools, 2000 V3: 123
bleaches, 1999 V2: 230
breakdown chlorination, 2000 V3: 149
chlorine-resistant grates, 1999 V2: 15
cyanide and, 2000 V3: 93
gas, 2000 V3: 146, 148
microbial control, 1999 V2: 311
pure water systems, 1999 V2: 323
reflecting pools and fountains, 2000 V3: 108
removing, 1999 V2: 300
residuals, 2000 V3: 146, 147, 148
reverse osmosis and, 2000 V3: 47
small drinking water systems, 1999 V2: 318
superchlorination, 2000 V3: 149
swimming pool heaters and, 2000 V3: 138
swimming pool water chemistry, 2000 V3: 146
in water chemistry, 1999 V2: 281, 284
chlorofluorocarbons (CFCs), 2000 V3: 22
chloroform, 2000 V3: 70
chrome-plated brass, 2000 V3: 145
chromium III, 2000 V3: 93
chromium-iron, 2004 V1: 141
chromium VI, 2000 V3: 93
Church, James, 1999 V2: 114
churches, numbers of fixtures for, 2003 V4: 19, 22
Ciba-Geigy Pipe Systems, Inc., 2000 V3: 97
cigarette burn testing, 2003 V4: 2
CIN (cubic inches), 2004 V1: 14
cinders as backfill, 1999 V2: 222
circles, calculating area, 2004 V1: 5
circuit venting, 2004 V1: 20, 1999 V2: 43–44, 64
circuits (ckt, CKT), 2004 V1: 14, 20
circular lavatories, 2003 V4: 11
circulating pumps in pools, 2000 V3: 139
circulating water systems
in geothermal energy systems, 2004 V1: 131
hot water systems, 1999 V2: 165
standby losses in, 2004 V1: 127
circulation loops, 2000 V3: 47
CISPI (Cast Iron Soil Pipe Institute)
abbreviation, 2004 V1: 20
address, 2004 V1: 58
Cast Iron Soil Pipe and Fittings Engineering Manual, 1999 V2: 114
CISPI 301 standard, 2003 V4: 28
CISPI 310 standard, 2003 V4: 28
publications, 2004 V1: 53

cisterns, 1999 V2: 21, 247
citing codes and standards, 2004 V1: 67
citric acid, 2004 V1: 146
city rainfall rate tables, 1999 V2: 69–78
city water. *See* municipal water supply
ckt, CKT (circuits), 2004 V1: 14, 20
CL, C/L (critical level), 2004 V1: 21
clad steel tanks, 2000 V3: 155, 165, 172
Claes, 2004 V1: 154
clamp gate valves, 2004 V1: 20
clamp joints
  cast iron pipes, 2003 V4: 28
clams, 1999 V2: 282
clappers
  deluge valves, 2000 V3: 14
  dry-pipe systems, 2000 V3: 11
clarification treatments for water, 1999 V2: 294, 314
clarifying tanks, 2000 V3: 40
classes of service, standpipe systems, 2004 V1: 30, 2000 V3: 18, 19
classifications
  bedding, 2000 V3: 234, 235
  disabilities, 2004 V1: 107
  fires, 2000 V3: 3, 19, 27
  liquid fuel, 2000 V3: 153–154
  steam and condensate systems, 2000 V3: 175–189
claw-type pumps, 1999 V2: 259
clay loams, 2000 V3: 100, 243
clay pipe joints, 1999 V2: 223
clay piping
  industrial discharge piping, 1999 V2: 346
  noise insulation, 1999 V2: 15
  pipe sizing, 1999 V2: 89–92
  surface roughness, 1999 V2: 122
  underground piping, 1999 V2: 68
  vitrified clay pipe, 2003 V4: 49, 56–57
clay soils, 1999 V2: 26, 27
clays
  in feed water, 1999 V2: 289
  in soil texture, 1999 V2: 218
Clean Agent Extinguishing Systems (NFPA 2001), 2000 V3: 22, 23, 25, 29
Clean Air Act Amendments (CAAA), 2000 V3: 154
clean extinguishing agents, 2000 V3: 22
Clean Water Act, 1999 V2: 345, 2000 V3: 87, 88–89, 96
cleaning
  cold-water systems, 1999 V2: 154–155
  filters, 2000 V3: 150
  fixtures, 2003 V4: 1
  medical gas pipes, 2000 V3: 74, 80
  pipes and piping, 2003 V4: 25
  pool filters, 2000 V3: 137
  pools and fountains, 2000 V3: 107, 112
  pure-water systems, 2000 V3: 47
  radioactive waste piping, 1999 V2: 341
  section in specifications, 2004 V1: 71, 92
  septic tanks, 1999 V2: 228, 229–230
  swimming pools, 2000 V3: 146
cleanout plugs (CO), 2004 V1: 11
cleanouts
  chemical-waste systems, 1999 V2: 346
  cleaning drains, 1999 V2: 15–16
  defined, 2004 V1: 20
  manholes, 1999 V2: 99, 2000 V3: 240, 241
  radioactive waste systems, 1999 V2: 343
  roof drainage, 1999 V2: 88
  roof leaders, 1999 V2: 86
  sanitary drainage systems, 1999 V2: 9–10
  types, 1999 V2: 17–18
  vacuum cleaning systems, 1999 V2: 276
cleanouts to grade (CO), 2004 V1: 11
cleanup/utility rooms, 2000 V3: 32
clear floor space
  bathtub accessibility, 2004 V1: 117
  bathtubs, 2004 V1: 117
  drinking fountains and water coolers, 2004 V1: 112
  laundry equipment, 2004 V1: 123
  lavatories and sinks, 2004 V1: 117
  urinal design, 2004 V1: 116
  water closet and toilet accessibility, 2004 V1: 113–116
  for wheelchairs, 2004 V1: 109, 110
clear space in septic tanks, 1999 V2: 228
clear-water wastes
  defined, 2004 V1: 20
  in roof drains, 1999 V2: 84
clearance
  clean agent gas fire containers, 2000 V3: 23
  fixtures in health-care facilities, 2000 V3: 33
  piping and, 2003 V4: 25
clg load, CLG LOAD (cooling loads), 2004 V1: 14
climate, storm-drainage systems and, 1999 V2: 68
clinic sinks, 2000 V3: 32
clinics, 1999 V2: 147, 2000 V3: 83
clo, converting to SI units, 2004 V1: 39
CLOAD (cooling loads), 2004 V1: 14
clockwise (cw, CW), 2004 V1: 14
clogging in leaching trenches, 1999 V2: 222
close-coupled centrifugal pumps, 2000 V3: 115
close-coupled water closets, 2003 V4: 3
close nipples, 2004 V1: 20
closed-circuit cooling systems, 2004 V1: 151, 1999 V2: 243
closed proprietary specifications, 2004 V1: 67
closed-type sprinklers, 2000 V3: 9
clothes washers. *See* laundry systems and washers
cloudy water in pools, 2000 V3: 147
CMPR (compressors). *See* compressors
cndct, CNDCT (conductivity), 2004 V1: 14, 33
CO (cleanout plugs), 2004 V1: 11
CO (yard cleanouts or cleanouts to grade). *See* cleanouts; cleanouts to grade
CO_2 (carbon dioxide). *See* carbon dioxide
coagulants in clarification, 1999 V2: 294
coagulation in gray-water treatment, 1999 V2: 27, 28
coal tar epoxy, 2000 V3: 156
coalescence and filtration of oil spills, 1999 V2: 347
coalescing filters in vacuum systems, 1999 V2: 260
coalescing media, 2000 V3: 93
coarse sands, 1999 V2: 26, 27, 103, 2000 V3: 100
coat hooks
  accessibility in toilet and bathing rooms, 2004 V1: 113
  ambulatory accessible toilet compartments, 2004 V1: 115–116
coated metal
  cathodic protection, 2004 V1:150

coated steel filters, 2000 V3: 131
corrosion protection, 2004 V1: 147
natural gas piping, 1999 V2: 176
passivation, 2004 V1: 146–147
septic tanks, 1999 V2: 228
sprinkler head ratings, 2000 V3: 17
storage tanks, 2000 V3: 172
storm piping, 1999 V2: 68
coaxial truck delivery hoses, 2000 V3: 157
coaxial vapor recovery, 2000 V3: 163, 167
cocks, 2004 V1: 20
Code of Federal Regulations (CFR), 1999 V2: 317, 2000 V3:88, 2000 V3: 96, 154
codes and standards
chemical-waste systems, 1999 V2: 345
citing, 2004 V1: 67
codes, defined, 2004 V1: 20
concrete pipe, 2003 V4: 32
domestic water supply, 2000 V3: 216
ductile iron pipe, 2003 V4: 32
fire protection, 2000 V3: 1, 225
fixtures, 2003 V4: 2
gasoline and diesel-oil systems, 2000 V3: 154
gray-water systems, 1999 V2: 22
health-care facilities, 2000 V3: 31–34
hot-water systems, 1999 V2: 170
industrial wastewater treatment, 2000 V3:87–90
infectious and biological waste systems, 1999 V2: 343–344
medical gas systems, 2000 V3: 83
natural gas services, 2000 V3: 248
NFPA standards, 2000 V3: 1
plumbing materials and equipment, 2004 V1: 41–57
plumbing standards for people with disabilities, 2004 V1: 105–106
reference-based standards, 2004 V1: 66
searching, 2000 V3: 215
seismic protection, 2004 V1: 171–184
special-waste drainage systems, 1999 V2: 327–328
storm sewers, 2000 V3: 240
swimming pools, 2000 V3: 127
vacuum-cleaning systems, 1999 V2: 266
vacuum systems, 1999 V2: 262
water analysis, treatment and purification, 1999 V2: 279, 317
water heaters, 2004 V1: 129
coefficients (coeff., COEF), 2004 V1: 14
coefficients of expansion, 2004 V1: 20
coefficients of hydrant discharge, 2000 V3: 4, 5
coefficients of permeability (K factor), 1999 V2: 100–101, 104–105, 242
coefficients of transmissibility (Q factor), 1999 V2: 101–102
coefficients of valve flow (C_v

commercial/industrial gas service, 2000 V3: 249
estimating sewage quantities, 1999 V2: 234
firefighting demand flow rates, 2000 V3: 232
gray-water systems, 1999 V2: 25
grease interceptors, 1999 V2: 13
natural gas appliance demand, 1999 V2: 175
oil interceptors in drains, 1999 V2: 12–13
radioactive waste drainage and vents, 1999 V2: 337
commercial kitchen sinks, 2003 V4: 12, 13
commercial laundries. *See* laundry systems and washers
Commercial Standards (CS), 2004 V1: 21
Commercial Water Use Research Project, 1999 V2: 34
commissioning section in specifications, 2004 V1: 71, 92
Commodity Specification for Air (CGA G-7.1/ANSI ZE 86.1), 2000 V3: 65, 83, 86
Commodity Specification for Nitrogen (CGA G-10.1), 2000 V3: 86
commodity tube, 2003 V4: 35
common vents (dual vents), 2004 V1: 21, 1999 V2: 41, 64
community bathhouses, 1999 V2: 235
Compact Fittings, 2003 V4: 32
compacted fill, building sewers and, 1999 V2: 15
companion flanges, 2004 V1: 21
comparative cost analysis, 2004 V1: 254
comparing functions in value engineering, 2004 V1: 243
compartments in septic tanks, 1999 V2: 229
competition swimming pools, 2000 V3: 128, 129, 139
components section in specifications, 2004 V1: 91
composite tanks, 2000 V3: 156
composting toilets, 2004 V1: 136, 265
compound gauges, 2000 V3: 144
compound water meters, 1999 V2: 115, 116, 117
compounds in water, 1999 V2: 281
Comprehensive Environmental Response Compensation and Liability Act (CERCLA), 2000 V3:88, 2000 V3: 89–90, 96
compressed air (A, X#, X#A). *See also* compressed air systems
compared to free air, 2000 V3: 199
defined, 2004 V1: 18
laboratory or medical compressed air, 2004 V1: 8, 2000 V3: 37–39, 65–68, 75, 82–83
overview, 2000 V3: 199
piping, 1999 V2: 177
supplies to water tanks, 1999 V2: 247
symbols for, 2004 V1: 8
tools and equipment, 2000 V3: 208
uses, 2000 V3: 199
water vapor in air, 2000 V3: 200–201
Compressed Air and Gas Data, 1999 V2: 214
Compressed Air and Gas Handbook, 2000 V3: 214
"Compressed Air Data," 2000 V3: 214
"Compressed Air Design for Industrial Plants," 2000 V3: 214
Compressed Air for Human Respiration (CGA G-7.0), 2000 V3: 86
Compressed Air Fundamentals, 2000 V3: 214
Compressed Air Handbook, 2000 V3: 214
Compressed Air Magazine, 2000 V3: 214
compressed air systems
accessories, 2000 V3: 202–203
air dryers, 2000 V3: 203–204, 207
air receivers, 2000 V3: 205–206
compressors, 2000 V3: 201–202, 210–213
condensate removal, 2000 V3: 213
conditioning, 2000 V3: 207
contaminants, 2000 V3: 201
definitions, 2000 V3: 199–200
earthquake bracing for piping, 2004 V1: 167
measurement units, 2000 V3: 200
overview, 2000 V3: 199
piping system design, 2000 V3: 206–213
air-consuming devices, 2000 V3: 206–207
air dryers, 2000 V3: 207
design sequence, 2000 V3: 206
duty cycles, 2000 V3: 207
filters, 2000 V3: 207
future expansion, 2000 V3: 210
leakage, 2000 V3: 209
materials, 2000 V3: 210
sizing piping, 2000 V3: 74, 78, 210
use factors, 2000 V3: 209
pressure drops, 2000 V3: 212
references, 2000 V3: 214
regulation methods, 2000 V3: 205
starting unloaders, 2000 V3: 205
tools and equipment, 2000 V3: 208
water vapor in air, 2000 V3: 200–201
compressed gas. *See* natural gas systems
Compressed Gas Association, Inc. (CGA), 2000 V3: 56
address, 2004 V1: 58, 2000 V3: 86
list of standards, 2004 V1: 53
publications
CGA C-9: Standard for Color-marking of Compressed Gas Cylinders Intended for Medical Use, 2000 V3: 86
CGA G-7.0: Compressed Air for Human Respiration, 2000 V3: 86
CGA G-7.1/ANSI ZE 86.1: Commodity Specification for Air, 2000 V3: 83, 86
CGA G-8.1: Standard for the Installation of Nitrous Oxide Systems at Consumer Sites, 2000 V3: 86
CGA G-10.1: Commodity Specification for Nitrogen, 2000 V3: 86
CGA P-2: Characteristics and Safe Handling of Medical Gases, 2000 V3: 86
CGA P-9: Inert Gases: Argon, Nitrogen and Helium, 2000 V3: 81, 82, 86
CGA V-5: Diameter-Index Safety System, 2000 V3: 83, 86
Compressed Air and Gas Handbook, 2000 V3: 214
standard air definition, 2000 V3: 200
compression couplings
clay pipe, 2003 V4: 49
glass pipe, 2003 V4: 48
compression fittings
cast iron, 2003 V4: 27, 28
defined, 2004 V1: 24
compression joints, 2004 V1: 21
compressive strength of plastic pipe, 2003 V4: 59–60
compressors (cprsr, CMPR)
defined, 2004 V1: 21
earthquake protection, 2004 V1: 164

symbols for, 2004 V1: 14
computer processing of specifications, 2004 V1: 71–72
computer programs
abbreviations in, 2004 V1: 14–16
computer analysis of piping systems, 2004 V1: 186
ETI (Economic Thickness of Insulation), 2004 V1: 127
plumbing cost estimation, 2004 V1: 93, 98
specifications programs, 2004 V1: 71–72
computer room waste heat usage, 2004 V1: 134
concealed piping, 2000 V3: 73
concealed sprinklers, 2004 V1: 29
concentration cells
attack corrosion, 2004 V1: 141
defined, 2004 V1: 152
concentration gradients, 1999 V2: 308
concentration polarization, 2004 V1: 152
concentration tests, 2000 V3: 82
concentric reducers, 2004 V1: 10, 2000 V3: 115
concrete, 2000 V3: 147
concrete anchors
floor-mounted equipment, 2004 V1: 163
problems in seismic protection, 2004 V1: 188
concrete ballast pads, 2000 V3: 172
concrete barriers around tanks, 2000 V3: 169
concrete base devices, 2004 V1: 204–205
concrete covers on seepage pits, 1999 V2: 225
concrete embedments, 2004 V1: 190
concrete floors, leveling around, 1999 V2: 17
concrete inertia bases, 2004 V1: 203
Concrete Pipe Handbook, 1999 V2: 102, 114
concrete piping
flow rate, 2000 V3: 245
noise insulation, 1999 V2: 15
pipe sizing, 1999 V2: 89–92
standards, 2003 V4: 32
surface roughness, 1999 V2: 122
underground piping, 1999 V2: 68, 2003 V4: 32
concrete restraints, 2000 V3: 229
concrete roofing drains, 1999 V2: 82, 83
concrete sand fill, 1999 V2: 103
concrete septic tanks, 1999 V2: 228
concrete shielding from radiation, 1999 V2: 339
concrete-tank saddles, 2004 V1: 164
concrete tanks, 2000 V3: 91, 165
concrete thrust blocks, 1999 V2: 251
cond, COND (condensers, condensation). *See* condensation; condensers
condensate drains (CD), 2004 V1: 8, 1999 V2: 13
condensate grooving, 2000 V3: 190
condensate receivers, 2000 V3: 188–189
condensate return methods, 2000 V3: 186–189
gravity return, 2000 V3: 186–187
mechanical return, 2000 V3: 186–189
boiler feed pumps, 2000 V3: 188–189
condensate transfer pumps, 2000 V3: 187
vacuum pumps, 2000 V3: 189
condensate transfer pumps, 2000 V3: 188, 189
condensates, 2000 V3: 138. *See also* steam and condensate systems
corrosion inhibitors, 2004 V1: 151
defined, 2004 V1: 21, 1999 V2: 213
condensation (cond, COND)
air drying, 2000 V3: 204
compressed air systems, 2000 V3: 213
corrosion and, 2004 V1: 146
dew points, 2000 V3: 201
earthquakes and, 2004 V1: 170
gray water systems, 2004 V1: 267
non-circulating hot water systems, 2004 V1: 127
protecting against, 1999 V2: 18
swimming pools, 2000 V3: 129
symbols for, 2004 V1: 14
condensation loads
equations, 2000 V3: 194, 195
safety factors, 2000 V3: 194
steam piping, 2000 V3: 193
condensers
condenser system water treatments, 1999 V2: 315
distilled water systems, 2000 V3: 46
scale deposits, 1999 V2: 289
symbols for, 2004 V1: 14
waste heat reclamation, 2004 V1: 132, 133
water measurement in, 2000 V3: 124
condensing gas water heaters, 2004 V1: 130
conditioning compressed air, 2000 V3: 207, 211
conditioning water. *See* water treatment
conditions in creativity checklist, 2004 V1: 234
conductance (C), 2004 V1: 14, 33
conductivity (cndct, CNDCT, K)
evaporation and, 2000 V3: 121
measurements, 2004 V1: 33
mho (specific conductivity), 1999 V2: 287
symbols for, 2004 V1: 14
conductors
defined, 2004 V1: 21
number of, 2004 V1: 14
conduits
defined, 2004 V1: 21
seismic protection, 2004 V1: 155
cones
calculating volume, 2004 V1: 4
of depression, 1999 V2: 242
"Conference Generale de Poids et Measures," 2004 V1: 32
confluent vents, 2004 V1: 21, 1999 V2: 51, 52
connected loads, defined, 1999 V2: 214
connected standbys, 2000 V3: 23
connections section in specifications, 2004 V1: 91
conserving energy
alternate energy sources, 2004 V1: 130–131
Bernoulli's equation, 2004 V1: 5–6
domestic water temperatures, 2004 V1: 124–125
glossary, 2004 V1: 136–137
hot water system improvements, 2004 V1: 127
introduction, 2004 V1: 124
nondepletable and alternate energy sources, 2004 V1: 130–131
off-peak power, 2004 V1: 128–129
reduced water flow rates, 2004 V1: 126–127
references, 2004 V1: 137
saving utility costs, 2004 V1: 128–130
standby losses in circulating systems, 2004 V1: 127
thermal insulation thickness, 2004 V1: 127
waste heat usage, 2004 V1: 131–134
conserving water

air-conditioning system water, 1999 V2: 243
design techniques, 2004 V1: 134–135
domestic water supply, 2000 V3: 43
green design, 2004 V1: 263–267
institutional wastewater systems, 1999 V2: 232
introduction, 2004 V1: 124
large sewage systems and, 1999 V2: 231
urinals, 2003 V4: 8–9
water closet fixtures, 2003 V4: 3
constant-speed pumps, 1999 V2: 152
constantly-used fixtures, 1999 V2: 121
Constructed Science Research Foundation Spectext, 2004 V1: 71
construction change directives, 2004 V1: 63
construction contract documents (CD)
contract documents defined, 2004 V1: 61
defined, 2004 V1: 61
overview, 2004 V1: 61
project manuals, 2004 V1: 62–63
value engineering clauses in, 2004 V1: 258, 260
construction costs in value engineering, 2004 V1: 212
Construction Specifications Canada (CSC) Uniformat, 2004 V1: 64
Construction Specifications Institute (CSI)
classes, 2004 V1: 72
Constructed Science Research Foundation, 2004 V1: 71
general conditions documents, 2004 V1: 62
Manual of Practice, 2004 V1: 61
MasterFormat, 2004 V1: 64
MasterFormat 2004, 2004 V1: 64–65, 77–88
MasterFormat Level Four (1995), 2004 V1: 76
MasterFormat Level One (1995), 2004 V1: 73
MasterFormat Level Three (1995), 2004 V1: 76
MasterFormat Level Two (1995), 2004 V1: 73–75
section shell outline, 2004 V1: 88–92
Sectionformat, 2004 V1: 65
Uniformat, 2004 V1: 64, 73
web site, 2004 V1: 65
Consultation phase in value engineering, 2004 V1: 243, 254
consumption. *See* demand
contact corrosion, defined, 2004 V1: 152
contact factors (CF), 2004 V1: 14
contact sheets, 2000 V3: 215
contact time for microbial control, 1999 V2: 311
Containment Control in Biotechnology Environments, 1999 V2: 350
containment floors or dikes, 2000 V3: 90
containment of biological wastes, 1999 V2: 343
containment pipes and gas piping, 1999 V2: 176
containment sumps, 2000 V3: 156, 163, 167
contamination issues
backflow prevention, 1999 V2: 144–149
bored wells, 1999 V2: 241
compressed air, 2000 V3: 201
contaminant classification, 2000 V3: 222
contaminators, defined, 2004 V1: 21
dug wells, 1999 V2: 240
gray-water irrigation systems and, 1999 V2: 26
well protection, 1999 V2: 243
contingency
plans for industrial wastes, 2000 V3: 89
in plumbing cost estimation, 2004 V1: 94
continuing education, 2004 V1: 72
continuous acid-waste treatment systems, 1999 V2: 338
continuous deionization (CDI), 1999 V2: 306–307
continuous duty pumps, 2000 V3: 26
continuous flow. *See* steady flow
continuous flow pool gutters, 2000 V3: 142
continuous vents, defined, 2004 V1: 21, 1999 V2: 64
continuous waste, 2004 V1: 21
continuous wastewater treatment, 2000 V3: 95
continuous welding technique, 2003 V4: 48
contract documents. *See* construction contract documents
contraction of pipes
calculating, 2004 V1: 3
pool temperature and, 2000 V3: 145
protecting against, 1999 V2: 18
Control of Pipeline Corrosion, 2004 V1: 154
control panels
clean gas systems, 2000 V3: 24
fire alarm, 2004 V1: 12
fountains, 2000 V3: 120–121
control systems in geothermal energy systems, 2004 V1: 131
control valves
medical gas systems, 2000 V3: 71–72
swimming pools, 2000 V3: 139
controlled-flow storm-drainage systems, 1999 V2: 88, 93–94
controlled-substance spills, 1999 V2: 277
controllers
defined, 2004 V1: 21
for irrigation systems, 2000 V3: 104
controls
in accessible shower compartments, 2004 V1: 120
in bathtubs, 2004 V1: 118
defined, 2004 V1: 21
on gas boosters, 1999 V2: 182
on water heaters, 1999 V2: 160
vacuum systems, 1999 V2: 260, 268, 2000 V3: 70
convection, 2000 V3: 121
convention halls, numbers of fixtures for, 2003 V4: 21
convergent thinking in evaluation, 2004 V1: 235
converging seismic plates, 2004 V1: 158
conversion factors and converting
Fahrenheit and Centigrade, 2004 V1: 38
feet of head to pounds per square inch, 2004 V1: 2
fuel gas, 1999 V2: 212
IP and metric units, 2000 V3: 29
IP and SI, 2004 V1: 39–40, 1999 V2: 256
measurements, 2004 V1: 32
meters of head to pressure in kilopascals, 2004 V1: 2
vacuum acfm and scfm, 1999 V2: 256, 257
vacuum pressures, 1999 V2: 254
water impurity measurements, 1999 V2: 285
cooling compressors, 2000 V3: 201
cooling equipment, green building and, 2004 V1: 264
cooling fire areas, 2000 V3: 20
cooling loads (clg load, CLG LOAD, CLOAD), 2004 V1: 14
cooling-tower water
constant use and, 1999 V2: 121
corrosion inhibitors, 2004 V1: 151
exclusion from gray-water systems, 1999 V2: 21

Legionella pneumophila, 1999 V2: 169
reducing makeup water, 2004 V1: 264
use of gray water in, 1999 V2: 21
waste heat usage, 2004 V1: 131
water demand, 1999 V2: 243
water treatments, 1999 V2: 315–316
coordination disabilities, 2004 V1: 107
coordination with other designers, 1999 V2: 79, 81, 84
COP (coefficient of performance), 2004 V1: 136
copper
corrosion, 2004 V1: 139
in electromotive series, 2004 V1: 144
in galvanic series, 2004 V1: 141
pool lighting, 2000 V3: 145
swimming pool main drains, 2000 V3: 143
copper alloy piping, 1999 V2: 14, 2003 V4: 27
copper-copper sulfite half-cells, 2004 V1: 144
Copper Development Association (CDA), 2004 V1: 20, 1999 V2: 65
copper drainage tube, 2003 V4: 45, 46
copper joints, 1999 V2: 222
copper-nickel alloys, 2004 V1: 141
copper-phosphorous-silver brazing (BCuP), 2003 V4: 45
copper-phosphorus brazing, 2003 V4: 45
copper piping
aboveground piping, 1999 V2: 14, 68
commodity tube, 2003 V4: 35
compressed air systems, 2000 V3: 210
conserving energy, 2004 V1: 128
copper K piping, 1999 V2: 262
copper L piping, 1999 V2: 262
fountains, 2000 V3: 116
fuel-gas piping, 1999 V2: 196
gas piping, 1999 V2: 176
pure-water system, 2000 V3: 47
radioactive waste systems, 1999 V2: 341
roughness, 1999 V2: 122
sizing, 1999 V2: 133
sprinkler systems, 2000 V3: 12, 17
swimming pools, 2000 V3: 145
types, 2003 V4: 34–36
copper rings over joints, 1999 V2: 223
copper salts, 2000 V3: 145, 148
Copper Sovent Single-stack Plumbing System Handbook Supplement, 1999 V2: 65
copper sulfate, 1999 V2: 223
copper-sulfate electrodes, 2004 V1:150
copper tube size (CTS), 2003 V4: 59, 61
copper water tube, 2003 V4: 34–44
Copson, H.R., 2004 V1: 154
corona-discharge generators, 1999 V2: 312
corporation cocks, 2004 V1: 21
correction factors, 2004 V1: 14
correctional centers, numbers of fixtures for, 2003 V4: 20
corroded end of galvanic series, 2004 V1: 141
corrosion
backflow preventers and, 1999 V2: 149
boilers, 1999 V2: 314
calcium carbonate and, 1999 V2: 291
cathodic protection, 2004 V1: 147–151
causes, 1999 V2: 289–290
coatings, 2004 V1: 147
control of, 2004 V1: 145–151, 1999 V2: 18, 244
cooling towers, 1999 V2: 316
corrosion cells, 2004 V1: 139, 140, 148
corrosion mitigation, 2004 V1: 152
corrosion potential, 2004 V1: 152
corrosion-resistant materials, 2004 V1: 146, 1999 V2: 15
corrosion-resistant sprinklers, 2004 V1: 29
corrosive wastes, 1999 V2: 14
deaeration and, 1999 V2: 294
defined, 2004 V1: 139, 152
electromotive force series, 2004 V1: 144
factors in rate of, 2004 V1: 144–145
fatigue and fatigue limits, 2004 V1: 152
glossary, 2004 V1: 151–154
hot-water relief valves, 1999 V2: 166
inhibitors, 2004 V1: 151
introduction, 2004 V1: 139
natural gas piping, 1999 V2: 176
passivation, 2004 V1: 146–147
plastic water pipes, 1999 V2: 252
predicting water deposits and corrosion, 1999 V2: 290–292
prevention, 2004 V1: 152
protection, 2000 V3: 165
references, 2004 V1: 154
sacrificial anodes, 2004 V1: 148
steam systems, 2000 V3: 190
storage tanks, 2000 V3: 91, 155, 165
swimming pool heaters, 2000 V3: 146
total organic carbon and, 1999 V2: 288
types of, 2004 V1: 141
water mains, 2000 V3: 8
Corrosion, 2004 V1: 154
Corrosion and Resistance of Metals and Alloys, 2004 V1: 154
Corrosion Causes and Prevention, 2004 V1: 154
Corrosion Control, 2004 V1: 154
Corrosion Engineering, 2004 V1: 154
corrosion fatigue, 2004 V1: 152
Corrosion Handbook, 2004 V1: 154
Corrosion in Swimming Pools and General Guide to Materials Selection (NSPI 18), 2000 V3: 145
corrosion mitigation, 2004 V1: 152
corrosion potential, 2004 V1: 152
corrosion prevention, 2004 V1: 152
Corrosion Prevention for Practicing Engineers, 2004 V1: 154
corrosion-resistant materials, 2004 V1: 146, 1999 V2: 15
Corrosion Resistant Materials Handbook, 2000 V3: 97
corrosion-resistant sprinklers, 2004 V1: 29
corrosive wastes, 1999 V2: 14, 2000 V3: 40, 2003 V4: 27
corrugated steel piping, 1999 V2: 122, 2000 V3: 245
cosmic radiation, 1999 V2: 339
Cost Analysis phase in value engineering, 2004 V1: 235, 241–243, 254
costs and economic concerns
administrative and operation costs, 2004 V1: 212
collecting data on, 2004 V1: 222–225
construction costs, 2004 V1: 212
cost fitting, defined, 2004 V1: 258

cost information in value engineering, 2004 V1: 222–225
cost of goods, 2004 V1: 222
cost-to-function relationship, 2004 V1: 225
defined, 2004 V1: 213, 222–225
development costs, 2004 V1: 212
economic values, 2004 V1: 213–214
engineering and design costs, 2004 V1: 212
estimating costs, 2004 V1: 93–98
idea development and estimated cost forms, 2004 V1: 241–242
labor costs, 2004 V1: 212
life-cycle costs, 2004 V1: 137
material costs, 2004 V1: 212
overhead, 2004 V1: 212
Pareto principle, 2004 V1: 224
relationships, 2004 V1: 223
specific applications
air dryers, 2000 V3: 207
cathodic protection costs, 2004 V1:150, 2004 V1:151
controlled-flow systems, 1999 V2: 88, 93
corrosion resistant materials, 2004 V1: 146
driven wells, 1999 V2: 241
fuel product dispensing systems, 2000 V3: 164
galvanic cathodic protection costs, 2004 V1: 150
gas booster location, 1999 V2: 180
gray-water system costs, 1999 V2: 29–32
hot-water systems, 1999 V2: 157
ion-exchange cartridges, 1999 V2: 306, 323
ion-exchange resins, 1999 V2: 302, 305
laboratory acid-waste drainage, 1999 V2: 334
pool filtration systems, 2000 V3: 135
reduced-size venting, 1999 V2: 50
sanitary drainage systems, 1999 V2: 1
seismic protection costs, 2004 V1: 156, 183
single septic tank installations, 1999 V2: 231
sovent single-stack plumbing systems, 1999 V2: 54
sovent system fittings, 1999 V2: 62
special-waste drainage systems, 1999 V2: 328
subsurface site drainage, 1999 V2: 100
swimming pool heaters, 2000 V3: 138, 139
utility costs, 2004 V1: 128–130
vacuum system piping, 1999 V2: 262
water distillers, 1999 V2: 298
wet venting, 1999 V2: 49
in specifications, 2004 V1: 69
supporting details for, 2004 V1: 257–258
types of, 2004 V1: 222–225
value engineering process and, 2004 V1: 211
vs. prices, 2004 V1: 222
cotton gin, creativity and, 2004 V1: 231
coulombs (C)
corrosion, 2004 V1: 139
SI units, 2004 V1: 33
coulombs per cubic meter (C/m^3), 2004 V1: 33
Council for National Cooperation in Aquatics, 2000 V3: 151
Council of American Building Officials (CABO), 2004 V1: 123
countdown timer delays, 2000 V3: 24
counter-e.m.f.s, 2004 V1: 153
counter-mounted kitchen sinks, 2003 V4: 12
counter-mounted lavatories, 2003 V4: 11
counter sinks, 2000 V3: 32
counterclockwise (ccw, CCW), 2004 V1: 14
counterflow piping designs, 2000 V3: 178, 183
counterzoning, 2000 V3: 24
couple action. *See* galvanic corrosion
couples, defined, 2004 V1: 152
couplings
asbestos concrete piping, 2003 V4: 26
cast iron hubless pipes, 2003 V4: 28
defined, 2004 V1: 21
glass pipe, 2003 V4: 47
nonrigid couplings, 2004 V1: 186
course vacuum, 1999 V2: 253
covers on seepage pits, 1999 V2: 225
c_p

crutches, 2004 V1: 107
cryogenic tanks, 2000 V3: 61, 62
CS (Commercial Standards), 2004 V1: 21
CSA. *See* Canadian Standards Association (CSA)
CSC (Construction Specifications Canada) Uniformat, 2004 V1: 64
CSI and CSI format. *See* Construction Specifications Institute (CSI)
CSI (Calcium Saturation Index), 2000 V3: 123
CTS (copper tube size), 2003 V4: 59, 61
CU IN (cubic inches), 2004 V1: 14
CU FT (cubic feet), 2004 V1: 14, 2000 V3: 29
cubes, calculating volume, 2004 V1: 4
cubic feet (ft^3, CU FT, CUFT, CFT), 2004 V1: 14, 2000 V3: 29
cubic feet per hour (cfh), 2000 V3: 200, 248
cubic feet per minute (cfm, CFM), 2000 V3: 200. *See also* scfm, SCFM (standard cubic feet per minute)
  compressed air systems, 2000 V3: 211
  converting to metric units, 2000 V3: 29
  defined, 1999 V2: 213
  medical vacuum systems, 2000 V3: 69
  symbols for, 2004 V1: 14
  vacuum exhausters and, 1999 V2: 274–275
  vacuum measurements, 1999 V2: 253, 255
cubic feet per second, standard (scfs, SCFS), 2004 V1: 14
cubic foot meters (cfms)
  defined, 1999 V2: 213
  vacuum exhausters and, 1999 V2: 274–275
  vacuum measurements, 1999 V2: 253, 255
cubic inches (in^3, CU IN, CUIN, CIN), 2004 V1: 14
cubic meters, 2004 V1: 33
cubic meters per kilogram, 2004 V1: 33
cubic meters per minute, 2000 V3: 200
cubic meters per second, 2004 V1: 33
CUFT (cubic feet), 2004 V1: 14, 2000 V3: 29
cultured marble acrylic fixtures, 2003 V4: 2
cultured marble fixtures, 2003 V4: 2
Culvert Pipe, 2003 V4: 32
culvert pipes, 1999 V2: 99
cup sinks, 2000 V3: 32, 37, 38
curb boxes, 2004 V1: 21
curies (c), 1999 V2: 339
current
  cathodic protection, 2004 V1: 147
  in corrosion, 2004 V1: 139, 144
  electromotive force series, 2004 V1: 144
  large anode current requirements, 2004 V1: 150
  measurements, 2004 V1: 33
current good manufacturing practices (cGMP), 1999 V2: 325, 328
curve radii for water pipes, 1999 V2: 250
cuspidors, dental, 2000 V3: 38
Cutting and Welding Processes, 1999 V2: 214
cutting oils, 1999 V2: 13
CV (check valves). *See* check valves
c_v, c_v CV (sp ht at constant volume), 2004 V1: 16

dbt, DBT (dry-bulb temperature), 2004 V1: 23
dbt, DBT (effective temperature), 2004 V1: 14
DC current, 2004 V1: 14, 147, 1999 V2: 306
dc, DC (direct current), 2004 V1: 14, 147, 1999 V2: 306
DCBP (double-check backflow preventers), 2004 V1: 10
DCV (double-check valves), 2000 V3: 223, 224, 226
DCVA (double-check valve assemblies), 1999 V2: 144, 145, 149
DD (design development phase), 2004 V1: 64
DE (deionized water), 2004 V1: 8
DE (diatomaceous earth). *See* diatomaceous earth
deactivation, defined, 2004 V1: 152
dead-end service in pressure-regulated valves, 1999 V2: 152
dead ends, defined, 2004 V1: 21
dead legs in pure water systems, 1999 V2: 324
dead loads on roof, 1999 V2: 79
"dead-man" abort stations, 2000 V3: 24
deaerators
  boiler feed water, 1999 V2: 314
  deaeration water treatment, 1999 V2: 294–295
  sovent deaerators
    connections, 1999 V2: 60
    fittings, 1999 V2: 54
    illustrated, 1999 V2: 56, 61, 62
    operations of, 1999 V2: 46
    in sovent systems, 1999 V2: 19
dealkalizing treatment, 1999 V2: 295
dealloying, defined, 2004 V1: 152
debris in pools and fountains, 2000 V3: 108, 110, 138
decarbonation, 1999 V2: 295
dechlorination, 2000 V3: 123
"deci" prefix, 2004 V1: 34
decibel (A) scale (dB(A)), 2004 V1: 206
decibels (dB, DB)
  defined, 2004 V1: 206
  symbols for, 2004 V1: 14
deck drains, 1999 V2: 69
decomposition potential, 2004 V1: 152
decontaminating radioactive waste piping, 1999 V2: 341
decorative pools, gray water and, 1999 V2: 22
deep-bed sand filtration, 1999 V2: 298, 300
deep chambers, 1999 V2: 149
deep (dp, DP, DPTH). *See* depth
deep ends of swimming pools, 2000 V3: 128
deep fill, building sewers and, 1999 V2: 15
deep-seal p-traps, 1999 V2: 13, 84
deep-seated fires, 2000 V3: 23
deep wells, 1999 V2: 240, 245
definitions. *See* glossaries
definitions section in specifications, 2004 V1: 69, 88
deg., °, DEG (degrees), 2004 V1: 14
degasification, 1999 V2: 295
degradation of pure water, 1999 V2: 323
degrees (deg., °, DEG), 2004 V1: 14
degrees celsius, 2004 V1: 34
DEHA (diethylhydroxylamine), 1999 V2: 315
deionization, 1999 V2: 300. *See also* demineralizer systems
deionized water (DE), 2004 V1: 8
"deka" prefix, 2004 V1: 34
delay relays, 2000 V3: 24
delays in clean gas extinguishing systems, 2000 V3: 24
deliquescent dryers, 2000 V3: 207
delivery pressure in natural gas systems, 1999 V2: 183
delivery rooms. *See* birthing rooms
delivery section in specifications, 2004 V1: 70, 89–90
Delphia method of evaluation, 2004 V1: 254
delta (diff.,), DIFF, D, DELTA), 2004 V1: 14
delta t (temperature differential), 2004 V1: 136
DELTP (pressure drops or differences). *See* pressure drops or differences
Deluge Foam-water Sprinkler Systems and Foam-water Spray Systems (NFPA 16), 2000 V3: 21, 29
deluge systems, 2004 V1: 29, 2000 V3: 13–15
deluge valves, 2004 V1: 13, 2000 V3: 13, 14
demand
  cold-water systems, 1999 V2: 121
  defined, 1999 V2: 213
  drinking water, 1999 V2: 243–244, 245
  fire demand, 2000 V3: 3
  fire hydrant water demand, 2000 V3: 5–8
  flow rates, 2000 V3: 230–232
  hot water, 2004 V1: 136, 1999 V2: 157
  hydropneumatic-tank systems, 1999 V2: 150
  medical air systems, 2000 V3: 66
  medical gas systems, 2000 V3: 49, 50, 53, 59
  medical school-laboratory water demand, 2000 V3: 45
  natural gas, 1999 V2: 175, 177, 2000 V3: 253–254
  sprinkler systems, 2000 V3: 3–8, 17
  vacuum systems, 2000 V3: 55, 70
  water conservation and paybacks, 2004 V1: 126
  water heater types and, 1999 V2: 160
  water supply piping and, 1999 V2: 249
  water treatment methods and, 1999 V2: 308
demineralizer systems, 1999 V2: 295, 300, 2000 V3: 46–47
demolition work, in plumbing cost estimation, 2004 V1: 93
Denoncourt, 1999 V2: 325
dens, DENS (density). *See* density
density (dens, DENS, RHO)
  measurements, 2004 V1: 33
  of natural gas, 1999 V2: 180
  symbols for, 2004 V1: 14
dental equipment, 2000 V3: 39, 51
department connections, 2004 V1: 12
departments having jurisdiction, 2004 V1: 22
dependent functionality
  defined, 2004 V1: 225
  in FAST approach, 2004 V1: 230
depolarization, defined, 2004 V1: 152
depolarizing cathodes, 2004 V1: 145
deposition corrosion, defined, 2004 V1: 152
deposits from feed water, 1999 V2: 289–290. *See also* scale and scale formation; sediment; slime; sludge
depth (dp, DP, DPTH)
  of leaching trenches, 1999 V2: 222
  of liquids in septic tanks, 1999 V2: 230
  of media beds in sand filters, 2000 V3: 132
  of reflecting pools, 2000 V3: 107
  of septic tanks, 1999 V2: 228
  of soils, 1999 V2: 219
  symbols for, 2004 V1: 14
  of water pipes, 1999 V2: 251
  of wells, 1999 V2: 240
depth filters, 1999 V2: 308

derived units of measurement, 2004 V1: 33
description in value engineering phases, 2004 V1: 214
descriptive specifications, 2004 V1: 66
desiccant air dryers, 2000 V3: 204, 207
design
  for people with disabilities, 2004 V1: 107
  reducing corrosion, 2004 V1: 146
  seismic, 2004 V1: 160–161, 186–188
  value engineering and, 2004 V1: 212
design areas for sprinkler systems, 2000 V3: 16
design density, 2000 V3: 15
design development phase (DD), 2004 V1: 64
design flow in gas boosters, 1999 V2: 182
Design Information for Large Turf Irrigation Systems, 2000 V3: 105
Design of Hoffman Industrial Vacuum Cleaning Systems, 1999 V2: 277
design standards, 2004 V1: 66
design storms, 2000 V3: 242–244
desolver tanks, 1999 V2: 307
destruction phase in ozonation, 1999 V2: 313
destructive forces in pipes. *See* water hammer
details in projects, checklists, 2004 V1: 220
detector-check water meters, 1999 V2: 116
detectors, smoke, 2004 V1: 22
detention centers, numbers of fixtures for, 2003 V4: 20
detention systems for storm water, 1999 V2: 105–107, 107
detention times for treated water, 1999 V2: 294
detergents
  factors in trap seal loss, 1999 V2: 36
  high-expansion foam, 2000 V3: 21
  in septic tanks, 1999 V2: 230
  venting for, 1999 V2: 36–37, 39
developed length, 2004 V1: 22
developers
  perception of engineering, 2004 V1: 260
  value engineering and, 2004 V1: 212
development costs
  defined, 2004 V1: 222
  in value engineering, 2004 V1: 212
Development phase in value engineering
  activities, 2004 V1: 235, 243, 254
  idea development and estimated cost forms, 2004 V1: 241–242
  in process, 2004 V1: 213
  sketches, 2004 V1: 254, 255
Development Presentation phase in value engineering, 2004 V1: 213
deviations in measurements, 2004 V1: 32
dew-point temperature (dpt, DPT), 2004 V1: 14
dew points
  defined, 2004 V1: 22, 2000 V3: 201
  lowering, 2000 V3: 204
  medical gas system tests, 2000 V3: 83
  monitors, 2000 V3: 66
  refrigerated air dryers, 2000 V3: 207
dezincification of brass, 2004 V1: 141
DFRAD (diffuse radiation), 2004 V1: 14
dfu (drainage fixture units), 2004 V1: 24, 1999 V2: 64
DHEC (Department of Health and Environmental Control), 1999 V2: 170
DI (deionization), 1999 V2: 300
dia., DIA (diameters). *See* diameters
diagnostic facilities, 1999 V2: 340
dialogue in FAST approach, 2004 V1: 231
dialysis machines, 2000 V3: 39
Diameter-Index Safety System (CGA V-5), 2000 V3: 83, 86
diameters (dia., DIA)
  defined, 2004 V1: 22
  inside (ID), 2004 V1: 14
  outside (OD), 2004 V1: 14
  symbols for, 2004 V1: 14
diaper changing stations, 2003 V4: 23
diaphragm gauges, 1999 V2: 260
diaphragm pumps, 1999 V2: 259
diaphragm reciprocating compressors, 2000 V3: 201
diaphragm tanks, 2000 V3: 21
diaphragm valves, 2004 V1: 22, 1999 V2: 332
diaphragms
  defined, 2004 V1: 22
  in deluge valves, 2000 V3: 14
diatomaceous earth filtration
  advantages and disadvantages, 1999 V2: 318
  compared to sand filtration, 2000 V3: 135–137
  maintenance, 2000 V3: 112
  materials for filter tanks, 2000 V3: 131
  overview, 2000 V3: 134–135
  pressure and vacuum filters, 2000 V3: 132, 141
  swimming pool usage, 2000 V3: 130, 131
  types of, 2000 V3: 139
die-cast metals, 2000 V3: 33
dielectric fittings, 2004 V1: 22
dielectric insulation, 2004 V1: 146, 2004 V1:151
dielectric isolation, 2000 V3: 116
dielectric unions, 2000 V3: 156
diesel drivers, 2000 V3: 25
diesel engines, 2000 V3: 26
diesel fuel, 1999 V2: 13
diesel-oil systems
  aboveground tank systems, 2000 V3: 165–169
    connections and access, 2000 V3: 166
    construction, 2000 V3: 165
    corrosion protection, 2000 V3: 165
    filling and spills, 2000 V3: 166–167
    leak prevention and monitoring, 2000 V3:167–168
    materials, 2000 V3: 165
    overfill prevention, 2000 V3:167
    product dispensing systems, 2000 V3:168
    tank protection, 2000 V3:169
    vapor recovery, 2000 V3:168
    venting, 2000 V3:167
  codes and standards, 2000 V3: 154
  components, 2000 V3: 155
  definitions and classifications, 2000 V3: 153–154
  designing
    installation considerations, 2000 V3:172–173
    piping materials, 2000 V3:169
    piping sizing, 2000 V3:169–170
    submersible pump sizing, 2000 V3:170
    testing, 2000 V3:170–172
  overview, 2000 V3: 153
  references, 2000 V3:173
  resources, 2000 V3:173
  underground tank systems, 2000 V3: 155–165

leak detection and system monitoring, 2000 V3: 158–163
product dispensing systems, 2000 V3: 163–165
storage tanks, 2000 V3: 155–158
vapor recovery systems, 2000 V3: 163
dietary services in health-care facilities, 2000 V3: 32
diethylhydroxylamine, 1999 V2: 315
diff., DIFF (difference or delta), 2004 V1: 14
difference (diff., (, DIFF, D, DELTA), 2004 V1: 14
differential aeration cells, 2004 V1: 152
differential environmental conditions, corrosion by, 2004 V1: 141
differential movement in earthquakes, 2004 V1: 161
differential pressure
in sand filtration, 2000 V3: 113
in sizing steam traps, 2000 V3: 193
differential regulators, 2000 V3: 251
differentials, defined, 2004 V1: 22
difficulties in value engineering presentations, 2004 V1: 258
diffuse radiation (DFRAD), 2004 V1: 14
diffuser plates, 2000 V3: 120
diffusion aerators, 1999 V2: 293, 318
diffusion wells, 1999 V2: 105
digestion, 2004 V1: 22
digits, 2004 V1: 32
dikes
for aboveground storage tanks, 2000 V3: 165, 167
for hazardous waste areas, 2000 V3: 90
for leaching trenches, 1999 V2: 223
dilution air, defined, 1999 V2: 213
dilution, pollution and, 2000 V3:87
dimensions
in creativity checklist, 2004 V1: 234
defined, 2004 V1: 32
wheelchairs, 2004 V1: 108
DIN 52218, 2004 V1: 194
dir radn, DIR RADN (direct radiation), 2004 V1: 14
DIRAD (direct radiation), 2004 V1: 14
direct-acting gas regulators, 2000 V3: 250
direct-count epifluorescent microscopy, 1999 V2: 282
direct current (dc, DC)
cathodic protection, 2004 V1: 147
in deionization, 1999 V2: 306
symbols for, 2004 V1: 14
direct-fill ports, 2000 V3: 156
direct-filtration package plants, 1999 V2: 318
direct-fired gas water heaters, 2004 V1: 130, 2000 V3: 138, 146
direct-operated pressure-regulated valves, 1999 V2: 153
direct pump water supplies, 2000 V3: 8
direct radiation (dir radn, DIR RADN, DIRAD), 2004 V1: 14
directly-heated, automatic storage water heaters, 1999 V2: 160
dirt cans for vacuum systems, 1999 V2: 268
dirt in feed water, 1999 V2: 289
dirty filters, 2000 V3: 115
dirty gas, 2000 V3: 250
disabled individuals. *See* people with disabilities
disc water meters, 1999 V2: 116
discharge characteristic fixture curves, 1999 V2: 3
discharge coefficients, 2004 V1: 5
discharge curves, 2000 V3: 220
discharge permits, 2000 V3: 88
discharge piping for vacuum cleaning systems, 1999 V2: 274
discharge times in fire suppression, 2000 V3: 23
discharge-type check valves, 1999 V2: 179
disconnect switches for pumps, 2000 V3: 120
discontinuous regulation in air compressors, 2000 V3: 205
discs, defined, 2004 V1: 22
discussions in FAST approach, 2004 V1: 231
dished ends on tanks, 2000 V3: 156
dishwashers
acoustic ratings of, 2004 V1: 195
defined, 2004 V1: 22
fixture-unit loads, 1999 V2: 3
health-care facilities, 2000 V3: 36
heat recovery systems, 2004 V1: 266
water fixture unit values, 2000 V3: 217
water temperatures, 2000 V3: 45
disinfecting
codes for, 2004 V1: 43
cold-water systems, 1999 V2: 154–155
decontaminating infectious wastes, 1999 V2: 344–345
disinfectant residuals, 2000 V3: 122
drinking water, 1999 V2: 245
feed water, 1999 V2: 289, 311–313
gray water, 1999 V2: 23, 27
reflecting pools and fountains, 2000 V3: 123
septic tanks, 1999 V2: 230
small drinking water systems, 1999 V2: 318
swimming pools
algaecides, 2000 V3: 150
aluminum sulfate, 2000 V3: 149–150
breakdown chlorination, 2000 V3: 149
calcium hypochlorite, 2000 V3: 148–149
chemical feeding equipment, 2000 V3: 150–151
chlorine gas, 2000 V3: 148
cleaning filters, 2000 V3: 150
cyanurates, 2000 V3: 149
sodium hypochlorite, 2000 V3: 149
sulfuric acid, 2000 V3: 150
superchlorination, 2000 V3: 149
water systems, 1999 V2: 252
Disinfecting, 2003 V4: 32
Disinfection of Escherichia Coli by Using Water Dissociation Effect on Ion Exchange Membranes, 1999 V2: 325
disintegrations per second (dps), 1999 V2: 338, 339
disk filters, 1999 V2: 308
dispenser pans, 2000 V3: 165
dispensers
aboveground tanks, 2000 V3: 168
fuel product dispensers, 2000 V3: 164–165
high-rate dispensers, 2000 V3: 169
multiple dispenser flow rates, 2000 V3: 170
dispersed oil, 1999 V2: 347
displacement
defined, 2004 V1: 22
in earthquakes, 2004 V1: 159
swimming pools, 2000 V3: 143
water meters, 1999 V2: 117

displays in fountains
display piping, 2000 V3: 111–112
filtration turnover, 2000 V3: 110
height of, 2000 V3: 120
piping for, 2000 V3: 119
pumps, 2000 V3: 113–115
remote controls, 2000 V3: 120
selecting, 2000 V3: 108–110
types of, 2000 V3: 111
weirs and waterfalls, 2000 V3: 109
disposal fields (sewage). *See* leaching trenches (leach fields)
disposal wells in geothermal energy, 2004 V1: 131
disposers. *See* food waste grinders
DISS connectors, 2000 V3: 83
dissolved elements and materials in water
dissolved gases, 1999 V2: 284, 294, 314
dissolved inorganics, 1999 V2: 288
dissolved metals, 2000 V3: 93
dissolved minerals, 1999 V2: 314
dissolved oil, 1999 V2: 347
dissolved organics, 1999 V2: 300
dissolved oxygen, 2000 V3: 93
dissolved solids, 1999 V2: 288
distances in standpipe systems, 2000 V3: 18
distilled water (DL)
distillation treatment, 1999 V2: 295–298, 299
health-care facility stills, 2000 V3: 39
producing, 2000 V3: 46
symbols for, 2004 V1: 8
distribution boxes, 1999 V2: 223, 231
distribution gray-water pumps, 2004 V1: 267
distribution of wealth, 2004 V1: 224
distribution system in seepage beds, 1999 V2: 224
ditches, 2000 V3: 247–248
divergent thinking
in creativity, 2004 V1: 231–235
in evaluation, 2004 V1: 235
diversity factor
compressed air tools, 2000 V3: 208
defined, 1999 V2: 213
health-care facility systems, 2000 V3: 45
liquid fuel piping, 2000 V3:170
medical gas, 2000 V3: 50, 75
medical vacuum, 2000 V3: 54, 55, 75
natural gas systems, 1999 V2: 176–177, 194, 195, 2000 V3: 249, 253
nitrogen systems, 2000 V3: 74, 75
nitrous oxide, 2000 V3: 75
oxygen, 2000 V3: 75
vacuum systems, 1999 V2: 262–263, 263
diverter plates, 2000 V3: 119–120
diverters, spray accessories on sinks, 2003 V4: 14
diving pools, 2000 V3: 128, 143
divinyl benzene, 1999 V2: 302
division in SI units, 2004 V1: 34
Divisions in MasterFormat 2004, 2004 V1: 65, 77–88
DL. *See* distilled water (DL)
DN (nominal diameter), 1999 V2: 253
DNA materials, 1999 V2: 344
docks, 1999 V2: 147
dolomite limestone chips, 1999 V2: 334
dome grates in shower rooms, 1999 V2: 11
dome roof drains, 1999 V2: 80
dome strainers, 1999 V2: 82
domestic sewage, 2004 V1: 22
domestic spaces, acoustic plumbing design for, 2004 V1: 196
domestic systems. *See* domestic water supply; residential systems
Domestic Water Heating Design Manual, 1999 V2: 166, 2000 V3: 45
domestic water supply
codes and standards, 2000 V3: 216
combined with fire-protection supply, 2000 V3: 225–226
health-care facilities, 2000 V3: 43–48
overview, 2000 V3: 216
preliminary information, 2000 V3: 215–216
service components and design, 2000 V3: 217–224
backflow prevention, 2000 V3: 221–224
elevation differences, 2000 V3: 224
piping runs, 2000 V3: 221
strainer losses, 2000 V3: 224
taps, 2000 V3: 221
valves and fittings, 2000 V3: 221
water meters, 2000 V3: 224
water pressure, 2000 V3: 217–221
service connection, 2000 V3: 221
system requirements, 2000 V3: 216–217
water fixture unit values, 2000 V3: 217
water mains, 2000 V3: 216
water utility letters, 2000 V3: 216, 256
doors, accessibility and, 2004 V1: 113, 114, 115
dope, pipe, 1999 V2: 284
dormitories
acoustic plumbing design for, 2004 V1: 196
numbers of fixtures for, 2003 V4: 20, 21
doses of radiation, 1999 V2: 339
dosimeters, 1999 V2: 339
dosing tanks, 2004 V1: 22
dot products, defined, 2004 V1: 93
DOTn. *See* U.S. Department of Transportation (DOTn)
double. *See also entries beginning with dual-, multiple-, or two-*
double-acting altitude valves, 1999 V2: 249
double-acting cylinders in compressors, 2000 V3: 201
double-check backflow preventers (DCBP), 2004 V1: 10
double-check valve assemblies, 1999 V2: 144, 145, 149
double-check valves (DCV), 2000 V3: 223, 224, 226
double-compartment sinks, 2003 V4: 11, 12
double-contained piping systems, 1999 V2: 345, 346, 2000 V3: 40, 162–163
double-contained tanks, 2000 V3: 156
double discs, 2004 V1: 22
double extra-strong steel pipe, 2003 V4: 48
double-leaf barriers, 2004 V1: 193
double offsets, 2004 V1: 22
double-ported valves, 2004 V1: 22
double-seated pressure-regulated valves, 1999 V2: 152
double-side-entry fittings, 1999 V2: 62
double-sweep tees, 2004 V1: 22
double tees, 2000 V3: 119–120, 2003 V4: 6–7
double-wall piping, 1999 V2: 327
double-wall tanks, 2000 V3: 156

double wedges, 2004 V1: 22
double wyes, common vents and, 1999 V2: 43
Dow Chemical Corp., 1999 V2: 325
down, defined, 2004 V1: 22
downfeed risers, 2000 V3: 185
downspouts and leaders. *See also* vertical stacks
  defined, 2004 V1: 22, 26
  roof drainage systems, 1999 V2: 81, 85–88
  roof expansion and, 1999 V2: 85
  roof leaders, 1999 V2: 87
  sizing, 1999 V2: 81
downstream, defined, 2004 V1: 22
downward-tapered weirs, 2000 V3: 109
dp, DP (depth). *See* depth
dps (disintegrations per second), 1999 V2: 338, 339
dpt, DPT (dew-point temperature), 2004 V1: 14
DPTH (depth). *See* depth
draft hoods on appliances, 1999 V2: 178, 213
drain bodies. *See* sumps and sump pumps
drain cleaners in septic tanks, 1999 V2: 230
drain-down times, 1999 V2: 94
drain fields. *See* leaching trenches (leach fields)
drain line carry tests, 2003 V4: 6
drain outlets, types of, 1999 V2: 17–18
drain tiles, 1999 V2: 221
drain valves, 2000 V3: 103, 191
drain, waste, and vent branches (DWV), 1999 V2: 19, 54, 60
drain, waste, and vent pipes (DWV)
  copper drainage tube, 2003 V4: 45
  copper pipe, 2003 V4: 36
  defined, 2004 V1: 23
  DWV pattern schedule 40 plastic piping, 1999 V2: 14
  DWV piping, 1999 V2: 68
  glass pipe, 2003 V4: 47
  plastic pipes, 2003 V4: 58
  PVC pipes, 2003 V4: 62
drain, waste, and vent stacks (DWV)
  copper, 2003 V4: 34
  DWV stacks, 1999 V2: 19, 54, 60
drainage channels, irrigation systems and, 1999 V2: 26
drainage (corrosion), defined, 2004 V1: 152
drainage fittings, 2004 V1: 22
drainage fixture units (dfu), 2004 V1: 24, 1999 V2: 64. *See also* fixture units and unit values
drainage inlets in site storm systems, 1999 V2: 98
drainage piping
  acoustic ratings of fixtures, 2004 V1: 194
  copper pipe, 2003 V4: 34
  glass pipe, 2003 V4: 45
  nonreinforced concrete pipe, 2003 V4: 32
drainage structures
  defined, 2000 V3: 234–236
  manholes, 2000 V3: 234–236
drainage systems. *See also specific types of drainage systems*
  air compressor systems, 2000 V3: 213
  condensate drainage, 2000 V3: 189–197
  defined, 2004 V1: 22, 1999 V2: 1
  health-care facilities, 2000 V3: 39–42
  laboratories
    acid-waste drainage, 2000 V3: 39–40
    acid-waste metering, 2000 V3: 41–42
    acid-waste solids interceptors, 2000 V3: 41, 43
    acidic-waste neutralization, 2000 V3: 40–41
    corrosive-waste piping materials, 2000 V3: 40
    discharge to sewers, 2000 V3: 40
    sink traps, 2000 V3: 42
    waste and vent piping, 2000 V3: 42
  reflecting pools and fountains, 2000 V3: 112, 125
  storm water, 2000 V3: 245–247
  swimming pools, 2000 V3: 131, 143
drainage, waste, and vents (DWV). *See* drain, waste, and vent
drainline heat reclamation, 2004 V1: 134
drains (D). *See also* building drains; horizontal drains; *specific types of drains*
  defined, 2004 V1: 22
  multilevel pools, 2000 V3: 108
  pools and fountains, 2000 V3: 110
  secondary containment areas, 2000 V3: 90
  symbols for, 2004 V1: 11
drawdowns (wells), 1999 V2: 242, 245
drawings, plumbing. *See* plumbing drawings
drawn temper (hard), 2003 V4: 37, 45
drawoff installations. *See specific kinds of interceptors*
drench equipment for emergencies, 1999 V2: 332
drench showers, 2000 V3: 32, 37
dressing facilities, 2000 V3: 130
drift
  defined, 2004 V1: 22
  problems in seismic protection, 2004 V1: 190
drilled anchor bolts, 2004 V1: 163, 190
drinking fountains
  access to, 2004 V1: 109–112
  energy use, 2004 V1: 266
  gray-water systems, 2004 V1: 135
  health-care facilities, 2000 V3: 32, 33, 38
  minimum numbers of, 2003 V4: 18–22
  standards, 2003 V4: 2
  swimming pool bathhouses, 2000 V3: 130
  types, 2003 V4: 14
  water fixture unit values, 2000 V3: 217
  wheelchair approaches, 2004 V1: 112
drinking water
  amount of, 2004 V1: 263
  chilled systems, 2004 V1: 265
  drinking water supply (DWS), 2004 V1: 8
  drinking water supply recirculating (DWR), 2004 V1: 8
  drinking water systems. *See* private water systems
  health-care facilities, 2000 V3: 43, 45
  material codes, 2004 V1: 43
  potable water, 2004 V1: 27, 263
  treatments for, 1999 V2: 316–317, 318
drip irrigation, 2004 V1: 266
drip lips on weirs, 2000 V3: 109
drip pots, 2000 V3: 252
drive impellers in gas boosters, 1999 V2: 179
drive points, 1999 V2: 241
driven wells, 1999 V2: 241
droop, 2004 V1: 22
drop elbows, 2004 V1: 22
drop manholes, 2000 V3: 234, 238
drop nipples on pendant sprinklers, 2004 V1: 13

drop tees, 2004 V1: 23
drop tubes, 2000 V3: 157, 163
drops, 2004 V1: 11, 22, 2000 V3: 156
dross, 2004 V1: 23
drug rooms, 2000 V3: 35
drum traps, 2000 V3: 42
dry (DRY), 2004 V1: 14
dry acid (sulfuric acid), 2000 V3: 150
dry-bulb temperature (dbt, DBT, DB), 2004 V1: 14, 23
dry cast pipe, 2003 V4: 32
dry-chemical extinguishing systems, 2000 V3: 19–20, 27
Dry Chemical Extinguishing Systems (NFPA 17), 2000 V3: 20, 29
dry chlorine, 2000 V3: 123
dry gas, 2000 V3: 254
dry hose stations, 2004 V1: 13
dry ice, 2000 V3: 20
dry nitrogen, 2000 V3: 20, 252
dry pendent sprinklers, 2004 V1: 29
dry-pipe systems
  accelerators, 2000 V3: 12–13
  air compressors, 2000 V3: 12
  combined dry-pipe and pre-action systems, 2000 V3: 15
  defined, 2004 V1: 29
  normal conditions, 2000 V3: 11–12
  riser diagram, 2000 V3: 11
  sprinklers, 2000 V3: 9–13
dry-pipe valves, 2004 V1: 13, 23
dry-powder extinguishing systems, 2000 V3: 20
dry pumps, 2000 V3: 113, 115
dry returns, 2000 V3: 178–179, 183
dry standpipes, 2004 V1: 13, 30
dry-storage water softeners, 1999 V2: 307
dry surfaces, 2004 V1: 16
dry upright sprinklers, 2004 V1: 29
dry-vacuum cleaning systems (DVC), 2004 V1: 9, 1999 V2: 266, 268, 275–276, 2000 V3: 69
dry venting, reduced-size venting and, 1999 V2: 49
dry-weather flows, 2004 V1: 23
dry wells (leaching wells), 2004 V1: 26, 2000 V3: 247
dryers in laundry facilities, 2000 V3: 36
du Moulin, G.C., 1999 V2: 325
dual. *See also entries beginning with* double-, multiple-, *or* two-
dual-bed deionization (two-step), 1999 V2: 302, 303
dual-flush water closets, 2004 V1: 136, 265
dual-gas booster systems, 1999 V2: 181
dual sensors, 2000 V3: 125
dual vents (common vents), 2004 V1: 21. *See also* common vents
dual water-supply systems, 2000 V3: 43
ductile action of building systems, 2004 V1: 183
ductile iron fittings, 1999 V2: 196, 2000 V3: 116
ductile iron grates, 1999 V2: 15
ductile iron piping
  characteristics and standards, 2003 V4: 32–33
  curve radii for, 1999 V2: 250
  radioactive waste and, 1999 V2: 341
  sizing, 1999 V2: 89–92, 2000 V3: 245
  underground piping, 1999 V2: 68
ducts. *See* vents and venting systems
dug wells, 1999 V2: 240
Dumfries Triangle and Occoquan-Woodbridge Sanitary District, 1999 V2: 34
dump loads, 2000 V3: 45
Dunleavy, M., 1999 V2: 325
duplex. *See also entries beginning with* double-, dual-, *or* two-
duplex air compressors, 2000 V3: 66, 213
duplex bed pressure swing dryers, 2000 V3: 204
duplex manifolds, 2000 V3: 63, 65
duplex sump pump systems, 1999 V2: 9, 69, 105
duplex vacuum pump arrangements, 1999 V2: 262, 263
duration of rainfall, 1999 V2: 69–78, 2000 V3: 244
Durham systems, 2004 V1: 23
durion, 2004 V1: 23
duty cycles, 2000 V3: 206, 207, 211
duty-cycling controls, 2000 V3: 67, 70
DVC (dry vacuum cleaning), 2004 V1: 9, 1999 V2: 266, 268, 275–276
dwellings. *See* buildings
DWR (drinking water supply recirculating), 2004 V1: 8
DWS (drinking water supply), 2004 V1: 8
DWV. *See* drain, waste, and vent stacks (DWV)
DWV piping, 2003 V4: 36, 45
dye tests, 2003 V4: 5, 9
dyes in gray water, 1999 V2: 22, 29, 33
dynamic air compressors, 2000 V3: 65, 66, 201
dynamic fountain displays, 2000 V3: 111, 119
dynamic head, 1999 V2: 245
dynamic pressure, 2004 V1: 15
dynamic properties of piping, defined, 2004 V1: 191
dynamic response (K) to ground shaking, 2004 V1: 159, 161
dynamic viscosity
  converting to SI units, 2004 V1: 39
  measurements, 2004 V1: 33
dyne, converting to SI units, 2004 V1: 39

E

E (exa) prefix, 2004 V1: 34
E (roughness), 2004 V1: 16. *See also* roughness
E (volts). *See* volts
E-33.08B (Plumbing Noise), 2004 V1: 194
early flame knockdown, 2000 V3: 20
early-suppression fast-response systems (ESFR), 2000 V3: 2
earth loads
  on water pipes, 1999 V2: 250
  in pipe selection, 2003 V4: 26
  protecting against, 1999 V2: 18
earthquake protection of plumbing equipment. *See* seismic protection
Earthquake Resistance of Buildings, 2004 V1: 191
Earthquake Resistant Design Requirements Handbook, 2004 V1: 191
Eaton, Herbert N., 1999 V2: 4, 19, 38
eccentric fittings, 2004 V1: 23
eccentric reducers, 2004 V1: 10, 2000 V3: 115
eccentricity in connections, 2004 V1: 189
economic concerns. *See* costs and economic concerns
Economic Thickness of Insulation, 2004 V1: 127
economic values, 2004 V1: 213–214
Eddy, 1999 V2: 238

edge distances, problems in seismic protection, 2004 V1: 190
edr, EDR (equivalent direct radiation), 2004 V1: 14, 39, 2000 V3: 178, 180
educating public on gray-water systems, 1999 V2: 33
educational facilities. *See* schools
eff, EFF (efficiency). *See* efficiency
effect water in fountains, 2000 V3: 124
effective openings, 2004 V1: 23
effective temperature (ET*, ET), 2004 V1: 14
effectiveness (EFT), 2004 V1: 14
effects in multi-effect distillation, 1999 V2: 298
effects of earthquakes, 2004 V1: 156–158
efficiency (eff, EFF)
  fin (FEFF), 2004 V1: 14
  surface (SEFF), 2004 V1: 14
  symbols for, 2004 V1: 14
  thermal, 2004 V1: 136
effluent
  asbestos concrete piping, 2003 V4: 26
  chemicals in special-waste effluent, 1999 V2: 328
  defined, 2004 V1: 23
  estimating sewage quantities, 1999 V2: 233–238
  layers of in septic tanks, 1999 V2: 227
  samples of radioactive waste effluent, 1999 V2: 342
  special-waste drainage systems, 1999 V2: 327
  temperature of special-waste effluent, 1999 V2: 328
  treatment of sewage effluent, 1999 V2: 227–228
Effluent Guideline program, 2000 V3: 88–89
EFT (effectiveness), 2004 V1: 14
Egozy, 1999 V2: 325
EJ (expansion joints). *See* expansion joints
EJCDC (Engineers Joint Contract Documents Committee), 2004 V1: 63
ejector pumps and pits, 2000 V3: 236
ejectors
  fixture-unit values, 1999 V2: 9
  in sanitary drainage systems, 1999 V2: 9
EL (elevation). *See* elevation
elastic limits, 2004 V1: 23
elastic rebound theory, 2004 V1: 158
elastic vibration in pipes, 2004 V1: 6
elasticity of plastic pipes, 2003 V4: 60
elastomeric seals or gaskets
  radiation and, 1999 V2: 341
  reinforced concrete pipe, 2003 V4: 32
  swimming pools, 2000 V3: 144
  water closets, 2003 V4: 6
elbows
  ells, 2004 V1: 23
  risers up or down, 2004 V1: 10
elderly
  aging disabilities, 2004 V1: 107
  fixtures and, 2004 V1: 107
electric capacitance measurements, 2004 V1: 33
electric charge density measurements, 2004 V1: 33
electric fire pumps, 2000 V3: 26
electric hot-water heaters, 2004 V1: 129–130
electric inductance, 2004 V1: 33
electric instantaneous water heaters, 2004 V1: 265
electric irrigation valves, 2000 V3: 103
electric-operated, solenoid valve trap primers, 1999 V2: 14
electric permeability measurements, 2004 V1: 33
electric permitivity measurements, 2004 V1: 33
electric resistance, 2004 V1: 33
electric-resistance welding (ERW), 2003 V4: 48
electric resistivity measurements, 2004 V1: 33
electric vaporizers, 2000 V3: 61
electric water heaters, 1999 V2: 158–159, 2000 V3: 121
electrical components in gas boosters, 1999 V2: 179
electrical connections for pool heaters, 2000 V3: 138
electrical engineers, 2000 V3: 27–28
electrical equipment
  fires, 2000 V3: 21
  installation of pipe and, 2003 V4: 25
electrical makeup water method, 2000 V3: 124
electrical phases, 2004 V1: 15
electricity
  conversion factors, 2004 V1: 35
  measurements, 2004 V1: 33
  off-peak power savings, 2004 V1: 128–129
electrochemical equivalents in corrosion, 2004 V1: 139
Electrochemical Society, 2004 V1: 153
electrodeionization, 1999 V2: 306–307
electrodes, defined, 2004 V1: 152
electrolysis, 2004 V1: 23. *See also* galvanic action
electrolytes
  defined, 2004 V1: 139, 152, 1999 V2: 280
  specific resistance, 1999 V2: 285–287
electromagnetic radiation, 1999 V2: 338
electrometric compression liners, 2003 V4: 48
electromotive force (emf, EMF)
  counter-e.m.f.s, 2004 V1: 153
  electromotive force series, 2004 V1: 144
  measurements, 2004 V1: 33
  symbols for, 2004 V1: 14
electromotive force series, 2004 V1: 144, 152
electron microscopes, 2000 V3: 38, 39, 45, 51
electronegative potential, 2004 V1: 153
electronic grade water, 2003 V4: 58
electronic product level gauges, 2000 V3: 168
electronic tank gauging, 2000 V3: 160
electronics-grade water, 1999 V2: 317, 320
electroplating wastewater treatment, 2000 V3: 94
electropositive potential, 2004 V1: 153
electroregeneration, 1999 V2: 307
elements in water, 1999 V2: 281
elev., ELEV (elevation). *See* elevation
elevated water storage tanks, 1999 V2: 247
elevated water supplies, 2000 V3: 8
elevation (elev., EL, ELEV)
  adjustments for vacuum, 1999 V2: 257, 275
  air compressors and, 2000 V3: 66
  altitude (alt, ALT), 2004 V1: 14
  altitude valves, 1999 V2: 249
  compressed air and, 2000 V3: 199, 211
  medical vacuum systems and, 2000 V3: 69
  pressure losses and, 2000 V3: 224
  in sprinkler hydraulic calculations, 2000 V3: 17
  symbols for, 2004 V1: 14
elevator shafts
  medical gas piping and, 2000 V3: 73
  protection systems, 2000 V3: 25
ellipses, calculating area, 2004 V1: 4

ells (elbows), 2004 V1: 23
elongated bowls on water closets, 2003 V4: 4
elutriation, 2004 V1: 23
embedments, problems in seismic protection, 2004 V1: 190
emergency drains for pools and fountains, 2000 V3: 125
emergency equipment for acid spills, 1999 V2: 332, 333
emergency fixtures
  emergency eyewashes, 2003 V4: 17–18
  emergency showers, 2003 V4: 17–18
  floor drains (copy all HERE), 2003 V4: 17
  standards, 2003 V4: 2
Emergency Planning and Community Right-To-Know Act (EPCRA) (SARA Title III), 2000 V3: 154
emergency power for fire pumps, 2000 V3: 26
emergency rooms, 2000 V3: 32
  fixtures, 2000 V3: 35
  medical gas stations, 2000 V3: 51, 58
  medical vacuum, 2000 V3: 54
  water demand, 2000 V3: 45
emergency showers, 2000 V3: 32, 37
emergency shutoffs for fuel dispensers, 2000 V3: 165
emergency tank vents, 2000 V3: 166, 167
e.m.f. series, 2004 V1: 144, 152
emitters in irrigation systems, 1999 V2: 27
empirical tank capacity equation, 1999 V2: 151
employee facilities, numbers of fixtures for, 2003 V4: 20, 21
emptying noises, acoustic design and, 2004 V1: 195
emulsions, 1999 V2: 347
enameled cast iron fixtures
  defined, 2003 V4: 1–2
  health care facilities, 2000 V3: 33
  standards, 2003 V4: 2
enameled floor drains, 1999 V2: 16
enameled sediment buckets, 1999 V2: 14
enclosures for showers, 2004 V1: 120
The Encyclopedia of Chemical Technology, 2000 V3: 97
end connections, 2004 V1: 23
end-head flows, 2000 V3: 17, 18
end-of-main vents, 2000 V3: 180
end-suction pumps, 2004 V1: 24, 2000 V3: 115, 142
end-use restrictions
  conserving energy, 2004 V1: 126
  reduced water usage, 2004 V1: 126
end venting, 1999 V2: 41
endotoxins, 1999 V2: 282, 288
energy
  conversion factors, 2004 V1: 35
  defined, 2004 V1: 137
  measurements, 2004 V1: 33
  non-SI units, 2004 V1: 34
  nondepletable, 2004 V1: 130–131, 137
  recovered, 2004 V1: 137
Energy & Atmosphere design (LEED), 2004 V1: 263
energy code list of agencies, 2004 V1: 42
energy conservation. *See* conserving energy
energy efficiency. *See* conserving energy
Energy Policy Act (EPACT), 2004 V1: 124, 136, 264
Energy Policy and Conservation Act (EPCA), 2004 V1: 124
Energy Saving and the Plumbing System, 2004 V1: 137
enflurane, 2000 V3: 70
engineered dry-chemical systems, 2000 V3: 19
Engineered Plumbing Design, 2004 V1: 40, 1999 V2: 114
engineered plumbing systems, 2004 V1: 23
engineering and design costs, 2004 V1: 212
Engineering Manual of the War Department, 1999 V2: 97, 114
Engineers Joint Contract Documents Committee (EJCDC), 2004 V1: 63
engines, earthquake protection for, 2004 V1: 164
entering (entr, ENT), 2004 V1: 14
enthalpy (H), 2004 V1: 14
entr (entering), 2004 V1: 14
entropy (S)
  measurements, 2004 V1: 33
  symbols for, 2004 V1: 14
environmental conditions, corrosion by, 2004 V1: 141
environmental design, 2004 V1: 263–267
Environmental Protection Agency. *See* U.S. Environmental Protection Agency
Environmental Quality design (LEED), 2004 V1: 263
environs (facilities with radiation), 1999 V2: 339
EPA. *See* U.S. Environmental Protection Agency
The EPA Effluent Guidelines Series (EPA 440), 2000 V3: 96
EPACT (Energy Policy Act), 2004 V1: 124, 136, 264
EPCA (Energy Policy and Conservation Act), 2004 V1: 124
EPCRA (Emergency Planning and Community Right-To-Know Act) (SARA Title III), 2000 V3: 154
EPDM (ethylene-propylene diene monomer), 2003 V4: 37
epicenters of earthquakes, 2004 V1: 156
epicyclic gears, 2004 V1: 196
epm (equivalents per million), 1999 V2: 285
epoxy
  as thermoset, 2003 V4: 58
  coatings, 2004 V1: 147, 2000 V3: 169
  linings for pipes, 2003 V4: 26
EQFT (equivalent feet), 2004 V1: 14
EQIN (equivalent inches), 2004 V1: 14
eqiv ft, EQIV FT (equivalent feet), 2004 V1: 14
eqiv in, EQIV IN (equivalent inches), 2004 V1: 14
equalization fittings, 2000 V3: 137
equalizer lines, 2000 V3: 108
equations
  acfm to scfm, 2000 V3: 65–66
  air receiver sizing, 2000 V3: 206
  anode expected life, 2004 V1: 148
  areas and volumes, 2004 V1: 3–5
  Bernoulli's equation, 2004 V1: 5–6
  calculating seismic forces, 2004 V1: 183–186
  collection legs in condensate drainage, 2000 V3: 195
  condensate loads, 2000 V3: 194
  corrosion rates, 2004 V1: 144
  Darcy's Law, 2004 V1: 2, 3, 1999 V2: 7
  Faraday's Law, 2004 V1: 144
  flow at outlets, 2004 V1: 3, 5
  flow capacity in vertical stacks, 1999 V2: 4
  flow from outlets, velocity of, 2004 V1: 6
  flow rates, 2004 V1: 1
  fountain head formulas, 2000 V3: 118
  friction head, 2004 V1: 6
  friction head loss, 2004 V1: 2
  gas laws, 1999 V2: 179
  gravity circulation, 2004 V1: 5

Hazen-Williams formula, 2004 V1: 2, 1999 V2: 7, 116, 118, 119, 121, 2000 V3: 118
hot-water systems, 1999 V2: 158
hydrant flow tests, 2000 V3: 5
hydraulic shock, 2004 V1: 6
International System of Units (SI), 2004 V1: 1
Joukowsky's formula, 1999 V2: 132
kinetic energy, 2004 V1: 2
Manning formula, 2000 V3: 244–245, 246
alternative sewage-disposal systems, 1999 V2: 226
open-channel flow, 2004 V1: 1, 1999 V2: 7, 8
runoff and, 1999 V2: 97
site drainage and, 1999 V2: 98
sloping drains, 1999 V2: 8
storm-drainage pipes, 1999 V2: 88
subsurface drainage rates, 1999 V2: 105
medical gas pipe sizing, 2000 V3: 74
mixing flows of water, 2004 V1: 126
natural gas systems
natural gas equivalent length, 1999 V2: 184
NFPA formula, 1999 V2: 186, 187, 188, 189
Spitzglass formula, 1999 V2: 183, 210–211
Weymouth formula, 1999 V2: 183, 190, 191, 198–209
NFPA formula, 1999 V2: 186, 187, 188, 189
Ohm's Law, 2004 V1: 144
pipe expansion and contraction, 2004 V1: 3
plumbing cost estimation, 2004 V1: 93–98
potential energy, 2004 V1: 2
Prandtl-Colebrook equation, 1999 V2: 60
pump affinity laws, 2004 V1: 6
pump efficiency, 2004 V1: 6–7
pump noise levels, 2004 V1: 198
Rational Method formulas, 2004 V1: 7, 1999 V2: 95–98, 2000 V3: 242
references, 2004 V1: 40
Reynold's number, 2004 V1: 2
site storm drainage, 1999 V2: 88, 95–98, 107–108
soil resistivity, 2004 V1: 150
Spitzglass formula, 2004 V1: 7, 1999 V2: 183, 210–211
sprinkler demand, 2000 V3: 17
sprinkler design density, 2000 V3: 16
sprinkler end-head pressures, 2000 V3: 18
square feet EDR, 2000 V3: 178
stack terminal velocity and length, 2004 V1: 3
steady-state heat balance equations, 1999 V2: 158
steam system traps, 2000 V3: 194–195
steam warm-up loads, 2000 V3: 195
storm drainage, 2004 V1: 7
tank capacity empirical equation, 1999 V2: 151
tank capacity rule of thumb equation, 1999 V2: 151
terminal velocity and terminal length, 1999 V2: 1
vacuum system demand, 2000 V3: 70
value, worth and cost, 2004 V1: 213
velocity head, 2004 V1: 5
vent piping length, 2004 V1: 3
water flow in pipes, 2004 V1: 2
water hammer, 2004 V1: 198
well equilibrium equations, 1999 V2: 242–243
Weymouth formula, 2004 V1: 7, 1999 V2: 183, 190, 191, 198–209
equilibrium equations for wells, 1999 V2: 242–243
equipment
acoustic concerns in selection, 2004 V1: 200
defined, 2004 V1: 191
section in specifications, 2004 V1: 91
seismic protection, 2004 V1: 163–171
steam and condensate systems, 2000 V3: 178
equivalent direct radiation (edr, EDR)
cast iron radiators, 2000 V3: 180
EDR hot water, 2004 V1: 39
EDR steam, 2004 V1: 39
operating pressure steam classification, 2000 V3: 178
steam heating, 2000 V3: 178
symbols for, 2004 V1: 14
equivalent feet (eqiv ft, EQIV FT, EQFT), 2004 V1: 14
equivalent inches (eqiv in, EQIV IN, EQIN), 2004 V1: 14
equivalent length
compressed air piping, 2000 V3: 211
defined, 1999 V2: 214
medical gas piping, 2000 V3: 73
natural gas equations, 1999 V2: 184
equivalent static force, calculating, 2004 V1: 183
equivalent weight, 1999 V2: 280, 281
equivalents per million, 1999 V2: 285
erosion, 2004 V1: 23, 2000 V3: 47, 99
erosion corrosion, 1999 V2: 290
ERW (electric-resistance welding), 2003 V4: 48
ESFR (early-suppression fast-response systems), 2000 V3: 2
essential facilities, defined, 2004 V1: 191
estates, septic tank systems for, 1999 V2: 231–232
estimating costs. *See also* costs and economic concerns
factors in estimates, 2004 V1: 98
idea development and estimated cost forms, 2004 V1: 241–242
overestimating, 2004 V1: 224
per-area costs, 2004 V1: 97–98
per-fixture or per-appurtenance estimates, 2004 V1: 97
plumbing cost estimation, 2004 V1: 93–98
software for cost estimation, 2004 V1: 98
in value engineering, 2004 V1: 243
estimating medical gas and vacuum stations, 2000 V3: 50, 51–52
estimating sewage quantities, 1999 V2: 234, 235, 237
ET*, ET (effective temperature), 2004 V1: 14
ethylene-propylene diene monomer (EPDM), 2003 V4: 37
ETI (Economic Thickness of Insulation), 2004 V1: 127
EVAC stations, 2000 V3: 51–52
Evaluation phase in value engineering
activities, 2004 V1: 235–243
checklists, 2004 V1: 237–238
comparing functions, 2004 V1: 243
functional evaluation worksheets, 2004 V1: 243–251
idea evaluation checklist, 2004 V1: 243, 253
in process, 2004 V1: 213
second creativity, cost, and evaluation analysis, 2004 V1: 254
evap, EVAP. *See* evaporation; evaporators
evaporation (evap, EVAP)
staged, 1999 V2: 298
storage tanks, 2000 V3: 172
swimming pools, 2000 V3: 131
symbols for, 2004 V1: 14

evaporative coolers. *See* cooling-tower water
evaporators (evap, EVAP), 2004 V1: 14, 2000 V3: 46
evapotranspiration
  defined, 2004 V1: 23
  in irrigation, 2000 V3: 105
  sewage treatment, 1999 V2: 227
"exa" prefix, 2004 V1: 34
exact conversions, 2004 V1: 32
exam/treatment rooms
  fixtures, 2000 V3: 35
  health-care facilities, 2000 V3: 32
  medical gas stations, 2000 V3: 51
  medical vacuum, 2000 V3: 54
examination section in specifications, 2004 V1: 71, 91
excavation
  labor productivity rates, 2004 V1: 95–97
  plumbing cost estimation, 2004 V1: 93
excess air, defined, 1999 V2: 213
excess pressure pumps, 2004 V1: 24
excess water pressure, 1999 V2: 152–154
excessive costs, value engineering and, 2004 V1: 212
exchange capacity of resins, 1999 V2: 302
exchangers in distillers, 1999 V2: 298
Execution section in specifications, 2004 V1: 69, 91–92
exhaust
  filters on vacuum systems, 1999 V2: 262
  natural gas combustion waste, 1999 V2: 177
  pressure loss in vacuum systems, 1999 V2: 274
  vacuum exhaust pipe sizing, 1999 V2: 263
  vacuum system piping, 1999 V2: 259, 274, 2000 V3: 70
  vacuum system stacks, 2000 V3: 70
exhausted cartridges in ion exchange, 1999 V2: 305–306
exhausters (dry-pipe systems), 2000 V3: 11
exhausters (vacuum)
  air-bleed controls, 1999 V2: 268–269
  defined, 1999 V2: 266–269, 268
  locating, 1999 V2: 270
  sizing, 1999 V2: 272, 274–275
exhibition halls, numbers of fixtures for, 2003 V4: 19
existing work, 2004 V1: 23
exp, EXP (expansion). *See* expansion
expanded air in vacuums, 1999 V2: 256
expansion (exp, EXP, XPAN)
  buildings, 2000 V3: 49
  calculating pipe expansion, 2004 V1: 3
  enlargement of water systems, 1999 V2: 249
  foam extinguishing agents, 2000 V3: 21
  future expansion of compressed air systems, 2000 V3: 210
  glass pipe, 2003 V4: 48
  HDPE pipe, 2003 V4: 61
  hot-water systems and, 1999 V2: 167–168
  linear expansion in PVC pipe, 2003 V4: 62
  plastic pipe, 2003 V4: 60
  plastic pipe thermal expansion, 1999 V2: 251
  protecting against pipe expansion, 1999 V2: 18
  roof drains and, 1999 V2: 85, 87
  sanitary drainage systems, 1999 V2: 18
  storage tanks and piping, 2000 V3: 172
  swimming pool piping, 2000 V3: 145
  symbols for, 2004 V1: 14
  thermal expansion tanks, 1999 V2: 167
  water pipes and, 1999 V2: 251–252
expansion bends, 1999 V2: 18
expansion joints (EJ)
  defined, 2004 V1: 23
  plastic water pipes, 1999 V2: 251
  roofs, 1999 V2: 79, 85, 87
  symbols for, 2004 V1: 10
  thermal expansion and, 1999 V2: 18
expansion loops
  bracing and, 2004 V1: 171
  defined, 2004 V1: 23
  protecting against thermal expansion, 1999 V2: 18
expert costs, 2004 V1: 223
explosions
  explosion-proof (XP) construction, 1999 V2: 179
  explosion-relief devices for vacuums, 1999 V2: 268
  fire-protection systems, 2000 V3: 22
  hot-water heaters, 1999 V2: 157
  nitric acid, 1999 V2: 333
exposed ends of piping, 2003 V4: 25
exposures, fire hazards and, 2000 V3: 2
extended-coverage sidewall sprinklers, 2004 V1: 29
exterior piping for storm drainage, 1999 V2: 98
extinguishing systems, 2004 V1: 12
extra-hazard occupancies
  defined, 2004 V1: 29
  deluge systems, 2000 V3: 13
  firefighting hose streams, 2000 V3: 230
  portable fire extinguishers, 2000 V3: 27, 28
extra-heavy cast-iron soil pipe (XH), 2003 V4: 27, 29–30
extra-heavy piping, 2004 V1: 23
extra materials section in specifications, 2004 V1: 70, 90
extra-strength vitrified clay piping, 1999 V2: 68
extra-strong steel pipe, 2003 V4: 48
extra-strong weight brass pipe (Schedule 40), 2003 V4: 27
extractors in laundry facilities, 2000 V3: 36
extruded steel piping, 2003 V4: 48
eyeball inlet fittings, 2000 V3: 137
eyewashes for emergencies, 1999 V2: 332, 2000 V3: 37, 2003 V4: 17–18

F

°F, F (Fahrenheit), 2004 V1: 14, 38
F (farads), 2004 V1: 33
f (femto) prefix, 2004 V1: 34
F (fire-protection water supply). *See* fire-protection systems
f to f, F TO F (face to face), 2004 V1: 14, 23
f & t (flow and thermostatic traps), 2000 V3: 182, 194
F-477 standard, 2003 V4: 62
F-876 standard, 2003 V4: 61
F-877 standard, 2003 V4: 61
F-1281 standard, 2003 V4: 62
F-1282 standard, 2003 V4: 62
F/m (farads per meter), 2004 V1: 33
fa, FA (face area), 2004 V1: 14
fabrication section in specifications, 2004 V1: 91
face area (fa, FA), 2004 V1: 14
face-entry fittings on sovent systems, 1999 V2: 62
face piping, 2000 V3: 115
face to face (f to f, F TO F)
  face-to-face dimensions, defined, 2004 V1: 23

symbols for, 2004 V1: 14
face velocity (fvel, FVEL, FV), 2004 V1: 14
face washes, 2000 V3: 37
faceplates for pool lighting fixtures, 2000 V3: 145
Facility Piping System Handbook, 1999 V2: 277, 325, 350, 2000 V3: 173, 214
factories, numbers of fixtures for, 2003 V4: 19
factors
correction factors (CFAC, CFACT), 2004 V1: 14
friction factors (FFACT, FF), 2004 V1: 14
Factory Mutual Research Corporation (FM)
air compressors in dry-pipe systems, 2000 V3: 12
design density requirements, 2000 V3: 16
Factory Mutual (FM) Loss Prevention Data Sheets, 1999 V2: 177, 2000 V3: 225
gas-train vents, 1999 V2: 177
seismic protection recommendations, 2004 V1: 184
Fahrenheit (°F, F)
conversion factors, 2004 V1: 38
symbols for, 2004 V1: 14
fail-safe mixing valves, 2003 V4: 18
Failsafe Neutralization of Wastewater Effluent, 1999 V2: 350
failure values of anchors, 2004 V1: 190
Fair Housing Accessibility Guidelines, 2004 V1: 106
fairly-rough piping, 1999 V2: 141
fairly-smooth piping, 1999 V2: 140
fall-off pressure, 1999 V2: 122, 152
false alarms for sprinkler systems, 2000 V3: 9
fan-coil units, 2004 V1: 267
fan-cooled electric motors, 2004 V1: 196
fan pressurization tests, 2000 V3: 24–25
fans (FAN)
pulsation from, 2004 V1: 196
silencers, 2004 V1: 197
symbols for, 2004 V1: 14
Faraday's Law, 2004 V1: 139, 144
farads, 2004 V1: 33
farads per meter, 2004 V1: 33
FAST approach to function analysis, 2004 V1: 227–231
fasteners, sound damping, 2004 V1: 195
fats in kitchens. *See* grease
faucets
accessible shower compartments, 2004 V1: 120
acoustic design and pressure, 2004 V1: 200
backflow preventions, 2003 V4: 13–14
centersets, 2003 V4: 10
Energy Policy Act requirements, 2004 V1: 264
flow rates, 2003 V4: 10, 13
health-care facilities, 2000 V3: 33
leakage, 2004 V1: 134
low flow, 2004 V1: 136
patient rooms, 2000 V3: 34
reduced water usage, 2004 V1: 126–127
reducing flow rates, 2004 V1: 135
residential kitchen sinks, 2003 V4: 11
self-metering, 2003 V4: 13
sinks, 2004 V1: 117
standards, 2003 V4: 2
types of, 2003 V4: 13–14
wasted water, 2004 V1: 136
faults and fault zones, 2004 V1: 156–158
FC (flexible connectors). *See* flexible connectors
FCO (floor cleanouts), 2004 V1: 11
FD (floor drains with p-traps), 2004 V1: 11
FDA (Food and Drug Administration), 1999 V2: 279, 321, 324, 328
features, defined, 2004 V1: 32
fecal matter. *See* black-water systems; effluent
federal agencies. *See specific agencies under "US"*
Federal Energy Management Improvement Act (FEMIA), 2004 V1: 124
Federal Food, Drug and Cosmetic Act, 1999 V2: 317
Federal Register (FR), 2000 V3:88
federal specifications (FS), 2004 V1: 25, 54, 58
Federation Internationale de Natation Amateur (FINA), 2000 V3: 127, 151
feed-gas treatment units in ozone generators, 1999 V2: 312
feed water
defined, 1999 V2: 280
pure-water systems, 1999 V2: 320
feet (ft, FT)
converting to metric units, 2000 V3: 29
converting to SI units, 2004 V1: 39
feet per minute (fpm, FPM), 2004 V1: 14, 2000 V3: 29
feet per second (fps, FPS), 2004 V1: 14
foot-pounds (ft-lb, FT LB), 2004 V1: 14
of head, converting, 2004 V1: 2
symbols for, 2004 V1: 14
FEFF (efficiency, fin), 2004 V1: 14
felt, 2004 V1: 195
female threads, 2004 V1: 23
female urinals, 2003 V4: 9
FEMIA (Federal Energy Management Improvement Act), 2004 V1: 124
"femto" prefix, 2004 V1: 34
ferric hydroxide, 1999 V2: 281
ferric iron, 1999 V2: 281, 283
ferrous bicarbonate, 1999 V2: 283
ferrous iron, 1999 V2: 281, 283
ferrous pipes, 2004 V1: 51–52, 2000 V3: 12
FF (friction factors), 2004 V1: 14
FF (full-flow conditions), 2004 V1: 1
FFACT (friction factors), 2004 V1: 14
FI (film coefficients), 2004 V1: 14
fiber piping, 1999 V2: 122
fiberglass fixtures, 2003 V4: 2
fiberglass-reinforced plastic (FRP)
exposed piping on storage tanks, 2000 V3: 165
fixtures, 2003 V4: 2
fuel product dispensing, 2000 V3: 169
liquid fuel tanks, 2000 V3: 155
storage tanks, 2000 V3: 165, 172
sulfuric acid and, 2000 V3: 93
velocity, 2000 V3: 170
VOCs and, 1999 V2: 284
fiberglass-reinforced storage tanks
aboveground storage tanks, 2000 V3: 165
high-purity water, 1999 V2: 323
liquid fuel tanks, 2000 V3: 155
storage tanks, 2000 V3: 172
storage tanks and hazardous wastes, 2000 V3: 91
fiberglass sealants, 2004 V1: 193

fiberglass septic tanks, 1999 V2: 228
field checklists, 2004 V1: 102–103
field orders, 2004 V1: 63
field quality control section in specifications, 2004 V1: 71, 91–92
fill
  fill layers, 1999 V2: 104
  leaching trenches, 1999 V2: 223
  sewers, 1999 V2: 15
  subsurface drainage pipes, 1999 V2: 102, 103
  types of, around building sewers, 1999 V2: 15
  water pipes, 1999 V2: 250
fill hoses, 2000 V3: 157
fill lines for pools, 2000 V3: 116
fill ports, 2000 V3: 166
fill spouts in pools, 2000 V3: 145
filling
  aboveground tank systems, 2000 V3: 166–167
  swimming pools, 2000 V3: 144
  underground liquid fuel tanks, 2000 V3: 156–157
film coefficients
  inside (FI, HI), 2004 V1: 14
  outside (FO, HO), 2004 V1: 14
film-processing areas, 2000 V3: 39, 45
films
  carbonate, 2004 V1: 151
  film formation in rate of corrosion, 2004 V1: 145
  sodium hexametaphosphate, 2004 V1: 151
  sodium silicate, 2004 V1: 151
filter alum, 1999 V2: 294
filter cakes, 2000 V3: 134
filter coats, 2000 V3: 134
filter intakes, 2000 V3: 66
filter pumps, 2000 V3: 115–116, 120
filter tanks, 2000 V3: 131
filters and filtration
  air compressors, 2000 V3: 203
  cleaning filters, 2000 V3: 150
  compressed air systems, 2000 V3: 207
  defined, 2004 V1: 23
  filter bags on vacuum systems, 1999 V2: 268
  filter elements or media, 2004 V1: 23, 2000 V3: 134–135
  filtration water systems, 2000 V3: 47
  fountains
    design criteria, 2000 V3: 112–113
    filter pumps, 2000 V3: 115–116
    piping, 2000 V3: 111–112, 119
    turnover time, 2000 V3: 110
  fuel dispensers, 2000 V3: 165
  gas line filters, 2000 V3: 250
  granular filters, 2000 V3: 132–134
  gray water, 2004 V1: 267, 1999 V2: 22, 23, 27, 28, 29
  infectious waste systems, 1999 V2: 345
  iron-removal filters, 2000 V3: 147
  membrane filtration and separation, 1999 V2: 308–311
  microorganisms, 1999 V2: 312
  oil spills, 1999 V2: 347, 348
  pure water systems, 1999 V2: 322–323
  sand filters, 2000 V3: 149–150
  slurry feeding, 2000 V3: 134–135
  small drinking water systems, 1999 V2: 318
  subsurface drainage, 1999 V2: 102, 103–104
  swimming pools, 2000 V3: 131–137
    backwash, 2000 V3: 137
    backwash pits, 2000 V3: 137, 140
    diatomaceous earth, 2000 V3: 134–135
    filter tanks, 2000 V3: 131
    gutters and, 2000 V3: 137
    housing, 2000 V3: 129
    hydraulic design, 2000 V3: 140
    inlet fittings, 2000 V3: 137
    main drains, 2000 V3: 137
    media types, 2000 V3: 131–137
    return inlets, 2000 V3: 110–111
    role, 2000 V3: 131
    selecting components, 2000 V3: 139–140
    skimmers, 2000 V3: 137
    surge tanks, 2000 V3: 137
    types of filters, 2000 V3: 130
  utility water, 1999 V2: 314
  vacuum systems, 1999 V2: 268
  water quality and, 1999 V2: 244
  water systems, 1999 V2: 125
  water treatment, 1999 V2: 299, 300
fin efficiency (FEFF), 2004 V1: 14
FINA (Federation Internationale de Natation Amateur), 2000 V3: 127, 151
final checklists, 2004 V1: 103
fine sands
  fill above subsurface drainage pipes, 1999 V2: 103
  gray-water irrigation systems and, 1999 V2: 26, 27
  irrigating, 2000 V3: 100
fine vacuum, 1999 V2: 254
finish coats, 2004 V1: 147
finish inspection, 2004 V1: 103
Finnemore, E. John, 1999 V2: 19
fire areas, 2000 V3: 16
fire departments, 2000 V3: 2, 216
fire hydrants. *See* hydrants
fire loads, 2000 V3: 2–3
fire marshals, 2000 V3: 2, 216
Fire Protection Handbook, 2000 V3: 8, 29
fire-protection systems. *See also* sprinkler systems (fire protection)
  alarms
    electric gongs, 2000 V3: 11
    fire alarm control panels, 2004 V1: 12, 2000 V3: 24
    fire alarm systems, 2004 V1: 23–24
  automatic systems, 2000 V3: 1–18
  codes and standards, 2004 V1: 42–43
  defined, 1999 V2: 18
  detection, 2000 V3: 13, 19
  extinguishers, 2004 V1: 12, 13, 2000 V3: 27
  fire department connections, 2004 V1: 24, 2000 V3: 11
  fire-department connections, 2004 V1: 12
  fire extinguishers, 2000 V3: 27
  fire hazards
    defined, 2004 V1: 24
    evaluation, 2000 V3: 2–3
    fire loads and resistance ratings, 2000 V3: 2–3
    flammable or volatile liquids, 1999 V2: 13, 347–349
    oxygen storage areas, 2000 V3: 63
  fire lines

defined, 2004 V1: 24
fire-line water meters, 1999 V2: 116
fire mains, 2000 V3: 8
fire-protection engineers, 2000 V3: 28
fire pumps, 2004 V1: 12, 24, 2000 V3: 25–26, 225
firefighting equipment, 2004 V1: 13
firefighting water drainage, 1999 V2: 346–347
flow tests, 2000 V3: 3–4
hydrants
distance between, 1999 V2: 250
flow tests, 1999 V2: 122
pressure drop and, 1999 V2: 249
public hydrants, 2004 V1: 12
valves, 2004 V1: 24
other trades and, 2000 V3: 27–28
overview, 2000 V3: 1
references, 2000 V3: 29
seismic protection, 2004 V1: 183–184
special extinguishing systems, 2000 V3: 19–25
carbon-dioxide systems, 2000 V3: 20–21
dry-chemical extinguishing systems, 2000 V3: 19–20
dry-powder extinguishing systems, 2000 V3: 20
elevator shaft protection systems, 2000 V3: 25
foam extinguishing systems, 2000 V3: 21–22
gaseous fire-suppression systems, 2000 V3: 22–25
sprinkler systems. *See* sprinkler systems (fire protection)
standpipe systems, 2000 V3: 18–19
symbols, 2004 V1: 12–13
terminology, 2004 V1: 17–31
water lines, 2003 V4: 35
water supply for
building water supply, 2000 V3: 225–226
codes and standards, 2000 V3: 225
fire risers, 2000 V3: 16
firefighting water systems, 1999 V2: 249, 250
flow rates, 2000 V3: 230–232
graphs, 2000 V3: 5, 6
guard posts, 2000 V3: 228, 229
hydrants, 2000 V3: 226–228
hydraulic calculations, 2000 V3: 17
joint restrainers, 2000 V3: 228–229
overview, 2000 V3: 224–225
piping system layout, 2000 V3: 8
post indicator valves, 2000 V3: 228
preliminary information, 2000 V3: 215–216
quantity and availability, 2000 V3: 3–8
reliability, 2000 V3: 8
sizing system, 2000 V3: 229–232
standpipe systems, 2000 V3: 19
symbols for water supply (F), 2004 V1: 8
tank capacity, 2000 V3: 232
water demands, 1999 V2: 243–244, 247
fire-rated sealants, 2004 V1: 193
Fire Resistance (UL 2085), 2000 V3: 154
fires
classes of, 2000 V3: 3
growth rate, 2000 V3: 2
firm gas services, 2000 V3: 249
first-degree burns, 1999 V2: 169
Fitting, 2003 V4: 32
fittings. *See also specific types of fittings*
acoustic ratings, 2004 V1: 194–195
cast bronze threaded fittings, 2003 V4: 27
cast iron radiators, 2000 V3: 179
codes and standards, 2004 V1: 44
compressed air, 2000 V3: 210, 211
compression, 2004 V1: 24
copper and bronze, 2003 V4: 37–38
copper drainage tubes, 2003 V4: 45, 46
copper pipe, 2003 V4: 34
cross-linked polyethylene, 2003 V4: 61
defined, 2004 V1: 24
domestic pressure drops and, 2000 V3: 221
ductile iron water and sewer pipe, 2003 V4: 32–33
earthquake damage, 2004 V1: 162
earthquake protection, 2004 V1: 166
flanged, 2004 V1: 24
fountains, 2000 V3: 119
friction loss and, 1999 V2: 128
glass pipe, 2003 V4: 48, 49–50
grab bars, 2004 V1: 121–122
hub and spigot, 2003 V4: 27
hubless pipe and fittings, 2003 V4: 28
lead pipe, 2003 V4: 49
liquefied petroleum gas, 1999 V2: 196
medical gas tube, 2003 V4: 45
natural gas fitting sizes, 1999 V2: 184
natural gas pipes, 2000 V3: 252
plastic pipes, 2003 V4: 58
pressure drops in water systems and, 1999 V2: 125, 126, 127
PVC piping, 2003 V4: 62
radioactive waste systems, 1999 V2: 343
red brass pipe, 2003 V4: 27
screwed fittings, 2004 V1: 162
seamless copper water tube, 2003 V4: 37
standards, 2003 V4: 2
steel or galvanized piping, 2003 V4: 48
steel pipe, 2003 V4: 48
swimming pools, 2000 V3: 137, 144, 145
tank manways, 2000 V3: 156
types of, 2003 V4: 1
vacuum cleaning systems, 1999 V2: 269
welded, 2004 V1: 24
Fitzgerald, 2004 V1: 154
fixed costs, in plumbing cost estimation, 2004 V1: 93
fixed floor-mounted equipment, 2004 V1: 163
fixed shower heads, 2004 V1: 120
fixed suspended equipment, 2004 V1: 164
fixture branches, 2004 V1: 24
fixture carrier fittings, 2004 V1: 24
fixture carriers, 2004 V1: 24
fixture drains
defined, 2004 V1: 24
discharge characteristics, 1999 V2: 3
flow in, 1999 V2: 2
flow rate in, 2004 V1: 3
simultaneous use of fixtures, 1999 V2: 3, 4
fixture supplies, 2004 V1: 24
fixture units and unit values
cold-water system demand, 1999 V2: 121

conversion to gpm, 1999 V2: 120, 124, 126, 2000 V3: 218, 234
demand weight of fixtures, 1999 V2: 123
drainage fixture units (dfu), 2004 V1: 24, 1999 V2: 64
drainage vents and, 1999 V2: 40–41
fixture units (fu) defined, 1999 V2: 64
maximum for vertical stacks, 1999 V2: 4, 5
pipe sizing and, 1999 V2: 133–142, 136
reduced-size venting and, 1999 V2: 50
sanitary drainage system loads, 1999 V2: 3
slope of drains, 1999 V2: 7, 9
sovent systems, 1999 V2: 57–59, 63
steady flow in horizontal drains, 1999 V2: 9
supply fixture units (sfu), 2004 V1: 24
water hammer and, 1999 V2: 144
fixtures and fixture outlets. *See also specific types of fixtures (water closets, showers, etc.)*
accessibility standards, 2003 V4: 2
batteries of fixtures, 2004 V1: 18, 1999 V2: 64
building requirement tables, 2003 V4: 18–23
codes and standards, 2004 V1: 43–44
cold-water system demand, 1999 V2: 121
defined, 2004 V1: 27, 2003 V4: 1
demand weight of, 1999 V2: 123
domestic water supply and, 2000 V3: 216
fittings, 2003 V4: 1
fixture traps and vents, 1999 V2: 40
flow and pressure requirements, 1999 V2: 129
governing fixtures, 1999 V2: 125, 129
health-care facilities, 2000 V3: 31–39
general requirements, 2000 V3: 33
kitchens and laundries, 2000 V3: 36
laboratory rooms, 2000 V3: 37–39
selection, 2000 V3: 31–34
special equipment, 2000 V3: 39
specific areas, 2000 V3: 33–36
unique fixtures, 2000 V3: 37, 38
inspection, 2004 V1: 103
installation productivity rates, 2004 V1: 97
laboratory acid-waste drainage systems, 1999 V2: 334
materials, 2003 V4: 1–2
minimum numbers of, 2003 V4: 18–22
per-fixture cost estimation, 2004 V1: 97
plumbing cost estimation, 2004 V1: 93
plumbing fixtures, defined, 2004 V1: 24
reduced water usage, 2004 V1: 126–127
reducing flow rates, 2004 V1: 134–135
resilient-mounting design, 2004 V1: 206, 207
resiliently mounted plumbing fixtures, 2004 V1: 207
sizing vents, 1999 V2: 50
standards, 2003 V4: 2
supply-water trap primers, 1999 V2: 14
types of, 2003 V4: 1
vibration of, 2004 V1: 205
wastewater trap primers, 1999 V2: 14
water fixture unit values, 2000 V3: 217
water-saving fixtures, 2004 V1: 126
flame arresters, 2000 V3: 158
Flammable and Combustible Liquids Code (NFPA 30), 2000 V3: 29, 95, 173
automatic fire-protection systems, 2000 V3: 2
dike construction, 2000 V3: 167
foam systems, 2000 V3: 21
liquid fuel system codes, 2000 V3: 154
liquid fuel system definitions, 2000 V3: 153
tank construction, 2000 V3: 165
flammable gases, 2000 V3: 83
flammable or volatile liquids, 1999 V2: 13, 347–349, 2000 V3: 153
flanged end connections, 2004 V1: 23
Flanged Pipe, 2003 V4: 32
flanges
bonnets, 2004 V1: 25
defined, 2004 V1: 25
fittings, 2004 V1: 25
flange ends, 2004 V1: 25
flange faces, 2004 V1: 25
flanged fittings, 2003 V4: 38
problems in seismic protection, 2004 V1: 190
flap valves, 2004 V1: 25
flare nuts, frost proof, 1999 V2: 196
flared fittings, 2003 V4: 34
flash attacks, 2004 V1: 146, 153
flash fires, 2000 V3: 16
flash points
defined, 2004 V1: 25, 2000 V3: 83, 153
foam extinguishing systems and, 2000 V3: 21
liquid fuels, 2000 V3: 153
flash tanks, 2000 V3: 195, 196
flash tubes for liquefied petroleum gas, 1999 V2: 197
flashing condensate, 2000 V3: 197
flashing flanges, 1999 V2: 17
flashing flow, 2000 V3: 196–197
flashing L flanges, 1999 V2: 17
flashing rings, 1999 V2: 12, 17, 80
flat-area leaching trenches, 1999 V2: 223–224
flat roof drains, 1999 V2: 80
flat-spray irrigation sprinklers, 2000 V3: 103
flexible connectors (FC)
acoustics and, 2004 V1: 200
illustrated, 2004 V1: 204, 210
symbols for, 2004 V1: 10
vibration control devices, 2004 V1: 203, 205
flexible gas hoses, 1999 V2: 196
flexible hose connections, 2003 V4: 14
flexible plastic piping, 2000 V3: 169
flexural strength of plastic pipe, 2003 V4: 60
float switches, 2000 V3: 188
float-type level controls, 1999 V2: 249
float valves, 2004 V1: 25, 2000 V3: 124, 144
floatation devices for oil spills, 1999 V2: 348
floatation of oil in spills, 1999 V2: 347
floatation vibration isolation, 2004 V1: 164
floating ball devices in tanks, 2000 V3: 158
floating floors, soundproofing, 2004 V1: 196
floc, 1999 V2: 294
flocculation, 1999 V2: 294, 2000 V3: 150
flood level rims, 2004 V1: 25
flooded, defined, 2004 V1: 25
flooding factors
clean agent gas fire suppression, 2000 V3: 23
rainfall, 2000 V3: 244
underground storage tanks and, 2000 V3: 155
floor cleanouts (FCO), 2004 V1: 11

floor drains (FD)
acid-resistant floor drains, 1999 V2: 16
blood-type, 2000 V3: 35
chemical-waste systems, 1999 V2: 346
components, 1999 V2: 11
end venting, 1999 V2: 41
fire-suppression drainage and, 1999 V2: 347
fixture-unit loads, 1999 V2: 3
floor leveling around, 1999 V2: 17
food-preparation areas, 2000 V3: 36
grate open areas, 1999 V2: 10
gravity drains, 2000 V3: 140
health-care facilities, 2000 V3: 32, 38
infectious and biological waste systems, 1999 V2: 345
kitchen areas, 1999 V2: 16–17, 17
mechanical spaces and vaults, 2000 V3: 111
with p-traps (FD), 2004 V1: 11
public areas in health-care facilities, 2000 V3: 34
radioactive waste systems, 1999 V2: 342
sanitary drainage systems, 1999 V2: 10
standards, 2003 V4: 2
swimming pool bathhouses, 2000 V3: 130
types, 1999 V2: 17–18, 2003 V4: 17
waterproofing, 1999 V2: 17
floor inlets in pools, 2000 V3: 137, 143
floor-mounted back-outlet water closets, 2003 V4: 4
floor-mounted bidets, 2003 V4: 17
floor-mounted pumps, 2004 V1: 205
floor mounted urinals, 2003 V4: 10
floor-mounted vibration-isolated equipment, 2004 V1: 164–166
floor-mounted water closets, 2003 V4: 4, 6–7
floor sinks, 1999 V2: 10, 16
floors
bathhouses, 2000 V3: 130
design considerations in seismic protection, 2004 V1: 186
floor penetrations of pipes, 2004 V1: 201
leveling, 1999 V2: 17
motions in earthquakes, 2004 V1: 160
shaking in earthquakes, 2004 V1: 161
flow. *See also* flow rates
at outlet, 2004 V1: 3
building drains, 1999 V2: 2
critical flows, defined, 2004 V1: 2
fixture drains, 2004 V1: 3, 1999 V2: 2
gravity and sheet actions, 1999 V2: 12
hydraulic jumps in, 1999 V2: 2, 6
open-channel flow, 2004 V1: 1, 1999 V2: 7
outlet velocity, 2004 V1: 6
overland flow for sites, 1999 V2: 96
rate of flow, calculating, 2004 V1: 1
stacks, 1999 V2: 1–2
steady flow, 1999 V2: 6–7
surging flows, 1999 V2: 5
symbols for, 2004 V1: 11
velocity and water hammer, 2004 V1: 198
velocity of uniform flow, 2004 V1: 1
water flow in pipes, calculating, 2004 V1: 2
flow and thermostatic traps (f & t), 2000 V3: 182, 194
flow-control storm devices, 1999 V2: 94
flow equalization in gray-water treatment, 1999 V2: 27
flow hydrants, 2000 V3: 4
flow indicators, 2000 V3: 142
flow meters, 2000 V3: 140
flow pressure, 2004 V1: 25
flow rate totalizers, 2000 V3: 142
flow rates
acoustic ratings and, 2004 V1: 194, 200
air flow in vacuum pressure, 1999 V2: 253
air flow rates (QAR, QAIR), 2004 V1: 14
altitude and, 1999 V2: 258
at outlets, 2004 V1: 5
capacity, 2004 V1: 20, 33
cold-water systems, 1999 V2: 115, 121, 153
compressed air systems, 2000 V3: 212
air compressors, 2000 V3: 205
air-consuming devices, 2000 V3: 206–207
measurements, 2000 V3: 200
tools and equipment, 2000 V3: 208
conserving energy, 2004 V1: 126–127
conversion factors, 2004 V1: 37
diatomaceous earth filters, 2000 V3: 134, 139
domestic water supply, 2000 V3: 216
emergency showers and eyewashes, 2003 V4: 18
Energy Policy Act requirements, 2004 V1: 264
faucets, 2003 V4: 13
fire-protection demand, 2000 V3: 230–232
fixture drains, 2004 V1: 3
fixture requirements, 1999 V2: 129
flash steam, 2000 V3: 197
fluctuating flows in horizontal drains, 1999 V2: 5
fluid (QFL), 2004 V1: 14
fountain systems
displays, 2000 V3: 108–110, 115
filtration, 2000 V3: 110, 112
fuel-gas systems and boosters, 1999 V2: 178
fuel product dispensers, 2000 V3: 164–165
gas boosters, 1999 V2: 179, 180, 182
gas flow rates (QGA, QGAS), 2004 V1: 14, 1999 V2: 173
high-rate dispensers, 2000 V3: 169
hydrants, 2000 V3: 217
kitchen sinks, 2003 V4: 11
lavatories, 2003 V4: 10
liquid fuel piping, 2000 V3:169–170
measurements, 2004 V1: 33, 1999 V2: 253
medical air, 2000 V3: 74
medical gas, 2000 V3: 50–54
medical oxygen, 2000 V3: 74
medical vacuum, 2000 V3: 74, 79
natural gas systems, 1999 V2: 183, 2000 V3: 253
nitrogen, 2000 V3: 68, 74
nitrous oxide, 2000 V3: 74
pump capacity, 2004 V1: 6
rate of flow, calculating, 2004 V1: 1
reduced-pressure backflow devices, 1999 V2: 148
reducing for fixtures, 2004 V1: 134–135
resin bead regeneration, 1999 V2: 305
roof drainage in horizontal branches, 1999 V2: 88
sand filters, 2000 V3: 113, 132
showers, 2003 V4: 15
special-waste drainage systems, 1999 V2: 329
sprinkler hydraulic calculations, 2000 V3: 16

steam piping, 2000 V3: 182
submersible fuel pumps, 2000 V3: 170
swimming pool filtration, 2000 V3: 131, 139
urinals, 2003 V4: 10
vacuum cleaning systems, 1999 V2: 270, 271
vacuum exhauster sizing, 1999 V2: 274
vacuum systems, 1999 V2: 255–256, 262
water closets, 2003 V4: 8
water fountains, 2004 V1: 109
water heater types and, 1999 V2: 160
weirs and waterfalls, 2000 V3: 108, 109
flow restrictors, 2004 V1: 126
flow switches (FS), 2004 V1: 10, 2000 V3: 121
flow tests
equations, 2000 V3: 5
fire-protection systems, 2000 V3: 3–4
hydrants, 2000 V3: 217, 219
medical gas systems, 2000 V3: 81
flowing pressure. *See* residual pressure
flowing subsurface water, 1999 V2: 100
fluctuating flows in horizontal drains, 1999 V2: 5
flue gases
defined, 1999 V2: 213
temperatures, 1999 V2: 178
flues, 2004 V1: 25
fluid flow rates, 2004 V1: 14
Fluid Mechanics with Engineering Applications, 1999 V2: 19
fluoride, 1999 V2: 245, 284
fluorine, 1999 V2: 281
fluoroprotein-mixed chemical concentrates, 2000 V3: 21
flush controls
urinals, 2004 V1: 116
water closet and toilet accessibility, 2004 V1: 114
water closet requirements, 2004 V1: 116
flush sprinklers, 2004 V1: 29
flush tanks, acoustic design, 2004 V1: 195
flush valves. *See also* flushometer valves
wasted water and, 2004 V1: 136
water closet acoustic design, 2004 V1: 200
flushing
acoustic ratings of toilets, 2004 V1: 194
acoustic ratings of urinals, 2004 V1: 194
cold-water systems, 1999 V2: 154
Energy Policy Act requirements, 2004 V1: 264
gray water use, 2004 V1: 267
performance testing, 2003 V4: 5–6
resin beds, 1999 V2: 305
urinal tests, 2003 V4: 9
water closet system types, 2003 V4: 6–8
water conservation and toilets, 2003 V4: 3
water systems, 1999 V2: 252
flushing rims, 1999 V2: 16
flushing-type floor drains, 2004 V1: 25
flushometer tanks, 2003 V4: 3, 8
flushometer valves
back-siphonage and, 1999 V2: 14
defined, 2004 V1: 25, 2003 V4: 3, 8
sanitation and, 1999 V2: 16
urinals, 2003 V4: 10
flushometer water closets, 2003 V4: 3, 8
flux
in joints, 2004 V1: 266
membrane productivity, 1999 V2: 321
natural osmosis, 1999 V2: 308
standards, 2003 V4: 37
FM. *See* Factory Mutual Research Corporation (FM)
FMRC (Factory Mutual). *See* Factory Mutual Research Corporation (FM)
FO (film coefficients), 2004 V1: 14
foam extinguishing systems, 2000 V3: 21–22, 27
foam-water sprinkler heads, 2000 V3: 21
foaming in gray water, 1999 V2: 29
fog nozzles, 1999 V2: 332
fogging in swimming pools, 2000 V3: 129
Follow-up phase in value engineering, 2004 V1: 213
Fontana, Mars G., 2004 V1: 154
Food and Drug Administration (FDA), 1999 V2: 279, 321, 324, 328
food courts, numbers of fixtures for, 2003 V4: 19
food dyes in gray water, 1999 V2: 33
food-processing areas and kitchens
drains, 1999 V2: 16–17
grease interceptors, 1999 V2: 13
health-care facility fixtures, 2000 V3: 36
medical gas piping and, 2000 V3: 73
natural gas and, 1999 V2: 174
numbers of fixtures for, 2003 V4: 19
rates of sewage flows, 1999 V2: 237
sanitation, 1999 V2: 16
sewage estimates, 1999 V2: 235
typical gray-water demand, 1999 V2: 25
water fixture-unit values, 2000 V3: 217
water temperatures, 2000 V3: 45
food-processing plants
cross-flow hazards, 1999 V2: 147
pure water and, 1999 V2: 317
food waste grinders
acoustic ratings of, 2004 V1: 195
defined, 2004 V1: 22
discharges from, 1999 V2: 237
fixture-unit loads, 1999 V2: 3
sink outlets and, 2003 V4: 11
foot controls on faucets, 2000 V3: 33
foot or feet. *See* feet
foot pedals for nitrogen systems, 2000 V3: 68
foot-pounds (ft-lb, FT LB), 2004 V1: 14
foot valves, 2004 V1: 25, 2000 V3: 119
footing drains (subsoil drains, SSD), 2004 V1: 8, 30
footings of buildings
defined, 2004 V1: 25
water pipes and, 1999 V2: 251
FOR (fuel oil return), 2004 V1: 8
force
conversion factors, 2004 V1: 35
factors in seismic force calculations, 2004 V1: 183
measurements, 2004 V1: 33
in seismic design, 2004 V1: 188
force mains, 2000 V3: 234, 236–240, 241
forced-air vaporizers, 2000 V3: 61
forced distortions of piping, 2004 V1: 161
forced drainage (corrosion), defined, 2004 V1: 153
forcing functions in earthquakes, 2004 V1: 160
forcing pipes, 2003 V4: 25

formazin turbidity unit, 1999 V2: 287
forms. *See* checklists and forms
formula rooms, 2000 V3: 32
formulas. *See* equations
forward approaches and reaches
  approaches for wheelchairs, 2004 V1: 110
  drinking fountains and water coolers, 2004 V1: 109
  reach for wheelchairs, 2004 V1: 109, 111
FOS (fuel oil supply), 2004 V1: 8
fouling of water, 1999 V2: 289, 316
Foundation for Cross-Connection Control and Hydraulic Research, 2000 V3: 224
foundations of buildings, 1999 V2: 103, 231
foundations of pumps, 1999 V2: 243, 245
fountains
  controls, 2000 V3: 120–121
  discharge devices, 2000 V3: 119–120
  filtration systems, 2000 V3: 112–113
  gray water in, 1999 V2: 22
  lighting, 2000 V3: 121
  makeup-water systems, 2000 V3: 124–125
  overflow and drainage, 2000 V3: 125
  overview, 2000 V3: 107
  piping and valves, 2000 V3: 116–119
  pool design, 2000 V3: 107–111
    displays and flow rates, 2000 V3: 108–110
    general considerations, 2000 V3: 107–108
    inlets, outlets, and devices, 2000 V3: 110–111
    multilevel pools, 2000 V3: 108
  pumps, 2000 V3: 113–116
    display pumps, 2000 V3: 113–115
    filter pumps, 2000 V3: 115–116
  references, 2000 V3: 125–126
  systems and components, 2000 V3: 111–112
    display system, 2000 V3: 111
    illustrated, 2000 V3: 114
    lighting systems, 2000 V3: 112
    make-up water system, 2000 V3: 112
    overflow and drainage, 2000 V3: 112
    piping systems, 2000 V3: 111–112
    water-heating system, 2000 V3: 112
    water-treatment system, 2000 V3: 112
  valves, 2000 V3: 118–119
  water-heating equipment, 2000 V3: 121–122
  water-treatment systems, 2000 V3: 122–124
FOV (fuel oil vents), 2004 V1: 8
fp, FP (freezing points), 2004 V1: 14
fpm, FPM (feet per minute), 2004 V1: 14, 2000 V3: 29
fps, FPS (feet per second), 2004 V1: 14
FR (Federal Register), 2000 V3:88
fracture rooms, 2000 V3: 32, 36
framing drawings for facilities, 2000 V3: 31
Frankel, Michael, 1999 V2: 114, 277, 325, 350, 2000 V3: 173, 214
Franzini, Joseph B., 1999 V2: 19
fraternities and sororities, numbers of fixtures for, 2003 V4: 20
Frederick, Ralph H., 1999 V2: 114
free air
  defined, 2004 V1: 18, 2000 V3: 200
  properties, 2000 V3: 199
  water vapor in, 2000 V3: 200–201
free chlorine, 2000 V3: 149
free-floating oils, 2000 V3: 93
free oil, 1999 V2: 347
free residuals, 2000 V3: 146
free vibration, 2004 V1: 160
freeboard in ditches, 2000 V3: 248
freestanding lights for fountains, 2000 V3: 121
freestanding siamese fire-department connections, 2004 V1: 12
freestanding sprinkler heads in irrigation, 2000 V3: 102
freezing points (fp, FP), 2004 V1: 14, 2003 V4: 61
"freezing," preventing in cleanouts, 1999 V2: 9
freezing temperatures
  backflow preventers and, 1999 V2: 149
  buried water pipes and, 1999 V2: 251
  dry-pipe sprinkler systems and, 2000 V3: 9, 11
  fountains and, 2000 V3: 121–122
  frost lines, 2000 V3: 226
  gas piping and, 1999 V2: 196
  ice and oxygen storage, 2000 V3: 61
  ice inside water storage tanks, 1999 V2: 247
  irrigation system valves and, 2000 V3: 103
  leaching trenches and, 1999 V2: 222
  reduced-size venting and, 1999 V2: 50
  swimming pool maintenance and, 2000 V3: 131
  testing of cold-water systems, 1999 V2: 154
  water meters and, 1999 V2: 115
  well heads and, 1999 V2: 243
french drains, 2004 V1: 25
French, John L., 1999 V2: 38
frequencies (Hz, HZ)
  measurements, 2004 V1: 33
  symbols for, 2004 V1: 15
frequency of ion regeneration cycles, 1999 V2: 305
fresh-air inlets, 2004 V1: 25
friction clamps, 2000 V3: 229
friction connectors, 2004 V1: 189
friction factors, 2004 V1: 14
friction head, calculating, 2004 V1: 6
friction losses in flow
  calculating friction head loss, 2004 V1: 2
  compressed air, 2000 V3: 78, 210, 211
  counterflow piping designs, 2000 V3: 178
  fountain display pumps, 2000 V3: 115
  fuel dispensers, 2000 V3: 170
  Hazen-Williams formula, 2004 V1: 2, 1999 V2: 116, 118, 119, 121
  liquid fuel piping, 2000 V3:170
  medical air, 2000 V3: 68, 74, 78
  medical gas piping, 2000 V3: 73
  medical vacuum systems, 2000 V3: 74, 79
  natural gas systems, 1999 V2: 183, 2000 V3: 253
  nitrogen systems, 2000 V3: 74, 77
  nitrous oxide, 2000 V3: 74, 76
  oxygen, 2000 V3: 74, 76
  pipe pressure and, 1999 V2: 122–132
  pressure and, 1999 V2: 125, 130
  sizing of branches, 1999 V2: 127
  standpipe systems, 2000 V3: 19
  steam pipes, 2000 V3: 187
  submersible fuel pumps, 2000 V3: 170
  swimming pool gutters and, 2000 V3: 142

vacuum cleaning systems, 1999 V2: 271, 272–274, 275
vacuum exhauster sizing, 1999 V2: 274
valves and threaded fittings, 1999 V2: 128
water mains, 2000 V3: 8
water supply piping and, 1999 V2: 249
well pumps, 1999 V2: 245
front-end documents, 2004 V1: 63, 65
front-loading skimmers, 2000 V3: 110
frost. *See* freezing temperatures
frost lines, 2000 V3: 226
frost proof flare nuts, 1999 V2: 196
frostproof closets, 2004 V1: 25
FRP. *See* fiberglass-reinforced plastic
FS (federal specifications), 2004 V1: 25, 58
FS (flow switches), 2004 V1: 10
ft, FT (feet). *See* feet
ft-lb, FT LB (foot-pounds), 2004 V1: 14
ft^2 EDR, 2000 V3: 178, 180
ft^3 (cubic feet), 2004 V1: 14
FTUs (formazin turbidity units), 1999 V2: 287
fu values. *See* fixture units and unit values
fuel double containment systems, 2003 V4: 58
fuel gas codes, list of agencies, 2004 V1: 42
Fuel Gas Piping, 1999 V2: 214
fuel-gas piping systems. *See also* diesel-oil systems; gasoline systems
conversion factors, 1999 V2: 212
fuel gas, defined, 1999 V2: 213
glossary, 1999 V2: 213–214
liquefied petroleum gas, 1999 V2: 194, 196–197
methane, 2004 V1: 130
natural gas systems, 1999 V2: 173–194, 2003 V4: 35, 36
values of fuel gas, 1999 V2: 212
fuel loads (fire hazards), 2000 V3: 2
fuel oil
copper pipe, 2003 V4: 35
fuel oil return (FOR), 2004 V1: 8
fuel oil supply (FOS), 2004 V1: 8
fuel oil vents (FOV), 2004 V1: 8
pipe bracing, 2004 V1: 166, 167
full-flow conditions (FF), 2004 V1: 1
full-port ball valves, 2000 V3: 72
fully-sprinklered spaces, 2004 V1: 12
fume hoods, 1999 V2: 334, 342
fumes, hazardous. *See also* gases
acid-waste drainage systems, 2000 V3: 39
acids, 1999 V2: 332, 333
filter cleaners, 2000 V3: 150
in soil profiles, 2000 V3: 162
vent piping, 2000 V3: 42
VOCs, 1999 V2: 284
fuming grade sulfuric acid, 1999 V2: 332
Function Analysis phase in value engineering
defined, 2004 V1: 224
FAST approach, 2004 V1: 227–231
function definitions forms, 2004 V1: 225–227, 228
in process, 2004 V1: 213
rules, 2004 V1: 225
Function phase in value engineering, 2004 V1: 213
Functional Analysis System Technique (FAST), 2004 V1: 227–231
functions
basic or secondary, 2004 V1: 225
comparing in evaluation phase, 2004 V1: 243
cost-to-function relationship, 2004 V1: 225
defined, 2004 V1: 224
evaluation checklists, 2004 V1: 237–241
in evaluation phase, 2004 V1: 235
in FAST approach, 2004 V1: 230
interrelationships, 2004 V1: 227
levels of importance, 2004 V1: 225
ranking and comparing, 2004 V1: 243
sketches of, 2004 V1: 237, 239–240
specific and dependent, 2004 V1: 225
two-word expressions, 2004 V1: 225
fundamental corrosion cells, defined, 2004 V1: 139
Fundamentals Handbook, 2000 V3: 197
Fundamentals of Underground Corrosion Control, 2004 V1: 154
fungi, 1999 V2: 282, 289
funnel-type collectors for backflow devices, 1999 V2: 148
funnel-type drains, 1999 V2: 346, 2000 V3: 39
furring-out requirements for roofs, 1999 V2: 79, 81
fusible link sprinklers, 2000 V3: 9
Fusion-Bonded Epoxy Coating, 2003 V4: 32
fusion-joint plastic piping systems, 2000 V3: 42
future expansion of compressed air systems, 2000 V3: 210
future expansion of water systems, 1999 V2: 249
FV (face velocity), 2004 V1: 14
fvel, FVEL (face velocity), 2004 V1: 14

G

G (giga) prefix, 2004 V1: 34
G (low-pressure gas), 2004 V1: 8
g, G (gravitational constants), 2004 V1: 15
G pipes, 2003 V4: 36
ga, GA (gauges). *See* gauges
Gabrielson, M. Alexander, 2000 V3: 151
GACs (granulated carbon filters), 1999 V2: 318, 323. *See also* activated carbon filtration
GAGE (gages). *See* gages
gages (ga, GA, GAGE). *See also* gauges
cast iron radiators, 2000 V3: 180
defined, 2004 V1: 15
pressure, 2000 V3: 200
gal, GAL (gallons). *See* gallons (gal, GAL)
galleries, numbers of fixtures for, 2003 V4: 19
gallons (gal, GAL)
converting to metric units, 2000 V3: 29
converting to SI units, 2004 V1: 39
gallons per day (gpd, GPD), 2004 V1: 15
gallons per hour (gph, GPH), 2004 V1: 15, 39
gallons per minute (gpm), 1999 V2: 120, 124, 126, 240
converting to fixture units, 2000 V3: 218, 234
converting to metric units, 2000 V3: 29
fountains, 2000 V3: 115
grains per gallon (gpg), 1999 V2: 285
standard gallons per hour (std gph, SGPH), 2004 V1: 15
symbols for, 2004 V1: 15
galvanic action, 2004 V1: 25. *See also* electrolysis
galvanic anodes, 2004 V1: 147–150
galvanic cells, defined, 2004 V1: 153

galvanic corrosion, 2004 V1: 141, 153, 1999 V2: 290
galvanic series of metals
defined, 2004 V1: 153
dielectric insulation and, 2004 V1: 146
listing, 2004 V1: 141
galvanized coatings for corrosion prevention, 2004 V1: 147
galvanized-iron joints, 1999 V2: 222
galvanized-iron piping, 1999 V2: 14, 136
galvanized pipe fittings, 2003 V4: 48
galvanized-steel filters, 2000 V3: 131
galvanized-steel piping
aboveground piping, 1999 V2: 14, 68
fountains and, 2000 V3: 116
fuel product dispensing and, 2000 V3: 169
liquefied petroleum gas, 1999 V2: 196
vacuum systems, 1999 V2: 262
galvanizing, defined, 2004 V1: 25
galvomag alloy, 2004 V1: 144
gamma ray radiation, 1999 V2: 337, 338, 339
garbage disposers. *See* food waste grinders
garnet in filters, 1999 V2: 300
gas. *See* gases; medical-gas systems; natural gas systems; *specific types of gases*
Gas and Vacuum Systems, 2003 V4: 45
gas boosters
design considerations, 1999 V2: 180–182
gas laws, 1999 V2: 179
glossary, 1999 V2: 182–183
heat exchanger loop systems, 1999 V2: 181, 182
high-rise buildings, 1999 V2: 180
materials and components, 1999 V2: 179
overview, 1999 V2: 178–183
simplex and dual gas booster systems, 1999 V2: 181
sizing, 1999 V2: 182–183
gas chlorinators
disinfecting swimming pools, 2000 V3: 148
iron removal, 2000 V3: 147
gas-fired water heaters
conserving energy, 2004 V1: 129
defined, 2004 V1: 129–130
fountains, 2000 V3: 121
instantaneous heaters, 2004 V1: 265
net efficiency of, 2004 V1: 130
swimming pools, 2000 V3: 138
gas flow rates, 2004 V1: 14, 1999 V2: 173
gas laws, 1999 V2: 179
gas logs, defined, 1999 V2: 213
gas piping codes, 2004 V1: 42
gas piping systems. *See also* fuel-gas piping systems; gasoline systems; liquefied petroleum gas; natural gas systems
bracing, 2004 V1: 167
defined, 2004 V1: 191
gas cocks, 2004 V1: 9
gas line earthquake-sensitive valves, 2004 V1: 162
gas main inspection checklist, 2004 V1: 103
gas pressure regulators, 1999 V2: 214, 2000 V3: 250–252
gas stops (gas cocks), 2004 V1: 9
gas-train vents, 1999 V2: 177, 213
gas trains, 1999 V2: 213, 2000 V3: 251
gas turrets, 1999 V2: 177
gas vents (GV), 2004 V1: 8, 1999 V2: 213
high-pressure (HG), 2004 V1: 8
line filters, 2000 V3: 250
low-pressure (G), 2004 V1: 8
medium-pressure (MG), 2004 V1: 8
plastic pipes, 2003 V4: 58
services at laboratory outlets, 2000 V3: 37–39
Spitzglass formula, 2004 V1: 7
gas stations, 2000 V3: 166, 2003 V4: 20
gas stripping, 1999 V2: 288
gas-transfer vacuum pumps, 1999 V2: 259
gaseous chlorine, 2000 V3: 123
gaseous fire-suppression systems, 2000 V3: 22–25
gases. *See also* fuel-gas piping systems; liquefied petroleum gas; natural gas systems
as fluids, 2000 V3: 199
contamination in compressed air, 2000 V3: 201
dissolved gases in water, 1999 V2: 284
forcing upward through terminal stack, 1999 V2: 36
hazardous, 1999 V2: 332
nitrous fumes, 1999 V2: 333
preventing concentration with vents, 1999 V2: 35
sulfuric acid, 1999 V2: 333
volatile organic compounds, 1999 V2: 284
gaskets
fire-protection water supply, 2000 V3: 228–229
fuel piping, 2000 V3: 169
special-waste systems, 1999 V2: 328
gasoline, 1999 V2: 13, 2000 V3: 154, 168
gasoline blends, 2000 V3: 154, 168
gasoline systems
aboveground tank systems, 2000 V3: 165–169
connections and access, 2000 V3: 166
construction, 2000 V3: 165
corrosion protection, 2000 V3: 165
filling and spills, 2000 V3: 166–167
leak prevention and monitoring, 2000 V3:167–168
materials, 2000 V3: 165
overfill prevention, 2000 V3:167
product dispensing systems, 2000 V3:168
tank protection, 2000 V3:169
vapor recovery, 2000 V3:168
venting, 2000 V3:167
codes and standards, 2000 V3: 154
components, 2000 V3: 155
definitions and classifications, 2000 V3: 153–154
designing
installation considerations, 2000 V3:172–173
piping materials, 2000 V3:169
piping sizing, 2000 V3:169–170
submersible pump sizing, 2000 V3:170
testing, 2000 V3:170–172
overview, 2000 V3: 153
references, 2000 V3:173
resources, 2000 V3:173
underground tank systems, 2000 V3: 155–165
leak detection and system monitoring, 2000 V3: 158–163
product dispensing systems, 2000 V3: 163–165
storage tanks, 2000 V3: 155–158
vapor recovery systems, 2000 V3: 163
gate valves (GV), 2004 V1: 9, 1999 V2: 332

gauge pressure, 2000 V3: 200
gauge taps, 2000 V3: 115
gauges (ga, GA, GAGE). *See also* gages (ga, GA, GAGE)
  fuel product level gauging, 2000 V3: 167, 168
  gauge pressure, 1999 V2: 253, 254
  hazardous materials, 2000 V3: 90
  medical gas systems, 2000 V3: 72
  symbols for, 2004 V1: 15
  vacuum systems, 1999 V2: 260
gear journals, 2004 V1: 196
gear pumps, 1999 V2: 247
gearbox silencing enclosures, 2004 V1: 197
gears, acoustic problems, 2004 V1: 196
Geiger-Mueller counters, 1999 V2: 339
gel-coated plastic fixtures, 2003 V4: 2
general conditions in contract documents, 2004 V1: 62
General Conditions of the Contract for Construction, 2004 V1: 62
General Conference of Weights and Measures (CGPM), 2004 V1: 32
general corrosion, 2004 V1: 153, 1999 V2: 289–290
General Electric Company, 2004 V1: 211
general laboratory-grade water, 1999 V2: 317
General phase in value engineering, 2004 V1: 213
General section in specifications, 2004 V1: 68
General Services Administration (GSA), 2004 V1: 263
General Storage (NFPA 231), 2000 V3: 2, 29
generalized total costs, 2004 V1: 223
generally-accepted standards, defined, 2004 V1: 25
Geogehegan, R.F., 1999 V2: 350
geography
  cost estimates and, 2004 V1: 98
  in plumbing cost estimation, 2004 V1: 94
geological stability of sites, 1999 V2: 26
geothermal energy, 2004 V1: 131
geothermal heat pumps, 1999 V2: 243
Get Your Process Water to Come Clean, 1999 V2: 325
GFCI (government furnished, contractor installed), 2004 V1: 71
"giga" prefix, 2004 V1: 34
glass borosilicate piping, 1999 V2: 14, 15, 122
glass-bulb sprinklers, 2000 V3: 9
glass-lined pipes, 2000 V3: 48
glass piping
  characteristics, 2003 V4: 45–48
  expansion, 2003 V4: 48
  fittings, 2003 V4: 48, 49–50
  special wastes, 1999 V2: 334, 341
glass washers
  demineralized water, 2000 V3: 46
  health-care facilities, 2000 V3: 32, 36
  heat recovery systems, 2004 V1: 266
  laboratory rooms, 2000 V3: 37
  pure water systems for, 2000 V3: 46
glazed fixture surfaces, 2003 V4: 1
Glidden, R., 1999 V2: 277
globe valves (GLV), 2004 V1: 9
glossaries
  acoustics in plumbing systems, 2004 V1: 206–210
  conserving energy, 2004 V1: 136–137
  corrosion, 2004 V1: 151–154
  fuel-gas systems, 1999 V2: 213–214
  gas boosters, 1999 V2: 182–183
  health-care facilities, 2000 V3: 83–86
  industrial wastewater, 2000 V3: 88
  measurement units, 2004 V1: 32
  plumbing terminology, 2004 V1: 17–31
  pressure-regulating valves, 1999 V2: 152
  references for, 2004 V1: 40
  seismic protection, 2004 V1: 191
  vents and venting, 1999 V2: 64
glove boxes, 1999 V2: 342, 343
GLSP (good large-scale production), 1999 V2: 343
glues, 1999 V2: 284
GLV (globe valves), 2004 V1: 9
gold, 2004 V1: 141
Gold-level LEED certification, 2004 V1: 263
golf clubs, 1999 V2: 237
good engineering practice, 1999 V2: 329
good large-scale production (GLSP), 1999 V2: 343
"good value," defined, 2004 V1: 213
goods, costs of, 2004 V1: 222
gooseneck spouts, 2003 V4: 14
Gorry, M., 1999 V2: 325
governing fixtures, 1999 V2: 125, 129
government furnished, contractor installed (GFCI), 2004 V1: 71
gpd, GPD (gallons per day), 2004 V1: 15
gpg (grains per gallon), 1999 V2: 285
gph, GPH (gallons per hour), 2004 V1: 15
gph, standard (std gph, SGPH), 2004 V1: 15
gpm (gallons per minute)
  converting to fixture units, 1999 V2: 120, 124, 126, 2000 V3: 218, 234
  converting to metric units, 2000 V3: 29
  fountains, 2000 V3: 115
  orifice size and, 2000 V3: 7
  wells, 1999 V2: 240
gr, GR (grains). *See* grains
grab bars
  ambulatory accessible toilet compartments, 2004 V1: 115
  bathtub accessibility, 2004 V1: 117
  clearance, 2004 V1: 122
  health care facilities, 2000 V3: 34
  shower stalls, 2004 V1: 121–122
  standards for, 2004 V1: 114–122
  water closet and toilet accessibility, 2004 V1: 114
grades
  defined, 2004 V1: 25
  maintaining for piping, 2003 V4: 25
grain size, 2000 V3: 132
grains (gr, GR)
  converting to SI units, 2004 V1: 39
  grains per gallon, 1999 V2: 285
  symbols for, 2004 V1: 15
grandstands, numbers of fixtures for, 2003 V4: 19
granular filters
  compared to diatomaceous earth filtration, 2000 V3: 135–137
  overview, 2000 V3: 132–134
  swimming pool usage, 2000 V3: 131–134
  types of, 2000 V3: 139

granulated carbon filters, 1999 V2: 318, 323. *See also* activated carbon filtration
granule tests, 2003 V4: 5
graphic annunciators, 2000 V3: 24
graphic conventions in plumbing drawings, 2004 V1: 108
graphite, 2004 V1: 141
graphite anodes, 2004 V1: 150
graphitic corrosion, 2004 V1: 153
graphitization
  cast iron, 2004 V1: 141
  defined, 2004 V1: 153
graphs, water supply, 2000 V3: 5, 6
grate-type inlets in site storm systems, 1999 V2: 98
grates
  anti-vortex grating, 2000 V3: 110
  buffing, 1999 V2: 11
  grate open areas for floor drains, 1999 V2: 10
  materials for, 1999 V2: 14
  on swimming pool drains, 2000 V3: 143
  sanitary drainage systems, 1999 V2: 10–12
gravel filters, 2000 V3: 132
gravels
  fill above subsurface drainage pipes, 1999 V2: 103
  gray-water irrigation systems and, 1999 V2: 26, 27
gravimetric measurement of solids, 1999 V2: 287
gravitational acceleration units, 2004 V1: 1
gravitational constants (*g*,

GSA (General Services Administration), 2004 V1: 263
GSA Guide Specification Number 3-1515-71 (Public Building Service), 2004 V1: 199
GTD (greatest temperature difference), 2004 V1: 15
guaranty bonds, 2004 V1: 62
guard posts for hydrants, 2000 V3: 228, 229
A Guide to Airborne, Impact and Structure-Borne Noise Control in Multifamily Dwellings, 2004 V1: 199
guide-vane tips, acoustic modifications, 2004 V1: 197
Guidelines for Seismic Restraints of Mechanical Systems, 2004 V1: 191
Gut Feel Index, 2004 V1: 254
gutters (pools)
  drains, 2000 V3: 142
  filtration and, 2000 V3: 137
  skimmers and, 2000 V3: 137
  surge tanks and, 2000 V3: 137
gutters (roofs), 1999 V2: 81, 86
gutters (street), 1999 V2: 99
GV (gas vents), 2004 V1: 8, 1999 V2: 213
GV (gate valves), 2004 V1: 9, 1999 V2: 332
gymnasiums, numbers of fixtures for, 2003 V4: 19
gypsum board, lining with lead, 1999 V2: 340

H

H (enthalpy), 2004 V1: 14
h (hecto) prefix, 2004 V1: 34
H (henrys), 2004 V1: 33
h (hours), 2004 V1: 15, 34
h (velocity head), 2004 V1: 5
H-I alloy, 2004 V1: 144
H/m (henrys per meter), 2004 V1: 33
ha (hectares), 2004 V1: 34
hair strainers, 2000 V3: 150
HALAR piping, 2000 V3: 48
half-circle rotary sprinkler heads, 2000 V3: 102
half-dome ends on tanks, 2000 V3: 156
half-full conditions (HF), 2004 V1: 1
half lives, defined, 1999 V2: 340
halogenated agents, 2000 V3: 22, 27, 70, 83
halon 1211, 2000 V3: 22
halon 1301, 2004 V1: 25, 2000 V3: 22
Halon 1301 Fire Extinguishing Systems (NFPA 12A), 2000 V3: 23, 29
halon system types, 2004 V1: 25–26
halothane, 2000 V3: 70
hammer. *See* water hammer
hand-held extinguishers, 2000 V3: 19, 20
hand-held shower heads, 2004 V1: 120
hand tools for vacuum cleaning systems, 1999 V2: 269–270
hand trenching, labor productivity rates, 2004 V1: 95–97
Handbook for Mechanical Engineers, 2004 V1: 2, 3, 5, 40
Handbook of Chlorination, 1999 V2: 155
Handbook of Corrosion Resistant Pipeline, 2000 V3: 97
Handbook of Fundamentals, 2004 V1: 2, 5, 6, 40
Handbooks (ASHRAE), 1999 V2: 214
handicapped individuals. *See* people with disabilities
handling section in specifications, 2004 V1: 70, 89–90
hands-free controls on sinks, 2000 V3: 33, 34
handwashing lavatories, 2000 V3: 32, 36, 45
hangers. *See* supports and hangers
hard conversions, 2004 V1: 32
hard-temper tubing, 1999 V2: 14, 68, 2000 V3: 73
hardness of water
  boiler feed water, 1999 V2: 314
  degrees of hardness, 1999 V2: 283
  ion exchange treatment, 1999 V2: 300
  pH and alkalinity, 1999 V2: 293
  private water systems, 1999 V2: 244
  swimming pools and, 2000 V3: 147
  water softener treatments, 1999 V2: 307–308
Harris, Nigel, 1999 V2: 277
Hastelloy B, 1999 V2: 333
Hastelloy C, 2004 V1: 141, 144
hazardous materials, emergency fixtures and, 2003 V4: 17
hazardous wastes
  defined, 2000 V3: 88
  permits, 2000 V3: 89
hazards
  accidental acid spills, 1999 V2: 332
  asbestos, 2003 V4: 26
  backflow prevention, 1999 V2: 145, 146
  chemical material safety data sheets, 2000 V3: 90
  classes of hazard occupancies, 2004 V1: 29, 2000 V3: 17
  cold-water systems, 1999 V2: 115
  controlled substance spills, 1999 V2: 277
  diatomaceous earth filters, 2000 V3: 134
  exposed piping and accessibility, 2004 V1: 117
  fire hazards, 2004 V1: 24, 2000 V3: 2–3
  flammable and volatile liquids, 1999 V2: 347–349
  gas appliances, 1999 V2: 178
  gas boosters, 1999 V2: 179
  gases in septic tanks, 1999 V2: 230
  gray-water systems, 1999 V2: 32–33
  hazardous gases, 1999 V2: 332
  hazardous materials, defined, 2000 V3: 88
  hazardous substances, defined, 2000 V3: 88
  hazardous wastes, defined, 2000 V3: 88
  hot-water systems, 1999 V2: 157, 169–170
  liquefied petroleum gas, 1999 V2: 194, 197
  plumbing systems and, 2004 V1: 266
  radiation, 1999 V2: 337–338
  radioactive waste-drainage systems, 1999 V2: 341
  sanitary precautions for wells, 1999 V2: 243
  types of acids, 1999 V2: 332–334
  vacuum cleaning system issues, 1999 V2: 276
Hazen-Williams formula
  chart explanation, 1999 V2: 121
  charts, 1999 V2: 118, 119
  defined, 2004 V1: 2, 1999 V2: 7
  friction losses, 1999 V2: 116, 2000 V3: 118
HB (hose bibbs), 2004 V1: 10, 1999 V2: 121
HCFCs (hydrochlorofluorocarbons), 2000 V3: 22
hd, HD (head). *See* pressure (PRESS, PRES, P)
HDPE (high density polyethylene), 2000 V3: 252, 254, 2003 V4: 58, 61
head (hd, HD). *See* pressure (PRESS, PRES, P)
head loss. *See* pressure drops or differences (PD, DELTP)
head walls on culverts, 1999 V2: 99
header systems, 1999 V2: 127
headroom around pipes, 2003 V4: 25
headwall gas systems, 2000 V3: 56–57
health-care facilities

defined, 2000 V3: 84
drainage systems, 2000 V3: 39–42
acid-waste metering, 2000 V3: 41–42
acid-waste solids interceptors, 2000 V3: 41, 43
acidic-waste neutralization, 2000 V3: 40–41
discharge to sewers, 2000 V3: 40
sink traps, 2000 V3: 42
waste and vent piping, 2000 V3: 42
fixtures and equipment, 2000 V3: 31–39
general requirements, 2000 V3: 33
kitchens and laundries, 2000 V3: 36
laboratory rooms, 2000 V3: 37–39
numbers of fixtures for, 2003 V4: 20
selection process, 2000 V3: 31–34
special equipment, 2000 V3: 39
for specific areas, 2000 V3: 33–36
unique fixtures, 2000 V3: 37, 38
glossary, 2000 V3: 83–86
medical gas and vacuum systems, 2000 V3: 49–83
certification, 2000 V3: 77–83
codes and standards, 2000 V3: 83
design checklist, 2000 V3: 49–50
dispensing equipment, 2000 V3: 54–59
gas flow rates, 2000 V3: 50–54
gas storage, 2000 V3: 59–68
number of stations, 2000 V3: 50
piping, 2000 V3: 73–77
system control valves, 2000 V3: 71–72
vacuum systems, 2000 V3: 54, 68–70
warning systems, 2000 V3: 72–73
waste anesthetic gas management, 2000 V3: 70–71
plumbing overview, 2000 V3: 32
references, 2000 V3: 86
resources, 2000 V3: 86
water-supply systems, 2000 V3: 43–48
non-potable water, 2000 V3: 45
potable water, 2000 V3: 45
pure-water systems, 2000 V3: 46–48
Health-Care Facilities (NFPA 99), 2000 V3: 50, 56, 66–67, 68, 77
health hazards. *See* hazards
hearing disabilities, 2004 V1: 107
heart-and-lung machines, 2000 V3: 39
heat (HT)
compression, 2000 V3: 204
conversion factors, 2004 V1: 36
heat detectors, 2000 V3: 25
latent, 2004 V1: 15, 137
measurements, 2004 V1: 33
protecting against, 1999 V2: 19
sensible, 2004 V1: 16, 137
symbols for, 2004 V1: 15
water-heater heat recovery, 1999 V2: 158–159
heat-activated air dryers, 2000 V3: 204
heat-actuated devices (H.A.D), 2000 V3: 13
heat distortion of plastic pipe, 2003 V4: 60
Heat Exchange Institute, 1999 V2: 265
heat exchangers and exchange systems
air dryers, 2000 V3: 204
corrosion inhibitors, 2004 V1: 151
geothermal energy, 2004 V1: 131
in green building, 2004 V1: 266
heat exchanger loop gas booster systems, 1999 V2: 181, 182
mineral deposits and, 2000 V3: 147
swimming pools, 2000 V3: 138
vibration isolation, 2004 V1: 205
waste heat usage, 2004 V1: 131–134
heat fusion joints
heat-fused socket joints, 1999 V2: 334
PEX piping, 2003 V4: 61
special wastes and, 2000 V3: 40
heat gain (HG, HEATG)
latent (LHG, HGL), 2004 V1: 15
sensible (SHG, HGS), 2004 V1: 15, 16
symbols for, 2004 V1: 15
heat loss (HL, HEATL)
defined, 2004 V1: 15
heat loss retardants, 2000 V3: 150
swimming pools, 2000 V3: 144
water heater energy savings and, 2004 V1: 265
water heater location and, 2004 V1: 129
heat pumps, waste heat usage, 2004 V1: 134
heat recovery systems, 2004 V1: 134, 266
heat-trace systems, 1999 V2: 165–166
heat transfer (Q)
condensate drainage and, 2000 V3: 189
heat transfer coefficients (*U,* U), 2004 V1: 15
symbols for, 2004 V1: 15
heat-up method of condensate drainage, 2000 V3: 191
heated water. *See* hot-water systems
heaters (HTR), 2004 V1: 15. *See also* water heaters
HEATG (heat gain). *See* heat gain
heating engineers, 2000 V3: 27–28
heating feed water
for microbial control, 1999 V2: 312
for pure water systems, 1999 V2: 322
heating hot water return (HHWR), 2004 V1: 9
heating hot water supply (HHWS), 2004 V1: 9
heating systems. *See* HVAC systems
heating values of natural gas, 1999 V2: 173, 212, 214
heating, ventilation, and air-conditioning systems. *See* HVAC systems
heating water. *See* water heaters
HEATL (heat loss), 2004 V1: 15
heavy clay loams, 2000 V3: 100
heavy equipment earthquake recommendations, 2004 V1: 163
heavy metals, 2000 V3: 95
heavy process gas service, 2000 V3: 249
hectares, 2004 V1: 34
"hecto" prefix, 2004 V1: 34
heel inlets on traps, 1999 V2: 16
heel-proof grates, 1999 V2: 10
heel-proof strainers, 1999 V2: 80
height (hgt, HGT, HT)
of fountains, 2000 V3: 120
grab bars for accessibility, 2004 V1: 114
laundry equipment, 2004 V1: 123
sinks, 2004 V1: 117
symbols for, 2004 V1: 15
toilet seats, 2004 V1: 114
helium, 2000 V3: 56
Henriques, F.C., Jr., 1999 V2: 169, 170

henrys, 2004 V1: 33
henrys per meter, 2004 V1: 33
HEPA filters, 1999 V2: 268, 345
heptafluorocarbons (HFCs), 2000 V3: 22
heptafluoropropane, 2000 V3: 22
herbicides, 1999 V2: 230
hermetic gas boosters, 1999 V2: 179
hertz, 2004 V1: 33, 206
Hesser, Henry H., 1999 V2: 277
hexametaphosphate, 1999 V2: 244
HF (half-full conditions), 2004 V1: 1
HFCs (heptafluorocarbons), 2000 V3: 22
HG (heat gain). *See* heat gain
Hg, HG (mercury), 2004 V1: 15
HG (high-pressure gas), 2004 V1: 8
HGL (latent heat gain), 2004 V1: 15
HGS (sensible heat gain), 2004 V1: 15, 16
hgt, HGT (height). *See* height
HHWR (heating hot water return), 2004 V1: 9
HHWS (heating hot water supply), 2004 V1: 9
HI (film coefficients), 2004 V1: 14
Hicks, Tyler G., 1999 V2: 114
high-backflow hazard, 2000 V3: 222
high-capacity wells, 1999 V2: 240
high-density polyethylene (HDPE), 2000 V3: 252, 254
high-efficiency water heaters, 2004 V1: 265, 267
high-energy beta radiation, 1999 V2: 337
high-expansion foam extinguishers, 2000 V3: 21
high-hazard fires, 2000 V3: 16
high-hose retrievers, 2000 V3: 165
high-level water tank alarms, 1999 V2: 151, 2000 V3: 90
high-piled storage, 2000 V3: 230
high-pressure carbon dioxide systems, 2000 V3: 20–21
high-pressure condensate (HPC), 2004 V1: 9
high-pressure cylinders, 2000 V3: 49
high-pressure gas (HG), 2004 V1: 8
high-pressure nitrogen systems, 2000 V3: 68
high-pressure piping, 2000 V3: 196–197
high-pressure steam (hps, HPS), 2004 V1: 9, 15, 2000 V3: 175, 182
high-pressurization air drying, 2000 V3: 203–204
high-purity water. *See* water purification
high-radiation areas, 1999 V2: 339, 341
high-rate dispensers, 2000 V3: 169
high-rate filters, 2000 V3: 113, 132
high-rise buildings, 1999 V2: 180, 195
High-rise Plumbing, 1999 V2: 114
high-silicas cast iron piping, 1999 V2: 14, 15, 2000 V3: 40, 42
high-silicon iron anodes, 2004 V1: 150
high-suds detergents, 1999 V2: 36–37, 39
High Temperature Condensate Return (TES 582), 2000 V3: 197
high-temperature hot water (hthw, HTHW), 2004 V1: 15
high-temperature withstand, 1999 V2: 166
high-to-low pressure loss in vacuum systems, 1999 V2: 263
high vacuum, 1999 V2: 262
high-velocity filters, 2000 V3: 139
high-velocity fixtures, acoustic design and, 2004 V1: 195
high-velocity jetted well digging, 1999 V2: 241
high-volume sprinklers in irrigation, 2000 V3: 100
highest order functions, 2004 V1: 227
Hillman, 2004 V1: 191
hip baths, 2000 V3: 35
history
  of earthquake damage, 2004 V1: 161–163
  of fire-protection systems, 2000 V3: 1–2
HL (heat loss), 2004 V1: 15
HO (film coefficients), 2004 V1: 14
Hodnott, Robert M., 2004 V1: 191
Hoffman Industries, 1999 V2: 277
Hoffman Steam Heating Systems Design Manual and Engineering Data (TES 181), 2000 V3: 197
hoists for immersion baths, 2000 V3: 35
hold-down straps on storage tanks, 2000 V3: 172
holding rooms, 2000 V3: 58
holes
  in coatings, 2004 V1: 147
  for perc tests, 1999 V2: 219
holidays
  in coatings, 2004 V1: 147, 2000 V3: 172
  in labor costs, 2004 V1: 94
hollow-fiber modules
  in cross-flow filtration, 1999 V2: 311
  in reverse osmosis, 1999 V2: 289, 309
homogeneity in rate of corrosion, 2004 V1: 145
horizontal branches
  branch intervals, 1999 V2: 64
  defined, 1999 V2: 64
  laboratory gas piping, 1999 V2: 177
  roof drainage, 1999 V2: 88
  sovent systems, 1999 V2: 57–60
  storm drainage calculation form, 1999 V2: 110
horizontal drains
  cross-sections of, 1999 V2: 2
  fixture loads, 1999 V2: 7, 9
  flow in, 1999 V2: 2
  hydraulic jumps in, 1999 V2: 6
  minimum slope of piping, 1999 V2: 7
  sloping drains in sanitary drainage systems, 1999 V2: 5–9
  steady flow in, 1999 V2: 6–7
horizontal filters, 2000 V3: 131
horizontal loads of piping, 2004 V1: 184, 185–186
horizontal pressure-media filters, 1999 V2: 300
horizontal pumps
  centrifugal, 2000 V3: 140
  defined, 2004 V1: 24
  split-case pumps, 2004 V1: 24, 2000 V3: 25, 115, 142
horizontal wet-vented systems, 1999 V2: 45–46
horsepower (hp, HP)
  air horsepower (ahp, AHP), 2004 V1: 14
  brake horsepower (bhp, BHP), 2004 V1: 6, 14
  converting to SI units, 2004 V1: 39
  indicated horsepower (ihp, IHP), 2004 V1: 15
  shaft horsepower (sft hp, SFT HP, SHP), 2004 V1: 16
  symbols for, 2004 V1: 15
hose bibbs (HB), 2004 V1: 10, 1999 V2: 121, 2000 V3: 36, 2003 V4: 25
hose demand, 2000 V3: 17
hose outlets, 2004 V1: 12
hose stations, dry, 2004 V1: 13, 2000 V3: 27
hose streams in firefighting, 2000 V3: 230
hose thread outlets, 2003 V4: 14

hose valves, 2000 V3: 18
hoses
bed pans, 2000 V3: 38
compressed air pipe sizing, 2000 V3: 210
flexible gas hoses, 1999 V2: 196
fuel dispensers, 2000 V3: 165
medical gas tubing, 2000 V3: 77
retrievers, 2000 V3: 165
vacuum cleaning hose capacity, 1999 V2: 270
vacuum cleaning hose materials, 2000 V3: 146
vacuum cleaning systems. *See* tubing
hosing out cartridge filters, 2000 V3: 113
hospitals, 1999 V2: 16, 147, 2003 V4: 20, 21. *See also* health-care facilities
hot fluids, glass piping and, 2003 V4: 47
hot-vapor atmospheric vents, 2004 V1: 9
hot-water heat exchangers, 2000 V3: 121
hot water recirculating (HWR), 2004 V1: 8, 265
hot-water returns, 2004 V1: 8
hot-water supply (HW)
heating hot water supply, 2004 V1: 8
potable water, 2000 V3: 45
symbols for, 2004 V1: 8
hot-water systems
avoiding standby losses, 2004 V1: 127
circulation systems, 1999 V2: 165
codes and standards, 1999 V2: 170
components, 1999 V2: 166
conserving energy, 2004 V1: 124–125, 127, 128
corrosion rates, 2004 V1: 145
earthquake damage, 2004 V1: 162
equations, 1999 V2: 158
exposed piping and accessibility, 2004 V1: 117
heat exchangers, 2000 V3: 121
hot water properties, 1999 V2: 168
hot-water temperatures, 2004 V1: 120, 1999 V2: 159, 161–165, 2000 V3: 36, 45, 139
insulation, 1999 V2: 166
introduction, 1999 V2: 157–158
maintaining temperatures, 1999 V2: 165
mixed-water temperatures, 1999 V2: 159–160
natural gas heating, 1999 V2: 174
pipe codes, 2004 V1: 45
pipe vibration isolation, 2004 V1: 205
relief valves, 1999 V2: 166–167
safety and health concerns, 1999 V2: 169–170
scalding water, 1999 V2: 169–170
thermal efficiency, 1999 V2: 169
thermal expansion, 1999 V2: 167–168
types of domestic systems, 2004 V1: 129–134
waste heat usage, 2004 V1: 131–134
water heater heat recovery, 1999 V2: 158–159
water heaters, 1999 V2: 160–165
hot-water temperatures
accessible shower compartments, 2004 V1: 120
charts, 1999 V2: 161–164
health-care facilities, 2000 V3: 36, 45
high-temperature hot water, 2004 V1: 15
maintaining temperatures, 1999 V2: 165
mixed-water temperatures, 1999 V2: 159–160
scalding water, 1999 V2: 169–170
swimming pools, 2000 V3: 139
hotels
acoustic plumbing design for, 2004 V1: 196
numbers of fixtures for, 2003 V4: 20
septic tank/soil-absorption systems for, 1999 V2: 231–232
vacuum calculations for, 1999 V2: 269
hours (h, HR), 2004 V1: 15, 34
house drains. *See* building drains
housed-spring mountings, 2004 V1: 204
houses. *See* buildings
housing project sewers, 1999 V2: 231–232
housings for gas boosters, 1999 V2: 179
housings for gas filters, 2000 V3: 250
HOW logic path, 2004 V1: 230, 231
How to Design Spencer Central Vacuum Cleaners, 1999 V2: 277
hp, HP (horsepower). *See* horsepower
HPC (high-pressure condensate), 2004 V1: 9
hps, HPS (high-pressure steam), 2004 V1: 9, 15
HR (hours), 2004 V1: 15, 34
HT (heat). *See* heat
HT (height). *See* height
hthw, HTHW (high-temperature hot water), 2004 V1: 15. *See also* hot-water temperatures
HTR (heaters), 2004 V1: 15. *See also* water heaters
hub-and-spigot piping and joints. *See also* bell-and-spigot joints and piping
acid wastes and, 2000 V3: 42
cast-iron soil pipe, 2003 V4: 27, 29–31
defined, 2004 V1: 26
sanitary piping, 1999 V2: 14
hubless piping
bracing cast-iron pipe, 2004 V1: 177
cast-iron soil pipe, 2003 V4: 27, 28, 31
hubless, defined, 2004 V1: 26
riser bracing for hubless pipes, 2004 V1: 178
sanitary piping, 1999 V2: 14
HUD (Housing and Urban Development), 2004 V1: 105, 106
humidity
humidity ratios (*W,* W), 2004 V1: 15
relative (rh, RH), 2004 V1: 15
Hunter, Roy B., 1999 V2: 3, 4, 49, 65, 155
Hunter's curve for peak load, 1999 V2: 60
Hurricane filters, 1999 V2: 300
HVAC engineers, 2000 V3: 27–28, 213
HVAC systems
copper pipes, 2003 V4: 35, 36
exhaust ducts, 1999 V2: 274
glass pipes, 2003 V4: 47
heating systems, 2000 V3: 178
roof drains, 1999 V2: 83
steel pipe, 2003 V4: 48
HW (hot water supply), 2004 V1: 8
HWR (hot water recirculating), 2004 V1: 8, 265
hybrid vaporizers, 2000 V3: 61
hydrant wrenches, 2000 V3: 4
hydrants
butt caps, 2000 V3: 4, 219
coefficients of discharge, 2000 V3: 4, 5
distance between, 1999 V2: 250
fire-protection water supply, 2000 V3: 226–228

fire pumps for, 2000 V3: 25
flow tests, 1999 V2: 122, 2000 V3: 4, 5, 217, 219
guards, 2000 V3: 228, 229
hydrant butts, 2000 V3: 7, 8
outlets, 2000 V3: 5
pressure drop and, 1999 V2: 249
public hydrants, 2004 V1: 12
valves, 2004 V1: 24
wall hydrants, 2004 V1: 10, 12
hydraulic balancing in fountains, 2000 V3: 117–118
hydraulic calculations
fountain displays, 2000 V3: 121
sprinkler systems, 2000 V3: 15, 16–17
hydraulic design
sprinkler systems, 2000 V3: 15–18
swimming pool filters, 2000 V3: 140
hydraulic irrigation valves, 2000 V3: 103
hydraulic jumps in flow, 1999 V2: 2, 6, 67
hydraulic mean depth of flow, 2004 V1: 1
hydraulic radii (R), 2004 V1: 1
hydraulic shock, calculating, 2004 V1: 6
hydraulic soil conditions, 1999 V2: 217–220
hydraulics of wells, 1999 V2: 241–243
hydrazine, 1999 V2: 315
Hydro 35 (National Weather Service), 2000 V3: 242

converting, 1999 V2: 256, 2000 V3: 29
flow rates and pressure measurements, 2000 V3: 200
natural gas piping sizing, 1999 V2: 197
use of, 1999 V2: 253
inches
converting to metric units, 2000 V3: 29
converting to SI units, 2004 V1: 39
of mercury (in. Hg), 2004 V1: 39, 1999 V2: 254, 257
per hour (in./h), 2000 V3: 99
incident angles (INANG), 2004 V1: 15
incineration systems, 2004 V1: 130–131
incinerator toilets, 2004 V1: 265
inconel, 2004 V1: 141, 144
incrustation in water, 1999 V2: 244
independent functions in FAST approach, 2004 V1: 230
indicated horsepower (ihp, IHP), 2004 V1: 15
indirect discharges, 2000 V3: 89
indirect drains (D), 2004 V1: 8
indirect-fired gas water heaters, 2000 V3: 138, 146
indirect waste pipes, 2004 V1: 26, 2003 V4: 12
indirect waste receptors, 1999 V2: 16, 17, 2003 V4: 17. *See also* floor sinks
individual aerobic waste treatment plants, 1999 V2: 232–233
Individual Home Wastewater Characterization and Treatment, 1999 V2: 238
individual vents, 2004 V1: 26. *See also* revent pipes
indoor gas boosters, 1999 V2: 180
indoor gas hose connectors, 1999 V2: 196
indoor swimming pools. *See also* swimming pools
components for, 2000 V3: 139
considerations, 2000 V3: 129
induced siphonage, 2004 V1: 26, 1999 V2: 36, 39–40
industrial acid-waste drainage systems
acid-waste treatment, 1999 V2: 334–337
continuous acid-waste treatment systems, 1999 V2: 338
defined, 1999 V2: 332
health and safety concerns, 1999 V2: 332
large facilities, 1999 V2: 336
types of acids, 1999 V2: 332–334
industrial chemical-waste systems, 1999 V2: 345–346
industrial facilities
asbestos concrete piping, 2003 V4: 26
firefighting demand flow rates, 2000 V3: 232
firefighting water drainage, 1999 V2: 346–347
industrial steam systems, 2000 V3: 175
numbers of fixtures for, 2003 V4: 19, 21
radiation in, 1999 V2: 340
water content in wastes, 2000 V3: 99
Industrial Risk Insurers (IRI), 1999 V2: 177, 2000 V3: 16
industrial waste, defined, 2004 V1: 26
industrial wastewater treatment
codes and standards, 2000 V3: 95
definitions, 2000 V3: 88
designing systems, 2000 V3: 90–91
government publications, 2000 V3: 96
industry and technical handbooks, 2000 V3: 97
overview, 2000 V3:87
permits, 2000 V3:87
references, 2000 V3: 95–97
regulatory framework, 2000 V3:87–90
resources, 2000 V3: 97
system elements, 2000 V3: 91–95
inert gases, 2000 V3: 22
Inert Gases: Argon, Nitrogen and Helium (CGA P-9), 2000 V3: 81, 82, 86
inert materials, 2000 V3: 47
inertia
conversion factors, 2004 V1: 36
measurements, 2004 V1: 33
inerting atmospheres, 2000 V3: 20
infant bathtubs, 2000 V3: 32, 34
infectious and biological waste systems. *See also* disinfecting; microorganisms
biosafety levels, 1999 V2: 343–344
codes and standards, 1999 V2: 343–344
components, 1999 V2: 345
introduction, 1999 V2: 343
liquid-waste decontamination systems, 1999 V2: 344–345
infectious disease rooms, 2000 V3: 45
infiltration rates
pipes, 1999 V2: 102
soils, 1999 V2: 96, 104
inflexibility, creativity and, 2004 V1: 231
Information phase in value engineering, 2004 V1: 213, 214–222
information sources in value engineering, 221, 2004 V1: 214
infrared controls on faucets and fixtures, 2004 V1: 135, 264
infrequently-used fixtures, 1999 V2: 121
Ingersoll-Rand Company, 1999 V2: 214, 2000 V3: 214
inhibitors (corrosion), 2004 V1: 151, 153
initial pressure in natural gas systems, 1999 V2: 193, 194
initial vacuum pressure, 1999 V2: 272
ink tests, 2003 V4: 5, 9
inlet cubic feet per minute (icfm), 1999 V2: 256, 2000 V3: 65, 66
inlets. *See also* outlets; stations
gas boosters, 1999 V2: 179
gas or vacuum. *See* stations
inlet filters in pools, 2000 V3: 203, 211
inlet filters on vacuum systems, 1999 V2: 260
inlet inverts on septic tanks, 1999 V2: 228
inlet pressure in cold-water systems, 1999 V2: 153
inlet pressure in gas boosters, 1999 V2: 182
inlet times, 2000 V3: 244, 245
louver velocity, 2000 V3: 212
number of in vacuum systems, 1999 V2: 262
for reflecting pools and fountains, 2000 V3: 110–111
for storage tanks, 1999 V2: 248
for storm drainage, 1999 V2: 98
for swimming pools, 2000 V3: 137, 143, 145
for vacuum cleaning systems, 1999 V2: 268, 269–270, 272, 274
in vacuum sizing calculations, 1999 V2: 263
Innovation & Design Process (LEED), 2004 V1: 263
innovation in green building, 2004 V1: 266
Innovative Wastewater Technologies, 2004 V1: 264
input motion of earthquakes, 2004 V1: 160
insanitary, defined, 2004 V1: 26, 1999 V2: 64
inside-caulk outlets, 1999 V2: 17

inside diameters (ID), 2004 V1: 14, 2000 V3: 156
inside film coefficients, 2004 V1: 14
inspecting. *See also* cleanouts
  checklists, 2004 V1: 102–103
  drains in sanitary drainage systems, 1999 V2: 9
  hazardous waste systems, 2000 V3: 90
  septic tanks, 1999 V2: 229–230
  sewage-disposal systems, 1999 V2: 238
installation
  anchor bolts, seismic problems, 2004 V1: 190
  backflow preventers, 1999 V2: 148–149
  condensate traps, 2000 V3: 195
  estimating productivity rates, 2004 V1: 97
  grab bars, 2004 V1: 121–122
  installation costs, 2004 V1: 223
  lavatories, 2003 V4: 11
  liquid fuel storage systems, 2000 V3:172–173
  medical gas piping, 2000 V3: 73
  pressure-regulated valves, 1999 V2: 153–154
  reduced-size venting, 1999 V2: 52
  section in specifications, 2004 V1: 91
  showers, 2003 V4: 16
  sovent systems, 1999 V2: 62
  steam traps, 2000 V3: 195
  storage tank checklist, 2000 V3: 173
  urinals, 2003 V4: 9–10
  water closets, 2003 V4: 6–7
  water system pipes, 1999 V2: 250–252
Installation, 2003 V4: 32
Installation of Centrifugal Fire Pumps (NFPA 20), 2000 V3: 25, 29
Installation of Closed-head Foam-water Sprinkler Systems (NFPA 16A), 2000 V3: 21, 29
Installation of Private Fire Mains (FM 3-10), 2000 V3: 225
Installation of Private Fire Service Mains and Their Appurtenances (NFPA 24), 2000 V3: 29, 225
Installation of Sprinkler Systems (NFPA 13), 2000 V3: 2, 12, 15, 16, 21, 29, 232
Installation of Standpipe and Hose Systems (NFPA 14), 2000 V3: 2, 18, 29
Installation of Underground Gasoline Tanks and Piping at Service Stations (API 1615), 2000 V3: 173
instantaneous water heaters, 1999 V2: 160
institutional facilities
  estimating sewage quantities, 1999 V2: 234
  numbers of fixtures for, 2003 V4: 20, 21
  septic tank systems for, 1999 V2: 231–232
instructions to bidders, 2004 V1: 62
instrument sterilizers, 2000 V3: 36, 38
instruments, nitrogen-pressure-driven, 2000 V3: 68
insulation
  airborne sound, 2004 V1: 193
  dielectric insulation, 2004 V1: 146
  energy savings and, 2004 V1: 265
  in geothermal energy systems, 2004 V1: 131
  hot-water systems, 2004 V1: 127, 1999 V2: 166
  noise insulation, 1999 V2: 15
  pure water systems, 1999 V2: 324
  roof drainage, 1999 V2: 85
  short-circuiting installations, 2004 V1:151
  thickness and energy conservation, 2004 V1: 127
insurance
  certificates, 2004 V1: 62
  in labor costs, 2004 V1: 94
insurance carriers, 2000 V3: 1, 2, 22, 216
intake silencers on compressors, 2000 V3: 202
intake sump acoustic problems, 2004 V1: 197
integral check valves on gas turrets, 1999 V2: 177
intensity-duration-frequency curves, 2000 V3: 242, 243
intensity (luminous), 2004 V1: 33
intensive-care rooms
  fixtures, 2000 V3: 35
  health-care facilities, 2000 V3: 32
  medical gas stations, 2000 V3: 51, 58
interceptors, 2004 V1: 26. *See also specific kinds of interceptors*
interface controls for medical gas systems, 2000 V3: 73
intergranular corrosion, 1999 V2: 290
interlocking, gas boosters and, 1999 V2: 182
intermediate chambers in dry-pipe systems, 2000 V3: 11
intermediate coats, 2004 V1: 147
intermediate gas regulators, 2000 V3: 251
intermediate-level sprinklers, 2004 V1: 29
intermittent flow in roof drainage, 1999 V2: 88
intermittent heating in pools, 2000 V3: 145
intermittent sand filters, 1999 V2: 232
International Association of Plumbing and Mechanical Officials (IAPMO), 2004 V1: 54, 58, 1999 V2: 34, 214, 2003 V4: 18
International Building Code, 2004 V1: 183
International Code Council (ICC), 2004 V1: 55, 59
International Conference of Building Officials (ICBO), 2004 V1: 191
International Organization for Standardization (ISO), 2004 V1: 194
International Pipe Standard (IPS), 2004 V1: 15
International Plumbing Code, 1999 V2: 39, 2003 V4: 18
International Safety Equipment Association (ISEA), 2004 V1: 59
international swimming meets, 2000 V3: 128
International System of Units (SI)
  conversion factors, 2004 V1: 39–40
  converting, 2004 V1: 39, 1999 V2: 256, 2000 V3: 29
  equations, 2004 V1: 1
  listing, 2004 V1: 32–40
  natural gas piping sizing, 1999 V2: 197
  non-SI units, 2004 V1: 34
  prefixes and symbols, 2004 V1: 34
  pressure and flow rate measurements, 2000 V3: 200
  style and use, 2004 V1: 34, 1999 V2: 253
interrelationships of functions, 2004 V1: 227, 230
interruptible gas services, 2000 V3: 249
interruption of water service, 1999 V2: 239
interstitial monitoring, 2000 V3: 160–161
interstitial spaces in tanks, 2000 V3: 156, 165
inventory control in storage tanks, 2000 V3: 161–162
invertebrates, 1999 V2: 282
inverted bucket traps, 2000 V3: 182, 186, 194
inverted-membrane roofs, 1999 V2: 82
inverts
  defined, 2004 V1: 26
  on septic tanks, 1999 V2: 228

An Investigation of the Adequacy of Performance of Reduced-size Vents Installed on a Ten-Story Drain, Waste and Vent System, 1999 V2: 65
Investigation phase in value engineering, 2004 V1: 213, 235, 243, 254
iodine, 2000 V3: 149
iodine 131, 1999 V2: 340
ion-exchange and removal systems, 1999 V2: 300–308
  continuous deionization, 1999 V2: 306
  design considerations, 1999 V2: 308
  regenerable ion exchange, 1999 V2: 301
  regeneration cycle, 1999 V2: 302–305
  resins, 1999 V2: 301
  service deionization, 1999 V2: 305
  small drinking water systems, 1999 V2: 318
  total dissolved solids and, 1999 V2: 288
  water softening, 1999 V2: 307
ionized salts (NaCI), 2000 V3: 46
ions
  defined, 2004 V1: 153
  in electromotive force series, 2004 V1: 144
  in pH values, 1999 V2: 329
IP units, 1999 V2: 197, 253, 256, 2000 V3: 200
IPS. *See* International Pipe Standard (IPS); iron pipe size (IPS)
IPS outlets, 1999 V2: 18
IRI (Industrial Risk Insurers), 1999 V2: 177
iron
  corrosion, 2004 V1: 139
  in electromotive force series, 2004 V1: 144
  in galvanic series, 2004 V1: 141
  removing, 1999 V2: 292
  sludge and, 1999 V2: 289
  in soils, 1999 V2: 219
  in water, 1999 V2: 244, 245, 281, 283
iron bacteria, 1999 V2: 282
iron coagulants, 1999 V2: 294
iron oxide, 2004 V1: 139, 2000 V3: 147
iron oxide films, 2004 V1: 145
iron pipe size (IPS), 2004 V1: 15, 2003 V4: 59, 61
iron piping
  corrosion, 2004 V1: 139
  ductile iron water and sewer pipe, 2003 V4: 32–33
iron-removal filters, 2000 V3: 147
irradiation treatment of water, 1999 V2: 245, 311–312, 318, 323, 324
Irrigation Association
  The ABC's of Lawn Sprinkler Systems, 2000 V3: 105
  address, 2000 V3: 105
irrigation systems
  design information, 2000 V3: 104–105
  gray-water demand, 1999 V2: 26–27
  gray-water systems and, 1999 V2: 21, 22, 30
  green roof designs, 2004 V1: 266
  methods, 2000 V3: 100–101
  overview, 2000 V3: 99
  rainwater harvesting, 2004 V1: 135, 267
  references, 2000 V3: 105
  resources, 2000 V3: 105
  sample information sheet, 2000 V3: 106
  soil considerations, 2000 V3: 99–100
  system components, 2000 V3: 101–104
  water conservation and, 2004 V1: 264
  water demand, 1999 V2: 243
  water quality and requirements, 2000 V3: 99
  water supply, 2000 V3: 105
ischoric processes, 2000 V3: 199
ISEA (International Safety Equipment Association), 2004 V1: 59
island venting, 2000 V3: 42
ISO 3822/1 (Laboratory Tests on Noise Emission by Appliances and Equipment Used in Water Supply Installations), 2004 V1: 194
ISO (International Organization for Standardization), 2004 V1: 194
isoascorbic acid, 1999 V2: 315
isobaric processes, 2000 V3: 199
isolating medical gas zones, 2000 V3: 71
isolating premises with backflow hazards, 1999 V2: 145–147
isolating valves, 1999 V2: 149
isolation rooms, 2000 V3: 32, 45, 51
isolation valves, 2000 V3: 49, 115
isolation, vibration
  dishwasher isolation mounts, 2004 V1: 195
  flexibility and, 2004 V1: 199
  isolation hangers, 2004 V1: 203, 204
  isolation springs, 2004 V1: 166
  isolators within hangers, 2004 V1: 166
  in piping systems, 2004 V1: 202–206
  problems in seismic protection, 2004 V1: 188–191, 189, 206
  types of vibration control devices, 2004 V1: 203–206
  washing machine isolation mounts, 2004 V1: 195
isolators, 2000 V3: 213
isosceles triangles, calculating area, 2004 V1: 4
isothermal processes, 2000 V3: 199
isotopes, 1999 V2: 337, 340
ITT Fluid Handling
  Training Manual TES 181: Hoffman Steam Heating Systems Design Manual and Engineering Data, 2000 V3: 197
  Training Manual TES 582: High Temperature Condensate Return, 2000 V3: 197
Izod impact, 2003 V4: 60

J

J (joules), 2004 V1: 33
J/K (joules per kelvin), 2004 V1: 33
J/kg K (joules per kg per kelvin), 2004 V1: 33
Jackson, T., 1999 V2: 65
Jackson turbidity units (JTUs), 1999 V2: 287
janitors' closets, 2000 V3: 32, 2003 V4: 13
Janoschek, R., 1999 V2: 325
Jayawardena, N., 1999 V2: 325
JCAHO (Joint Commission for the Accreditation of Hospitals Organization), 2000 V3: 33, 50
jet pumps, 1999 V2: 241
jetted wells, 1999 V2: 241
job preparation checklists, 2004 V1: 99
jockey pumps, 2004 V1: 24, 2000 V3: 26
Joint Commission for the Accreditation of Hospitals Organization (JCAHO), 2000 V3: 33, 50
joint compounds, 1999 V2: 223

joints
acid-waste systems, 1999 V2: 334
asbestos concrete piping, 2003 V4: 26
bonded joints and cathodic protection, 2004 V1:150
bronze joints and fittings, 2003 V4: 37–38
cast-iron soil pipes, 2003 V4: 27
caulked joints on floor drains, 1999 V2: 16
chemical-waste systems, 1999 V2: 345–346
clay pipe joints, 1999 V2: 223
copper drainage tubes, 2003 V4: 45, 46
copper joints, 1999 V2: 222, 2003 V4: 37–38
copper rings over joints, 1999 V2: 223
copper water tube, 2003 V4: 37
CPVC piping, 2003 V4: 62
cross-linked polyethylene, 2003 V4: 61
cross-linked polyethylene/aluminum/cross-linked polyethylene (PEX-AL-PEX), 2003 V4: 61–62
ductile iron water and sewer pipe, 2003 V4: 32–33
earthquake damage to, 2004 V1: 162
earthquake protection and, 2004 V1: 167
expansion joints, 1999 V2: 18, 79, 85, 87, 251
fill and pipe joints, 1999 V2: 15
for fountains, 2000 V3: 119
galvanized iron joints, 1999 V2: 222
glass pipe, 2003 V4: 47–48
heat-fused socket joints, 1999 V2: 334
inspection, 2000 V3: 80
joint compounds, 1999 V2: 223
labor productivity rates, 2004 V1: 96
lead pipe, 2003 V4: 49
liquefied petroleum gas and, 1999 V2: 196
materials, 2004 V1: 43
mechanical clay pipe joints, 1999 V2: 223
medical gas tubing, 2000 V3: 77, 2003 V4: 45
mortar joints on septic tanks, 1999 V2: 228
natural gas systems, 2000 V3: 254
o-ring gaskets, 2004 V1: 266
plastic joints, 1999 V2: 222
plastic pipes, 2003 V4: 59–60
pure-water systems, 2000 V3: 47
PVC piping, 2003 V4: 62
radioactive waste systems, 1999 V2: 341
red brass pipe, 2003 V4: 27
reinforced concrete pipe, 2003 V4: 32
restrainers, 2000 V3: 228–229
sanitary, 2000 V3: 48
screwed mechanical joints, 1999 V2: 334
seamless copper pipe, 2003 V4: 34
special-waste drainage systems, 1999 V2: 328
steel pipe, 2003 V4: 48
tubing, 1999 V2: 196
welded joints in radioactive waste systems, 1999 V2: 341
Joukowsky's formula, 1999 V2: 132
joules, 2004 V1: 33
joules per kelvin, 2004 V1: 33
joules per kg per kelvin, 2004 V1: 33
journeyman plumbers, 2004 V1: 26
JTUs (Jackson turbidity units), 1999 V2: 287
judgementalism, 2004 V1: 232–235
Judgment phase in value engineering, 2004 V1: 213
juveniles. *See* children, fixtures and

K

k, K (conductivity), 2004 V1: 14, 16, 33
K (dynamic response to ground shaking), 2004 V1: 159, 161
K (kelvin), 2004 V1: 15, 34
k (kilo) prefix, 2004 V1: 34
K factor (coefficient of permeability), 1999 V2: 100–101, 104–105, 242
K factor (sprinkler heads), 2000 V3: 17
K piping. *See* Type K copper
Kalinske, A.A., 1999 V2: 19
Kaminsky, G., 1999 V2: 350
KE (kinetic energy), 2004 V1: 2, 5
kelvin (K), 2004 V1: 15, 33
kerosene, 1999 V2: 13, 2000 V3: 154
keyboards, inflexible thinking and, 2004 V1: 231
kg (kilograms). *See* kilograms
kg/m (kilograms per meter), 2004 V1: 33
kg/m^2 (kilograms per meter squared), 2004 V1: 33
kg/m^3 (kilograms per meter cubed), 2004 V1: 33
kg/ms (kilogram-meters per second), 2004 V1: 33
kg/s (kilograms per second), 2004 V1: 33
kill tanks, 1999 V2: 344–345
"kilo" prefix, 2004 V1: 34
kilocalories, converting to SI units, 2004 V1: 39
kilograms (kg)
defined, 2004 V1: 33
kilograms per cubic meter, 2004 V1: 33
kilograms per meter, 2004 V1: 33
kilograms per meter squared, 2004 V1: 33
kilograms per second, 2004 V1: 33
kilometers (km)
converting to SI units, 2004 V1: 39
kilometers per hour, 2004 V1: 34
kilopascals (kPa)
converting meters of head loss to, 2004 V1: 2
converting to psi, 2000 V3: 29
in SI units, 2000 V3: 200
vacuum pump ratings, 1999 V2: 257
vacuum work forces, 1999 V2: 254
kiloponds, converting to SI units, 2004 V1: 39
kilowatt hours (kWh, KWH), 2004 V1: 15, 34
kilowatts (kW, KW), 2004 V1: 15
kinematic viscosity
converting to SI units, 2004 V1: 39
measurements, 2004 V1: 33
water temperature variations, 1999 V2: 121
Kinematic Viscosity Centistokes, 2000 V3: 154
kinetic energy (KE)
calculating, 2004 V1: 2
velocity head and, 2004 V1: 5
kip ft, KIP FT (thousand foot-pounds), 2004 V1: 16
kip, KIP (thousand pounds), 2004 V1: 16
KIPFT (thousand foot-pounds), 2004 V1: 16
kitchen sinks
faucets, 2003 V4: 13
types, 2003 V4: 11–12
kitchens. *See* food-processing areas and kitchens
km/h (kilometers per hour), 2004 V1: 34
knee space for wheelchairs, 2004 V1: 109
knockout panels for swimming pool filters, 2000 V3: 140
knockout pots in vacuum systems, 1999 V2: 260

Konen, Thomas K., 1999 V2: 34, 65
Kowalsky, L., 2000 V3: 125
kPa (kilopascals). *See* kilopascals
Kullen, Howard P., 2004 V1: 154
kW, KW (kilowatts), 2004 V1: 15
kWh, KWH (kilowatt hours), 2004 V1: 15, 34
KYNAR piping, 2000 V3: 48

L

L (length). *See* length
L (liters). *See* liters
L/min (liters per minute), 2000 V3: 66, 69, 200
L piping. *See* Type L copper
L/s (liters per second), 2000 V3: 7, 200
L-shaped bath seats, 2004 V1: 122
LA (laboratory compressed air), 2004 V1: 8
labels
  labeled, defined, 2004 V1: 26
  labeled fire pumps, 2000 V3: 25
  medical gas tubing, 2000 V3: 77, 81
  medical gas valves, 2000 V3: 71
  parts of gray-water systems, 1999 V2: 22, 33
labor and materials payment bonds, 2004 V1: 62
labor costs
  defined, 2004 V1: 222
  factors in, 2004 V1: 94
  ongoing and one-time, 2004 V1: 223
  overtime, 2004 V1: 94
  in plumbing cost estimation, 2004 V1: 93
  productivity rates, 2004 V1: 95–97
  in take-off estimating method, 2004 V1: 94
  in value engineering, 2004 V1: 212
labor rooms
  fixtures, 2000 V3: 36
  health-care facilities, 2000 V3: 32
  medical gas stations, 2000 V3: 52, 58
laboratories
  acid-waste drainage systems, 1999 V2: 332, 2000 V3: 39–42
    acid-waste treatment, 1999 V2: 334–337, 2000 V3: 40–41
    continuous acid-waste treatment systems, 1999 V2: 338
    discharge to sewers, 2000 V3: 40
    health and safety concerns, 1999 V2: 332
    large facilities, 1999 V2: 336
    metering, 2000 V3: 41–42
    piping and joint material, 1999 V2: 334
    sink traps, 2000 V3: 42
    solids interceptors, 2000 V3: 41, 43
    system design considerations, 1999 V2: 334
    types of acids, 1999 V2: 332–334
    waste and vent piping, 2000 V3: 42
  classroom water demand, 2000 V3: 45
  compressed air use factors, 2000 V3: 209
  defined, 2000 V3: 84
  fixtures and pipe sizing, 1999 V2: 328
  gas service outlets, 2000 V3: 37–39
  gas systems, 1999 V2: 176–177
  in health-care facilities, 2000 V3: 32, 37–39
  infectious waste systems, 1999 V2: 343
  isolating, 1999 V2: 147
  lab animals, 1999 V2: 344
  medical gas stations, 2000 V3: 51
  natural gas piping, 1999 V2: 177
  plastic pipes, 2003 V4: 58
  pure water systems for, 1999 V2: 317–325, 2000 V3: 46
  radioactive isotopes in, 1999 V2: 337
  vacuum systems
    codes and standards, 1999 V2: 262
    diversity factor calculations for vacuums, 1999 V2: 263
    leakage, 1999 V2: 265, 267
    piping, 1999 V2: 262
    pump assemblies, 1999 V2: 261
    sizing, 1999 V2: 262–266
    vacuum-pump systems, 2000 V3: 70
  water systems filtration, 1999 V2: 300
laboratory compressed air (LA), 2004 V1: 8
Laboratory Studies of the Hydraulic Performance of One-story and Split-level Residential Plumbing Systems with Reduced-size Vents, 1999 V2: 65
Laboratory Testing on the Noise Emitted by Valves, Fittings, and Appliances Used in Water Supply Installations, 2004 V1: 194
Laboratory Tests on Noise Emission by Appliances and Equipment Used in Water Supply Installations, 2004 V1: 194
laboratory vacuum (LV), 2004 V1: 9
ladders
  aboveground storage tanks, 2000 V3: 165
  swimming pools, 2000 V3: 145–146
lagging (pipe wrappings), 2004 V1: 196, 201–202, 1999 V2: 68, 196
lagoons, 1999 V2: 232
laid mat filters, 2000 V3: 131
lakes, 1999 V2: 26, 27
LAL test, 1999 V2: 282
laminar flow devices, 2000 V3: 33
laminar flow in pipes, 2004 V1: 2
landscaping
  irrigation. *See* irrigation systems
  water efficient, 2004 V1: 263–264
landslides, 2004 V1: 158
lanes in swimming pools, 2000 V3: 128
Langelier saturation index (LSI), 1999 V2: 291–292, 2000 V3: 123
Langelier, W.F., 1999 V2: 291
Laque, F.L., 2004 V1: 154
large buildings
  acid-waste systems, 1999 V2: 336
  enlargement of water systems, 1999 V2: 249
  fixture drainage loads, 1999 V2: 3
  large private sewage-disposal systems, 1999 V2: 231–232
  sovent single-stack plumbing systems, 1999 V2: 19
large-drop sprinklers, 2004 V1: 29, 2000 V3: 2
large-scale biohazard facilities, 1999 V2: 343
Large Welded Petroleum Tanks (API 12D), 2000 V3: 95
lat, LAT (leaving air temperature), 2004 V1: 15
latent heat (LH, LHEAT), 2004 V1: 15, 137, 2000 V3: 175, 189
latent heat gain, 2004 V1: 15

lateral and longitudinal sway bracing, 2004 V1: 181–182, 184–186
lateral force
  calculating for seismic protection, 2004 V1: 183
  defined, 2004 V1: 191
  problems in seismic protection, 2004 V1: 189
lateral lines, 2000 V3: 85
lateral sewers, 2004 V1: 26
lateral stability of suspended equipment, 2004 V1: 164
laterals in leaching fields, 1999 V2: 221
laundry sinks or trays, 2003 V4: 13
laundry systems and washers
  accessibility, 2004 V1: 123
  acoustic ratings of machines, 2004 V1: 195
  clothes washer fixture-unit loads, 1999 V2: 3
  commercial laundries, 1999 V2: 121, 147
  gray water use, 2004 V1: 135, 267, 1999 V2: 22, 25
  health-care facilities, 2000 V3: 32, 36
  heat recovery systems, 2004 V1: 266
  laundry sinks and clothes washers, 2003 V4: 13
  laundry tray fixture-unit loads, 1999 V2: 3
  natural gas and, 1999 V2: 174
  rates of sewage flows, 1999 V2: 237
  sound damping materials, 2004 V1: 196
  suds problems, 1999 V2: 37, 39
  waste heat usage, 2004 V1: 131–134
  water fixture unit values, 2000 V3: 217
  water temperatures, 2000 V3: 45
lavatories. *See also* sinks and wash basins
  accessibility, 2004 V1: 117
  faucets and overflows, 2003 V4: 10–11, 13
  fixture-unit loads, 1999 V2: 3
  flow rates, 2003 V4: 10
  gray-water systems, 2004 V1: 135, 1999 V2: 22
  health-care facilities, 2000 V3: 32, 33, 38
  installation requirements, 2003 V4: 11
  minimum numbers of, 2003 V4: 18–22
  patient rooms, 2000 V3: 34
  recovery rooms, 2000 V3: 36
  reduced water usage, 2004 V1: 126–127
  shapes and sizes, 2003 V4: 10–11
  sovent systems, 1999 V2: 62
  standards, 2003 V4: 2
  temperatures, 2000 V3: 45
  typical gray-water supply, 1999 V2: 25
  typical use, 1999 V2: 25
  vents, 1999 V2: 37
Law of Inverse Proportions, 2004 V1: 224
lawn imperviousness factors, 2000 V3: 243
lawn sprinkler supply (LS), 2004 V1: 8, 1999 V2: 121
layer-type dezincification, 2004 V1: 142
layers of effluent in septic tanks, 1999 V2: 227
layers of fill, 1999 V2: 15
lb, LBS (pounds). *See* pounds
leaching trenches (leach fields)
  choosing absorption systems, 1999 V2: 220
  construction of, 1999 V2: 222–223
  drain fields defined, 2004 V1: 23
  flat areas, 1999 V2: 223–224
  introduction, 1999 V2: 221–224
  serial distribution, 1999 V2: 223–224
  sloping area trenches, 1999 V2: 224
leaching wells, 2004 V1: 26. *See also* dry wells
lead
  corrosion, 2004 V1: 139
  in electromotive force series, 2004 V1: 144
  in galvanic series, 2004 V1: 141
  joint seals, 2003 V4: 27, 28
lead-caulked, cast-iron piping, 1999 V2: 223
lead-lined concrete blocks, 1999 V2: 340
lead-lined lath for plaster, 1999 V2: 340
lead piping, 2004 V1: 266, 1999 V2: 14, 68, 122, 2003 V4: 48–49
lead shielding on radioactive drainage systems, 1999 V2: 339–340
lead-tin solders, 2004 V1: 141
leaders. *See* downspouts and leaders; vertical stacks
Leadership in Energy and Environmental Design (LEED), 2004 V1: 263–265
leakage
  clean agent gas fire suppression, 2000 V3: 23
  compressed air systems, 2000 V3: 209, 211
  eliminating, 2004 V1: 134
  leaking oil into water, 1999 V2: 347–349
  waste anesthetic gas management, 2000 V3: 71
  water conservation and, 2004 V1: 124
leakage detection
  aboveground tank systems, 2000 V3:167–168
  annuciators, 2000 V3: 167
  chemical wastes, 1999 V2: 345, 346
  connectors, 2000 V3: 166
  industrial waste, 2000 V3: 90
  infectious waste drainage systems, 1999 V2: 344
  ion exchange systems, 1999 V2: 308
  special-waste drainage systems, 1999 V2: 327
  underground liquid fuel storage tanks, 2000 V3: 158–163
leakage tests
  cold-water systems, 1999 V2: 154
  liquefied petroleum gas systems, 1999 V2: 197
  private water systems, 1999 V2: 252
  storage tanks, 2000 V3: 172
  vacuum systems, 1999 V2: 265, 267
least mean temperature difference (LMTD), 2004 V1: 15
least temperature difference (LTD), 2004 V1: 15
leaving air temperature (lat, LAT), 2004 V1: 15
leaving water temperature (lwt, LWT), 2004 V1: 15
lecture halls, numbers of fixtures for, 2003 V4: 19
LEED (Leadership in Energy and Environmental Design), 2004 V1: 263–265
leg baths, 2000 V3: 32, 35, 38
leg clearances
  drinking fountains and water coolers, 2004 V1: 112
  toilet and bathing rooms, 2004 V1: 113
Legionella pneumophila, 1999 V2: 144, 169
legislation regarding people with disabilities, 2004 V1: 106–107
legs in piping systems, 2000 V3: 47
legs on tanks
  cast-iron tank legs, 2004 V1: 163
  problems in seismic protection, 2004 V1: 188, 189
Lehr, Valentine A., 1999 V2: 34
length (lg, LG, L)
  conversion factors, 2004 V1: 36

in measurements, 2004 V1: 33
of stacks, 2004 V1: 3
symbols for, 2004 V1: 15
of vent piping, 2004 V1: 3
Level I vacuum systems, 2000 V3: 85
Level III alarm systems, 2000 V3: 83
Level III vacuum systems, 2000 V3: 86
level sensors
boiler feed pumps, 2000 V3: 188
hazardous materials, 2000 V3: 90
tank gauges, 2000 V3: 158
levels in water tanks, 1999 V2: 249
levels of radiation, 1999 V2: 339
Lewis, G.N., 2004 V1: 153
LF (linear feet), 2004 V1: 15
lg, LG (length). *See* length
LH (latent heat), 2004 V1: 15, 137
LHEAT (latent heat), 2004 V1: 15, 137
LHG (latent heat gain), 2004 V1: 15
libraries, numbers of fixtures for, 2003 V4: 19
life-cycle costs, 2004 V1: 137
life safety
in fire protection, 2000 V3: 1
residential sprinkler systems, 2000 V3: 2
lifts of fill, 1999 V2: 15
light conversion factors, 2004 V1: 36
light hazard occupancies
defined, 2004 V1: 29
firefighting hose streams, 2000 V3: 230
portable fire extinguishers, 2000 V3: 27, 28
light heating oil, 2000 V3: 154
light process gas service, 2000 V3: 249
light wall pipe (Schedule 10), 2003 V4: 48
lighting systems in pools and fountains, 2000 V3: 112, 121, 125, 145
lightwall pipes, 2000 V3: 17
lime (calcium carbonate), 2000 V3: 147
lime-soda method of water softening, 1999 V2: 244, 307
limestone chips, 1999 V2: 334
limited-care facilities, 2000 V3: 84
limited-discharge roof drains, 2000 V3: 247
limiting conditions in seismic protection, 2004 V1: 189, 190
limulus amoebocyte lysate test, 1999 V2: 282
lin ft (linear feet), 2004 V1: 15
Lin, S.H., 1999 V2: 325
line-pressure sensors, 2000 V3: 72
line regulators, 2000 V3: 251
linear acceleration
conversion factors, 2004 V1: 35
measurements, 2004 V1: 33
linear expansion in PVC pipe, 2003 V4: 62
linear feet (lin ft, LF), 2004 V1: 15
linear velocity measurements, 2004 V1: 33
lined piping, 2003 V4: 26
lined steel
storage tanks and hazardous wastes, 2000 V3: 91
sulfuric acid and, 2000 V3: 93
linen holding areas, 2000 V3: 32
lining materials
for dug wells, 1999 V2: 240
for seepage pits, 1999 V2: 225
Linstedt, K.C., 1999 V2: 238
lint interceptors, 2000 V3: 36, 150
liq, LIQ (liquid). *See* liquids
liquefaction, 2004 V1: 158
liquefied petroleum gas. *See also* fuel-gas piping systems
codes and standards, 2004 V1: 43
defined, 1999 V2: 214
flexible gas hoses, 1999 V2: 196
gas boosters, 1999 V2: 178–183
glossary, 1999 V2: 213–214
introduction, 1999 V2: 194
pipes, 2003 V4: 35, 36
storage, 1999 V2: 194
system materials, 1999 V2: 196
warnings, 1999 V2: 197
liquid chlorine, 2000 V3: 123
liquid contamination in compressed air, 2000 V3: 201
liquid fuel systems. *See* diesel-oil systems; gasoline systems
liquid monitoring, 2000 V3: 160
liquid oxygen (LOX)
defined, 2000 V3: 85
fire hazards, 2000 V3: 61
medical gas systems, 2000 V3: 60
symbol, 2004 V1: 8
liquid petroleum, 2000 V3: 154
liquid piston compressors, 2000 V3: 201
liquid ring compressors, 2000 V3: 67, 201
liquid ring pumps, 1999 V2: 259, 260, 262
liquid waste
decontamination systems, 1999 V2: 344–345
defined, 2004 V1: 26
liquid waterproofing, 2000 V3: 144
liquids (liq, LIQ)
levels in septic tanks, 1999 V2: 228–229
symbols for, 2004 V1: 15
vacuuming, 1999 V2: 266
listed, defined, 2004 V1: 26
listing agencies, 2004 V1: 26
liters
converting to gallons units, 2000 V3: 29
converting to SI units, 2004 V1: 39
liters per minute (L/min, Lpm), 1999 V2: 253, 2000 V3: 66, 69, 200
liters per second (L/s), 1999 V2: 124, 126, 2000 V3: 7, 200
non-SI units, 2004 V1: 34
live loads
on roof, 1999 V2: 79
in pipe selection, 2003 V4: 26
living roof designs, 2004 V1: 266–267
lm (lumens), 2004 V1: 33
LMTD (least mean temperature difference), 2004 V1: 15
ln, LN (logarithms, natural), 2004 V1: 15
LO (lubricating oil), 2004 V1: 8, 1999 V2: 13
loading tables
fixture-unit values in drainage systems, 1999 V2: 3
sovent systems, 1999 V2: 63
subsurface piping loads, 1999 V2: 102
vertical stacks, 1999 V2: 4
loads
computer analysis of loads, 2004 V1: 186
connected loads, defined, 1999 V2: 214

design considerations in seismic protection, 2004 V1: 186–188
earth load on water pipes, 1999 V2: 250
horizontal loads of piping, 2004 V1: 184
live loads on roof, 1999 V2: 79
load factors, defined, 2004 V1: 26
settlement loads, 2004 V1: 186
sway bracing, 2004 V1: 185–186
vertical seismic load, 2004 V1: 184
vibration control materials, 2004 V1: 203
loams, 2000 V3: 100
local alarms, 2000 V3: 83. *See also* area alarms
local application systems (carbon dioxide), 2000 V3: 20
local application systems (halon), 2004 V1: 26
local authorities, 1999 V2: 68, 327
local barometric pressure in vacuums, 1999 V2: 254
local rainfall rate tables, 1999 V2: 69–78
localized corrosion, 1999 V2: 289–290
location of piping, earthquake protection and, 2004 V1: 167
lock-out regulators, 2000 V3: 252
locker rooms, 2000 V3: 32
Loevenguth, 2004 V1: 191
log, LOG (logarithm to base 10), 2004 V1: 15
logarithms
logarithm to base 10 (log, LOG), 2004 V1: 15
natural (ln, LN), 2004 V1: 15
long runs in vacuum cleaning systems, 1999 V2: 274–275
long-term thermal stability for hot-water systems, 1999 V2: 166
long-turn tee-wyes, 1999 V2: 4
longitudinal bracing
defined, 2004 V1: 191
longitudinal and transverse bracing, 2004 V1: 180
longitudinal brace points, 2004 V1: 168
longitudinal-only bracing, 2004 V1: 180
seismic protection, 2004 V1: 172
sway bracing, 2004 V1: 184–186
longitudinal forces, 2004 V1: 191
Looking to Treat Wastewater? Try Ozone, 1999 V2: 325
loop systems
fire hydrants, 1999 V2: 249
fire mains, 2000 V3: 8
loop vents, 2004 V1: 31, 1999 V2: 43–44, 64, 2000 V3: 42
louvers in air compression, 2000 V3: 212
LOV (lubricating oil vents), 2004 V1: 8
low backflow hazard, 2000 V3: 222
low-expansion borosilicate glass, 2003 V4: 47
Low-expansion Foam (NFPA 11), 2000 V3: 21, 29
low-expansion foams, 2000 V3: 21
low-fire input in gas boosters, 1999 V2: 182
low-flow fixtures
green building and, 2004 V1: 264
low-flow control valves, 2000 V3: 103
low-flush toilets and water closets
acoustic design, 2004 V1: 195
conserving water in, 1999 V2: 232
low-flow water closets, 1999 V2: 19, 232
ultra-low-flow water closets, 2004 V1: 134–136, 264, 1999 V2: 19
low-level water tank alarms, 1999 V2: 151
low-pressure carbon dioxide systems, 2000 V3: 20–21
low-pressure condensate (LPC), 2004 V1: 9
low-pressure fire pumps, 2000 V3: 25
low-pressure gas (G), 2004 V1: 8
low-pressure natural gas systems, 1999 V2: 173–194, 192, 194
low-pressure steam (lps, LPS), 2004 V1: 9, 15, 2000 V3: 175, 182, 187
low-pressure tanks, 2000 V3: 153
low-temperature hot water (lthw, LTHW), 2004 V1: 15
low-velocity pressure sand filters, 2000 V3: 139
low-voltage lighting, 2000 V3: 121
low-water cutoffs, 2000 V3: 124
low-water pressure, 1999 V2: 149–152
lower order functions, 2004 V1: 230
Lowther plate units, 1999 V2: 313
LOX (liquid oxygen), 2004 V1: 8
LP-gases at Utility Gas Plants, 1999 V2: 214
LPC (low-pressure condensate), 2004 V1: 9
lpg. *See* liquefied petroleum gas
Lpm (liters per minute). *See* liters
lps, LPS (low-pressure steam), 2004 V1: 9, 15
LS (lawn sprinkler supply), 2004 V1: 8
LSI (Langelier saturation index), 1999 V2: 291–292
LTD (least temperature difference), 2004 V1: 15
lthw, LTHW (low-temperature hot water), 2004 V1: 15
lubricating oil (LO), 2004 V1: 8, 1999 V2: 13
lubricating oil vents (LOV), 2004 V1: 8
lubricators
in compressed air pipe sizing, 2000 V3: 210
compressed air systems, 2000 V3: 207
lumens, 2004 V1: 33
luminance measurements, 2004 V1: 33
luminous flux, 2004 V1: 33
luminous measurements, 2004 V1: 33
lump copper sulfate, 1999 V2: 223
lux, 2004 V1: 33
LV (laboratory vacuum), 2004 V1: 9
LWDS (liquid-waste decontamination systems), 1999 V2: 344–345
LWT (leaving water temperature), 2004 V1: 15
lx (lux), 2004 V1: 33
lye (sodium hydroxide), 2000 V3: 150

M

M alkalinity, 1999 V2: 282
M (mega) prefix, 2004 V1: 34
m (meters). *See* meters (measurements)
m (milli) prefix, 2004 V1: 34
M piping. *See* Type M copper
m/s (meters per second), 2004 V1: 33
m/s^2 (meters per second squared), 2004 V1: 33
m^2 (meters squared), 2004 V1: 33
m^2/s (meters squared per second), 2004 V1: 33
m^3 (cubic meters), 2004 V1: 33
m^3/kg (cubic meters per kilogram), 2004 V1: 33
m^3/min (cubic meters per minute), 2000 V3: 200
m^3/s (cubic meters per second), 2004 V1: 33
MA. *See* medical compressed air
Mach numbers (Mach, MACH), 2004 V1: 15
MacHatton, J.G., 1999 V2: 238
machine trenching, labor productivity rates, 2004 V1: 95–97

magnesium
corrosion, 2004 V1: 139
dry-power extinguishing systems, 2000 V3: 20
in electromotive force series, 2004 V1: 144
in galvanic series, 2004 V1: 141
lifespan of anodes, 2004 V1: 150
sacrificial anodes, 2004 V1: 147
in water, 1999 V2: 281, 283
zeolite process and, 1999 V2: 244
magnesium alloys, 2004 V1: 141
magnesium anodes, 2000 V3: 131
magnesium bicarbonate, 1999 V2: 283
magnesium carbonate, 1999 V2: 281, 283, 290
magnesium chloride, 1999 V2: 283
magnesium hydroxide, 1999 V2: 281
magnesium sulfate, 1999 V2: 281
magnetic field pulsation, 2004 V1: 196
magnetic field strength measurements, 2004 V1: 33
magnetic flux density, 2004 V1: 33
magnetic flux measurements, 2004 V1: 33
magnetism, conversion factors, 2004 V1: 35
magnetostrictive tank gauging, 2000 V3: 160
main drains
head loss and, 2000 V3: 115
reflecting pools and fountains, 2000 V3: 110
swimming pools, 2000 V3: 137, 143, 145
main relief valves, 2000 V3: 25
main shut-off valves, 2000 V3: 71
main vents, 2004 V1: 26, 2000 V3: 184
mains. *See also* water mains
defined, 2004 V1: 26, 2000 V3: 85
fire mains, 2000 V3: 8
force mains, 2000 V3: 234, 236–240, 241
natural gas mains, 2000 V3: 253
pipe, 2004 V1: 12
steam, 2000 V3: 182, 187
maintenance
air compressors, 2000 V3: 213
costs, 2004 V1: 223
fountains and pools, 2000 V3: 107
section in specifications, 2004 V1: 70, 90
swimming pool filters, 2000 V3: 139
maintenance hot-water temperatures, 1999 V2: 166
major or prime costs, 2004 V1: 222
makeup
defined, 2004 V1: 137
reducing use of, 2004 V1: 264
makeup water systems
condensation usage, 2004 V1: 267
piping for, 2000 V3: 116
pools and fountains, 2000 V3: 112, 119, 124–125
swimming pools, 2000 V3: 144
malleable (mall)
defined, 2004 V1: 26
iron fittings, 1999 V2: 196
malls, 1999 V2: 25, 2003 V4: 20
Management of Small Waste Flows, 1999 V2: 34
Manas, Vincent T., 1999 V2: 65, 114, 155
manganese, 1999 V2: 245, 292
manholes
acid-waste systems, 1999 V2: 334, 335
chemical-waste systems, 1999 V2: 346
cleanouts, 2000 V3: 240, 241
drop manholes, 2000 V3: 234, 238
precast manholes, 2000 V3: 234, 237
sampling manholes, 2000 V3: 41–42, 44
sanitary sewer systems, 2000 V3: 234–236, 237
septic tanks, 1999 V2: 228, 229
shallow manholes, 2000 V3: 234, 238
spacing, 2000 V3: 236, 240
steps and covers, 2000 V3: 111, 236
storm-drainage systems, 1999 V2: 98, 99
venting, 2000 V3: 236, 239
waterproof, 2000 V3: 236, 239
manifolds
compressed air, 2000 V3: 65
nitrogen systems, 2000 V3: 68
nitrous oxide systems, 2000 V3: 64, 65
oxygen, 2000 V3: 59, 62–63, 64
Manning formula
alternative sewage-disposal systems, 1999 V2: 226
ditches, 2000 V3: 247–248
open-channel flow, 2004 V1: 1, 1999 V2: 7, 8
runoff and, 1999 V2: 97
site drainage and, 1999 V2: 98
sloping drains, 1999 V2: 8, 2000 V3: 233
storm-drainage pipes, 1999 V2: 88, 2000 V3: 244–245, 246
subsurface drainage rates, 1999 V2: 105
manual-control irrigation valves, 2000 V3: 103
manual fill lines, 2000 V3: 124
manual fill valves, 2000 V3: 124
manual flushometer valves, 2003 V4: 8
Manual of Practice
introduction, 2004 V1: 61
section shell outline, 2004 V1: 88–92
Uniformat, 2004 V1: 64
Manual of Septic Tank Practice, 1999 V2: 237, 238
Manual on the Design and Construction of Sanitary and Storm Sewers, 1999 V2: 95, 114
manual overfill prevention, 2000 V3: 167
manual overrides, 2000 V3: 104
manual pull stations, 2000 V3: 19
manual release stations, 2000 V3: 24
manual tank gauging, 2000 V3: 159
manual trap primers, 1999 V2: 10, 14
manufacturers
in specifications, 2004 V1: 70, 90
Manufacturers Standardization Society of the Valve and Fittings Industry, Inc. (MSS), 2004 V1: 26, 55, 59, 2003 V4: 45
Manufacturing, 2003 V4: 32
manufacturing facilities, 2000 V3:87
manways in tanks, 2000 V3: 156, 157, 163, 169
maps
frost lines, 2000 V3: 226
seismic risk maps, 2004 V1: 155–157
soils, 1999 V2: 218
marble acrylic fixtures, 2003 V4: 2
marble fixtures, 2003 V4: 2
marinas, 1999 V2: 147
mark-ups, in plumbing cost estimation, 2004 V1: 93–94, 94
markets
in creativity checklist, 2004 V1: 234

sanitation in, 1999 V2: 16
markings, corrosion and, 2004 V1: 146
Marks, Lionel S., 2004 V1: 1, 2, 3, 5, 40
mass
conversion factors, 2004 V1: 36
mass law in acoustics, 2004 V1: 193
mass per unit area measurements, 2004 V1: 33
mass per unit length measurements, 2004 V1: 33
in measurements, 2004 V1: 33
non-SI units, 2004 V1: 34
mass flow, 1999 V2: 255
mass flow rates (mfr, MFR)
measurements, 2004 V1: 33
symbols for, 2004 V1: 15
massive soil structure, 1999 V2: 218
master alarms
defined, 2000 V3: 83
medical gas systems, 2000 V3: 49, 72, 81
master plumbers, 2004 V1: 26
MasterFormat
defined, 2004 V1: 64
specifications sections, 2004 V1: 68–71
MasterFormat 2004, 2004 V1: 64–65, 77–88
MasterFormat expansion task team (MFETT), 2004 V1: 64
MasterFormat Level Four (1995), 2004 V1: 76
MasterFormat Level One (1995), 2004 V1: 73
MasterFormat Level Three (1995), 2004 V1: 76
MasterFormat Level Two (1995), 2004 V1: 73–75
Masterspec, 2004 V1: 71
material costs
defined, 2004 V1: 222
in plumbing cost estimation, 2004 V1: 93
in take-off estimating method, 2004 V1: 94
in value engineering, 2004 V1: 212
material safety data sheets, 2000 V3: 90
materials. *See specific materials or system fixtures*
detail/product/material specification checklist, 2004 V1: 220
fixtures, 2003 V4: 1–2
ongoing and one-time costs, 2004 V1: 223
in plumbing cost estimation, 2004 V1: 93
value engineering questions, 2004 V1: 213–214
Materials & Resources design (LEED), 2004 V1: 263
materials section in specifications, 2004 V1: 70, 90–91
maximum (max., MAX), 2004 V1: 15
maximum capacity rating (MCR), 1999 V2: 182
maximum design flow, 1999 V2: 182
maximum discharge rates, 2004 V1: 5
maximum outlet pressure in gas boosters, 1999 V2: 183
maximum resistance values, 1999 V2: 286
mbars (millibars), 1999 V2: 254
mc (millicuries), 1999 V2: 339
McClelland, Nina I., 1999 V2: 238
Mcf, MCF (thousand cubic feet), 2004 V1: 16
Mcm, MCM (thousand circular mils), 2004 V1: 16
MCR (maximum capacity rating), 1999 V2: 182
McSweeney, D.P., 1999 V2: 277
MDPE (medium density) 2406 pipe, 2003 V4: 58
mean effective temperatures (MET), 2004 V1: 15
mean temperature difference (MTD), 2004 V1: 15
measurable nouns in function analysis, 2004 V1: 224, 225
measurement units
compressed air, 2000 V3: 200
converting, 2000 V3: 29
earthquake measurement, 2004 V1: 160–161
flow rates, 1999 V2: 255–256
International System of Units, 2004 V1: 32–40
microorganisms, 1999 V2: 282
non-SI units, 2004 V1: 34
pressure, 2000 V3: 200
pure water, 2000 V3: 46
radiation, 1999 V2: 338–339
types of conversions, 2004 V1: 32
units and symbols, 2004 V1: 33
usage of, 1999 V2: 253
vacuum pressure, 1999 V2: 254–256
water impurities, 1999 V2: 285
measuring tank leakage, 2000 V3: 159–162
Measuring Water Purity by Specific Resistance, 1999 V2: 325
mechanical aerators, 1999 V2: 293, 294
mechanical areas
grates and strainers, 1999 V2: 10
sediment buckets, 1999 V2: 12
trap primers in drains, 1999 V2: 13
mechanical clay pipe joints, 1999 V2: 223
mechanical code agencies, 2004 V1: 42
mechanical cross-connection protection devices, 1999 V2: 144
mechanical emulsions, 2000 V3: 93
Mechanical Engineering Reference Manual, 1999 V2: 214
mechanical filtration, 2000 V3: 112, 123
mechanical foam extinguishers, 2000 V3: 21
mechanical joints, 2004 V1: 168, 266, 2000 V3: 40, 228–229
mechanical rooms, earthquake protection, 2004 V1: 166
mechanical rotary-type vacuum pumps, 1999 V2: 259
mechanical spaces, 2000 V3: 111
mechanical steam and condensate return, 2000 V3: 186–189
mechanical steam traps, 2000 V3: 182
mechanical tank gauging, 2000 V3: 159–160
mechanical water makeup, 2000 V3: 124
mechanically-dispersed oil, 1999 V2: 347
Meckler, Milton, 2004 V1: 40
medical air systems. *See also* medical compressed air (MA)
color coding, 2000 V3: 56
concentrations, 2000 V3: 82
defined, 2000 V3: 84
medical compressed air (MA)
altitude and, 2000 V3: 66
compressors, 2000 V3: 49, 84
storage, 2000 V3: 65–68
surgical use, 2000 V3: 57
symbol, 2004 V1: 8
system description, 2000 V3: 65
peak demand, 2000 V3: 53
pipe sizing, 2000 V3: 74
stations, 2000 V3: 50, 51–52
testing, 2000 V3: 82–83
medical cabinets, 2004 V1: 113
medical compressed air (MA)
altitude and, 2000 V3: 66
compressors, 2000 V3: 49, 84
storage, 2000 V3: 65–68

surgical use, 2000 V3: 57
symbol, 2004 V1: 8
system description, 2000 V3: 65
medical-gas systems
certification, 2000 V3: 77–83
codes and standards, 2000 V3: 83
color coding, 2000 V3: 54, 56
design checklist, 2000 V3: 49–50
dispensing equipment, 2000 V3: 54–59
ceiling-mounted, 2000 V3: 57–59
nitrogen equipment, 2000 V3: 59
patient headwall systems, 2000 V3: 56–57
station terminals, 2000 V3: 54–56
types, 2000 V3: 58
diversity factors, 2000 V3: 75
earthquake bracing for, 2004 V1: 166
gas flow rates, 2000 V3: 50–54
gas storage, 2000 V3: 59–68
medical compressed air, 2000 V3: 65–68
nitrogen, 2000 V3: 68
nitrous oxide, 2000 V3: 64–65
oxygen, 2000 V3: 59–63
health-care facilities, 2000 V3: 49–83
number of stations, 2000 V3: 50
piping, 2000 V3: 73–77
installation, 2000 V3: 73
materials, 2000 V3: 74–77
sizing, 2000 V3: 73–74
system control valves, 2000 V3: 71–72
typical storage layout, 2000 V3: 60
warning systems, 2000 V3: 72–73
waste anesthetic gas management, 2000 V3: 70–71
medical-gas tube, 2000 V3: 77, 81, 2003 V4: 45
medical laboratories. *See* health-care facilities; laboratories
medical schools. *See* health-care facilities
medical vacuum (MV), 2004 V1: 9
medical waste systems. *See* infectious and biological waste systems
Medicare taxes, in labor costs, 2004 V1: 94
medicine sinks, 2000 V3: 35
Medium and High-expansion Foam Systems (NFPA 11A), 2000 V3: 21, 29
medium-backflow hazard, 2000 V3: 222
medium-expansion foams, 2000 V3: 21
medium-pressure condensate (MPC), 2004 V1: 9
medium-pressure gas (MG), 2004 V1: 8
medium-pressure natural gas systems, 1999 V2: 173–194
medium-pressure steam (mps, MPS), 2004 V1: 9, 15, 2000 V3: 175
medium-temperature hot water (mthw, MTHW), 2004 V1: 15
medium vacuum, 1999 V2: 254
"mega" prefix, 2004 V1: 34
megaohm-cm, 1999 V2: 285
Mellar, 2000 V3: 97
membrane filtration
cross-flow filters, 1999 V2: 300, 310–311
gray-water systems, 1999 V2: 27
in health care facilities, 2000 V3: 47
membrane flux, 1999 V2: 309
membrane productivity, 1999 V2: 321
membrane selection in reverse osmosis, 1999 V2: 310, 311
overview, 1999 V2: 308–311
pure water systems, 1999 V2: 321
reverse osmosis, 1999 V2: 308–309
tangential-flow filters, 1999 V2: 300
total dissolved solids and, 1999 V2: 288
membrane flux, 1999 V2: 309
membrane productivity, 1999 V2: 321
Membrane Technologies in the Power Industry, 1999 V2: 325
membranes in waterproofing, 1999 V2: 17
memory metal couplings, 2000 V3: 77
mercantile facilities
numbers of fixtures for, 2003 V4: 20
single-occupant toilet rooms, 2003 V4: 23
mercury (Hg, HG), 2004 V1: 15
mercury vapor lamps, 1999 V2: 312
Mermel, H., 1999 V2: 350
Meslar, H.W., 1999 V2: 350
MET (mean effective temperatures), 2004 V1: 15
metal-edged weirs, 2000 V3: 109
metal flashing on roof drains, 1999 V2: 79
metal-plating plants, 1999 V2: 147
metallic pipes. *See also specific metals*
bedding, 2000 V3: 234, 235
pure-water systems, 2000 V3: 47
metals. *See also specific metals*
corrosion losses, 2004 V1: 139
galvanic series table, 2004 V1: 141
metallic coatings, 2004 V1: 147
Metcalf, 1999 V2: 238
meter set assemblies, 1999 V2: 214
metered faucet requirements, 2004 V1: 264
meters (general devices)
acid wastes, 2000 V3: 41–42
fuel dispensers, 2000 V3: 165
natural gas, 2000 V3: 249, 250
meters (measurements)
converting units, 2000 V3: 29
meters, 2004 V1: 33
meters of head, 2004 V1: 2
meters per second, 2004 V1: 33
meters per second squared, 2004 V1: 33
meters squared, 2004 V1: 33
meters squared per second, 2004 V1: 33
meters (water)
disk-type, 1999 V2: 127
domestic cold water systems, 1999 V2: 115–116
flow pressure loss tables, 1999 V2: 117
irrigation, 2000 V3: 105
locations for, 2000 V3: 217
pressure and, 1999 V2: 123
pressure losses, 2000 V3: 224
sizing sewage systems and, 1999 V2: 233
methane. *See* fuel-gas piping systems
Method for Measuring the Minimum Oxygen Concentration to Support Candle-like Combustion of Plastics (ASTM D2863), 2000 V3: 85
Methods of Estimating Loads in Plumbing Systems, 1999 V2: 155
methoxyflurane, 2000 V3: 70

methyl orange alkalinity, 1999 V2: 282
Metric Conversion Act, 2004 V1: 32
metric tons, 2004 V1: 34
metric units. *See* International System of Units
Meyers, Vance A., 1999 V2: 114
Meyrick, C.E., 1999 V2: 325
MFETT (MasterFormat expansion task team), 2004 V1: 64
mfr, MFR (mass flow rates), 2004 V1: 15, 33
mg/L (milligrams per liter), 1999 V2: 285
MG (medium-pressure gas), 2004 V1: 8
MH (manholes). *See* manholes
mho (specific conductivity), 1999 V2: 287
"micro" prefix, 2004 V1: 34
microbial growth and control. *See also* bacteria; microorganisms; viruses in feed water
  cooling towers, 1999 V2: 316
  drinking water, 1999 V2: 316–317, 318
  feed water, 1999 V2: 321
  pure water systems, 1999 V2: 323
  utility water, 1999 V2: 314
  water softeners, 1999 V2: 307, 308
  water treatments, 1999 V2: 311–313
microbiological fouling of water, 1999 V2: 289, 316
microbiological laboratories, 1999 V2: 343. *See also* laboratories
micromhos, 1999 V2: 287
microns
  converting to SI units, 2004 V1: 39
  vacuum units, 1999 V2: 254
microorganisms. *See also* bacteria; microbial growth and control; viruses in feed water
  infectious waste drainage systems, 1999 V2: 343
  pure water systems, 1999 V2: 323, 2000 V3: 47
  water analysis of, 1999 V2: 282
  water treatments, 1999 V2: 311–313, 318
microscopes, electron, 2000 V3: 38, 39, 45, 51
MIL F-1183 Bronze Fittings for Brazed Joints, 2003 V4: 27, 34
miles
  converting to SI units, 2004 V1: 39
  miles per hour (mph, MPH), 2004 V1: 15
Millepore filters, 1999 V2: 288–289
"milli" prefix, 2004 V1: 34
millibars (mbar)
  converting to SI units, 2004 V1: 39
  vacuum units, 1999 V2: 254
millicuries (mc), 1999 V2: 339
milligrams per liter (mg/L), 1999 V2: 285
millimeters
  converting to inches, 2000 V3: 29
  converting to SI units, 2004 V1: 39
millirems (mrem), 1999 V2: 339
Mills, Lawrence E., 2004 V1: 214
min (minutes), 2004 V1: 34
min., MIN (minimum), 2004 V1: 15
mineral deposits
  swimming pools, 2000 V3: 131, 147–148
  well water, 2000 V3: 131
mineral salts, 1999 V2: 288, 290
mineral solids, 1999 V2: 289
mineral wool, 2004 V1: 193
minimum (min., MIN), 2004 V1: 15
minimum design flow, 1999 V2: 182
minimum inlet pressure in gas boosters, 1999 V2: 182
minor backflow hazard, 1999 V2: 145, 146, 2000 V3: 222
minutes, 2004 V1: 34
mirrors, 2004 V1: 113
misaligned wells, pumps for, 1999 V2: 245
miscellaneous gases, 2000 V3: 84
mist eliminators, 1999 V2: 295
MIUS Technology Evaluation: Collection, Treatment and Disposal of Liquid Wastes, 1999 V2: 238
mixed-bed deionization (single-step), 1999 V2: 302, 303, 304, 305, 2000 V3: 46
mixed media filters, 2000 V3: 132, 133, 139
mixes in specifications, 2004 V1: 91
mixing faucets, 2000 V3: 34
mixing flows of water
  conserving energy, 2004 V1: 126
  mixed-water temperatures, 1999 V2: 159–160
mixing stations, 2000 V3: 36
moderate backflow hazard, 1999 V2: 145, 146, 2000 V3: 222
Modern Vacuum Practice, 1999 V2: 277
modifications section in project manual, 2004 V1: 63
modified header systems, 1999 V2: 127
modular iron piping, 1999 V2: 196
Moffat, R., 1999 V2: 277
mole (mol), 2004 V1: 33
molecular weights of elements, 1999 V2: 281
moments of inertia
  conversion factors, 2004 V1: 36
  measurements, 2004 V1: 33
momentum measurements, 2004 V1: 33
monel, 2004 V1: 141, 144
monitor-type intermediate gas regulators, 2000 V3: 251
monitoring
  aboveground tank systems, 2000 V3:167–168
  ground water, 2000 V3: 162
  underground liquid fuel storage tanks, 2000 V3: 158–163
    measuring leakage, 2000 V3: 158–163
    piping leaks, 2000 V3: 162
    remote leakage, 2000 V3: 162–163
monthly inventory tank tightness testing, 2000 V3: 161–162
Montreal Protocol, 2000 V3: 22
mop basins, 2003 V4: 12
mop sinks, 1999 V2: 25, 2000 V3: 32, 34
morgues and mortuaries, 1999 V2: 16, 147
Moritz, A.R., 1999 V2: 169, 170
mortar joints on septic tanks, 1999 V2: 228
motels
  acoustic plumbing design, 2004 V1: 196
  numbers of fixtures for, 2003 V4: 20
  septic tanks, 1999 V2: 231–232
  vacuum calculations for, 1999 V2: 269
motion
  in creativity checklist, 2004 V1: 234
  in earthquakes, 2004 V1: 158–159
Motor Fuel Dispensing Facilities and Repair Garages Code (NFPA 30A), 2000 V3: 154
motor lubrication oil, 2000 V3: 154
motor-operated filter bag shakers, 1999 V2: 268

motor-operated valves, 2004 V1: 9
motorized valves, 2000 V3: 119
motors
  earthquake protection, 2004 V1: 164
  fan acoustic problems, 2004 V1: 197
  motor journals, 2004 V1: 196
  in pumps, 2004 V1: 196
  rotor acoustic modifications, 2004 V1: 197
mound soil-absorption systems, 1999 V2: 220, 226
mounting. *See also* installation
  fire extinguishers, 2000 V3: 27, 28
  water closets, 2003 V4: 4
MPC (medium-pressure condensate), 2004 V1: 9
mph, MPH (miles per hour), 2004 V1: 15
MPS (medium-pressure steam supply), 2004 V1: 9
mps, MPS (medium-pressure steam), 2004 V1: 15
mrem (millerems), 1999 V2: 339
MSDS (material safety data sheets), 2000 V3: 90
MSS (Manufacturers Standardization Society of the Valve and Fittings Industry, Inc.), 2004 V1: 26, 55, 59
MTD (mean temperature difference), 2004 V1: 15
mthw, MTHW (medium-temperature hot water), 2004 V1: 15
MU (viscosity), 2004 V1: 2, 16, 33, 2000 V3: 154
mudballing in filters, 2000 V3: 132, 150
muds in feed water, 1999 V2: 289
mufflers on vacuum systems, 2000 V3: 70
multi-effect distillation, 1999 V2: 298, 299
multi-graded sand filtration, 1999 V2: 298
multi-level pools, 2000 V3: 108, 109
multimedia filtration, 1999 V2: 298, 300, 322–323
multiple. *See also entries beginning with* double-, multi-, *or* two-

NFPA Fire Protection Handbook, 2000 V3: 8, 29
NFPA Standard no. 10: Standard for Portable Fire Extinguishers, 2000 V3: 27, 29
NFPA Standard no. 11: Low-expansion Foam, 2000 V3: 21, 29
NFPA Standard no. 11A: Medium and High-expansion Foam Systems, 2000 V3: 21, 29
NFPA Standard no. 12: Carbon Dioxide Extinguishing Systems, 2000 V3: 20, 29
NFPA Standard no. 12A: Halon 1301 Fire Extinguishing Systems, 2000 V3: 23, 25, 29
NFPA Standard no. 13: Installation of Sprinkler Systems, 2004 V1: 191, 2000 V3: 2, 12, 15, 16, 21, 29, 232
NFPA Standard no. 14: Installation of Standpipe and Hose Systems, 2000 V3: 2, 18, 29
NFPA Standard no. 15: Water Spray Fixed Systems for Fire Protection, 2000 V3: 2, 29
NFPA Standard no. 16: Deluge Foam-water Sprinkler Systems and Foam-water Spray Systems, 2000 V3: 21, 29
NFPA Standard no. 16A: Installation of Closed-head Foam-water Sprinkler Systems, 2000 V3: 21, 29
NFPA Standard no. 17: Dry Chemical Extinguishing Systems, 2000 V3: 20, 29
NFPA Standard no. 20: Installation of Centrifugal Fire Pumps, 2000 V3: 25, 29
NFPA Standard no. 24: Installation of Private Fire Service Mains and Their Appurtenances, 2000 V3: 29, 225
NFPA Standard no. 30: Flammable and Combustible Liquids Code, 2000 V3: 2, 21, 29, 95, 153, 154, 165, 167, 173
NFPA Standard no. 30A: Motor Fuel Dispensing Facilities and Repair Garages Code, 2000 V3: 154
NFPA Standard no. 50: Standard for Bulk Oxygen Systems at Consumer Sites, 2000 V3: 61, 86
NFPA Standard no. 54: National Fuel Gas Code, 2000 V3: 248, 254
NFPA Standard no. 59: LP-Gases at Utility Gas Plants, 1999 V2: 214
NFPA Standard no. 65: Standard for the Processing and Finishing of Aluminum, 2000 V3: 20
NFPA Standard no. 72: National Fire Alarm Code, 2000 V3: 24, 29
NFPA Standard no. 99: Standard for Health Care Facilities, 2003 V4: 45
NFPA Standard no. 99: Standard for Health-care Facilities, 2000 V3: 50, 56, 66–67, 68, 77, 86
NFPA Standard no. 99C: Gas and Vacuum Systems, 2003 V4: 45
NFPA Standard no. 231: General Storage, 2000 V3: 2, 29
NFPA Standard no. 231C: Rack Storage of Materials, 2000 V3: 2, 29
NFPA Standard no. 255: Standard Method of Test of Surface Burning Characteristics of Building Materials, 2000 V3: 77
NFPA Standard no. 291: Standard on Flow Testing and Marking of Fire Hydrants, 2000 V3: 3
NFPA Standard no. 329: Recommended Practice for Handling Releases of Flammable and Combustible Liquids and Gases, 2000 V3: 154
NFPA Standard no. 385: Standard for Tank Vehicles for Flammable and Combustible Liquids, 2000 V3: 154
NFPA Standard no. 480: Standard for the Storage, Handling and Processing of Magnesium Solids and Powders, 2000 V3: 20
NFPA Standard no. 481: Standard for the Production, Processing, Handling and Storage of Titanium, 2000 V3: 20
NFPA Standard no. 482: Standard for the Production, Processing, Handling and Storage of Zirconium, 2000 V3: 20
NFPA Standard no. 651: Standard for the Machining and Finishing of Aluminum and the Production and Handling Aluminum Products, 2000 V3: 20
NFPA Standard no. 2001: Clean Agent Extinguishing Systems, 2000 V3: 22, 23, 25, 29
sprinkler piping, 2004 V1: 183–184
sprinkler system statistics, 2000 V3: 2
National Fuel Gas Code (NFPA 54), 1999 V2: 214
equivalent lengths, 1999 V2: 184
gas pressures, 1999 V2: 183
industrial boiler gas trains, 1999 V2: 177
natural gas system design, 2000 V3: 248
pipe materials, 2000 V3: 254
pipe sizing, 1999 V2: 194
National Ground Water Association (NGWA), 1999 V2: 252
National Institutes of Health, 1999 V2: 262, 343
National Insulation Contractors' Association (NICA), 2004 V1: 127
National Oceanic and Atmospheric Administration (NOAA), 2000 V3: 242
NOAA, National Weather Service 5-60 Minute Precipitation Frequency for the Eastern and Central United States, 1999 V2: 114
Technical Paper no. 40, 2000 V3: 243
National Plumbing Code, 1999 V2: 65, 114, 155
National Pollutant Discharge Elimination System (NPDES), 2000 V3:88, 2000 V3: 89
National Sanitation Foundation (NSF)
address, 2004 V1: 59
hot-water system requirements, 1999 V2: 170
individual wastewater treatment plants, 1999 V2: 232
list of standards, 2004 V1: 56
PVC plastic ratings, 2000 V3: 145
recycled wastewater quality, 1999 V2: 22
Standard 61, 2003 V4: 26
swimming pool components, 2000 V3: 131
National Sanitation Foundation Testing Laboratory (NSFTL), 2004 V1: 26
National Society of Professional Engineers (NSPE), 2004 V1: 62, 63
National Spa and Pool Institute (NSPI)
address, 2000 V3: 151

ANSI/NSPI-1: Standard for Public Swimming Pools, 2000 V3: 125, 151
ANSI/NSPI-5: Standard for Residential, In-ground Swimming Pools, 2000 V3: 151
Report no. 18: Corrosion in Swimming Pools and General Guide to Materials Selection, 2000 V3: 145
swimming pool codes, 2000 V3: 127
National Standard Plumbing Code, 1999 V2: 37, 65
National Technical Information Service (NTIS), 2000 V3: 97
National Weather Service *Hydro 35,* 2000 V3: 242
natural drainage (corrosion), 2004 V1: 153
natural frequency of vibration control materials, 2004 V1: 202
natural gas. *See* fuel-gas piping systems; natural gas systems
natural gas systems, 2000 V3: 248–254
appliances, 1999 V2: 175, 177–178
bottled gas, 1999 V2: 174
codes and standards, 2000 V3: 248
compressed gas fires, 2000 V3: 21
compressed gases defined, 2000 V3: 199
design considerations, 1999 V2: 173–176
gas boosters, 1999 V2: 178–183
gas train vents, 1999 V2: 177
glossary, 1999 V2: 213–214
high-rise buildings and, 1999 V2: 180
laboratory gas systems, 1999 V2: 176–177
low and medium pressure systems, 1999 V2: 173–194
meters, 2000 V3: 250
overview, 2000 V3: 248
pipe sizing, 1999 V2: 183–194, 2000 V3: 252–254
preliminary information, 2000 V3: 215–216
pressure drops and sizing, 1999 V2: 192, 193
sample gas utility letter, 2000 V3: 249, 258–259
sizing by NFPA formula, 1999 V2: 186, 187, 188, 189
sizing by Spitzglass formula, 1999 V2: 183, 210–211
sizing by Weymouth formula, 1999 V2: 183, 190, 191, 198–209
system components, 2000 V3: 250–252
drip pots, 2000 V3: 252
gas line filters, 2000 V3: 250
gas meters, 2000 V3: 250
gas pressure regulators, 2000 V3: 250–252
natural gas pipes, 2003 V4: 35, 36
testing and purging, 2000 V3: 252, 253
types of services, 2000 V3: 249
natural gas water heaters. *See* gas-fired water heaters
natural logarithms, 2004 V1: 15
natural osmosis, 1999 V2: 308
natural period of vibration, 2004 V1: 160
Natural Resources Defense Council, 2000 V3: 88
natural water, 1999 V2: 280, 320
naturally-vented multiple tray aerators, 1999 V2: 293
naval rolled brass, 2004 V1: 144
NBBPVI (National Board of Boiler and Pressure Vessel Inspectors), 1999 V2: 166
NBR (acrylonitrile butadiene rubber), 2000 V3: 169
NBS (National Bureau of Standards). *See* National Bureau of Standards
NC (noise criteria), 2004 V1: 15, 206
NC (number of circuits), 2004 V1: 15
NCAA (National Collegiate Athletic Association), 2000 V3: 151
NCCLS (National Committee for Clinical Laboratory Standards, Inc.), 1999 V2: 279, 317, 319
NEC (National Electrical Code), 1999 V2: 170
negative gauge pressure, 1999 V2: 254
negative pressure. *See* vacuum
negativity in value engineering presentations, 2004 V1: 258
NEMA 4 listing, 1999 V2: 179
NEMA 4X listing, 1999 V2: 166
NEMA 12 listing, 1999 V2: 179
NEMA Class 1, Division 1, Group D listing, 1999 V2: 179
neoprene compression gaskets, 2003 V4: 27
neoprene floor and hanger mounts, 2004 V1: 203, 204, 205
neoprene gaskets, 2000 V3: 42
neoprene seal plugs in cleanouts, 1999 V2: 9
nephelometric test, 1999 V2: 287
nephelometric turbidity units (NTUs), 1999 V2: 287
net positive suction head (NPSH), 2004 V1: 199, 206, 1999 V2: 247, 2000 V3: 140
neutralizing acid in waste water
discharge from laboratories, 2000 V3: 40
health-care facility systems, 2000 V3: 40
laboratories, 2000 V3: 40–41
methods of treatment, 1999 V2: 334–337
sizing tanks, 2000 V3: 42
solids interceptors, 2000 V3: 41, 43
tank and pipe materials, 2000 V3: 91–92
types of acids, 1999 V2: 332, 333
neutralizing tanks, 2000 V3: 42
neutrons, 1999 V2: 337
New York City, ultra-low-flow toilets in, 2004 V1: 134–135
New York State Department of Environmental Conservation
address, 2000 V3: 97
Technology for the Storage of Hazardous Liquids, 2000 V3: 96
newton-meters, 2004 V1: 33
newtons, 2004 V1: 33
NF nomographs, 1999 V2: 317
NFPA. *See* National Fire Protection Association, Inc.
NGWA (National Ground Water Association), 1999 V2: 252
ni-resist cast iron, 2004 V1: 144
ni-resist ions, 2004 V1: 141
NICA (National Insulation Contractors' Association), 2004 V1: 127
niche lights for pools, 2000 V3: 121, 145
nickel
corrosion, 2004 V1: 139
electromotive force series, 2004 V1: 144
galvanic series, 2004 V1: 141
in stainless steel, 2003 V4: 2
nickel-bronze grates, 1999 V2: 15, 16
nightclubs, numbers of fixtures for, 2003 V4: 19
Nine Dots exercise, 2004 V1: 232, 261
nippled-up sprinklers, 2004 V1: 13
nipples for cast iron radiators, 2000 V3: 179
nitrates, 1999 V2: 281, 283
nitric acid, 2004 V1: 146, 1999 V2: 333

nitrifying bacteria, 1999 V2: 282
nitrile butadiene (Buna-N), 2000 V3: 169
nitrogen (N)
color coding outlets, 2000 V3: 56
control cabinets, 2000 V3: 58
cylinder supplies, 2000 V3: 60
defined, 2000 V3: 84
dry nitrogen, 2000 V3: 252
gas blankets in water tanks, 1999 V2: 324
high-pressure dispensing equipment, 2000 V3: 59
laboratory outlets, 2000 V3: 37–39
medical gas pipe sizing, 2000 V3: 74, 75, 77
medical gas stations, 2000 V3: 51–52
medical gas storage, 2000 V3: 68
oil-free, 2003 V4: 45
in raw water, 1999 V2: 284
surgical use, 2000 V3: 57
symbol, 2004 V1: 9
testing concentrations, 2000 V3: 82
in water chemistry, 1999 V2: 281
nitrogen NF, 2000 V3: 65, 84
nitrous fumes, 1999 V2: 333
nitrous oxide (N^2O)
color coding outlets, 2000 V3: 56
cylinder supplies, 2000 V3: 60
defined, 2000 V3: 84
medical gas pipe sizing, 2000 V3: 74, 76
medical gas storage, 2000 V3: 64–65
surgical use, 2000 V3: 57
symbol, 2004 V1: 9
testing concentrations, 2000 V3: 82
waste anesthetic gas management, 2000 V3: 70
nL/min (normal liters per minute), 2000 V3: 200
nm^3/min (normal cubic meters per minute), 2000 V3: 200
no-flow pressure in pressure-regulated valves, 1999 V2: 152
no-hub joints, earthquake protection and, 2004 V1: 168
no-hub outlets, 1999 V2: 18
no-man zones around building footers, 1999 V2: 103
no., NO (numbers), 2004 V1: 15
"no observed adverse effect level," 2000 V3: 22
no-slump concrete, 2003 V4: 32
NOAA (National Oceanic and Atmospheric Administration)
NOAA, National Weather Service 5-60 Minute Precipitation Frequency for the Eastern and Central United States, 1999 V2: 114
rainfall records, 2000 V3: 242
Technical Paper no. 40, 2000 V3: 243
NOAEL (no observed adverse effect level), 2000 V3: 22
noble potential, defined, 2004 V1: 153
noise. *See* acoustics in plumbing systems
noise criteria (NC), 2004 V1: 15, 206. *See also* preferred noise criteria (PNC) curves
nominal diameter (DN), 1999 V2: 253
nominal pipe size (NPS), 1999 V2: 253, 2003 V4: 61, 62
nominal values, 2004 V1: 32
nomographs, 1999 V2: 31–32
non-agreement states, 1999 V2: 340
non-ambulatory disabilities, 2004 V1: 107
non-aqueous liquid wastes, 2000 V3:87
non-aspirating nozzles, 2000 V3: 21
non-circular grab bars, 2004 V1: 121
non-circulating water systems, 2004 V1: 127
non-continuous joints, 2004 V1:150
non-depletable energy sources, 2004 V1: 137
Nondiscrimination on the Basis of Disability by Public Accommodations and in Commercial Facilities, 2004 V1: 106
non-electrolytes, 1999 V2: 280
non-flammable medical gas, 2000 V3: 49
Non-flammable Medical Gas Piping Systems (CSA Z305.1), 2000 V3: 86
non-looped piping systems, 2000 V3: 16
non-measurable nouns in function analysis, 2004 V1: 224
non-metallic coatings, 2004 V1: 147
non-oxidizing chemicals in microbial control, 1999 V2: 311
non-oxidizing piping, 1999 V2: 341
non-porous piping, 1999 V2: 341
non-porous soils, 2000 V3: 105
non-potable cold water (NPCW), 2004 V1: 9
non-potable hot water (NPHW), 2004 V1: 9
non-potable hot water return (NPHWR), 2004 V1: 9
non-potable water systems. *See* gray-water systems
non-pressure asbestos concrete pipe, 2003 V4: 26
non-pumping wells, 1999 V2: 241–243
non-puncturing membrane flashing, 1999 V2: 17
non-reactive silica, 1999 V2: 283
non-reinforced concrete pipe, 2003 V4: 32
non-rigid couplings, 2004 V1: 186
non-SI units, 2004 V1: 34
non-sprinklered spaces, 2004 V1: 12
Non-structural Damage to Buildings, 2004 V1: 191
non-tilting grates, 1999 V2: 11
non-vitreous china fixtures
defined, 2003 V4: 1
standards, 2003 V4: 2
"normal," compared to "standard," 2000 V3: 200
normal cubic meters per minute (nm^3/min), 2000 V3: 200
normal liters per minute (nL/min), 2000 V3: 200
normally closed (n c, N C), 2004 V1: 15
normally open (n o, N O), 2004 V1: 15
nose pieces in deaerators, 1999 V2: 56
not applicable (na, N/A), 2004 V1: 15
not in contract (n i c, N I C), 2004 V1: 15
not to scale (NTS), 2004 V1: 15
nouns in function analysis, 2004 V1: 224, 225, 231
nourishment stations in health-care facilities, 2000 V3: 32
nozzles
defined, 2004 V1: 29
dry-chemical systems, 2000 V3: 19
fountains, 2000 V3: 108–109, 112, 117–118, 119–120
fuel dispensers, 2000 V3: 165
irrigation sprinklers, 2000 V3: 103
pressure, 2000 V3: 19, 219
pressure flow tables, 2000 V3: 4, 7
sprinklers, 2000 V3: 9
standpipe systems, 2000 V3: 19
water level in pools and, 2000 V3: 112
NPCW (non-potable cold water), 2004 V1: 9
NPDES (National Pollutant Discharge Elimination System), 2000 V3:88, 2000 V3: 89
NPHW (non-potable hot water), 2004 V1: 9
NPHWR (non-potable hot water return), 2004 V1: 9

NPS (nominal pipe size), 1999 V2: 253
NPSH (net positive suction head), 2004 V1: 199, 206, 1999 V2: 247, 2000 V3: 140
NRC (Nuclear Regulatory Commission), 1999 V2: 339, 340
NSF. *See* National Sanitation Foundation (NSF)
NSPE (National Society of Professional Engineers), 2004 V1: 62, 63
NSPI. *See* National Spa and Pool Institute (NSPI)
NT (number of tubes), 2004 V1: 15
NTIS (National Technical Information Service), 2000 V3: 97
NTS (not to scale), 2004 V1: 15
NTUs (nephelometric turbidity units), 1999 V2: 287
nuclear power plants
  nuclear reactors, 1999 V2: 147
  regulatory requirements, 1999 V2: 337
  seismic protection, 2004 V1: 156
Nuclear Regulatory Commission, 1999 V2: 339, 340
numbers (no., NO, N)
  of circuits (NC), 2004 V1: 15
  in CSI format, 2004 V1: 65
  in measurements, 2004 V1: 32
  of swimmers, 2000 V3: 127–128
  symbol, 2004 V1: 15
  of tubes (NT), 2004 V1: 15
numerical weights in value engineering, 2004 V1: 243
nurse stations, 2000 V3: 32
nurseries
  fixtures for, 2000 V3: 34
  health-care facilities, 2000 V3: 32
  medical gas stations, 2000 V3: 52, 58
  sinks, 2000 V3: 38
nursing homes. *See* health-care facilities
Nussbaum, O.J., 1999 V2: 325

O

O-rings, 2003 V4: 37
o-ring gaskets, 2004 V1: 266
O_2. *See* oxygen (O_2, OX)
oa, OA (outside air), 2004 V1: 15
oakum seals, 2003 V4: 27, 28
objectives in FAST approach, 2004 V1: 230
obstructions to wheelchairs, 2004 V1: 111, 112
occupancy classification (sprinkler systems), 2004 V1: 29, 2000 V3: 2, 17
occupancy of pools, 2000 V3: 127–128
occupant loads of buildings, 2003 V4: 18
Occupational Safety and Health Administration (OSHA), 1999 V2: 333, 2000 V3: 153, 156
occupied domestic spaces, acoustic plumbing design for, 2004 V1: 196
ocean water, irrigation systems and, 1999 V2: 26
octave-band sound levels, 2004 V1: 194
octaves, 2004 V1: 206
OD (outside diameters), 2004 V1: 14
odor control in drinking water, 1999 V2: 245, 316
OFCI (owner furnished, contractor installed), 2004 V1: 71
off-peak power usage, 2004 V1: 128–129
office buildings, numbers of fixtures for, 2003 V4: 19, 21–22
Office of Statewide Health Planning and Development (OSHPD), 2004 V1: 191
offset stacks
  defined, 1999 V2: 64
  sizing, 1999 V2: 5, 6
  venting, 1999 V2: 44–45
offsets, defined, 2004 V1: 26
offshore facilities, 2004 V1: 150
ohm-centimeter units (-cm), 2000 V3: 46
ohm-meters, 2004 V1: 33
Ohm's Law, 2004 V1: 144
OHMS (resistance or resistors), 2004 V1: 15, 33
oil
  as seal liquid in liquid ring pumps, 1999 V2: 260
  contamination in compressed air, 2000 V3: 201
  intercepting in acid-waste systems, 1999 V2: 336
  intercepting in sanitary drainage systems, 1999 V2: 12–13
  oil-water separation, 2000 V3: 93
  skimming, 2000 V3: 93
  spills and containment, 1999 V2: 347–349
  storm-drainage systems and, 1999 V2: 67
  vegetable oil, 1999 V2: 10
oil draw-off pipes, 1999 V2: 13
oil-free compressors, 2000 V3: 67, 201
oil interceptors, 1999 V2: 12–13, 349
oil-mist filters in vacuums, 1999 V2: 260
oil-removal filters, 2000 V3: 203
oil systems. *See* diesel-oil systems; gasoline systems
oil-wet solids, 1999 V2: 347
oilless compressors, 2000 V3: 67
oilless pumps, 1999 V2: 259, 262
oleums, 1999 V2: 332, 333
on-site facility treatment systems. *See* special-waste drainage systems
on-site storm-water detention systems, 1999 V2: 105–107
On Site Wastewater Facilities for Small Communities and Subdivisions, 1999 V2: 238
on-site water reclamation. *See* gray-water systems
one-compartment septic tanks, 1999 V2: 229
one-compartment sinks, 2003 V4: 11
one-family dwellings, numbers of fixtures for, 2003 V4: 20, 21
one-occupant toilet rooms, 2003 V4: 18, 23
one-pass cooling for equipment, 2004 V1: 264
one-piece water closets, 2003 V4: 3
one-pipe heat-trace systems, 1999 V2: 165
one-pipe steam systems, 2000 V3: 178–180, 183, 186, 188
one-pipe systems (Philadelphia systems), 1999 V2: 46, 47, 48
one-stage distillation, 1999 V2: 295
one-tank residential filters, 2000 V3: 134
one-time costs, 2004 V1: 223
one-wall tanks, 2000 V3: 156
ongoing costs, 2004 V1: 223
Ongontz valves, 2000 V3: 125
open-channel flow, 2004 V1: 1, 1999 V2: 7
open-circuit potential, defined, 2004 V1: 153
open-head sprinklers, 2000 V3: 21
open-joint piping, 1999 V2: 102
open proprietary specifications, 2004 V1: 67, 68
open-spring floor and hanger mounts, 2004 V1: 203, 204
open sprinklers, 2004 V1: 29
open-type base pumps, 1999 V2: 243

open-web steel joists in pipe bracing, 2004 V1: 176
openings for tool access. *See* cleanouts
operating costs, 2004 V1: 223
operating hot-water temperatures, 1999 V2: 166
operating-pressure steam classification, 2000 V3: 175–178
  equipment ratings, 2000 V3: 178
  vacuum systems, 2000 V3: 178
  vapor systems, 2000 V3: 175–178
operating rooms
  articulated ceiling medical gas systems, 2000 V3: 59
  fixtures, 2000 V3: 35–36
  medical gas stations, 2000 V3: 52, 58
  medical vacuum, 2000 V3: 54
  water demand, 2000 V3: 45
operators of vacuum systems, 1999 V2: 269
oral surgery equipment, 2000 V3: 39, 52
orbital welding process, 1999 V2: 341
orders in creativity checklist, 2004 V1: 234
ordinary hazard occupancies
  defined, 2004 V1: 29
  firefighting hose streams, 2000 V3: 230
  portable fire extinguishers, 2000 V3: 27, 28
ordinary lobe pumps, 1999 V2: 259
organic free water, 1999 V2: 317
organic materials in water, 2000 V3: 46
organic polyelectrolytes, 1999 V2: 294
organisms in water, 1999 V2: 282, 2000 V3: 146. *See also* microorganisms
orifices
  on hydrants, 2000 V3: 7
  on nozzles, 2000 V3: 7
ornamental sprinklers, 2004 V1: 29
ORP (oxidation reduction potential), 2000 V3: 122, 123
orthotolidin tests, 1999 V2: 154
oscillating-type monitors, 2000 V3: 21
oscillation in pumps, 2004 V1: 201
OSHA (Occupational Safety and Health Administration), 1999 V2: 333
OSHPD (Office of Statewide Health Planning and Development), 2004 V1: 191
osmosis, defined, 1999 V2: 308
osmotic pressure, 1999 V2: 308
Otis, Richard J., 1999 V2: 238
OTO pumps, 1999 V2: 259
Otten, Gerald, 1999 V2: 325
Otto plate units, 1999 V2: 313
ounces (oz, OZ)
  converting to SI units, 2004 V1: 40
  symbols for, 2004 V1: 15
out-of-sequence work conditions, cost estimates for projects and, 2004 V1: 98
outdoor gas booster installation, 1999 V2: 180
outdoor gas hose connectors, 1999 V2: 196
outdoor swimming pools. *See also* swimming pools
  components for, 2000 V3: 139
  considerations, 2000 V3: 129
outfall sewers, 2004 V1: 26
outlet pressures
  outlet pressure regulators, 2000 V3: 14, 15
  standpipe systems, 2000 V3: 19
outlets. *See also* inlets; stations
  flow rates at outlets, 2004 V1: 3, 5
  gas boosters, 1999 V2: 179, 183
  gas or vacuum. *See* stations
  pools and fountains, 2000 V3: 110–111
  pressure in cold-water systems, 1999 V2: 153
  septic tanks, 1999 V2: 228
  symbols for, 2004 V1: 11
  velocity of flow from outlets, 2004 V1: 6
outpatient-services rooms, 2000 V3: 32, 45
outside air (oa, OA), 2004 V1: 15
outside diameters (OD), 2004 V1: 14
outside film coefficients, 2004 V1: 14
"outside the box" thinking, 2004 V1: 232
"outstanding value," defined, 2004 V1: 213
overall system thermal efficiency, 2004 V1: 136
overengineering, perception of, 2004 V1: 260
overestimating needs, 2004 V1: 224
overfill prevention, 2000 V3: 90, 2000 V3:167, 2000 V3: 167
overflow
  for bathtubs, 2003 V4: 16
  for lavatories, 2003 V4: 10–11
  for pools and fountains, 2000 V3: 112, 125
  storm drains. *See* secondary storm-drainage systems
overhead
  costs in value engineering, 2004 V1: 212, 222
  in plumbing cost estimation, 2004 V1: 93
overhead steam return lines, 2000 V3: 196
overheating vacuum exhausters, 1999 V2: 268–269
overland flow rates for sites, 2000 V3: 242, 244, 245
overland flow times for sites, 1999 V2: 96, 97, 98, 111
overlap in toilet accessibility, 2004 V1: 114
overload protection in fountain pumps, 2000 V3: 120
oversized steam traps, 2000 V3: 196
overspray areas in irrigation, 2000 V3: 104
overtime labor costs, in take-off estimating method, 2004 V1: 94
overturning, preventing, 2004 V1: 163, 189
overvoltage, defined, 2004 V1: 153
owner furnished, contractor installed (OFCI), 2004 V1: 71
owners
  perception of engineering, 2004 V1: 260
  value engineering and, 2004 V1: 212
OX (oxygen). *See* oxygen (O_2, OX)
oxidation, defined, 2004 V1: 153
oxidation reduction potential (ORP), 2000 V3: 122, 123
oxidized sewage, 2004 V1: 27
oxidizing chemicals in microbial control, 1999 V2: 311
oxidizing gases, 2000 V3: 84
OXY/ACR pipes, 2003 V4: 36
OXY/MED pipes, 2003 V4: 36
OXY, MED piping, 2003 V4: 36
oxygen concentration cells, 2004 V1: 153
oxygen-delivery equipment, 2000 V3: 85
oxygen-enriched atmospheres, 2000 V3: 85
Oxygen-fuel Gas Systems for Weldings and Cuttings, 1999 V2: 214
oxygen index, 2000 V3: 85
oxygen (O_2, OX)
  bulk oxygen systems, 2000 V3: 61–62, 63
  color coding outlets, 2000 V3: 56
  corrosion process, 2004 V1: 145, 1999 V2: 284
  cylinder-manifold supply systems, 2000 V3: 62–63, 64

defined, 2000 V3: 84–85
medical gas pipe sizing, 2000 V3: 74, 75, 76
medical gas stations, 2000 V3: 50, 51–52
medical gas storage, 2000 V3: 59–63
medical gas systems, 2000 V3: 49
medical reserve supply, 2000 V3: 60
oxygen depletion and gas appliances, 1999 V2: 178
oxygen pitting, 2000 V3: 190
oxygen USP, 2000 V3: 65, 84
oxygenated water, 1999 V2: 245, 2000 V3: 116
reducing with carbon dioxide, 2000 V3: 20
removing, 1999 V2: 294
saturation with, 1999 V2: 292–294
surgical use, 2000 V3: 57
symbols for, 2004 V1: 8
testing concentrations, 2000 V3: 82
in water, 1999 V2: 281
oxygen scavengers, 1999 V2: 314, 315
oxygen toxicity, 2000 V3: 85
oz, OZ (ounces), 2004 V1: 15, 40
ozonation
cooling tower water, 1999 V2: 316
pure water systems, 1999 V2: 323
small drinking water systems, 1999 V2: 318
water treatments, 1999 V2: 245, 312–313
ozone
layer, 2000 V3: 22
in pools and fountains, 2000 V3: 123–124
ozone generators, 1999 V2: 313

P

P alkalinity, 1999 V2: 282
P (peta) prefix, 2004 V1: 34
p (pico) prefix, 2004 V1: 34
P (pressure). *See* pressure
p-traps
floor drains with, 2004 V1: 11
laboratory sinks, 2000 V3: 42
storm drainage systems, 1999 V2: 84
Pa (pascals), 2004 V1: 33
PA (pipe anchors), 2004 V1: 10
Pa s (pascal-seconds), 2004 V1: 33
packed-bed, activated-carbon filters, 1999 V2: 300, 301
packed tower aeration, 1999 V2: 318
packerhead method, 2003 V4: 32
packing material
in seepage beds, 1999 V2: 224
sound damping, 2004 V1: 196
in vacuum deaerators, 1999 V2: 295
padding
for glass pipe, 2003 V4: 47
for vibration control, 2004 V1: 203, 204
pain, thresholds of, 1999 V2: 169
painting cast iron radiators, 2000 V3: 179
paints in septic tanks, 1999 V2: 230
Pair, Claude H., 2000 V3: 105
panels, lining with lead, 1999 V2: 340
paper towel clogs, 1999 V2: 11, 231
paraffin, 1999 V2: 13
paragraph numbering in CSI format, 2004 V1: 65
parallel approaches for wheelchairs, 2004 V1: 109, 110
parallel-condensate trapping, 2000 V3: 196
parallel-flow piping designs, 2000 V3: 178, 183
parallel installation of pressure-regulated valves, 1999 V2: 153
parallel-shaft gears, 2004 V1: 196
parapet wall scuppers, 1999 V2: 79, 82
Parekh, B.S., 1999 V2: 325
Pareto principle, 2004 V1: 224, 258
Pareto, Vilfredo, 2004 V1: 224
parking lot drainage pipes, 2003 V4: 32
Parmalee heads, 2000 V3: 1
part-circle rotary sprinkler heads, 2000 V3: 102
partially-sprinklered spaces, 2004 V1: 12
participation in value engineering presentations, 2004 V1: 258
particle size in sand filters, 2000 V3: 132
particulate radiation, 1999 V2: 339
particulate silica, 1999 V2: 283
particulates
contamination in compressed air, 2000 V3: 201
in water, 1999 V2: 282, 287–288
parts per million (ppm, PPM), 2004 V1: 15, 1999 V2: 285, 2000 V3: 46
pascal-seconds, 2004 V1: 33
pascals, 2004 V1: 33
passenger terminals, numbers of fixtures for, 2003 V4: 19
passivation, 2004 V1: 146–147
passive, defined, 2004 V1: 153
passive verbs in function analysis, 2004 V1: 224
pathogenic organisms, 1999 V2: 282
paths
of acoustic problems, 2004 V1: 199
of discharge, 2000 V3: 4
patient rooms
bathing areas, 2000 V3: 32
fixtures for, 2000 V3: 34
health-care facilities, 2000 V3: 32
medical gas stations, 2000 V3: 52, 58
medical vacuum, 2000 V3: 54
patient head wall stations, 2000 V3: 58
patient vacuum (VAC), 2000 V3: 85
paved areas
imperviousness factors, 2000 V3: 243
storm drainage, 1999 V2: 67
PB (polybutylene). *See* polybutylene (PB)
PCT (percentages), 2004 V1: 15
PCUs (platinum cobalt units), 1999 V2: 287
PD (pressure drops or differences). *See* pressure drops or differences
PD (pump discharge lines), 2004 V1: 8
PDI (Plumbing and Drainage Institute). *See* Plumbing and Drainage Institute (PDI)
PDI symbols for water hammer arresters, 1999 V2: 144
PE-AL-PE (polyethylene/aluminum/polyethylene), 2003 V4: 62
PE (polyethylene). *See* polyethylene (PE)
PE (potential energy), 2004 V1: 2, 5
pea gravel backfill, 2000 V3: 172
Peabody, A.W., 2004 V1: 154
peak consumption in gas boosters, 1999 V2: 182
peak demand
flushometer valves and, 2003 V4: 8
medical air, 2000 V3: 53, 66

medical gas, 2000 V3: 49
medical vacuum, 2000 V3: 55
swimming pools, 2000 V3: 127–128
urinals, 2003 V4: 10
vacuum systems, 2000 V3: 70
penal institutions, 2003 V4: 20, 22
pendent sprinklers, 2004 V1: 13, 29, 2000 V3: 13
penetration of irrigation water, 2000 V3: 99, 105
penetrations of walls and floors, 2000 V3: 25
people with disabilities
ambulatory-accessible toilet compartments, 2004 V1: 114
ANSI 117.1-1998, 2004 V1: 109–123
bathing rooms, 2004 V1: 112–113
bathtub and shower seats, 2004 V1: 122–123
bathtub design, 2004 V1: 117–119
design for, 2004 V1: 107
drinking fountains and water coolers, 2004 V1: 109–112
exposed piping and accessibility, 2004 V1: 117
fixture design standards and, 2003 V4: 2
grab bars, 2004 V1: 114–122
history of design and construction standards, 2004 V1: 105–106
introduction to plumbing for, 2004 V1: 105
laundry equipment, 2004 V1: 123
lavatories and sinks, 2004 V1: 117
legislation, 2004 V1: 106–107
references, 2004 V1: 122
shower compartments, 2004 V1: 119–122
swimming pool bathhouses, 2000 V3: 130
swimming pools, 2000 V3: 128
urinal design, 2004 V1: 116
water closets and toilets, 2004 V1: 113–116, 2003 V4: 5
per-area costs, 2004 V1: 97–98
per-fixture estimations, cost estimations, 2004 V1: 97
percentages (%, PCT), 2004 V1: 15
perception
in creativity, 2004 V1: 231
of engineers, 2004 V1: 260
perched water, 1999 V2: 100
perchloric acid, 1999 V2: 333–334
percolation
defined, 2004 V1: 27
rates for soils, 1999 V2: 217–220, 238
Perfect Gas law, 2000 V3: 66
perfect vacuums, 1999 V2: 254, 2000 V3: 200
perfluorocarbons (PFCs), 2000 V3: 22
perfluorohexane, 2000 V3: 22
perforated piping, 1999 V2: 102
performance bonds, 2004 V1: 62
performance criteria in specifications, 2004 V1: 69, 88
Performance of Reduced-size Venting in Residential Drain, Waste and Vent System, 1999 V2: 65
performance specifications, 2004 V1: 66
performance tests. *See* testing
perimeter diking, 2000 V3: 90
permeability
coefficient of (K factor), 1999 V2: 100–101, 104–105, 242
converting to SI units, 2004 V1: 40
permeable strata in soils, 1999 V2: 219
permeance, converting to SI units, 2004 V1: 40
permits
industrial wastewater, 2000 V3:87
RCRA hazardous waste, 2000 V3: 89
Perry's Chemical Engineering Handbook, 2000 V3: 97
persons with disabilities. *See* people with disabilities
pesticides in septic tanks, 1999 V2: 230
"peta" prefix, 2004 V1: 34
petroleum-based fuel systems. *See* diesel-oil systems; gasoline systems
petroleum-processing plants, 1999 V2: 147
petroleum products, 2000 V3: 154
PEX-AL-PEX (cross-linked polyethylene/aluminum/cross-linked polyethylene), 2003 V4: 61–62
PEX (cross-linked polyethylene), 2003 V4: 61
PFCs (perfluorocarbons), 2000 V3: 22
PG (pressure gauges with gauge cocks), 2004 V1: 10
pH
acid wastes, 1999 V2: 334–337
adjustments in pool water, 2000 V3: 123
adjustments to waste, 1999 V2: 328
alkalinity and, 1999 V2: 283
boiler feed water, 1999 V2: 314
control systems, 2000 V3: 123
copper piping and, 2000 V3: 145
in corrosion rates, 2004 V1: 145
defined, 2004 V1: 153
discharge from laboratories, 2000 V3: 40
feed water for pure water systems, 1999 V2: 322
industrial wastewater systems, 2000 V3: 91–92
limits for sanitary drainage systems, 2000 V3: 42
measuring, 1999 V2: 285, 2000 V3: 123
predicting water deposits, 1999 V2: 290
saturation, 1999 V2: 291, 293
swimming pools, 2000 V3: 147
testing in pools, 2000 V3: 147
values in waste, 1999 V2: 329
pH Control of Chemical Waste, 1999 V2: 350
ph, PH (phases, electrical), 2004 V1: 15
pharmaceutical facilities, 2000 V3:87
pharmaceutical pure water, 1999 V2: 317–325, 320, 322, 2000 V3: 46
Pharmaceutical Water, 1999 V2: 325
pharmaceutical water pipe, 2003 V4: 58
pharmacies
fixtures, 2000 V3: 35
health-care facilities, 2000 V3: 32
medical gas stations, 2000 V3: 52
Phase 1 vapor recovery, 2000 V3: 154, 163, 166, 168
Phase 2 vapor recovery, 2000 V3: 154, 163, 168
phases, electrical (ph, PH), 2004 V1: 15
PHCC-NA. *See* Plumbing-Heating-Cooling Contractors–National Association (PHCC-NA)
phenolics as thermoset, 2003 V4: 58
phenolphthalein alkalinity, 1999 V2: 282
Philadelphia venting system, 1999 V2: 46, 47, 48
phosphates, 2004 V1: 151, 1999 V2: 281, 282
phosphoric acid, 1999 V2: 281, 333
phosphorus, 1999 V2: 281
phosphorus 32, 1999 V2: 340
photographic badges for radiation levels, 1999 V2: 339
photolytic oxidation, 1999 V2: 288

photovoltaic water heaters, 2004 V1: 265
physical characteristics of drinking water, 1999 V2: 316, 318
physical therapy rooms, 2000 V3: 32, 35
physically challenged people. *See* people with disabilities
physics laboratories, 1999 V2: 262. *See also* laboratories
"pico" prefix, 2004 V1: 34
piers, 1999 V2: 147
pig lead, 2003 V4: 48
pilot-operated gas regulators, 2000 V3: 250, 251
pilot-operated makeup valves, 2000 V3: 124
pilot-operated pressure-regulated valves, 1999 V2: 153
pilot-valve discs, 2000 V3: 9
pints, converting to SI units, 2004 V1: 40
pipe anchors (PA), 2004 V1: 10
pipe dope, 1999 V2: 284
pipe glue, 1999 V2: 284
pipe guides, 2004 V1: 10
pipe hangers. *See* supports and hangers
pipe joints
  acid-waste systems, 1999 V2: 334
  chemical-waste systems, 1999 V2: 345–346
  clay pipe joints, 1999 V2: 223
  copper joints, 1999 V2: 222
  fill and, 1999 V2: 15
  galvanized iron joints, 1999 V2: 222
  heat-fused socket joints, 1999 V2: 334
  inspection, 2000 V3: 80
  liquefied petroleum gas, 1999 V2: 196
  material codes and standards, 2004 V1: 43
  mechanical clay pipe joints, 1999 V2: 223
  natural gas systems, 2000 V3: 254
  plastic joints, 1999 V2: 222
  plastic pipe expansion joints, 1999 V2: 251
  pure-water systems, 2000 V3: 47
  radioactive waste systems, 1999 V2: 341
  restrainers, 2000 V3: 228–229
  sanitary, 2000 V3: 48
  screwed mechanical joints, 1999 V2: 334
  special-waste drainage systems, 1999 V2: 328
  thermal expansion and, 1999 V2: 18
  welded joints, 1999 V2: 341
pipe nipple codes, 2004 V1: 43
pipe shafts, 2000 V3: 73
pipe sleeves
  acoustic design, 2004 V1: 201
  earthquake recommendations, 2004 V1: 162
pipe solvents, 1999 V2: 284
pipe supports. *See* supports and hangers
pipe wrappings, 2004 V1: 196, 201–202, 1999 V2: 68, 196
pipes and piping. *See also* sizing; *specific kinds of piping or piping functions*
  bedding, 2000 V3: 234, 235
  calculating water capacity per foot, 2000 V3: 12
  cleaning and covering exposed ends, 2003 V4: 25
  codes and standards, 2004 V1: 42–45
  compressed air systems, 2000 V3: 206–213
  computer analysis of piping systems, 2004 V1: 186
  condensate drainage, 2000 V3: 191–196
  corrosive wastes, 2000 V3: 40
  cost estimation, 2004 V1: 93
  damage to pipes, 2003 V4: 25
  defined, 2000 V3: 85
  draining, 2003 V4: 25
  exposed piping on storage tanks, 2000 V3: 165
  fire-protection systems, 2000 V3: 8, 23, 24
  fountain display and filter systems, 2000 V3: 111–112, 116–119
  hazardous waste incompatibilities, 2000 V3: 90, 91
  heat loss and, 2000 V3: 122
  high-pressure piping, 2000 V3: 196–197
  installation requirements, 2003 V4: 25
  laboratory waste and vent piping, 2000 V3: 42
  leakage, 2004 V1: 134
  liquid fuel systems, 2000 V3:169–170
  medical gas systems, 2000 V3: 73–77
  monitoring leakage, 2000 V3: 162
  natural gas systems, 2000 V3: 252–254
  pipe schedules, 2000 V3: 16, 18
  piping symbols, 2004 V1: 7–13
  pure-water systems, 2000 V3: 47–48
  seismic protection, 2004 V1: 155, 166–182
  specifications, 2003 V4: 25–26
  sprinkler system pipes, 2000 V3: 12, 15, 17
  steam systems, 2000 V3: 177, 195
  storm sewers, 2000 V3: 244–245, 246
  sustainable design and, 2004 V1: 264
  swimming pools, 2000 V3: 145
  symbols (PIPE), 2004 V1: 15
  tightness testing, 2000 V3: 172
  types
    asbestos concrete, 2003 V4: 26
    brass (copper alloy) pipe, 1999 V2: 14, 2003 V4: 27
    cast-iron soil pipe, 2003 V4: 27–31
    chlorinated polyvinyl-chloride (CPVC), 1999 V2: 284, 2000 V3: 48, 2003 V4: 59–60, 62
    concrete pipe. *See* concrete piping
    copper drainage tube, 2003 V4: 45, 46
    copper pipe. *See* copper piping
    copper water tube, 2003 V4: 34–44
    cross-linked polyethylene/aluminum/cross-linked polyethylene (PEX-AL-PEX), 2003 V4: 61–62
    cross-linked polyethylene (PEX), 2003 V4: 61–62
    ductile iron water and sewer pipe. *See* ductile iron piping
    glass pipe, 1999 V2: 334, 341, 2003 V4: 45–50
    gray cast-iron pressure pipe, 2003 V4: 32
    lead piping, 2004 V1: 266, 1999 V2: 14, 68, 122, 2003 V4: 48–49
    medical gas tubing, 2000 V3: 77, 81, 2003 V4: 45
    plastic. *See* plastic piping
    polybutylene pipes, 2003 V4: 58–60
    polyethylene/aluminum/polyethylene (PE-AL-PE), 2003 V4: 62
    polyvinyl chloride (PVC), 1999 V2: 68, 284, 2000 V3: 116, 119, 145, 2003 V4: 59–60, 62
    steel pipe. *See* steel piping
    vitrified clay piping, 1999 V2: 122, 346, 2000 V3: 245, 2003 V4: 49, 56–57
piping-arrangement steam classifications, 2000 V3: 178–186
  one-pipe systems, 2000 V3: 178–180
  traps, 2000 V3: 182–186

two-pipe systems, 2000 V3: 180–182
Piping Handbook, 1999 V2: 214
Piping Specifications and Installation Practices, 2000 V3: 97
Piping Systems Fundamentals and Application, 1999 V2: 155
piston reciprocating compressors, 2000 V3: 201
pit-type fire-department connections, 2004 V1: 12
pitch
defined, 2004 V1: 27
pitch down or up, 2004 V1: 11
radioactive waste systems, 1999 V2: 342
special-waste drainage systems, 1999 V2: 329
vacuum cleaning systems, 1999 V2: 276
pitless adapters, 1999 V2: 243
pitot pressure, 2000 V3: 5, 7, 220
pitot tubes, 2000 V3: 4, 217, 219
pitting, defined, 2004 V1: 153
pitting corrosion, 2004 V1: 141, 1999 V2: 290, 2000 V3: 190
PIV (post indicator valves), 2000 V3: 228
PL (Public Laws). *See* Public Laws
places of worship, numbers of fixtures for, 2003 V4: 19, 22
plain air chamvers, 1999 V2: 132, 143
plain-end steel pipe, 2003 V4: 55
plane angles, 2004 V1: 33, 36
plans. *See* construction contract documents; plumbing drawings
plant noise, 2004 V1: 197–198
planting area drains, 1999 V2: 83
plantings, types of, 2000 V3: 104
plaster, lining with lead, 1999 V2: 340
plaster traps, 2000 V3: 36
plastic filtration tanks, 2000 V3: 131
plastic fixtures
standards, 2003 V4: 2
types of, 2003 V4: 2
plastic joints, 1999 V2: 222
plastic piping
bedding, 2000 V3: 234, 235
codes, 2004 V1: 43
compressed air systems, 2000 V3: 210
corrosion, 1999 V2: 252
fittings, 2003 V4: 58
fountain piping, 2000 V3: 116
fuel product dispensing and, 2000 V3: 169
gas piping, 1999 V2: 176, 196, 2000 V3: 253, 254
joints, 2003 V4: 59–60
laboratory wastes, 2000 V3: 42
Manning formula and, 2000 V3: 245
polyolefin piping, 2003 V4: 61
sanitary drainage systems, 1999 V2: 14
storm-drainage systems, 1999 V2: 68, 89–92
thermal expansion and, 1999 V2: 251
types, 2003 V4: 58–65
plastic pumps, 2000 V3: 115
plastic swimming pool main drains, 2000 V3: 143
plastic valves, 2000 V3: 145–146
plastic-wrapped steel piping, 1999 V2: 196
plastic wraps on toilet seats, 2003 V4: 5
plate and frame modules in reverse osmosis, 1999 V2: 309, 310
plate tectonics, 2004 V1: 156–158
platform diving, 2000 V3: 128
platinum, 2004 V1: 141
platinum cobalt units (PCUs), 1999 V2: 287
Platinum-level LEED certification, 2004 V1: 263
platy soils, 1999 V2: 218
plot plans, irrigation systems and, 1999 V2: 26
plug-type dezincification, 2004 V1: 142
plug valves (PV), 2004 V1: 9
plumbing
appliances, 2004 V1: 27
appurtenances, 2004 V1: 27
code agencies, 2004 V1: 42
cost estimation, 2004 V1: 93–98
defined, 2004 V1: 27
designs, 2004 V1: 100–102
fittings. *See* fittings
fixtures. *See* fixtures
plumbing systems defined, 2004 V1: 27
specifications. *See* specifications
symbols, 2004 V1: 7–13
terminology, 2004 V1: 17–31
Plumbing and Drainage Institute (PDI)
abbreviation for, 2004 V1: 27
address, 2004 V1: 59
list of standards, 2004 V1: 56–57
PDI symbols for water hammer arresters, 1999 V2: 143, 144
Plumbing and Piping Industry Council (PPIC), 2004 V1: 170, 191
Plumbing Design and Installation Reference Guide, 1999 V2: 114
Plumbing Design Manual, 1999 V2: 114
plumbing drawings
abbreviations, 2004 V1: 14–16
checklists, 2004 V1: 100–102
costs analysis phase, 2004 V1: 241
defined, 2004 V1: 61
function evaluation, 2004 V1: 239–240
functional development, 2004 V1: 254, 255
graphic conventions, 2004 V1: 108
introduction, 2004 V1: 61
in specifications, 2004 V1: 69
Plumbing Efficiency through Gray-water Recycling, 1999 V2: 34
plumbing engineering, 2004 V1: 27, 2000 V3: 27–28
Plumbing-Heating-Cooling Contractors–National Association (PHCC-NA), 2004 V1: 57, 59, 95, 1999 V2: 65
plumbing inspectors, 2004 V1: 27
Plumbing Manual, 1999 V2: 155
Plumbing Noise, 2004 V1: 194
Plumbing Product Efficiency Act, 2003 V4: 3, 8, 10, 11
plumbing specifications. *See* specifications
PNC (preferred noise criteria curves), 2004 V1: 206
pneumatic pressures, 1999 V2: 2–3, 40, 2000 V3: 68
pneumatic tank gauging, 2000 V3: 160
pneumatic valves, 2000 V3: 119
POC (points of connection), 2004 V1: 11
point-of-use filters, 2000 V3: 203, 210
point-of-use ultrafiltration, 1999 V2: 300
point-of-use water heating, 2004 V1: 129, 2000 V3: 45

points of connection (POC), 2004 V1: 11
polar solvents, 2000 V3: 21
polarization
  defined, 2004 V1: 153
  hydrogen film buildup, 2004 V1: 139
polishing deionizers, 1999 V2: 301, 302, 307
polishing water in pure water systems, 1999 V2: 321
pollution
  contamination in compressed air, 2000 V3: 201
  dilution, 2000 V3:87
  dispersion from gas appliances, 1999 V2: 178
  filtering air pollution, 2000 V3: 66
  priority pollutants, 2000 V3: 88
  sanitary precautions for wells, 1999 V2: 243
polyamide membranes, 1999 V2: 310, 311
polybutylene (PB), 2004 V1: 27, 2003 V4: 59–60
polyelectrolytes, 1999 V2: 294
polyester fixtures, 2003 V4: 2
polyethylene/aluminum/polyethylene (PE-AL-PE), 2003 V4: 62
Polyethylene Encasement, 2003 V4: 32
polyethylene (PE), 2004 V1: 27, 2000 V3: 254, 2003 V4: 58–61
polyethylene piping, 1999 V2: 284
polyethylene storage tanks, 1999 V2: 323
polymer membranes, 1999 V2: 310, 311
polymeric silica, 1999 V2: 283
polymers, 2004 V1: 27
polyolefin piping, 2003 V4: 61
polypropylene piping
  laboratories, 1999 V2: 334, 2000 V3: 40
  pipe characteristics, 2003 V4: 59–60
  pure-water systems, 2000 V3: 48
  soil and waste piping, 1999 V2: 14
  sulfuric acid and, 2000 V3: 92
  USP water, 1999 V2: 324
  VOCs and, 1999 V2: 284
polypropylene storage tanks, 1999 V2: 323, 2000 V3: 91
polysulfone membranes, 1999 V2: 310, 311
polytropic processes, 2000 V3: 200
polyvinyl chloride (PVC)
  aboveground piping, 1999 V2: 68
  defined, 2004 V1: 28
  fixtures, 2003 V4: 2
  fountain piping, 2000 V3: 116, 119
  noise, 1999 V2: 15
  pipe characteristics, 2003 V4: 59–60
  piping, 1999 V2: 284
  pure-water systems, 2000 V3: 48
  sand filtration tanks, 2000 V3: 131
  sanitary drainage, 1999 V2: 14
  shower pans, 2003 V4: 15
  sizing, 1999 V2: 89–92
  skimmers, 2000 V3: 146
  storage tanks and hazardous wastes, 2000 V3: 91
  sulfuric acid and, 2000 V3: 92
  sunlight and, 2000 V3: 116
  swimming pool piping, 2000 V3: 145
  types of piping, 2003 V4: 62
  volatile organic compounds, 1999 V2: 284
  weirs, 2000 V3: 146
polyvinyl-fluoridine (PVDF), 2004 V1: 28
polyvinylidene fluoride piping, 1999 V2: 324, 2000 V3: 48
ponding
  on roofs, 1999 V2: 79
  slow-release storm-water systems, 1999 V2: 106
  storm water ponds, 1999 V2: 68
ponds, stabilization, 1999 V2: 232
Pool/Spa Operators Handbook, 2000 V3: 125
pools, 2004 V1: 27. *See also* reflecting pools; swimming pools
"poor value," defined, 2004 V1: 213
pop-up sprinkler heads, 2000 V3: 101, 102
porcelain enameled steel fixtures
  defined, 2003 V4: 2
  standards, 2003 V4: 2
pore size in filter membranes, 1999 V2: 310
porous piping, 1999 V2: 102
porous soils, 2000 V3: 99–100
portable fire extinguishers, 2004 V1: 13, 2000 V3: 27
portable vacuum systems, 2000 V3: 144
positive attachments, defined, 2004 V1: 191
positive-displacement air compressors, 2000 V3: 65, 201
positive-displacement water meters, 1999 V2: 115
positive pressure, backflow and, 1999 V2: 144
post indicator valves (PIV), 2000 V3: 228
pot and pan sinks, 2000 V3: 36
potable water. *See* drinking water; private water systems; wells
potash alum, 1999 V2: 294
potassium, 1999 V2: 281, 283
potassium bicarbonate, 1999 V2: 283
potassium carbonate, 1999 V2: 283, 2000 V3: 207
potassium chloride, 1999 V2: 283
potassium hydroxide, 1999 V2: 230
potassium permanganate, 1999 V2: 245
potential energy (PE)
  calculating, 2004 V1: 2
  velocity head and, 2004 V1: 5
potentiometric surfaces of aquifers, 1999 V2: 241
POTW (Publicly Owned Treatment Works), 2000 V3: 89
POU filtration, 1999 V2: 300
pounding forces in water. *See* water hammer
pounds (lb, LBS)
  converting to SI units, 2004 V1: 40
  pounds per square foot (psf, PSF), 2004 V1: 15
  pounds per square inch (psi, PSI), 2004 V1: 2, 15, 2000 V3: 29, 180, 200
  pounds per square inch absolute (psia), 2004 V1: 15, 1999 V2: 254, 2000 V3: 85, 200
  pounds per square inch gauge (psig), 2004 V1: 15, 1999 V2: 254, 2000 V3: 68, 85, 200
  symbols for, 2004 V1: 15
power
  conversion factors, 2004 V1: 36
  converting to SI units, 2004 V1: 39
  measurements, 2004 V1: 33
power company off-peak power savings, 2004 V1: 128–129
power control self-regulating index, 1999 V2: 166
power steam, 1999 V2: 298
power usage, economizing on, 2004 V1: 128–129
Powered Industrial Trucks, 1999 V2: 214
powered vaporizers, 2000 V3: 61
PP. *See* polypropylene piping

PPIC (Plumbing and Piping Industry Council), 2004 V1: 170, 191
ppm, PPM (parts per million), 2004 V1: 15, 1999 V2: 285, 2000 V3: 46
Practical Design of a High-purity Water System, 1999 V2: 325
Practical Plumbing Design Guide, 1999 V2: 114
Prandtl-Colebrook equation, 1999 V2: 60
pre-action systems, 2004 V1: 29, 2000 V3: 13, 15, 25
pre-action valves, 2004 V1: 13
pre-bid information, 2004 V1: 62
pre-cast concrete pipe, 2003 V4: 32
pre-cast manholes, 2000 V3: 234, 237
pre-cast septic tanks, 1999 V2: 228
pre-cast water storage tanks, 1999 V2: 247
pre-coat cakes in filtration, 2000 V3: 134
pre-compressed, glass-fiber pads, 2004 V1: 204
pre-engineered cathodically protected steel tanks, 2000 V3: 155, 156
pre-engineered dry-chemical systems, 2000 V3: 19
pre-engineered fountains, 2000 V3: 107
pre-fabricated roofing drains, 1999 V2: 82
pre-fabricated septic tanks, 1999 V2: 228
pre-fabricated shower bases, 2003 V4: 15
pre-fabricated shower enclosures, 2003 V4: 15
pre-fabricated water storage tanks, 1999 V2: 247
pre-heating input water, 2004 V1: 266
pre-manufactured skimmers, 2000 V3: 137
pre-treatment in pure water systems, 1999 V2: 321
pre-treatment ordinances, 2000 V3: 89
precipitates in water, 1999 V2: 245, 291
precipitation. *See* rainwater and precipitation
precision in measurements, 2004 V1: 32
predicting water deposits and corrosion, 1999 V2: 290–292
preferred noise criteria (PNC) curves, 2004 V1: 206
prefilters
  air compressors, 2000 V3: 203
  feed water, 1999 V2: 289
prefixes in SI units, 2004 V1: 34
premium grade PVC piping, 2000 V3: 48
preparation
  checklists, 2004 V1: 99
  in plumbing cost estimation, 2004 V1: 93
  section in specifications, 2004 V1: 91
  in value engineering presentations, 2004 V1: 258
Preparation phase in value engineering, 2004 V1: 213
preparing for jobs, checklists, 2004 V1: 99
PRES (pressure). *See* pressure
Presentation phase in value engineering, 2004 V1: 213, 257–258, 259
President's Committee on Employment of the Handicapped, 2004 V1: 105
press joints, 2004 V1: 266
PRESS (pressure). *See* pressure
pressure (PRESS, PRES, P). *See also* pressure drops or differences
  acoustic design for water pipes, 2004 V1: 195–196
  air-consuming devices, 2000 V3: 206–207
  barometric. *See* barometric pressure
  blocked storm leaders and, 1999 V2: 86
  bottled gas, 1999 V2: 174
  carbon dioxide extinguishing systems, 2000 V3: 20
  cold-water systems, 1999 V2: 115
  compressed air, 2000 V3: 200, 203, 207
  conversion factors, 2004 V1: 36
  critical (CRIP), 2004 V1: 15
  discharge pressure from gas boosters, 1999 V2: 178
  domestic water supply, 2000 V3: 217–221
  dynamic (velocity) (vp, VP), 2004 V1: 15
  eliminating with vents, 1999 V2: 35
  fall-off pressure, 1999 V2: 122
  fire pumps, 2000 V3: 25
  fixture requirements, 1999 V2: 129
  flow and air, 1999 V2: 2
  fluctuation warnings, 2000 V3: 72
  fountains, 2000 V3: 118
  friction head, 2004 V1: 2, 6
  friction loss and, 2004 V1: 2, 1999 V2: 130
  gas boosters, 1999 V2: 178–183
  heavy flow drains, 1999 V2: 9
  hot-water system pressures, 1999 V2: 157, 166–167
  hydraulic shock, 2004 V1: 6
  hydrostatic pressure, 1999 V2: 4
  induced siphonage, 1999 V2: 40
  interstitial tank monitoring, 2000 V3: 161
  low-pressure switches on gas boosters, 1999 V2: 179
  measurements, 2004 V1: 33, 1999 V2: 4, 253
  natural gas pressure, 1999 V2: 173, 174, 183, 2000 V3: 249, 252–253
  nitrogen surgical instruments, 2000 V3: 59
  nitrous oxide, 2000 V3: 64
  nozzle pressure flow tables, 2000 V3: 4
  plastic piping systems, 2000 V3: 48
  pneumatic pressures in sanitary drains, 1999 V2: 2–3
  pressure-regulating valves, 1999 V2: 152–154
  pressure surges, 1999 V2: 35
  pressure-volume relationships (gas laws), 1999 V2: 179
  pressure waves. *See* water hammer
  pump affinity laws, 2004 V1: 6
  relative discharge curves, 2000 V3: 220
  relief valves, 1999 V2: 166–167, 167
  residual pressure, 1999 V2: 123, 131
  soil pressures, 2000 V3: 155
  sprinkler systems, 2000 V3: 3, 17, 18
  stack flow capacity and, 1999 V2: 4
  static (sp, SP), 2004 V1: 15, 16
  static pressure loss, 1999 V2: 123
  storm-drainage stacks, 1999 V2: 67
  submersible fuel pumps, 2000 V3: 170
  suds pressure zones, 1999 V2: 37, 38, 39
  swimming pool pumps, 2000 V3: 140
  symbols for, 2004 V1: 15
  tests
    fountain piping systems, 2000 V3: 117
    medical gas systems, 2000 V3: 80, 82
    storage tanks, 2000 V3: 171
  vacuum cleaning system requirements, 1999 V2: 270
  vacuum defined, 1999 V2: 253
  vacuum pressure measurement, 1999 V2: 254–256
  vapor (vap pr, VAP PR, VAP), 2004 V1: 15
  velocity head (h), 2004 V1: 5
  velocity of water in pipes and, 1999 V2: 122–132
  water mains, 2000 V3: 216
  water pressure, 1999 V2: 149–152

water supply piping and, 1999 V2: 249
water vapor in air and, 2000 V3: 200–201
pressure-assist water closets, 2004 V1: 136
pressure-balancing fixtures. *See* pressure-regulating or reducing valves (PRV)
pressure diatomaceous earth filtration, 2000 V3: 132, 135, 139, 141
pressure differentials
condensate drainage, 2000 V3: 191–193
fittings, 2004 V1: 194
pressure-differential-actuated valve trap primers, 1999 V2: 14
steam systems, 2000 V3: 191
pressure drops or differences (PD, DELTP)
air filtration and, 2000 V3: 207
average pressure drops in water systems, 1999 V2: 125, 126, 127
backflow preventers and, 2000 V3: 224
calculating, 2004 V1: 2
compressed air systems, 2000 V3: 78, 207, 210, 211, 212
defined, 1999 V2: 214
double-check valves and, 2000 V3: 224
filter pumps, 2000 V3: 115
fire hydrants and, 1999 V2: 249
fittings, 2000 V3: 221
fountains, 2000 V3: 118
friction loss of head, 1999 V2: 118, 119, 121
fuel system checklist, 2000 V3: 171
gas boosters, 1999 V2: 182
gas line filters and, 2000 V3: 250
gas meters and, 1999 V2: 176
installing taps, 2000 V3: 221
liquefied petroleum gas storage, 1999 V2: 194
medical air, 2000 V3: 74
medical gas, 2000 V3: 73
natural gas systems, 1999 V2: 174, 183, 192, 193
piping runs, 2000 V3: 221
sanitary drainage, 1999 V2: 2
sizing vacuum piping, 1999 V2: 263
sprinkler hydraulic calculations, 2000 V3: 18
static pressure loss, 1999 V2: 123
strainers and, 2000 V3: 224
swimming pool pumps, 2000 V3: 140
symbols for, 2004 V1: 15
vacuum cleaning systems, 1999 V2: 272–274, 274
vacuum exhauster sizing, 1999 V2: 274
vacuum pressures, 1999 V2: 258, 263
valves, 2000 V3: 221
water meters, 2000 V3: 224
pressure-equalizing lines in sovent systems, 1999 V2: 60
pressure gauges
with gauge cocks (PG), 2004 V1: 10
measurements, 1999 V2: 254
swimming pools, 2000 V3: 140, 144
pressure loss. *See* pressure drops
pressure maintenance (jockey) pumps, 2004 V1: 24
pressure media filters, 1999 V2: 300
pressure piping
asbestos concrete, 2003 V4: 26
glass pipe, 2003 V4: 45
pressure-powered pumps, 2000 V3: 188
pressure product-dispensing systems, 2000 V3: 163–164
pressure-regulating or reducing valves (PRV)
acoustic design and pressure, 2004 V1: 200
fountains, 2000 V3: 119, 120
glossary, 1999 V2: 152–154
health-care water supplies, 2000 V3: 44
irrigation systems, 2000 V3: 103
shower valves, 2003 V4: 15
steam systems, 2000 V3: 191, 195
symbols for, 2004 V1: 9
tub valves, 2003 V4: 16
types of, 1999 V2: 153–154
pressure regulators
cold-water systems, 1999 V2: 122
compressed air systems, 2000 V3: 207
deluge valves, 2000 V3: 14, 15
flushometer tanks, 2003 V4: 8
gas train vents, 1999 V2: 177
natural gas systems, 1999 V2: 174, 214, 2000 V3: 250–252
outlet pressure protection in gas boosters, 1999 V2: 183
water storage tanks, 1999 V2: 248–249
pressure-relief lines in sovent systems, 1999 V2: 61
pressure-relief outlets in deaerators, 1999 V2: 56
pressure-relief valves (RV), 2004 V1: 10
pressure sand filters, 2000 V3: 112, 113, 132–133, 134, 139
Pressure Sewer Demonstration at the Borough of Phoenixville, Pennsylvania, 1999 V2: 238
pressure sewers, 1999 V2: 226
pressure surges, 1999 V2: 35
pressure swing air dryers, 2000 V3: 207
pressure switches (PS), 2004 V1: 10, 2000 V3: 121
pressure tanks, 2000 V3: 153
pressure vacuum breakers, 1999 V2: 145, 148
pressure-volume relationships (gas laws), 1999 V2: 179
pressure water filters, 1999 V2: 244
pressure waves. *See* water hammer
pressurized fuel delivery systems, 2000 V3: 162, 170
pressurized steam return lines, 2000 V3: 196
pri, PRI (primary), 2004 V1: 15
prices, 2004 V1: 222. *See also* costs and economic concerns
PRIM (primary), 2004 V1: 15
primary (pri, PRI, PRIM), 2004 V1: 15
primary barriers for infectious wastes, 1999 V2: 343
primary tanks
aboveground types, 2000 V3: 165, 167
construction, 2000 V3: 156
interstitial monitoring, 2000 V3: 160–161
underground tanks, 2000 V3: 155
prime costs, 2004 V1: 222
primers, 2004 V1: 147
priming in dry-pipe systems, 2000 V3: 12
priority pollutants, 2000 V3: 88
prism-like soils, 1999 V2: 218
prisons, numbers of fixtures for, 2003 V4: 20, 22
privacy, urinals and, 2003 V4: 9, 10
private sewage-disposal systems
aerobic wastewater treatment plants, 1999 V2: 232–233
collection and treatment alternatives, 1999 V2: 226–227

defined, 2004 V1: 27
distribution boxes, 1999 V2: 231
estimating sewage quantities, 1999 V2: 233–238
inspection, 1999 V2: 238
introduction, 1999 V2: 217
large systems, 1999 V2: 231–232
primary collection and treatment systems, 1999 V2: 217
private sewers, 2004 V1: 27
septic tanks, 1999 V2: 227–231
soil-absorption systems, 1999 V2: 217–224
private use
defined, 2004 V1: 27
lavatories, 2003 V4: 10
private water systems
drinking water demand, 1999 V2: 243–244
initial operation and maintenance, 1999 V2: 252
introduction, 1999 V2: 239–240
matching water storage to pump flow, 1999 V2: 248
pipe installation, 1999 V2: 250–252
sources of supply, 1999 V2: 239–240
system equipment, 1999 V2: 245–250
water quality, 1999 V2: 244–245
wells, 1999 V2: 240–243
problems
in condensate drainage, 2000 V3: 189–191
in seismic protection, 2004 V1: 188–191, 189
Proceedings of the Third National Conference on Individual On Site Wastewater Systems, 1999 V2: 238
process steam systems, 2000 V3: 175
Procurement and Contracting Requirements Group, 2004 V1: 65, 77
producer costs, 2004 V1: 222
producers (vacuum)
defined, 1999 V2: 266–269, 268
locating, 1999 V2: 270
sizing, 1999 V2: 272, 274–275
product costs, 2004 V1: 222, 223
product dispensing systems
aboveground tank systems, 2000 V3:168
underground tank systems, 2000 V3: 163–165
dispenser pans, 2000 V3: 165
pressure dispensing, 2000 V3: 164
product dispensers, 2000 V3: 164–165
product level gauging, 2000 V3: 167, 168
product standards, 2004 V1: 66
product substitutions, 2004 V1: 68
product water. *See* treated water
production wells in geothermal energy, 2004 V1: 131
productivity rates, in cost estimation, 2004 V1: 95–97
products
costs, 2004 V1: 222, 223
detail/product/material specification checklist, 2004 V1: 220
green building, 2004 V1: 264–265
section in specifications, 2004 V1: 69, 90–91
in specifications, 2004 V1: 70
value engineering questions, 2004 V1: 213–214
Professional Qualifications Standard for Medical Gas Systems Installers, Inspectors, Verifiers, Maintenance Personnel and Instructors, 2003 V4: 45
profit markup in cost determinations, 2004 V1: 222
programmers, irrigation systems, 2000 V3: 105
project conditions section in specifications, 2004 V1: 70, 90
project costs, 2004 V1: 222
project manuals
contents of, 2004 V1: 62–63
defined, 2004 V1: 61
promenade drains, 1999 V2: 83
propagation velocity, 2004 V1: 6
propane, 1999 V2: 194, 214. *See also* fuel-gas piping systems
propeller water meters, 1999 V2: 116
property protection in fire protection, 2000 V3: 1
prophylactic additives to water, 1999 V2: 245
proportions of septic tanks, 1999 V2: 228
proprietary names in specifications, 2004 V1: 66, 67
proprietary specifications, 2004 V1: 67–68
protected end of galvanic series, 2004 V1: 141
protecting storage tanks, 2000 V3:169
protection
section in specifications, 2004 V1: 92
value engineering contract document clauses, 2004 V1: 258, 260
protective coatings, 2004 V1: 147. *See also* coated metal
protective potential, defined, 2004 V1: 153
protein-mixed chemical concentrates, 2000 V3: 21
PRV (pressure-regulating or reducing valves). *See* pressure-regulating or reducing valves
prying actions in seismic protection, 2004 V1: 188
PS (pressure switches), 2004 V1: 10
pseudo-dynamic elastic analysis, 2004 V1: 161
Pseudo Value Engineers, 2004 V1: 258
psf, PSF (pounds per square foot)
psf absolute (psfa, PSFA), 2004 V1: 15, 1999 V2: 254
psf gage (psfg, PSFG), 2004 V1: 15, 1999 V2: 254
symbols for, 2004 V1: 15
psfa, PSFA (psf absolute), 2004 V1: 15, 1999 V2: 254
psfg, PSFG (psf gage), 2004 V1: 15, 1999 V2: 254
psi, PSI (pounds per square inch)
cast iron radiators, 2000 V3: 180
converting to metric units, 2000 V3: 29
measurements, 2000 V3: 200
psi absolute (psia, PSIA), 2004 V1: 15, 1999 V2: 254, 2000 V3: 85, 200
psi gage (psig, PSIG), 2004 V1: 15, 1999 V2: 254, 2000 V3: 68, 85, 200
symbols for, 2004 V1: 15
psia, PSIA (psi absolute), 2004 V1: 15, 1999 V2: 254, 2000 V3: 85, 200
psig, PSIG (psi gage), 2004 V1: 15, 1999 V2: 254, 2000 V3: 68, 85, 200
public, educating on gray-water systems, 1999 V2: 33
public areas
estimating sewage quantities, 1999 V2: 236
fixtures for, 2000 V3: 33–34
heel-proof grates, 1999 V2: 10
sediment buckets, 1999 V2: 12
Public Building Service, 2004 V1: 199

public facilities, numbers of fixtures for, 2003 V4: 21
public hydrants, 2004 V1: 12
Public Law 90-480, 2004 V1: 106
Public Law 93-112, 2004 V1: 106
Public Law 98, 2000 V3: 154
Public Law 616, 2000 V3: 154
public sewers
  availability of, 2000 V3: 234
  defined, 2004 V1: 27
  discharging into, 1999 V2: 328
  neutralizing acid wastes for, 1999 V2: 334–337
  public storm sewer systems, 1999 V2: 67, 98, 105, 2000 V3: 245–247
  radioactive waste systems and, 1999 V2: 342
public swimming pools. *See* swimming pools
public use
  defined, 2004 V1: 28
  lavatories, 2003 V4: 10
Publicly Owned Treatment Works (POTW), 2000 V3: 89
pubs, 2003 V4: 19, 22
puddle flanges, 2000 V3: 116
pull-out spray accessories, 2003 V4: 12, 14
pulsation
  air compressors, 2000 V3: 212
  electric fans, 2004 V1: 196
  magnetic field pulsation, 2004 V1: 196
pump discharge lines (PD), 2004 V1: 8
pump heads, 1999 V2: 105
pumped sewage-disposal systems, 1999 V2: 226
pumper connections, 2004 V1: 12
pumping
  septic tanks, 1999 V2: 227, 230
  wells, 1999 V2: 241–243
pumping head, 1999 V2: 245
pumps
  acoustics, 2004 V1: 196–197, 196–198, 198, 200–201
  automatic shutdown, 2000 V3: 90
  bases, 1999 V2: 243, 245
  bearings, 2004 V1: 197
  boiler feed pumps, 2000 V3: 188–189
  cavitation, 2000 V3: 112
  circulating pump efficiency, 2004 V1: 265
  condensate transfer pumps, 2000 V3: 188
  design of, 2004 V1: 200
  earthquake protection, 2004 V1: 164
  efficiency, 2004 V1: 6–7
  ejector pumps, 2000 V3: 236
  fire pumps, 2000 V3: 25–26
  fountains, 2000 V3: 108, 112, 120, 125
  geothermal energy systems, 2004 V1: 131
  gravity tank systems, 1999 V2: 150–152
  gray water use, 2004 V1: 267
  hydropneumatic-tank systems, 1999 V2: 150
  impellers, 2004 V1: 197
  liquid fuel systems, 2000 V3:170
  liquid-waste decontamination systems, 1999 V2: 344
  matching water storage to pump flow, 1999 V2: 248
  plant noise, 2004 V1: 197–198
  pulsation in, 2004 V1: 197
  pump affinity laws, 2004 V1: 6
  pump journals, 2004 V1: 196
  pump speeds, 2004 V1: 200–201
  pump suction, 1999 V2: 249
  secondary containment areas, 2000 V3: 90
  starter controls, 2000 V3: 120
  static deflection for vibration, 2004 V1: 205
  strainers and suction screens, 2000 V3: 116
  submersible, 1999 V2: 243, 2000 V3:170, 2000 V3: 170
  sulfuric acid and, 1999 V2: 332
  sump pumps in sanitary drainage systems, 1999 V2: 9
  swimming pools, 2000 V3: 129, 139, 140–142, 145–146
  systems for water supplies, 1999 V2: 245–247
  vacuum pumps, 2000 V3: 189
  vibration isolation, 2004 V1: 205, 206
  well pumps, 1999 V2: 245–247
Pumps and Pump Systems, 2004 V1: 40
Pumps and Pump Systems Handbook, 1999 V2: 152
purchasers in cost equation, 2004 V1: 223
pure tones, 2004 V1: 208
pure-water systems. *See also* water purification
  defined, 1999 V2: 279
  health-care facilities, 2000 V3: 43, 46–48
  piping materials, 2000 V3: 47–48
  types of pure water, 2000 V3: 46
purging
  medical gas zones, 2000 V3: 72, 80, 81–82
  natural gas systems, 2000 V3: 252
purified water (PW), 1999 V2: 320, 2003 V4: 47. *See also* pure-water systems; water purification
purity
  compressed air, 2000 V3: 207
  testing medical gas systems, 2000 V3: 82
push-on joints, 2000 V3: 228–229
push-seal gasketed outlets, 1999 V2: 18
putrefaction, 2004 V1: 28
Putting Industrial Vacuum to Work, 1999 V2: 277
puzzles
  Nine Dots exercise, 2004 V1: 232, 261
  Six Sticks exercise, 2004 V1: 232, 261
PV (plug valves), 2004 V1: 9
PVBs (pressure vacuum breakers), 1999 V2: 145, 148
PVC. *See* polyvinyl chloride (PVC)
PVDF (polyvinyl-fluoridine), 2004 V1: 28, 1999 V2: 14, 2000 V3: 48
PVE (Pseudo Value Engineers), 2004 V1: 258
PW (pure water), 1999 V2: 320. *See also* pure-water systems; water purification
pyramids, calculating volume, 2004 V1: 4
pyrogens, 1999 V2: 282, 310, 2000 V3: 46

Q

Q factor (coefficient of transmissibility), 1999 V2: 101–102
Q (heat transfer), 2004 V1: 15
QAIR (air flow rates), 2004 V1: 14
QAR (air flow rates), 2004 V1: 14
QFL (fluid flow rates), 2004 V1: 14
QGA, QGAS (gas flow rates), 2004 V1: 14, 1999 V2: 173
qt, QT (quarts), 2004 V1: 15, 40
quads, converting to SI units, 2004 V1: 40
quality
  in cost estimation, 2004 V1: 98
  quality assurance in specifications, 2004 V1: 69–70, 89
  quality control section in specifications, 2004 V1: 71, 91

of water, 1999 V2: 33, 244–245. *See also* water analysis; water purification
quantities. *See also* demand
clean gas agents, 2000 V3: 23
in creativity checklist, 2004 V1: 234
irrigation water, 2000 V3: 99
water supplies, 2000 V3: 3–8
quarter-circle rotary sprinkler heads, 2000 V3: 102
quarts (qt, QT)
converting to SI units, 2004 V1: 40
symbols for, 2004 V1: 15
questions in value engineering presentations, 2004 V1: 258
quick-coupling method of irrigation, 2000 V3: 100, 101
quick-disconnect couplings, 2000 V3: 210
quick-opening devices, 2000 V3: 13
quick-response sprinklers, 2004 V1: 29
quick valve closure, 1999 V2: 131, 132
quieting pipes, 1999 V2: 15

R

R (hydraulic radii), 2004 V1: 1
R, R- (refrigerants), 2004 V1: 15, 151
°R, R (rankines), 2004 V1: 15
R, R (thermal resistance), 2004 V1: 16
R (radii), 2004 V1: 15
R-13 and R-13A fire-protection systems, 2003 V4: 58
R-595 gas, 2000 V3: 22
ra, RA (return air), 2004 V1: 15
Rack Storage of Materials (NFPA 231C), 2000 V3: 2, 29
rad, RAD (radians). *See* radians
RAD (radiating or radiators), 2004 V1: 15
RAD (radiation). *See* radiation
rad/s (radians per second), 2004 V1: 33
rad/s^2 (radians per second squared), 2004 V1: 33
radians (RAD)
measurement unit conversions, 2004 V1: 33
radians per second, 2004 V1: 33
radians per second squared, 2004 V1: 33
symbols for, 2004 V1: 15
radiant heating in swimming pools, 2000 V3: 138, 146
radiating (RAD), 2004 V1: 15
radiation (RADN, RAD)
heat loss and, 2000 V3: 121
nature of, 1999 V2: 337–338
radiation equivalent to man (rem), 1999 V2: 339
rads (radioactive dosage), 1999 V2: 339
symbols for, 2004 V1: 15
treatment facilities, 1999 V2: 340
radiators (RAD), 2004 V1: 15, 2000 V3: 178, 181, 184
radicals (ions), 2004 V1: 144, 153, 1999 V2: 329
radii (R), 2004 V1: 15
radioactive waste drainage and vents
allowable radiation levels, 1999 V2: 339
approval process and applications, 1999 V2: 340
diluting radwaste, 1999 V2: 342
introduction, 1999 V2: 337
measuring radiation, 1999 V2: 338–339
nature of radiation, 1999 V2: 337–338
pipe selection, 1999 V2: 341–342
radioactive-material-processing plants, 1999 V2: 147
radioactive materials, 1999 V2: 340
shielding systems, 1999 V2: 339–340
system design criteria, 1999 V2: 340–343
radioactivity
defined, 1999 V2: 337
radioactive half lives, 1999 V2: 340
radioactive isotopes, 1999 V2: 337, 340
radiological characteristics of drinking water, 1999 V2: 284, 317
Radiological Safety Officers, 1999 V2: 340
radium 226, 1999 V2: 340
RADN (radiation). *See* radiation
radon gas in water, 1999 V2: 284, 317
radwaste (waterborne radioactive waste), 1999 V2: 337
Rainbird Company, 2000 V3: 105
rainwater and precipitation
capturing rainwater, 2004 V1: 135, 264, 267
cisterns, 1999 V2: 247
duration, 2000 V3: 244
flow rates, 1999 V2: 68
in gray-water systems, 1999 V2: 21
imperviousness factor, 2000 V3: 242–243
inlet times, 2000 V3: 244
intensity-duration-frequency curves, 2000 V3: 242, 243
precipitation, 2004 V1: 27
rainfall rates, 1999 V2: 69–78, 97, 2000 V3: 242, 243
rainwater drains (SD, ST). *See* storm-drainage systems
return periods, 2000 V3: 243–244
slow-release storm-water systems, 1999 V2: 106
storing in controlled flow systems, 1999 V2: 93–94
storm-drainage systems, 1999 V2: 67–68, 95–107
subsurface water and, 1999 V2: 99–105
swimming pools and, 2000 V3: 139
raised-floor areas, 2000 V3: 23
ramp-drain grates, 1999 V2: 11
rankines (°R, R), 2004 V1: 15
ranking functions in value engineering, 2004 V1: 243
rapid sand/direct filtration package plants, 1999 V2: 318
rate of corrosion
acidity, 2004 V1: 145
Faraday's Law, 2004 V1: 144
film formation, 2004 V1: 145
homogeneity in, 2004 V1: 145
oxygen content, 2004 V1: 145
temperature, 2004 V1: 145
velocity in, 2004 V1: 145
rate of flow. *See* flow rates
rate of temperature rise detection, 2000 V3: 13
rated vacuum levels, 1999 V2: 257–258
ratings for portable fire extinguishers, 2000 V3: 27
Rational Method, 2004 V1: 7, 1999 V2: 95–98, 98, 107, 2000 V3: 242–244
raw sewage, 2004 V1: 28
raw water, 1999 V2: 280, 320
RCIR (recirculate), 2004 V1: 15
RCP (reinforced concrete pipe), 2003 V4: 32
RCRA (Resource Conservation and Recovery Act), 1999 V2: 345, 2000 V3:87–88, 2000 V3: 89–90, 154
rcvr, RCVR (receivers), 2004 V1: 15, 199, 1999 V2: 260, 262
re-evaporation, 2000 V3: 197
re-flashing, 2000 V3: 20
reaction forces in earthquakes, 2004 V1: 186
reactive silencers, 2000 V3: 202

reactive silica, 1999 V2: 283
reagent grade water, 1999 V2: 317, 319
real costs, 2004 V1: 223
rear wall grab bars, 2004 V1: 114
reasoning against value engineering, 2004 V1: 232
REC (receivers), 2004 V1: 15, 199, 1999 V2: 260, 262
receiver tanks
  medical air compressors, 2000 V3: 66
  vacuum systems, 2000 V3: 70
receivers (rcvr, RCVR, REC)
  receivers of noise, 2004 V1: 199
  symbols for, 2004 V1: 15
  in vacuum systems, 1999 V2: 260, 262
receiving costs, 2004 V1: 223
receptors, 2004 V1: 28
recessed-box hose bibbs, 2004 V1: 10
recessed sprinklers, 2004 V1: 29
recharge basins, 2000 V3: 247
rechargeable air chambers, 1999 V2: 132, 143
recharging aquifers, 1999 V2: 240
reciprocating air compressors, 2000 V3: 65, 66, 201, 205
reciprocating (rotary) piston pumps, 1999 V2: 259
recirculate (recirc., RECIRC, RCIR, RECIR), 2004 V1: 15
recirculating hot-water systems, 2004 V1: 265
recirculating sand filter sewage systems, 1999 V2: 227, 232
recirculation rates
  gutters and, 2000 V3: 142
  swimming pools, 2000 V3: 140
recirculation systems
  for high purity water, 2000 V3: 47
  for hot water, 1999 V2: 165
reclaimed water. *See* gray-water systems
Recommendation phase in value engineering, 2004 V1: 213
  pre-recommendation questions, 2004 V1: 254–257
Recommendations for a New ADAAG, 2004 V1: 123
Recommended Minimum Requirements for Plumbing in Dwellings and Similar Buildings, 1999 V2: 65
Recommended Practice for Handling Releases of Flammable and Combustible Liquids and Gases (NFPA 329), 2000 V3: 154
recovered energy, 2004 V1: 137
recovering heat from water heaters, 1999 V2: 158–159
recovery in reverse osmosis, 1999 V2: 309
recovery rooms
  fixtures, 2000 V3: 36
  health-care facilities, 2000 V3: 32
  medical gas stations, 2000 V3: 52, 58
  medical vacuum, 2000 V3: 54
recreational establishments
  estimating sewage quantities, 1999 V2: 235, 237
  septic tank/soil-absorption systems for, 1999 V2: 231–232
recreational pools, 2000 V3: 128
rectangles, calculating area, 2004 V1: 3
rectangular bath seats, 2004 V1: 122
rectangular gutters, 1999 V2: 81, 86
rectangular leaders, 1999 V2: 81
rectangular solids, calculating volume, 2004 V1: 4
rectifiers, 2004 V1: 150, 151
recycled water in landscaping, 2004 V1: 264
recycled water systems. *See* gray-water systems
red brass, 2004 V1: 144
red brass piping, 1999 V2: 14, 2003 V4: 27
red water in pools, 2000 V3: 147
reduced noise transmission, 1999 V2: 15
reduced pressure
  conditions in water storage tanks, 1999 V2: 248
  in pressure-regulated valves, 1999 V2: 152
  reduced-pressure backflow preventers, 1999 V2: 115, 144, 145, 148, 149
  reduced pressure zones (RPZ), 2000 V3: 223, 226
reduced pressure zones (RPZ), 2000 V3: 223, 226
reduced-size venting
  confluent vent sizing, 1999 V2: 51
  example, 1999 V2: 53, 54
  installation, 1999 V2: 52
  introduction, 1999 V2: 49
  reduced size vents, defined, 2004 V1: 28
  sizing, 1999 V2: 50–53
Reduced-size Venting Design, 1999 V2: 65
reduced water-flow rates, 2004 V1: 126–127
reduced zone backflow preventers (RZBP), 2004 V1: 10
reducers, defined, 2004 V1: 28
redundancy
  fountain pumps, 2000 V3: 115
  hazardous waste systems, 2000 V3: 90
reference standard specifications, 2004 V1: 66–67
references
  cold water systems, 1999 V2: 155
  compressed air systems, 2000 V3: 214
  conserving energy, 2004 V1: 137
  designing for people with disabilities, 2004 V1: 123
  fire-protection systems, 2000 V3: 29
  formulae, symbols, and terminology, 2004 V1: 40
  gasoline and diesel-oil systems, 2000 V3:173
  gray-water systems, 1999 V2: 34
  health-care facilities, 2000 V3: 86
  irrigation systems, 2000 V3: 105
  reflecting pools and fountains, 2000 V3: 125–126
  sanitary drainage systems, 1999 V2: 19
  seismic protection, 2004 V1: 191
  special-waste drainage systems, 1999 V2: 350
  steam and condensate systems, 2000 V3: 197
  swimming pools, 2000 V3: 151
  vacuum systems, 1999 V2: 277
  vents, 1999 V2: 65
  water treatment and purification, 1999 V2: 325
references section in specifications, 2004 V1: 69, 88
reflecting pools
  controls, 2000 V3: 120–121
  defined, 2004 V1: 28
  design, 2000 V3: 107–111
  discharge devices, 2000 V3: 119–120
  displays, 2000 V3: 108–110, 111, 113–115
  filtration systems, 2000 V3: 112–113, 115–116
  flow rates, 2000 V3: 108–110
  inlets, outlets, and devices, 2000 V3: 110–111
  lighting, 2000 V3: 112, 121
  makeup-water systems, 2000 V3: 112, 124–125
  multilevel pools, 2000 V3: 108
  overflow and drainage, 2000 V3: 112, 125
  overview, 2000 V3: 107
  piping and valves, 2000 V3: 111–112, 116–119

pumps, 2000 V3: 113–116
references, 2000 V3: 125–126
systems and components, 2000 V3: 111–112
valves, 2000 V3: 118–119
water-heating system, 2000 V3: 112, 121–122
water-treatment systems, 2000 V3: 112, 122–124
reformatories, numbers of fixtures for, 2003 V4: 20
refrigerant after-coolers, 2000 V3: 203
refrigerants (R, R-), 2004 V1: 15, 151
refrigerated air dryers, 2000 V3: 204, 207
refrigeration mechanical rooms, 2004 V1: 166
refrigeration piping, 2003 V4: 34, 36
refrigeration systems
heat reclamation, 2004 V1: 131
waste heat usage, 2004 V1: 131, 132
refuse bins, 2004 V1: 196
refuse disposal installations, soundproofing, 2004 V1: 196
regenerable ion exchange, 1999 V2: 301
regenerants, dealkalizing and, 1999 V2: 295
regeneration cycle
in dealkalizing, 1999 V2: 295
in deionizing, 1999 V2: 302, 304
in demineralizers, 2000 V3: 46
in ion exchange, 1999 V2: 305
in water softeners, 1999 V2: 307
regional authorities, 1999 V2: 327
registers in fuel dispensers, 2000 V3: 165
regulated substances, 2000 V3: 153
regulations. *See* codes and standards
regulators. *See specific types of regulators*
Rehabilitation Act of 1973 (93-112), 2004 V1: 106
reinforced concrete pipe (RCP), 2003 V4: 32
reinforcing ribs in tanks, 2000 V3: 155
reject stream from reverse osmosis, 1999 V2: 309
relative discharge curves, 2000 V3: 220
relative humidity (rh, RH), 2004 V1: 15, 2000 V3: 200, 201
Relative Importance of Time and Surface Temperature in the Causation of Cutaneous Burns, 1999 V2: 170
relay interface controls, 2000 V3: 73
reliability of water supplies, 2000 V3: 3, 8
relief valves
fire pumps, 2000 V3: 25
gas regulators, 2000 V3: 251
hot-water systems, 1999 V2: 166–167
liquefied petroleum gas, 1999 V2: 197
sizing, 1999 V2: 167
water storage tanks, 1999 V2: 248
relief vents
circuit and loop venting, 1999 V2: 43
defined, 2004 V1: 28, 1999 V2: 64
gas trains, 2000 V3: 251
soil and waste stacks, 1999 V2: 44, 45
sovent systems, 1999 V2: 61
remote-control fountain controls, 2000 V3: 120
remote-control irrigation valves, 2000 V3: 103
remote-control pool panels, 2000 V3: 111
remote earth (remote electrodes), 2004 V1: 153
remote electrodes, 2004 V1: 153
remote fill ports, 2000 V3: 156, 167
remote leakage from tanks, 2000 V3: 162–163
remote portions of fire design areas, 2000 V3: 16
remote-readout water meters, 1999 V2: 116
remote secondary-containment enclosures, 2000 V3: 167
Remove Organics by Activated Carbon Adsorption, 1999 V2: 325
rems (radiation equivalent to man), 1999 V2: 339
renovations, cost estimating and, 2004 V1: 98
repetition in value engineering presentations, 2004 V1: 258
replacements for Halon gases, 2000 V3: 22
Report on Hydraulics and Pneumatics of Plumbing Drainage Systems, 1999 V2: 19
required costs, 2004 V1: 223
res, RES (resistance or resistors), 2004 V1: 16
research facilities, radiation in, 1999 V2: 340
reserves (connected standbys), 2000 V3: 23
reservoirs
municipal, 2000 V3: 8
private, 1999 V2: 239
residential care facilities, numbers of fixtures for, 2003 V4: 20
residential kitchen sinks
faucets, 2003 V4: 13
types and requirements, 2003 V4: 11–12
residential systems
cold-water systems, 1999 V2: 115–116, 154–155
estimating sewage quantities, 1999 V2: 233
firefighting demand flow rates, 2000 V3: 232
fixture drainage loads, 1999 V2: 3
hot-water systems. *See* hot-water systems
irrigation, 2000 V3: 100
lavatory flow rates, 2003 V4: 10
liquefied petroleum gas, 1999 V2: 194
natural gas appliance demand, 1999 V2: 175
numbers of fixtures, 2003 V4: 20
pool filters, 2000 V3: 112
reduced-size venting, 1999 V2: 50
sewage-disposal systems. *See* private sewage-disposal systems
sprinklers, 2004 V1: 30, 2000 V3: 2
typical gray-water supply and demand, 1999 V2: 25
water supply. *See* domestic water supply
residual pressure
defined, 2004 V1: 28, 1999 V2: 123
determining available pressure and, 1999 V2: 131
domestic water supply, 2000 V3: 217–221
fire hydrants, 2000 V3: 4, 8
sprinkler hydraulic calculations, 2000 V3: 16
residual radiation, 1999 V2: 341
resilient mounts
illustrated, 2004 V1: 207
noise and vibration control, 2004 V1: 199, 205
pipe run installations, 2004 V1: 209
seismic danger and, 2004 V1: 206
resilient pipe supports, 2004 V1: 199, 206
resin beads, 1999 V2: 304–305
resins, ion-exchange
continuous deionization, 1999 V2: 306
defined, 1999 V2: 300
in diluting compartments, 1999 V2: 307
overview, 1999 V2: 301–302
regenerating, 1999 V2: 304
strong-acid and weak-acid, 1999 V2: 302
volatile organic compounds in, 1999 V2: 284

resistance ratings (fire loads), 2000 V3: 2–3
resistance (res, RES, OHMS), 2004 V1: 15
resistivity
defined, 2004 V1: 154
soil, 2004 V1: 150
resistors (res, RES, OHMS), 2004 V1: 15
"resonant" air compression systems, 2000 V3: 212
resource conservation, 2004 V1: 124
Resource Conservation and Recovery Act, 2004 V1: 124, 1999 V2: 345, 2000 V3:87–90, 2000 V3: 96, 154
resources
gasoline and diesel-oil systems, 2000 V3:173
health-care facilities, 2000 V3: 86
industrial wastewater treatment, 2000 V3: 97
irrigation systems, 2000 V3: 105
respirators. *See* breathing apparatus
response in pressure-regulated valves, 1999 V2: 152
response spectrum in earthquakes, 2004 V1: 160–161, 186
restaurants, 1999 V2: 231–232, 2003 V4: 19, 22. *See also* food-processing areas and kitchens
restrained-spring mountings, 2004 V1: 204
restraint systems
for earthquakes, 2004 V1: 166, 189
for fire-protection joints, 2000 V3: 229
restricted areas (facilities with radiation), 1999 V2: 339
restrooms. *See* water-closet compartments; water closets
retail stores, numbers of fixtures for, 2003 V4: 20
retard chambers, 2000 V3: 9
retention basins, 2000 V3: 247
retirement costs, in labor costs, 2004 V1: 94
retractable ceiling medical gas columns, 2000 V3: 58
return air (ra, RA), 2004 V1: 15
return circuits, 2004 V1: 139
return offsets, 2004 V1: 28
return periods in rainfall, 1999 V2: 69–78, 2000 V3: 243–244
returns
condensate returns, 2000 V3: 186–189
fountain filtration, 2000 V3: 115, 117
parallel flow piping designs, 2000 V3: 178–179
return lines, 2000 V3: 195, 196
returning water to pools, 2000 V3: 119–120
swimming pools, 2000 V3: 143–144
reusing water. *See* gray-water systems
rev, REV (revolutions), 2004 V1: 15
revent pipes, 2004 V1: 28. *See also* individual vents
reverse osmosis
cartridges, 1999 V2: 289
continuous deionization and, 1999 V2: 307
defined, 1999 V2: 308–309
health-care facilities, 2000 V3: 47
membrane configurations, 1999 V2: 309
membrane selection, 1999 V2: 310
polymer membranes, 1999 V2: 311
silica and, 1999 V2: 283
small drinking water systems, 1999 V2: 318
VOCs in membranes, 1999 V2: 284
water supply (RO), 2004 V1: 8
Reverse Osmosis and Nanofiltration System Design, 1999 V2: 325
reverse osmosis water supply (RO), 2004 V1: 8
reverse-trap water closets, 2003 V4: 3
reversible potential, defined, 2004 V1: 153
revolutions (rev, REV)
revolutions per minute (rpm, RPM), 2004 V1: 15
revolutions per second (rps, RPS), 2004 V1: 16
Reynold's number for turbulence, 2004 V1: 2, 1999 V2: 41
rgh, RGH (roughness), 2004 V1: 16. *See also* roughness
rh, RH (relative humidity). *See* relative humidity
RHO (density). *See* density
rhomboids, calculating area, 2004 V1: 4
rhombuses, calculating area, 2004 V1: 4
RI (Ryzner stability index), 1999 V2: 292
Richardson, D.W., Sr., 1999 V2: 325
right-angle triangles, calculating area, 2004 V1: 4
rigid ceiling medical-gas columns, 2000 V3: 58
rigid plastic piping, 2000 V3: 169
rim top test, 2003 V4: 6
rims
defined, 2004 V1: 28
on urinals, 2004 V1: 116–117
rim top test, 2003 V4: 6
water closets, 2003 V4: 4–5
ring-securing methods around drains, 1999 V2: 17
rinsing in regeneration cycle, 1999 V2: 304, 305
riser clamps, 1999 V2: 86
riser-mounted sprinkler heads, 2000 V3: 102
risers
bracing, 2004 V1: 171, 178
checklists, 2004 V1: 102
defined, 2004 V1: 28, 2000 V3: 85
earthquake protection and joints, 2004 V1: 168
low-pressure steam (lps, LPS), 2000 V3: 187
riser clamps, 1999 V2: 86
riser down (elbows), 2004 V1: 10
riser-mounted sprinkler heads, 2000 V3: 102
riser up (elbows), 2004 V1: 10
steam piping, 2000 V3: 182, 185
symbols for, 2004 V1: 12
rises or drops, 2004 V1: 11
risk cabinets, 1999 V2: 344
Risk Guides in value engineering, 2004 V1: 254, 257
riveted steel piping, 1999 V2: 122
RO (reverse osmosis). *See* reverse osmosis
roadblocks to creativity, 2004 V1: 231–232
roadway drainage pipes, 2003 V4: 32
rock fill in seepage beds, 1999 V2: 224
rock guards for lights, 2000 V3: 121
rock salt, 1999 V2: 307
Roentgens, 1999 V2: 339
roll-in shower compartments, 2004 V1: 119–120
roll-out gutters, 2000 V3: 137
roof drainage, 1999 V2: 79–94
adjacent buildings and surfaces, 1999 V2: 80
avoiding septic tank disposal, 1999 V2: 231
controlled flow systems, 1999 V2: 88, 93–94
coordination with other designers, 1999 V2: 79, 81, 84
drain locations, 1999 V2: 79–80
drain types and components, 1999 V2: 80–81
expansion, 1999 V2: 85, 87
Form 4-1, 1999 V2: 109
green roof designs, 2004 V1: 266
gutters and downspouts, 1999 V2: 81
horizontal branches, 1999 V2: 88

insulation, 1999 V2: 85
leaders, 1999 V2: 81, 87
limited-discharge roof drains, 2000 V3: 247
piping system design, 1999 V2: 81
roof drain sizes, 1999 V2: 69
roof drains, defined, 2004 V1: 28
scuppers, 1999 V2: 93
sizing pipes, 1999 V2: 85, 89–92
storm-drainage systems and, 1999 V2: 67
roofing
design considerations in seismic protection, 2004 V1: 188
green roofs, 2004 V1: 266–267
imperviousness factors, 2000 V3: 243
root problems in leaching trenches, 1999 V2: 222
rope anchors in pools, 2000 V3: 145
rotary lobe compressors, 2000 V3: 202
rotary lobe (roots) pumps, 1999 V2: 259
rotary piston pumps, 1999 V2: 259
rotary pop-up sprinkler heads, 2000 V3: 102
rotary screw air compressors, 2000 V3: 65, 66, 202
rotary vane, once-through-oil pumps, 1999 V2: 259
rotating filters, 2000 V3: 95
rotors
in gas boosters, 1999 V2: 179
in pump engines, 2004 V1: 197
rough-ins
checklist, 2004 V1: 103
roughing in, defined, 2004 V1: 28
water closets, 2003 V4: 4
rough vacuum, 1999 V2: 253
roughness (rgh, RGH, E), 2004 V1: 16
roughness of pipes
factors in, 1999 V2: 88
fairly rough pipe, 1999 V2: 141
fairly smooth pipe, 1999 V2: 140
galvanized fairly rough pipe, 1999 V2: 136
rough pipe, 1999 V2: 142
smooth pipe, 1999 V2: 139
turbulence and, 1999 V2: 41
types of pipes and, 1999 V2: 122
round bowls on water closets, 2003 V4: 4
round leaders, 1999 V2: 81
rounded-edge weirs, 2000 V3: 109
routing hot-water pipes, 2004 V1: 265
RPBDs (reduced-pressure backflow preventers)
as cross-connection control devices, 1999 V2: 144
at building meters, 1999 V2: 115
degrees of protection, 1999 V2: 145
flow rates, 1999 V2: 148
installation, 1999 V2: 148–149
rpm, RPM (revolutions per minute), 2004 V1: 15
rps, RPS (revolutions per second), 2004 V1: 16
RPZ (reduced pressure zones), 2000 V3: 223, 226
RSOs (Radiological Safety Officers), 1999 V2: 340
rubber compression gaskets, 2003 V4: 27
rubber facing in dry-pipe clappers, 2000 V3: 11
Rubber-Gasket Joints, 2003 V4: 32
rubber gaskets, 2003 V4: 32
rubber-in-shear isolators, 2004 V1: 166
rubber isolation devices
concrete bases and, 2004 V1: 204–205
defined, 2004 V1: 204
dishwashers, 2004 V1: 195
reducing water hammer, 2004 V1: 198
vibration control, 2004 V1: 203
rubble drains (french drains), 2004 V1: 25
rule-of-thumb tank capacity equation, 1999 V2: 151
rules in Function Analysis, 2004 V1: 225
running traps, 2000 V3: 42
runoff
calculation sheet, 1999 V2: 111
coefficients in site storm drains, 1999 V2: 95
diversion ditches for leaching trenches, 1999 V2: 223
imperviousness factor, 2000 V3: 242–243
rational method and, 2000 V3: 242
Rational method for calculating, 2004 V1: 7, 1999 V2: 95, 98, 107
slow-release storm-water systems, 1999 V2: 106
weighted runoff coefficients, 1999 V2: 97
runouts in steam piping, 2000 V3: 182
runways, piping underneath, 1999 V2: 250
rust
formation in iron pipes, 2004 V1: 139
in pools, 2000 V3: 147
rusting, defined, 2004 V1: 154
RV (pressure-relief valves). *See* pressure-regulating or reducing valves
Ryzner stability index (RI), 1999 V2: 292
RZBP (reduced zone backflow preventers), 2004 V1: 10

S

S (entropy), 2004 V1: 14, 33
s, SEC (seconds), 2004 V1: 16, 33
S (siemens), 2004 V1: 33
S (soil sewers), 2004 V1: 8
S (surfaces), 2004 V1: 16
s traps (unvented traps), 1999 V2: 46, 2000 V3: 42
sa, SA (supply air), 2004 V1: 16
sacrificial anodes, 2004 V1: 147
saddles for tanks, 2000 V3: 172
Safe Drinking Water Act of 1974, 1999 V2: 244, 279, 316
Safe Handling of Acids, 1999 V2: 350
safety. *See also* hazards
condensation loads, 2000 V3: 194
controlled substance spills, 1999 V2: 277
flammable and volatile liquids, 1999 V2: 347–349
gas appliances, 1999 V2: 178
gas boosters, 1999 V2: 179
gases in septic tanks, 1999 V2: 230
hot-water systems, 1999 V2: 157, 169–170
life safety
in fire protection, 2000 V3: 1
residential sprinkler systems, 2000 V3: 2
liquefied petroleum gas, 1999 V2: 194, 197
radioactive waste-drainage systems, 1999 V2: 341
Radiological Safety Officers, 1999 V2: 340
reflecting pools and, 2000 V3: 107
safety factors (sf, SF), 2004 V1: 16
sanitary precautions for wells, 1999 V2: 243
types of acids, 1999 V2: 332–334
vacuum cleaning system issues, 1999 V2: 276
safety cabinets, 1999 V2: 344
safety shut-off devices, 1999 V2: 214

sales tax, in plumbing cost estimation, 2004 V1: 94
salesmanship in value engineering, 2004 V1: 257
salt-air dryers, 2000 V3: 207
salt splitting, 1999 V2: 295
salts
  disinfecting water with, 2000 V3: 150
  ions in reverse osmosis, 1999 V2: 280
  in irrigation water, 2000 V3: 99
saltwater pools, 2000 V3: 147
samples
  acid wastes, 2000 V3: 41–42
  infectious waste systems, 1999 V2: 345
  pure water systems, 1999 V2: 324
  radioactive waste effluent, 1999 V2: 342
sampling manholes, 2000 V3: 41–42, 44
San Diego Gas & Electric Company, 2004 V1: 137
San Francisco Earthquake, 2004 V1: 162
SAN (sanitary sewers), 2004 V1: 8, 28. *See also* sanitary drainage systems
sand filtration
  aluminum sulfate, 2000 V3: 149–150
  cleaning, 2000 V3: 150
  compared to diatomaceous earth, 2000 V3: 135–137
  drinking water, 1999 V2: 244, 318
  earthquake damage to filters, 2004 V1: 162
  fountains, 2000 V3: 112
  gravity and pressure systems, 2000 V3: 132
  high-rate pressure filters, 2000 V3: 113
  laboratory water, 1999 V2: 300
  pressure sand filters, 2000 V3: 132–133, 134
  pumps and, 2000 V3: 140
  pure water systems, 1999 V2: 322–323
  sand filters defined, 2004 V1: 28
  sewage treatment, 1999 V2: 227, 232
  swimming pools, 2000 V3: 130
  tanks, 2000 V3: 131
  types of, 2000 V3: 139
sand points, 1999 V2: 241
sand traps, 2000 V3: 113
sands
  backfilling around water system pipes, 1999 V2: 250
  fill above subsurface drainage pipes, 1999 V2: 103
  gray-water irrigation systems and, 1999 V2: 26, 27
  imperviousness factors, 2000 V3: 243
  porous soils, 2000 V3: 99–100, 105
  in soil texture, 1999 V2: 218
sanitary building drains. *See also* sanitary drainage systems
  cast-iron soil pipe, 2003 V4: 27
  defined, 2004 V1: 20
sanitary drainage fitting codes, 2004 V1: 44
sanitary drainage systems, 2000 V3: 232–240
  alternative disposal methods, 2000 V3: 240
  building sewers (house drains), 1999 V2: 15, 2003 V4: 27
  components, 1999 V2: 9–14, 2000 V3: 234–236
  connections, 2000 V3: 234, 236
  defined, 1999 V2: 1
  drainage loads, 1999 V2: 3
  drainage structures, 2000 V3: 234–236
  fittings, 2004 V1: 44
  fixture discharge characteristics, 1999 V2: 3
  floor leveling around drains, 1999 V2: 17
  flow in, 1999 V2: 1–2
  force mains, 2000 V3: 236–240
    connections, 2000 V3: 239
    sizing, 2000 V3: 236
    sizing ejector pumps and pits, 2000 V3: 236
  gray-water systems and, 1999 V2: 22
  health-care facilities, 2000 V3: 39–42
  joining methods, 1999 V2: 17–18
  kitchen areas, 1999 V2: 16–17
  laboratories
    acid-waste metering, 2000 V3: 41–42
    acid-waste neutralization, 2000 V3: 40–41
    acid-waste solids interceptors, 2000 V3: 41, 43
    discharge to sewers, 2000 V3: 40
    sink traps, 2000 V3: 42
    waste and vent piping, 2000 V3: 42
  materials for, 1999 V2: 14–15
  overview, 2000 V3: 232
  pipes, 2004 V1: 44
  pneumatic pressures in, 1999 V2: 2–3
  preliminary information, 2000 V3: 215–216
  protection from damage, 1999 V2: 18–19
  public sewer availability, 2000 V3: 234
  research, 1999 V2: 19
  sample letters, 2000 V3: 232
  sanitary sewers (SAN, SS), 2004 V1: 8, 28
  sanitation and cleaning, 1999 V2: 16
  sizing, 2000 V3: 232–233
  sloping drain capacities, 1999 V2: 5–9
  sovent systems, 1999 V2: 19, 20
  stack capacities, 1999 V2: 3–5
  storm-drainage systems and, 1999 V2: 67
  thermal expansion, 1999 V2: 18
  trenching and bedding, 2000 V3: 234, 235
  waterproofing, 1999 V2: 17
sanitary joints, 2000 V3: 48
sanitary sewer pipe codes, 2004 V1: 44
sanitary sewer systems. *See* sanitary drainage systems
sanitary tees
  common vents and, 1999 V2: 43
  flow capacity and, 1999 V2: 4
  water closet installation, 2003 V4: 6–7
sanitaryware. *See* fixtures
sanitation. *See also* cleanouts
  feed water, 1999 V2: 289
  fixture materials and, 2003 V4: 1
  floor drains, 2003 V4: 17
  precautions for wells, 1999 V2: 243
  sanitary seals on wells, 1999 V2: 240
  water softeners, 1999 V2: 308
sanitizers, 2000 V3: 38
Sansone, John T., 1999 V2: 114
SARA Title III act (Superfund Amendment and Reauthorization Act of 1986), 2000 V3: 154
sat., SAT (saturation). *See* saturation
saturated steam, 2000 V3: 175, 176
saturation (sat., SAT)
  of soils, 1999 V2: 219
  symbols for, 2004 V1: 16
  of water with calcium carbonate, 1999 V2: 291
SAVE. *See* Society of American Value Engineering

sawcutting trenches, labor productivity rates, 2004 V1: 96
Saybolt Seconds Furol (ssf, SSF), 2004 V1: 16, 2000 V3: 154
Saybolt Seconds Universal (ssu, SSU), 2004 V1: 16, 2000 V3: 154
SAZ (solar azimuth), 2004 V1: 14
SBCCI (Southern Building Code Congress International, Inc.), 1999 V2: 114, 2000 V3: 154
SC (shading coefficients), 2004 V1: 16
scalars, defined, 2004 V1: 93
scalding water, 1999 V2: 157, 169–170
scale and scale formation
  boilers, 1999 V2: 314
  chlorides and sulfates, 1999 V2: 283
  cooling towers, 1999 V2: 316
  hardness and, 1999 V2: 283
  heat transfer surfaces, 2000 V3: 190
  Langelier saturation index, 1999 V2: 291–292
  magnesium and, 1999 V2: 283
  pool water heaters and, 2000 V3: 138
  predicting water deposits and corrosion, 1999 V2: 290–292
  removing with water softening, 1999 V2: 307
  Ryzner stability index, 1999 V2: 292
  sequestering agents, 2000 V3: 150
  swimming pools, 2000 V3: 147
  total dissolved solids and, 1999 V2: 288
  water deposits and corrosion, 1999 V2: 289–290
  water piping systems, 1999 V2: 244
scanning electron microscopy, 1999 V2: 282. *See also* electron microscopes
scavenging adapters, 2000 V3: 71
SCCC (Spill Containment Control and Countermeasures), 2000 V3: 165
scfh (standard cfh), 1999 V2: 180
scfm, SCFM (standard cubic feet per minute)
  abbreviation, 2004 V1: 14
  ambient free air and, 1999 V2: 255–256
  compressed air pipe sizing, 2000 V3: 210
  compressed air tools, 2000 V3: 208
  defined, 2000 V3: 85, 200
  medical air compressors, 2000 V3: 65, 66
  medical vacuum systems, 2000 V3: 69
scfs, SCFS (cubic feet per second), 2004 V1: 33
Schedule 10 steel pipe, 2003 V4: 48
Schedule 40 brass pipe, 2003 V4: 27
Schedule 40 polyvinyl pipe, 2003 V4: 62
Schedule 40 PVC plastic, 2000 V3: 17, 116, 2003 V4: 62
Schedule 40 steel pipe, 2003 V4: 51–52
Schedule 80 brass pipe, 2003 V4: 27
Schedule 80 polyvinyl pipe, 2003 V4: 62
Schedule 80 PVC plastic, 2003 V4: 62
Schedule 80 steel pipe, 2003 V4: 53–54
schedules (project)
  checklist, 2004 V1: 102
  section in specifications, 2004 V1: 70, 90, 92
school laboratories. *See* laboratories
schools
  numbers of fixtures for, 2003 V4: 19, 22
  septic tank systems for, 1999 V2: 231–232
  shower room grates, 1999 V2: 11
  swimming pools and, 2000 V3: 129
  vacuum calculations for, 1999 V2: 269
scope lines, 2004 V1: 227
screening
  in downspouts, 1999 V2: 81
  in gray-water treatment, 1999 V2: 27
  urinals, 2003 V4: 10
  vacuum exhaust piping, 1999 V2: 274
screw compressors, 2000 V3: 201, 205
screw pumps, 1999 V2: 259
screw threads, 2004 V1: 17
screwed fittings, 2004 V1: 162
screwed mechanical joints, 1999 V2: 334
scrub-up sinks, 2000 V3: 32, 35–36, 38
"scuff-buff" grates, 1999 V2: 11
scum
  in septic tanks, 1999 V2: 227, 228, 229, 230
  in swimming pools, 2000 V3: 150
scuppers, 1999 V2: 79, 88, 93
SCW (soft cold water), 2004 V1: 8
SD (storm or rainwater drains). *See* storm-drainage systems
SDI (silt density index), 1999 V2: 288–289
SDR (standard dimension ratio)
  HDPE pipe, 2003 V4: 61
  SDR21 PVC pipe, 2003 V4: 62
  SDR26 PVC pipe, 2003 V4: 62
SE (sea level). *See* sea level
sea level (sl, SL, SE)
  atmospheric pressure, 2000 V3: 200
  symbols for, 2004 V1: 16
  vacuum ratings, 1999 V2: 257
sealed sprinklers, 2000 V3: 9, 11
sealing grouts in wells, 1999 V2: 243
seals
  acoustic pipe-penetration seals, 2004 V1: 201
  flashing rings, 1999 V2: 12
  floor drains in infectious waste systems, 1999 V2: 345
  seal liquids in vacuum pumps, 1999 V2: 260
  sound insulation, 2004 V1: 193
  trap seals in floor drains, 1999 V2: 10
  water closets, 2003 V4: 6
  well fixtures, 1999 V2: 243
seamless copper pipe, 2003 V4: 34–36
seamless copper water tube, 2003 V4: 34–44
seamless steel piping, 2003 V4: 48
seasonable condensate drains, 1999 V2: 13
seats
  accessible shower compartments, 2004 V1: 120
  bathtub and shower seats, 2004 V1: 115, 117, 122–123
  seat fouling tests, 2003 V4: 6
  water closets, 2003 V4: 5
second-guessing designs, 2004 V1: 213
secondary containment
  of hazardous wastes, 2000 V3: 90
  of infectious wastes, 1999 V2: 343
secondary containment tanks
  aboveground types, 2000 V3: 165, 167
  interstitial monitoring, 2000 V3: 160–161
  interstitial spaces, 2000 V3: 156
  underground tanks, 2000 V3: 155
secondary functions, 2004 V1: 225, 227, 230
secondary pipe liquid monitoring, 2000 V3: 162

secondary pipe vapor monitoring, 2000 V3: 162
secondary storm-drainage systems
controlled-flow systems, 1999 V2: 94
pipe sizing, 1999 V2: 69
piping systems, 1999 V2: 81
planning for in design, 1999 V2: 70
rainfall frequency and, 1999 V2: 79
scuppers, 1999 V2: 93
types of, 1999 V2: 88
Seconds Redwood, 2000 V3: 154
seconds (s, SEC), 2004 V1: 16, 33
Seconds Saybolt Furol (SSF), 2000 V3: 154
Seconds Saybolt Universal (SSU), 2000 V3: 154
Sectionformat, 2004 V1: 65, 68–71
sections
in *Manual of Practice,* 2004 V1: 88–92
of pump equipment, 1999 V2: 245
in specifications, 2004 V1: 63, 68–71
security of oxygen storage areas, 2000 V3: 63
sediment
removing, 1999 V2: 294
in water, 1999 V2: 282
sediment buckets
kitchen drains, 1999 V2: 16
materials, 1999 V2: 14
in oil collectors, 1999 V2: 13
in sanitary drainage systems, 1999 V2: 12
sediment pits, 1999 V2: 105
sedimentation
in gray-water treatment, 1999 V2: 27
in water treatment, 1999 V2: 294
seepage beds, 1999 V2: 217, 220, 224–225, 232
seepage flanges, 1999 V2: 17
seepage pits, 2004 V1: 28, 1999 V2: 27, 220, 225–226, 2000 V3: 240
SEFF (surface efficiency), 2004 V1: 14
seiches, 2004 V1: 158
seismic, defined, 2004 V1: 191
Seismic Design for Buildings, 2004 V1: 183, 191
seismic joints, crossing, 2004 V1: 162
seismic protection
air compressors and, 2000 V3: 213
calculating seismic forces, 2004 V1: 183–186
causes and effects of earthquakes, 2004 V1: 156–158
codes and standards, 2004 V1: 171–184
computer analysis of piping systems, 2004 V1: 186
damage from earthquakes, 2004 V1: 158
design considerations, 2004 V1: 186–188
earthquake measurement and seismic design, 2004 V1: 160–161
equipment protection, 2004 V1: 163–171
glossary, 2004 V1: 191
introduction, 2004 V1: 155–156
learning from past earthquakes, 2004 V1: 161–163
pipe restraints, 2004 V1: 166–182, 1999 V2: 14, 19, 2000 V3: 15
potential problems, 2004 V1: 188–191, 189
references, 2004 V1: 191
seismic loads, defined, 2004 V1: 155
seismic risk maps, 2004 V1: 155–157
underground storage tanks and, 2000 V3: 155
vibration isolation and, 2004 V1: 206
Seismic Restraint Manual Guidelines for Mechanical Systems, 2004 V1: 191
selective attack corrosion, 2004 V1: 141
selectivity coefficients, 1999 V2: 302
self-bracing problems in seismic protection, 2004 V1: 190
self-closing valves, 2000 V3: 33
self-contained breathing units, 1999 V2: 332, 333
self-contained fountains, 2000 V3: 107
self-jetting well points, 1999 V2: 241
self-metering faucets, 2003 V4: 13
self-priming dry pumps, 2000 V3: 113, 129–130, 142
self-regulating heat-trace systems, 1999 V2: 165–166
self-scouring traps, 1999 V2: 36
self-scouring velocity in sewers, 2000 V3: 232
self-siphonage
defined, 1999 V2: 36
in fixture drains, 1999 V2: 2
tests, 1999 V2: 38
self-venting in sovent systems, 1999 V2: 19, 54
selling functions, 2004 V1: 225
SEMI (Semiconductor Equipment Manufacturers Institute), 1999 V2: 279, 317
semi-ambulatory individuals
semi-ambulatory disabilities, 2004 V1: 107
water closet requirements, 2004 V1: 116
semi-circular gutters, 1999 V2: 81, 86
semi-circular lavatories, 2003 V4: 11
semi-instantaneous water heaters, 1999 V2: 160
semi-permeable membranes, 2000 V3: 47
Semiconductor Equipment Manufacturers Institute, 1999 V2: 279, 317
Sendelbach, M.G., 1999 V2: 325
sensible heat (SH)
condensate drainage and, 2000 V3: 189
defined, 2004 V1: 137
sensible heat gain (SHG), 2004 V1: 15, 16
sensible heat ratio (SHR), 2004 V1: 16
symbols for, 2004 V1: 16
sensitivity in pressure-regulated valves, 1999 V2: 152
sensors
corrosive-waste systems, 2000 V3: 40
electrical makeup water method, 2000 V3: 124, 125
faucet controls, 2004 V1: 135
hazardous material level sensors, 2000 V3: 90
line-pressure sensors, 2000 V3: 72
liquid fuel leakage, 2000 V3: 163
pH sensors, 2000 V3: 40
water-level sensors, 2000 V3: 124
separating systems
for acid waste, 1999 V2: 329, 334
for oil, 1999 V2: 347–349
separator/filters in air compressors, 2000 V3: 203
separators in vacuum cleaning systems
kinds of materials, 1999 V2: 275
location, 1999 V2: 270
pressure loss, 1999 V2: 274
types of systems, 1999 V2: 266, 268
septic tanks
biological treatment of sewage in, 1999 V2: 227
chemicals in, 1999 V2: 230–231
cleaning, 1999 V2: 229–230
clogging materials, 1999 V2: 231

compartments, 1999 V2: 229
defined, 2004 V1: 28
estimating sewage quantities, 1999 V2: 233–238
grease interceptors, 1999 V2: 230
institutional and recreational establishments, 1999 V2: 231–232
liquid discharge from, 1999 V2: 217
percolation rates and, 1999 V2: 238
sanitary sewers and, 2000 V3: 240
single septic tank installations, 1999 V2: 231
sizing, 1999 V2: 227
solids removal, 1999 V2: 227–228
specifications, 1999 V2: 228–229
usefulness and area served, 1999 V2: 231
venting, 1999 V2: 231
septum filters, 1999 V2: 318, 2000 V3: 134, 135
sequence
of project phases, cost estimates and, 2004 V1: 98
section in specifications, 2004 V1: 70, 90
sequential functions in FAST approach, 2004 V1: 230
sequential functions in FAST approach, 2004 V1: 230
sequestering agents, 2000 V3: 150
serial distribution of leaching trenches, 1999 V2: 223–224
service cocks, 1999 V2: 154
service deionization, 1999 V2: 305–306
service sinks, 2003 V4: 12–13, 18–22
Service Station Tankage Guide (API 1611), 2000 V3: 173
service stations, 2000 V3: 166, 2003 V4: 20
service-weight cast-iron soil pipe, 2003 V4: 27, 30–31
services
costs, 2004 V1: 222
ongoing and one-time costs, 2004 V1: 223
set pressure in pressure-regulated valves, 1999 V2: 152, 167
settlement. *See* bedding and settlement; creep
settling tanks, 2000 V3: 93
severe backflow hazard, 1999 V2: 145, 146, 2000 V3: 222
sewage, defined, 2004 V1: 28. *See also* effluent
sewage effluent. *See* effluent
sewage ejectors, 2004 V1: 28
sewage systems. *See* sewer systems
sewage treatment plants, 1999 V2: 22, 24, 147
sewer mains
asbestos concrete piping, 2003 V4: 26
nonreinforced concrete pipe, 2003 V4: 32
sewer systems. *See also* building sewers; private sewage-disposal systems; public sewers; *specific types of sewers*
combined systems, 2000 V3: 247
discharge from laboratories, 2000 V3: 40
preliminary information, 2000 V3: 215–216
sample sewer services letter, 2000 V3: 257
sanitary sewer systems, 2000 V3: 232–240. *See also* sanitary drainage systems
alternative disposal methods, 2000 V3: 240
components and design, 2000 V3: 234–236
force mains, 2000 V3: 234–236
overview, 2000 V3: 232
sample letters, 2000 V3: 232
sizing, 2000 V3: 232–233
sewer video equipment, 1999 V2: 10
storm sewers, 2000 V3: 240–248
calculations, 2000 V3: 244–245
codes and standards, 2000 V3: 240
disposal methods, 2000 V3: 245–247
overview, 2000 V3: 240
rational method and design glow, 2000 V3: 242–244
sizing ditches, 2000 V3: 247–248
swimming pool water and, 2000 V3: 131, 140
sf, SF (safety factors), 2004 V1: 16
sft hp, SFT HP (shaft horsepower), 2004 V1: 16
sfu (supply fixture units), 2004 V1: 24
SGPH (standard gallons per hour), 2004 V1: 15
SH (sensible heat), 2004 V1: 15, 16, 137
shading coefficients (SC), 2004 V1: 16
shaft horsepower (sft hp, SFT HP, SHP), 2004 V1: 16
shafts, piping and acoustic design for, 2004 V1: 196
shaking vacuum filter bags, 1999 V2: 268
shallow-end depth of swimming pools, 2000 V3: 128
shallow fill, building sewers and, 1999 V2: 15
shallow manholes, 2000 V3: 234, 238
shallow septic tanks, 1999 V2: 228
shallow wells, 1999 V2: 240, 247
shapes of swimming pools, 2000 V3: 129
shear motions, preventing, 2004 V1: 163, 189, 190
sheet copper, 2003 V4: 15
sheet flows, 2000 V3: 244
sheet lead, 2003 V4: 15
Sheet Metal and Air Conditioning Contractors' National Association (SMACNA), 2004 V1: 170, 191
Sheet Metal Industry Fund of Los Angeles, 2004 V1: 191
shell-and-tube heat exchangers, 2004 V1: 131
shelving
accessibility in toilet and bathing rooms, 2004 V1: 113
ambulatory accessible toilet compartments, 2004 V1: 115–116
Sherlin, G.C., 1999 V2: 65
SHG (sensible heat gain), 2004 V1: 15, 16
shielding on radioactive drainage systems, 1999 V2: 339–340
shine. *See* radiation
shipping costs, 2004 V1: 98, 223
shock absorbers. *See* water hammer arresters
shock intensity of water hammer, 1999 V2: 132
shock treatments in pools and fountains, 2000 V3: 123
Sholes, Christopher, 2004 V1: 231
shopping centers, 1999 V2: 25, 2003 V4: 20
shops, numbers of fixtures for, 2003 V4: 20
short-circuiting installations, 2004 V1:151
short cycling in boilers, 2000 V3: 180
shot-in concrete anchors, 2004 V1: 163, 190
shower pans, 2003 V4: 15
shower valves
flow rates, 2003 V4: 16
installation, 2003 V4: 16
types, 2003 V4: 15–16
showerheads
Energy Policy Act requirements, 2004 V1: 264
low flow, 2004 V1: 136
wasted water, 2004 V1: 136
showers
acoustic ratings of, 2004 V1: 194–195
body sprays, 2003 V4: 16

emergency showers, 1999 V2: 332, 333, 344, 2003 V4: 17–18
enclosures, 2004 V1: 120
fixture-unit loads, 1999 V2: 3
flow rates, 2003 V4: 15
grab bars, 2004 V1: 121–122
grates in school shower rooms, 1999 V2: 11
gray-water supply and demand, 1999 V2: 25
gray-water systems, 2004 V1: 135
health-care facilities, 2000 V3: 32, 38
heat recovery systems, 2004 V1: 266
hydrotherapy, 2000 V3: 35
labor rooms, 2000 V3: 36
minimum numbers of, 2003 V4: 18–22
patient rooms, 2000 V3: 34
public areas in health-care facilities, 2000 V3: 33
rates of sewage flows, 1999 V2: 237
reduced water usage, 2004 V1: 126
reducing flow rates, 2004 V1: 135
requirements, 2003 V4: 14–15
resilient-mounting design, 2004 V1: 206
seats, 2004 V1: 122–123
shower compartment accessibility, 2004 V1: 119–122
showerhead acoustic ratings, 2004 V1: 195
spray units, 2004 V1: 118, 120
standards, 2003 V4: 2
stop levers, 2004 V1: 136
swimming pool bathhouses, 2000 V3: 130
temperatures, 2000 V3: 45
thresholds, 2004 V1: 120
water fixture unit values, 2000 V3: 217
SHP (shaft horsepower), 2004 V1: 16
SHR (sensible heat ratio), 2004 V1: 16
Shreir, L.L., 2004 V1: 154
shrinkage of ceramic fixtures, 2003 V4: 1
shrub sprinkler heads, 2000 V3: 103
Shumann, Eugene R., 1999 V2: 114
shut-off devices
defined, 1999 V2: 214
fuel dispensers, 2000 V3: 165
shut-off valves
earthquake-sensitive valves, 2004 V1: 162
fountains, 2000 V3: 118
gas hose connectors, 1999 V2: 196
medical gases, 2000 V3: 71, 72
natural gas, 1999 V2: 176
shutdown relays, 2000 V3: 24
Shweitzer, 2000 V3: 97
SI units. *See* International System of Units
siamese fire-department connections, 2004 V1: 12, 28, 2000 V3: 11. *See also* fire-protection systems
side reach for wheelchairs, 2004 V1: 109, 112
side spray accessories, 2003 V4: 12, 14
side vents, 2004 V1: 28
sidesway prevention, 2004 V1: 189
sidewalk fire-department connections, 2004 V1: 12
sidewall grab bars, 2004 V1: 114
sidewall heat loss in pools, 2000 V3: 144
sidewall sprinklers, 2004 V1: 13, 30
Siegrist, R., 1999 V2: 34
siemens, 2004 V1: 33
sight disabilities, 2004 V1: 107
signals for fire alarms, 2000 V3: 9
significant digits, 2004 V1: 32
silencers
on air compressors, 2000 V3: 202, 212
on vacuum systems, 1999 V2: 268
silica, 1999 V2: 283
silica gel, 2000 V3: 204
silicates, 1999 V2: 282, 2000 V3: 147
silicon, 1999 V2: 281
silicon iron piping, 1999 V2: 15
silt
content of water, 2000 V3: 99
loams, 2000 V3: 100
removing, 1999 V2: 294
silt density index, 1999 V2: 288–289
in soil texture, 1999 V2: 218
in water, 1999 V2: 282
silt density index (SDI), 1999 V2: 288–289
silver, 2004 V1: 139, 141, 144
Silver-level LEED certification, 2004 V1: 263
silver salt, 2000 V3: 150
silver solder, 2004 V1: 141
A Simple Method for Retention Basin Design, 1999 V2: 114
simplex air compressors, 2000 V3: 213
simplex gas booster systems, 1999 V2: 181
simultaneous operators of vacuum systems, 1999 V2: 269, 272
simultaneous-use factors. *See* diversity factor
single-acting altitude valves, 1999 V2: 249
single-acting cylinders in compressors, 2000 V3: 201
single-compartment septic tanks, 1999 V2: 229
single-compartment sinks, 2003 V4: 11
single-degree-of-freedom systems, 2004 V1: 160, 161
single-family dwellings, 2003 V4: 20, 21
single-occupant toilet rooms, 2003 V4: 18, 23
single-seated pressure-regulated valves, 1999 V2: 152
single-side-entry fittings in sovent systems, 1999 V2: 62
single-stage distillation, 1999 V2: 295
single-step deionization (mixed bed), 1999 V2: 302, 303, 305
single-tank residential filters, 2000 V3: 134
single-wall tanks, 2000 V3: 156
sinistans, 2000 V3: 38
sink-disposal units. *See* food waste grinders
sinks and wash basins. *See also* lavatories
accessibility, 2004 V1: 117
faucets, 2003 V4: 13
fixture-unit loads, 1999 V2: 3
food-preparation, 2000 V3: 36
general category of, 2003 V4: 13
gray-water supply and demand, 1999 V2: 25
health-care facilities, 2000 V3: 32, 38
infectious waste drainage, 1999 V2: 344
kitchen sinks, 2003 V4: 11–12
laboratory rooms, 2000 V3: 37
laboratory sink drainage rates, 1999 V2: 337
laundry sinks, 2003 V4: 13
neutralizing acid from, 1999 V2: 336
pharmacies and drug rooms, 2000 V3: 35
public areas in health-care facilities, 2000 V3: 33
rates of sewage flows, 1999 V2: 237
service sinks, 2003 V4: 12–13

sound-damping materials, 2004 V1: 196
standards, 2003 V4: 2
suds problems, 1999 V2: 37, 39
surgical scrub-up areas, 2000 V3: 35–36
traps and acid wastes, 2000 V3: 42
vents, 1999 V2: 37
water fixture unit values, 2000 V3: 217
siphon jet urinals, 2003 V4: 9
siphon jet water closets, 2003 V4: 3
siphonage
eliminating with vents, 1999 V2: 35
factors in trap seal loss, 1999 V2: 36
reducing trap seal losses, 1999 V2: 39–40
water closets and, 1999 V2: 36
siphons in secondary containment areas, 2000 V3: 90
site storm drainage, 1999 V2: 95–107
equations, 1999 V2: 107–108
exterior piping and inlets, 1999 V2: 98–99
Rational Method formulas, 2004 V1: 7, 1999 V2: 95–98, 98, 107
storm-water detention, 1999 V2: 105–107
subsurface drainage, 1999 V2: 99–105, 100
site utilities
domestic water supply
codes and standards, 2000 V3: 216
overview, 2000 V3: 216
sample water service letter, 2000 V3: 256
service components and design, 2000 V3: 217–224
system requirements, 2000 V3: 216–217
water mains and pressure, 2000 V3: 216
water utility letters, 2000 V3: 216
fire-protection water supply, 2000 V3: 224–232
ancillary devices, 2000 V3: 226–229
building water supply, 2000 V3: 225–226
codes and standards, 2000 V3: 225
overview, 2000 V3: 224–225
sizing system, 2000 V3: 229–232
natural gas services, 2000 V3: 248–254
codes and standards, 2000 V3: 248
overview, 2000 V3: 248
sample gas utility letter, 2000 V3: 258–259
site distribution, 2000 V3: 252
sizing methods, 2000 V3: 252–254
system components, 2000 V3: 250–252
testing and purging, 2000 V3: 252
types of services, 2000 V3: 249
off-peak power savings, 2004 V1: 128–129
overview, 2000 V3: 215
preliminary information, 2000 V3: 215–216
sample general notes, 2000 V3: 255
sanitary sewer services, 2000 V3: 232–240
alternative disposal methods, 2000 V3: 240
components and design, 2000 V3: 234–236
force mains, 2000 V3: 236–240
overview, 2000 V3: 232
sample letters, 2000 V3: 232
sample sewer services letter, 2000 V3: 257
sizing, 2000 V3: 232–233
storm sewers, 2000 V3: 240–248
calculations, 2000 V3: 244–245
codes and standards, 2000 V3: 240
disposal methods, 2000 V3: 245–247
overview, 2000 V3: 240
rational method and design glow, 2000 V3: 242–244
sample sewer services letter, 2000 V3: 257
sizing ditches, 2000 V3: 247–248
swimming pool locations and, 2000 V3: 128
sites
geological stability of, 1999 V2: 26
irrigation system plans, 2000 V3: 104
obtaining plans, 2000 V3: 215
overland flow times for sites, 1999 V2: 96, 97, 98, 111
site conditions and storm drainage, 1999 V2: 69
slope of site, 1999 V2: 101, 224
sitz baths, 2000 V3: 32, 38
Six Sticks exercise, 2004 V1: 232, 261
sizing
acid-neutralization tanks, 2000 V3: 40, 42
acid-waste drainage system pipes, 1999 V2: 334
air compressors, 2000 V3: 68, 210–213
air receivers, 2000 V3: 205–206
clean agent gas pipes, 2000 V3: 24
cleanouts, 1999 V2: 9
cold-water system pipes, 1999 V2: 116–131, 133–142
condensate traps, 2000 V3: 193–195, 197
cryogenic tanks, 2000 V3: 62
fire extinguishers, 2000 V3: 27, 28
floor drains, 1999 V2: 10
force mains, 2000 V3: 236
fountain display pumps, 2000 V3: 115
fountain drains, 2000 V3: 110, 125
fountain filtration systems, 2000 V3: 110, 112, 113, 115–116
fountain nozzles, 2000 V3: 117–118
fountain return inlets, 2000 V3: 117–118
friction loss basis for pipes, 1999 V2: 127
gas boosters, 1999 V2: 182–183
gas line filters, 2000 V3: 250
gas meters, 2000 V3: 250
gas piping, 2004 V1: 7
gas regulators, 2000 V3: 251–252
grab bars, 2004 V1: 121
gutters, 1999 V2: 86, 2000 V3: 142
hot-water circulation systems, 1999 V2: 165
hypochlorinators, 2000 V3: 151
irrigation, 2000 V3: 100
liquid fuel piping, 2000 V3: 169, 2000 V3:169–170
medical air compressors, 2000 V3: 68
medical air piping, 2000 V3: 210
medical gas systems, 2000 V3: 49–50, 73–74, 75, 76–77
medical vacuum systems, 2000 V3: 69, 75
multilevel pools, 2000 V3: 108
natural gas fittings, 1999 V2: 184
natural gas piping, 1999 V2: 174–176, 183–194, 197–211, 2000 V3: 252–254
by NFPA formula, 1999 V2: 186, 187, 188, 189
by Spitzglass formula, 1999 V2: 210–211
by Weymouth formula, 1999 V2: 190, 191, 198–209
pressure drops and, 1999 V2: 192, 193
nitrogen gas systems, 2000 V3: 68, 75
nitrous oxide systems, 2000 V3: 65, 75, 76
nominal pipe size, 1999 V2: 253
oxygen systems, 2000 V3: 63, 75, 76
pressure and temperature relief valves, 1999 V2: 167

pressure-regulated valves, 1999 V2: 153–154
pressurized fuel product piping, 2000 V3: 170
project size and cost estimates, 2004 V1: 98
roof drainage systems, 1999 V2: 81, 85, 89–92
sanitary sewer systems, 2000 V3: 232–233
septic tanks, 1999 V2: 227
skimmers, 2000 V3: 110, 142
special-waste system pipes, 1999 V2: 328–329, 329, 330, 331
sprinkler system pipes, 2000 V3: 16, 18
standpipe systems, 2000 V3: 19
steam systems, 2000 V3: 177, 186–187, 191
steam traps, 2000 V3: 191, 193–195, 196
storm drainage systems, 1999 V2: 69, 110
storm sewers, 2000 V3: 244–245, 246
storm water ditches, 2000 V3: 247–248
submersible pumps, 2000 V3: 164, 2000 V3:170, 2000 V3: 170
subsurface pipes, 1999 V2: 104
sump pits for LSDS systems, 1999 V2: 344
surge chambers, 2000 V3: 143
in sustainable designs, 2004 V1: 264
swimming pool return systems, 2000 V3: 143
swimming pool water heaters, 2000 V3: 144–145
swimming pools, 2000 V3: 127–128
toilet compartments, 2004 V1: 113–114
vacuum systems, 1999 V2: 262–266, 2000 V3: 79
exhaust, 2000 V3: 70
pumps, 2000 V3: 70
vacuum cleaning inlets, tools, and tubing, 1999 V2: 269–270
vacuum cleaning piping network, 1999 V2: 270–274, 274
vacuum cleaning system separators, 1999 V2: 275–276
vacuum exhaust pipes, 1999 V2: 263
vacuum piping, 1999 V2: 263
vacuum producers (exhausters), 1999 V2: 272
vacuum pumps, 1999 V2: 263–264
vents, 1999 V2: 41–43, 50–63
vertical stacks, 1999 V2: 5, 6
water hammer arresters, 1999 V2: 143–144
water mains, 2000 V3: 8
water meters, 1999 V2: 116
water storage tanks, 1999 V2: 247–248
wells, 1999 V2: 240
skating rinks, numbers of fixtures for, 2003 V4: 19
sketches. *See also* plumbing drawings
costs analysis phase, 2004 V1: 241
function evaluation, 2004 V1: 239–240
functional development, 2004 V1: 254, 255
skimmers
dissolving tablets in, 2000 V3: 149
head loss and, 2000 V3: 115
pools and fountains, 2000 V3: 110
swimming pools, 2000 V3: 137, 142
skimming oils, 2000 V3: 93
sl, SL (sea level), 2004 V1: 16, 1999 V2: 257
slabs
below-slab drainage, 1999 V2: 103
in radioactive waste systems, 1999 V2: 342
slack cables in earthquake protection, 2004 V1: 166
slaughterhouses, 1999 V2: 16
sliding motions
preventing for pipes or equipment, 2004 V1: 163
of seismic plates, 2004 V1: 158
sliding vane compressors, 2000 V3: 201, 205
sliding vane pumps, 1999 V2: 262
slime, 1999 V2: 289
slime bacteria, 1999 V2: 282
slip-resistant bases in baths, 2003 V4: 16
slope
of ditches, 2000 V3: 248
of floors, 2000 V3: 130
of sewers, 2000 V3: 233
of sites, 1999 V2: 26, 101, 224, 2000 V3: 105, 244
sloping drains
fixture loads, 1999 V2: 7, 9
Manning formula, 2004 V1: 1
minimum slope of piping, 1999 V2: 7
sanitary drainage systems, 1999 V2: 5
steady flow in, 1999 V2: 6–7
ultra-low-flow fixtures and pipes, 2004 V1: 264
slow-release storm-water detention systems, 1999 V2: 105–107
slow sand filtration, 1999 V2: 318
sludge
activated sludge systems, 2000 V3: 95
defined, 2004 V1: 28, 1999 V2: 289
from water softeners, 1999 V2: 244
removal, 2000 V3: 93
in septic tanks, 1999 V2: 227, 228, 229, 230
slugs of water, 1999 V2: 2, 4, 38, 226
slurry feeding in filtration, 2000 V3: 134–135
SMACNA (Sheet Metal and Air Conditioning Contractors' National Association), 2004 V1: 170, 191
small bore pipes, 1999 V2: 341
small-diameter gravity sewers, 1999 V2: 226
Small Welded Petroleum Tanks (API 12F), 2000 V3: 95
smoke detectors, 2004 V1: 22, 2000 V3: 24
smoke, vacuum systems and, 2000 V3: 69
smooth piping, 1999 V2: 139
smothering fires, 2000 V3: 19
sniffer systems for gas, 1999 V2: 197
snow melting piping, 2003 V4: 35
snubbing devices for earthquake protection, 2004 V1: 164–166, 165, 186
soaking combustibles in inerting atmosphere, 2000 V3: 20
soap dispensers, 2003 V4: 12
soaps. *See also* suds
in gray water, 1999 V2: 29
in septic tanks, 1999 V2: 230
soapstone fixtures, 2003 V4: 2, 13
Social Security taxes, in labor costs, 2004 V1: 94
Society of American Value Engineering (SAVE), 2004 V1: 211, 213
socket-type joints, 2000 V3: 254
socket welding
defined, 1999 V2: 341
socket-weld end connections, 2004 V1: 23
soda ash (sodium carbonate), 2000 V3: 148, 149
sodium, 1999 V2: 281, 283
sodium aluminate, 1999 V2: 294
sodium bicarbonate, 1999 V2: 283

sodium bisulfate, 1999 V2: 245, 2000 V3: 93, 148, 149, 150
sodium carbonate (soda ash), 1999 V2: 283, 2000 V3: 148, 149
sodium chloride, 1999 V2: 283
sodium cycle ion exchange, 1999 V2: 307
sodium hexametaphosphate, 2004 V1: 151, 1999 V2: 244
sodium hydroxide (lye), 1999 V2: 230, 305, 2000 V3: 93, 149, 150
sodium hypochlorite, 1999 V2: 245, 2000 V3: 93, 149, 150–151
sodium silicate, 2004 V1: 151
sodium sulfate, 1999 V2: 281
sodium thiosulfate, 1999 V2: 245
soft cold water (SCW), 2004 V1: 8
soft conversions, 2004 V1: 32
soft water (SW). *See* water softeners
softening water. *See* water softeners
softness of vibration control materials, 2004 V1: 202
software. *See* computer programs
soil-absorption sewage systems, 1999 V2: 217–224
  allowable rates of sewage application, 1999 V2: 237
  estimating sewage quantities, 1999 V2: 233–238
  estimating soil absorption potential, 1999 V2: 217–220
  individual wastewater treatment plants, 1999 V2: 232
  inspection, 1999 V2: 238
  institutional and recreational establishments, 1999 V2: 231–232
  leaching trenches, 1999 V2: 220
  locations, 1999 V2: 220
  mound systems, 1999 V2: 226
  percolation rates for soils, 1999 V2: 219–220
  seepage beds, 1999 V2: 224–225
  seepage pits, 1999 V2: 225–226
  selecting systems, 1999 V2: 220–221
Soil Conservation Service, 1999 V2: 107, 114
soil-moisture monitors, 2000 V3: 104
soil pipes, 2004 V1: 28
soil sewers (S, SS), 2004 V1: 8
soil vents. *See* stack vents
soils
  color, 1999 V2: 218–219
  depth, 1999 V2: 219
  gray-water irrigation systems and, 1999 V2: 26, 27
  infiltration rates, 1999 V2: 96
  irrigation and, 2000 V3: 99–100, 104–105
  K factors of, 1999 V2: 101, 104–105
  maps of, 1999 V2: 218
  percolation tests, 1999 V2: 219–220
  profiles, 2000 V3: 99–100, 216
  resistivity, 2004 V1: 150
  in seismic force calculations, 2004 V1: 183
  structure, 1999 V2: 218
  swelling characteristics, 1999 V2: 219
  swimming pool locations and, 2000 V3: 128
  texture, 1999 V2: 218
  underground tanks and, 2000 V3: 155
SOL (solar), 2004 V1: 16
solar (SOL), defined, 2004 V1: 16
solar azimuth (SAZ), 2004 V1: 14
solar energy
  copper pipe, 2003 V4: 35, 36
  heating for swimming pools, 2000 V3: 138
  solar (SOL), defined, 2004 V1: 16
  solar energy sources, defined, 2004 V1: 137
  water heaters, 2004 V1: 130, 265
soldering
  clearance for, 2003 V4: 25
  copper water tube, 2003 V4: 37
  corrosion and, 2004 V1: 146
  reducing, 2004 V1: 266
  soldered joints and earthquake protection, 2004 V1: 167
solenoid valves
  makeup water systems, 2000 V3: 124
  solenoid valve trap primers, 1999 V2: 14
  symbols for, 2004 V1: 9
solid angles, 2004 V1: 33
solid chlorine, 2000 V3: 123
solid expansion traps, 2000 V3: 182
solid toilet seats, 2003 V4: 5
solid waste disposal
  as energy source, 2004 V1: 130–131
  solid waste incineration systems, 2004 V1: 130–131
  solids removal in septic tanks, 1999 V2: 227–228
solids
  loading in filtration beds, 2000 V3: 132
  rectangular, 2004 V1: 4
  solids interceptors, 2000 V3: 41, 43
  in water, 1999 V2: 288, 2000 V3: 132
soluble silica, 1999 V2: 283
solute. *See* treated water
solution sinks, 2000 V3: 35
solutions to puzzles, 2004 V1: 261
solvents
  PEX piping and, 2003 V4: 61
  in pure-water systems, 2000 V3: 48
sonic cleaners, 2000 V3: 38
sound power
  defined, 2004 V1: 208
  levels, 2004 V1: 194, 208
sound pressure, 2004 V1: 209
sounds. *See* acoustics in plumbing systems
sour gas, 2000 V3: 250
source shut-off valves, 2000 V3: 71
source water
  defined, 1999 V2: 280
  pure-water systems, 1999 V2: 320
sources of acoustic problems, 2004 V1: 199
sources of information in value engineering, 221, 2004 V1: 214
sources, vacuum, 1999 V2: 259–261, 262, 263–264
Southern Building Code Congress International, Inc. (SBCCI), 1999 V2: 114, 2000 V3: 154
sovent aerators, 1999 V2: 54–56, 60, 62
sovent deaerators, 1999 V2: 54, 56, 60, 61, 62
sovent single-stack plumbing systems
  building drain connections, 1999 V2: 60–61
  components and sizing, 1999 V2: 54–63
  illustrated, 1999 V2: 20
  installation, 1999 V2: 62
  introduction, 1999 V2: 19
  pressure-equalizing lines, 1999 V2: 60
  sizing, 1999 V2: 57–62
  venting, 1999 V2: 46–47

sp, SP (static pressure), 2004 V1: 15, 16
sp ht, SP HT (specific heat)
measurements, 2004 V1: 33
sp ht at constant pressure (c_p

spray effects in fountains, 2000 V3: 108–109, 119–120
spray heads on irrigation sprinklers, 2000 V3: 101–102
spray nozzle waterfall aerators, 1999 V2: 293
spray units
  in bathtubs, 2004 V1: 118
  in showers, 2004 V1: 120
spring isolators
  concrete bases and, 2004 V1: 205
  problems in seismic protection, 2004 V1: 188, 189
  pump isolation and, 2004 V1: 205
  stored energy in, 2004 V1: 166
spring-loaded check valves, 2000 V3: 118
spring-operated double-check valve devices, 1999 V2: 149
spring-operated pressure-regulating devices, 1999 V2: 122
spring supports, 2004 V1: 186
springing pipes, 2003 V4: 25
Sprinkler Irrigation, 2000 V3: 105
Sprinkler Irrigation Systems, 2000 V3: 105
sprinkler systems (fire protection)
  automatic sprinkler system types, 2004 V1: 29
  combined dry-pipe and pre-action, 2000 V3: 15
  concealed sprinklers, 2004 V1: 29
  corrosion-resistant sprinklers, 2004 V1: 29
  defined, 2004 V1: 28–37
  deluge systems, 2000 V3: 13–15
  design density, 2000 V3: 15
  drop nipples on pendent sprinklers, 2004 V1: 13
  dry upright sprinklers, 2004 V1: 29
  earthquake damage to, 2004 V1: 162
  effectiveness statistics, 2000 V3: 2
  in elevator shafts, 2000 V3: 25
  extended-coverage sidewall sprinklers, 2004 V1: 29
  fire hazard evaluation, 2000 V3: 2–3
  fire pumps for, 2000 V3: 25
  firefighting water drainage, 1999 V2: 346–347
  flush sprinklers, 2004 V1: 29
  foam extinguishers, 2000 V3: 21
  fully-sprinklered spaces, 2004 V1: 12
  gaseous fire-suppression systems and, 2000 V3: 22
  heads, 2004 V1: 13
  history of, 2000 V3: 1–2
  hydraulic design, 2000 V3: 15–18
  intermediate-level sprinklers, 2004 V1: 29
  large-drop sprinklers, 2004 V1: 29
  nippled-up sprinklers, 2004 V1: 13
  non-sprinklered spaces, 2004 V1: 12
  numbers of sprinklers in operation, 2000 V3: 16
  occupancy classification, 2004 V1: 29
  open sprinklers, 2004 V1: 29
  ornamental sprinklers, 2004 V1: 29
  partially-sprinklered spaces, 2004 V1: 12
  pendent sprinklers, 2004 V1: 13, 29
  pipe materials, 2000 V3: 12
  pre-action systems, 2000 V3: 13
  quick-response sprinklers, 2004 V1: 29
  recessed sprinklers, 2004 V1: 29
  residential sprinklers, 2004 V1: 30
  sediment buckets in drains, 1999 V2: 12
  seismic protection and, 2004 V1: 183–184
  sidewall sprinklers, 2004 V1: 13, 30
  special sprinklers, 2004 V1: 30
  sprinkler types, 2004 V1: 29, 2000 V3: 8–15
  supports and hangers, 2000 V3: 15
  system design, 2000 V3: 2–18
  water demands, 1999 V2: 243–244, 2000 V3: 3–8
sprinkler systems (irrigation)
  concepts, 2000 V3: 100–101
  impact heads, 2000 V3: 102–103
  lawn sprinklers, 2004 V1: 8, 1999 V2: 121
  sample information sheet, 2000 V3: 106
  shrub heads, 2000 V3: 103
  spray heads, 2000 V3: 101–102
  trickle irrigation, 2000 V3: 103
spurs, 2000 V3: 234
sq., SQ (squares). *See* squares
square feet, 2000 V3: 29
square feet EDR, 2000 V3: 178
square foot [m^2] method, defined, 2004 V1: 97–98
squares (sq., SQ)
  calculating area, 2004 V1: 3
  converting to SI units, 2004 V1: 40
  symbols for, 2004 V1: 16
sr (steradians), 2004 V1: 33
SS (sanitary sewers), 2004 V1: 8, 28. *See also* sanitary drainage systems
SSD (subsoil or footing drains), 2004 V1: 8, 30
ssf, SSF (Saybolt Seconds Furol), 2004 V1: 16, 2000 V3: 154
ssu, SSU (Saybolt Seconds Universal), 2004 V1: 16, 2000 V3: 154
ST (storm or rainwater drains). *See* storm-drainage systems
stability index (Ryzner), 1999 V2: 292
stabilization ponds, 1999 V2: 232
stack groups, 2004 V1: 30
stack inlets in deaerators, 1999 V2: 56
stack vents
  air in, 1999 V2: 2
  defined, 2004 V1: 30, 1999 V2: 64
  fixtures and, 1999 V2: 41, 43
  overview, 1999 V2: 47–49
  sizing, 1999 V2: 50
  stack venting defined, 2004 V1: 30
  vent headers, 1999 V2: 45
stacks. *See* vertical stacks
stadiums, numbers of fixtures for, 2003 V4: 19
staff areas (health-care facilities), 2000 V3: 33–34
staff lounges, 2000 V3: 32
staged evaporation, 1999 V2: 298
stages in pump equipment, 1999 V2: 245
stain-resistance testing, 2003 V4: 2
stainless steel
  commercial sinks, 2003 V4: 12
  electromotive force series, 2004 V1: 144
  filtration tanks, 2000 V3: 131
  fixtures, 2000 V3: 33, 2003 V4: 2
  fountains and, 2000 V3: 116
  glass pipe couplings, 2003 V4: 48
  nickel content, 2003 V4: 2
  passivation, 2004 V1: 146–147
  pump shafts, 2000 V3: 145
stainless-steel drains, 1999 V2: 342, 2000 V3: 143
stainless-steel grates, 1999 V2: 16
stainless-steel piping

compressed air systems, 2000 V3: 210
exposed piping on storage tanks, 2000 V3: 165
fountains and, 2000 V3: 119
industrial waste pipe, 1999 V2: 341
pure-water system, 2000 V3: 47–48
soil and waste pipe, 1999 V2: 14
USP water, 1999 V2: 324
vacuum systems, 1999 V2: 262
stainless-steel storage tanks, 1999 V2: 323, 2000 V3: 91
stairs and stairwells
aboveground storage tanks, 2000 V3: 165, 166–167
stairwell drains, 1999 V2: 69
standpipe systems, 2000 V3: 19
stale sewage, 2004 V1: 30
stall urinals, 2003 V4: 9, 10
standard (std, STD), 2004 V1: 16
standard air, 2004 V1: 18, 2000 V3: 200
standard atmospheric pressure
defined, 2000 V3: 200
in vacuums, 1999 V2: 254
standard cartridge depth filtration, 1999 V2: 300
standard cfh (scfh), 1999 V2: 180
standard cubic feet per minute (scfm). *See* scfm, SCFM (standard cubic feet per minute)
standard dimension ratio (SDR), 2003 V4: 61
standard fire-protection symbols, 2004 V1: 12–13
standard fire tests, 2000 V3: 3
Standard for Bulk Oxygen Systems at Consumer Sites (NFPA 50), 2000 V3: 61, 86
Standard for Color-marking of Compressed Gas Cylinders Intended for Medical Use (CGA C-9), 2000 V3: 86
Standard for Health Care Facilities, 2003 V4: 45
Standard for Health-care Facilities (NFPA 99), 1999 V2: 262, 2000 V3: 86
Standard for Hypochlorites, 1999 V2: 155
Standard for Liquid Chlorine, 1999 V2: 155
Standard for Portable Fire Extinguishers (NFPA 10), 2000 V3: 27, 29
Standard for Public Swimming Pools (ANSI/NSPI-1), 2000 V3: 125, 151
Standard for Residential, In-ground Swimming Pools (ANSI/NSPI-5), 2000 V3: 151
Standard for Tank Vehicles for Flammable and Combustible Liquids (NFPA 385), 2000 V3: 154
Standard for the Installation of Nitrous Oxide Systems at Consumer Sites (CGA G-8.1), 2000 V3: 86
Standard for the Installation of Sprinkler Systems, 2004 V1: 191
Standard for the Machining and Finishing of Aluminum and the Production and Handling Aluminum Products (NFPA 651), 2000 V3: 20
Standard for the Processing and Finishing of Aluminum (NFPA 65), 2000 V3: 20
Standard for the Production, Processing, Handling and Storage of Titanium (NFPA 481), 2000 V3: 20
Standard for the Production, Processing, Handling and Storage of Zirconium (NFPA 482), 2000 V3: 20
Standard for the Storage, Handling and Processing of Magnesium Solids and Powders (NFPA 480), 2000 V3: 20
standard free air
adjusting, 1999 V2: 257
at atmospheric pressure (scfm). *See* scfm, SCFM (standard cubic feet per minute)
in vacuum sizing calculations, 1999 V2: 263
standard gallons per hour, 2004 V1: 15
Standard Handbook for Mechanical Engineers, 2004 V1: 1
Standard Method of Test of Surface Burning Characteristics of Building Materials (NFPA 255), 2000 V3: 77
Standard on Flow Testing and Marking of Fire Hydrants (NFPA 291), 2000 V3: 3
standard plumbing and piping symbols, 2004 V1: 7–13
Standard Plumbing Code, 1999 V2: 79, 114
Standard Practice for Making Capillary Joints by Soldering of Copper and Copper Alloy Tube and Fittings, 2003 V4: 37
standard reference points (compressed air), 2000 V3: 200
Standard Specification for Concrete Sewer, Storm Drain, and Culvert Pipe for Non-reinforced Concrete, 2003 V4: 32
Standard Specification for Copper Drainage Tube (DWV), 2003 V4: 45
Standard Specification for Joints for Circular Concrete Sewer and Culvert Pipe, Using Rubber Gaskets, 2003 V4: 32
Standard Specification for Liquid and Paste Fluxes for Soldering Applications of Copper and Copper Alloy Tube, 2003 V4: 37
Standard Specification for Reinforced Concrete Culverts, Storm Drain, and Sewer Pipe, 2003 V4: 32
Standard Specification for Reinforced Concrete D-Load Culvert Storm Drain and Sewer Pipe for Reinforced Concrete Pipe, 2003 V4: 32
Standard Specification for Seamless Copper Pipe, Standard Sizes, 2003 V4: 34
Standard Specification for Seamless Copper Tube for Medical Gas Systems, 2003 V4: 45
Standard Specification for Seamless Red Brass Standard Sizes, 2003 V4: 27
standard time meridian (STM), 2004 V1: 16
standard water closets, 2003 V4: 4
standard-weight brass pipe (Schedule 40), 2003 V4: 27
standard-weight steel pipe, 2003 V4: 48
standards. *See* codes and standards
standby losses
in circulating systems, 2004 V1: 127
water heaters, 2004 V1: 265
standpipe systems
classifications and characteristics, 2000 V3: 18–19
defined, 2004 V1: 24, 30
fire pumps for, 2000 V3: 25
flat land storage tanks, 1999 V2: 247
overflow standpipes, 2000 V3: 125
standpipe air chambers, 1999 V2: 132, 143
swimming pools and, 2000 V3: 139
symbols for, 2004 V1: 13
system classes of service, 2004 V1: 30
system types, 2004 V1: 30
starting unloaders, 2000 V3: 205
startup conditions for gas appliances, 1999 V2: 178
state agencies, 1999 V2: 327, 340, 2000 V3: 88
state frost lines, 2000 V3: 226
state rainfall rate tables, 1999 V2: 69–78

states in creativity checklist, 2004 V1: 234
static deflection for pump vibration, 2004 V1: 205
static fountain displays, 2000 V3: 111, 119
static head
  calculating, 2004 V1: 2
  swimming pool gutters and, 2000 V3: 142
  velocity head and, 2004 V1: 5
  well pumps, 1999 V2: 245
static pressure (SP)
  domestic water supply, 2000 V3: 217–221
  fire hydrants, 2000 V3: 4–5
  irrigation flow, 2000 V3: 105
  sprinkler hydraulic calculations, 2000 V3: 16
  symbols, 2004 V1: 15, 16
  water mains, 2000 V3: 216
static pressure loss, 1999 V2: 123
static wells, 1999 V2: 241–243
stations (medical gas and vacuum)
  ceiling outlets, 2000 V3: 57
  estimating number, 2000 V3: 50, 51–52
  inlets, 2000 V3: 85
  medical gas diversity factors, 2000 V3: 75
  medical vacuum, 2000 V3: 54
  order of gas outlets, 2000 V3: 56
  outlets, 2000 V3: 85
  patient headwall gas systems, 2000 V3: 56–57
  surgical ceiling columns, 2000 V3: 57–58
  terminals, 2000 V3: 54–56
  types of, 2000 V3: 58
std, STD (standard), 2004 V1: 16
std gph (standard gallons per hour), 2004 V1: 15
steady flow
  in horizontal drains, 1999 V2: 6–7, 9
  roof drainage, 1999 V2: 88
steady-state heat balance equations, 1999 V2: 158
steam and condensate systems
  condensate drainage, 2000 V3: 189–197
    flashing flow and high-pressure piping, 2000 V3: 196–197
    problems, 2000 V3: 189–191
    proper drainage, 2000 V3: 191–196
  distilling water from steam, 1999 V2: 295–298
  geothermal, 2004 V1: 131
  high-pressure steam, 2004 V1: 9
  low-pressure steam, 2004 V1: 9, 15
  medium-pressure steam, 2004 V1: 9, 15
  overview, 2000 V3: 175
  references, 2000 V3: 197
  sizing pipes, 2000 V3: 177
  steam atmospheric vents, 2004 V1: 9
  steam tables, 2000 V3: 176
  steam traps. *See* steam traps
  system classifications, 2000 V3: 175–189
    condensate return methods, 2000 V3: 186–189
    operating pressure range, 2000 V3: 175–178
    piping arrangement classifications, 2000 V3: 178–186
  waste heat usage of condensate, 2004 V1: 131–134
steam deaerators, 1999 V2: 294
steam-fired water heaters, 2004 V1: 130
steam heat exchangers, 2000 V3: 121
steam plants, 1999 V2: 147
steam traps, 2000 V3: 182–186
  collection legs and, 2000 V3: 191
  oversizing, 2000 V3: 191, 196
  parallel trapping, 2000 V3: 196
  pressure differentials, 2000 V3: 191
  seat pressure ratings, 2000 V3: 193
  strainers, 2000 V3: 195
  symbol, 2004 V1: 11
steam vaporizers, 2000 V3: 61
steatite fixtures, 2003 V4: 2
steel. *See also* stainless steel; steel piping
  beam connections in pipe bracing, 2004 V1: 175, 176
  in electromotive force series, 2004 V1: 144
  fittings, 1999 V2: 196
  fixtures, 2003 V4: 2
  floor decks in earthquakes, 2004 V1: 167
  in galvanic series, 2004 V1: 141
  roofing drains, 1999 V2: 82
  springs, 2004 V1: 204, 208
  steel substrate roofing drains, 1999 V2: 82
  storage tanks, 2000 V3: 155
  underground tanks, 2000 V3: 172
  water tanks, 1999 V2: 247
Steel Above Ground Tanks for Flammable and Combustible Liquids (UL 142), 2000 V3: 95, 154, 165
steel fixtures, 2003 V4: 2
steel piping. *See also* galvanized-steel piping; stainless-steel piping
  dimensions, 2003 V4: 51–55
  fittings, 2003 V4: 48
  fuel-product dispensing, 2000 V3: 169
  liquefied petroleum gas, 1999 V2: 196
  Manning formula and, 2000 V3: 245
  natural gas, 2000 V3: 254
  radioactive wastes, 1999 V2: 341
  sizing, 1999 V2: 89–92
  surface roughness, 1999 V2: 122
  types, 2003 V4: 48, 51–55
  water systems, 1999 V2: 250
Steel Tank Institute (STI), 2000 V3: 154
Steel Tanks for Oil Storage (API 250), 2000 V3: 95
Steel Underground Tanks for Flammable and Combustible Liquids (UL 58), 2000 V3: 95
Steele, Alfred, 2004 V1: 40, 1999 V2: 114
Stenzel, Mark H., 1999 V2: 325
step heaters, 2000 V3: 144
steradians, 2004 V1: 33
sterilization
  feed water, 1999 V2: 289
  infectious waste systems, 1999 V2: 345
  pure water systems, 1999 V2: 324
  ultraviolet, 2000 V3: 47
sterilizers, 2000 V3: 36, 38, 39
Stevens Institute of Technology, 1999 V2: 65
Stevens's Building Technology Research Laboratory, 1999 V2: 49
STI (Steel Tank Institute), 2000 V3: 154
sticking (manual tank gauging), 2000 V3: 159
stilling wells, 2000 V3: 124
stills, 1999 V2: 295–298, 2000 V3: 39, 46
STM (standard time meridian), 2004 V1: 16
stop levers in showers, 2004 V1: 136

stop valves, 2004 V1: 30, 2000 V3: 33
storage
costs, 2004 V1: 223
fire hazard evaluation, 2000 V3: 2
of gray water, 1999 V2: 23, 26, 27
of medical gases
medical compressed air, 2000 V3: 65–68
nitrogen, 2000 V3: 68
nitrous oxide, 2000 V3: 64–65
oxygen, 2000 V3: 59–63
of pure water, 1999 V2: 323–324
of rainwater, 1999 V2: 93–94
section in specifications, 2004 V1: 70, 89–90
of sewage in septic tanks, 1999 V2: 228–229
storage plants, 1999 V2: 147, 2003 V4: 20
storage reservoirs, 2000 V3: 90
storage rooms, 2000 V3: 73
storage tanks. *See* tanks
stores, numbers of fixtures for, 2003 V4: 20
storm building drains. *See* storm-drainage systems
Storm Drainage Design and Detention using the Rational Method, 1999 V2: 114
storm drainage pipe codes, 2004 V1: 42
storm-drainage systems, 2000 V3: 240–248. *See also* rainwater and precipitation
building drainage systems, 1999 V2: 68–94
calculations, 2000 V3: 244–245
cast-iron soil-pipe building drains, 2003 V4: 27
codes, 2004 V1: 42–44, 2000 V3: 240
controlled-flow systems, 1999 V2: 88, 93–94
design criteria, 1999 V2: 68–69
design storms, 2000 V3: 242
disposal methods, 2000 V3: 245–247
drywells, 2000 V3: 247
existing flow paths, 2000 V3: 247
limited-discharge roof drains, 2000 V3: 247
public sewers, 2000 V3: 245–247
recharge basins, 2000 V3: 247
retention basins, 2000 V3: 247
equations, 1999 V2: 107–108
forms for calculations, 1999 V2: 109–113
green roof designs, 2004 V1: 266
green uses of, 2004 V1: 264
introduction, 1999 V2: 67–68
materials, 1999 V2: 68
overview, 2000 V3: 240
pipe sizing and layout, 1999 V2: 69
preliminary information, 2000 V3: 215–216
Rational method, 2004 V1: 7, 1999 V2: 95, 98, 107, 2000 V3: 242–244
reinforced concrete pipe building drains, 2003 V4: 32
roof drainage, 1999 V2: 79–94
sample utility letters, 2000 V3: 240
secondary drainage systems, 1999 V2: 70, 79
site drainage, 1999 V2: 95–107
sizing, 2000 V3: 244–245, 246
sizing ditches, 2000 V3: 247–248
storm drains (SD, ST), 2004 V1: 8
storm sewers defined, 2004 V1: 30
storm water in pools and fountains, 2000 V3: 110
swimming pool water and, 2000 V3: 131, 139
Storm Water Retention Methods, 1999 V2: 114
STPs (sewage treatment plants), 1999 V2: 22, 24, 147
straight lobe compressors, 2000 V3: 202
strain, defined, 2004 V1: 30
strainers
backflow preventers, 1999 V2: 149
basket strainers. *See* basket strainers
downspouts, 1999 V2: 81
fountain pumps, 2000 V3: 116
pressure losses, 2000 V3: 224
roof drains, 1999 V2: 80, 82
sanitary drainage systems, 1999 V2: 10–12
sediment buckets, 1999 V2: 12
steam traps, 2000 V3: 195
symbols for, 2004 V1: 10
strata of sites, 1999 V2: 101
stratification in water heaters, 1999 V2: 160, 165
stray current corrosion, 2004 V1: 141, 154
stream-spray irrigation sprinklers, 2000 V3: 103
streamline fittings (avoiding suds formation), 1999 V2: 37
streams, irrigation systems and, 1999 V2: 27
street gutters, 1999 V2: 99
street inlets in site storm systems, 1999 V2: 98
stress
conversion factors, 2004 V1: 36
measurements, 2004 V1: 33
stress-accelerated corrosion, 2004 V1: 154
stress corrosion, 2004 V1: 154
stress-corrosion cracking, 2004 V1: 141, 154, 1999 V2: 290
strip-chart recorder water meters, 1999 V2: 116
strip methods in pipe manufacturing, 2003 V4: 32
strong-base regeneration, 1999 V2: 302, 305
strongbacks, 2004 V1: 163
strontium 90, 1999 V2: 340
structural angle bracing, 2004 V1: 171
structural channel bracing, 2004 V1: 171
structural strength
bath and shower seats, 2004 V1: 122–123
grab bars, 2004 V1: 122
structure-borne sound, 2004 V1: 196, 199
strut bracing, 2004 V1: 173, 175
styrofoam blocking on glass pipe, 2003 V4: 47
sub-micron cartridge filtration, 1999 V2: 300
sub-sterilizing rooms, 2000 V3: 32, 36
subdrains, building, 2004 V1: 20
submain sewers, 2004 V1: 30
submersible pumps
fountain display pumps, 2000 V3: 113
protection of wells, 1999 V2: 243
shallow wells, 1999 V2: 247
sizing, 2000 V3:170
underground storage tanks, 2000 V3: 164
well pumps, 1999 V2: 245
submittals section in specifications, 2004 V1: 69, 88–89
subsoil drainage pipe, 2004 V1: 44
subsoil drains (SSD), 2004 V1: 8, 30
substances, amount (moles), 2004 V1: 33
substituting products
in proprietary specifications, 2004 V1: 68
value engineering process and, 2004 V1: 211
subsurface drainage
determining quantities of water, 1999 V2: 100
filter materials, 1999 V2: 103–104

ground water disposal, 1999 V2: 105
site drainage, 1999 V2: 99–105
site investigation, 1999 V2: 100
trenching, 1999 V2: 102–103
types of piping, 1999 V2: 102
subsurface drip irrigation systems, 1999 V2: 27
subsurface obstructions, swimming pool locations and, 2000 V3: 128
subsurface waste-disposal systems. *See* soil-absorption sewage systems
subsurface water. *See* ground water
SUC (suction), 2004 V1: 16
successive leaching trenches, 1999 V2: 223–224
suct., SUCT (suction), 2004 V1: 16
suction (suct., SUCT, SUC), 2004 V1: 16
suction basket strainers, 2000 V3: 115
suction diffusers, 2000 V3: 116
suction fuel-delivery systems, 2000 V3: 162–163
suction inlets
in fountains, 2000 V3: 117
in storage tanks, 1999 V2: 248
suction piping, 2004 V1: 202, 1999 V2: 248, 249, 2000 V3: 117
suction sand filters, 2000 V3: 134
suction screens, 2000 V3: 116
suction-type pumps, 1999 V2: 241, 245
suds
factors in trap seal loss, 1999 V2: 36
pressure zones, 1999 V2: 37, 38, 39
relief vents, 1999 V2: 37, 39
sovent single-stack plumbing systems and, 1999 V2: 54
venting, 1999 V2: 36–37, 39
sulfate-reducing bacteria, 1999 V2: 282
sulfates, 1999 V2: 281, 283, 302
sulfides, 2004 V1: 146
sulfites, 1999 V2: 281, 315, 2000 V3: 147
sulfur, 1999 V2: 281
sulfur-based joint compound, 1999 V2: 223
sulfur dioxide, 2000 V3: 93
sulfuric acid
pool chemicals, 2000 V3: 150
in regeneration, 1999 V2: 305
special wastes, 1999 V2: 332–333
storage tanks, 2000 V3: 91–92
in water chemistry, 1999 V2: 281
sulfurous acid, 1999 V2: 281
SUM (summary, summation), 2004 V1: 16
summary section in specifications, 2004 V1: 69, 88
summary, summation (SUM), 2004 V1: 16
sumps and sump pumps
acoustic problems, 2004 V1: 197
containment sumps, 2000 V3: 156
duplex sump pump systems, 1999 V2: 9
fixture-unit values, 1999 V2: 9
flexible pipe connectors, 2000 V3: 169
floor drains and, 1999 V2: 10
ground water disposal, 1999 V2: 105
liquid-waste decontamination systems, 1999 V2: 344
pool mechanical spaces, 2000 V3: 111
roof drainage and, 1999 V2: 79, 80, 88
sanitary drainage systems, 1999 V2: 9
storm drains and, 1999 V2: 69
subsurface water disposal, 1999 V2: 106
sump pits, 1999 V2: 344, 2000 V3: 111
sump pumps defined, 2004 V1: 30
sumps defined, 2004 V1: 30
vibration isolation, 2004 V1: 208
Sun, T.Y., 2004 V1: 191
sunlight
protecting against, 1999 V2: 19, 2000 V3: 116, 165
solar energy. *See* solar energy
SUP (supplies), 2004 V1: 16
superchlorination, 2000 V3: 147, 148, 149
supercritical flow, 1999 V2: 67. *See also* hydraulic jumps in flow
Superfund Amendment and Reauthorization Act of 1986 (SARA Title III), 2000 V3:88, 2000 V3: 154
superstrut bracing, 2004 V1: 170
supervised heat-up, 2000 V3: 191, 194
supervisory (tamper) switches, 2004 V1: 30
supplementary conditions, 2004 V1: 62
supplementary units of measurement, 2004 V1: 33
supplies (sply., SPLY, SUP)
abbreviations, 2004 V1: 16
ongoing and one-time costs, 2004 V1: 223
supply air (sa, SA), 2004 V1: 16
supply fixture units, 2004 V1: 24
supply valves, 2000 V3: 179
support mats in filtration, 2000 V3: 134
supports and hangers
alternate attachment to hangers, 2004 V1: 174
clean agent gas pipes, 2000 V3: 24
codes, 2004 V1: 43
defined, 2004 V1: 30
hanger rod connections in bracing, 2004 V1: 17l
hanger rod gravity forces in earthquakes, 2004 V1: 186
installation productivity rates, 2004 V1: 96
isolation hangers, 2004 V1: 203
materials, 2004 V1: 43
medical gas piping, 2000 V3: 73
natural gas pipes, 1999 V2: 176
resilient pipe hangers, 2004 V1: 199
roof drainage, 1999 V2: 88
in sanitary drainage systems, 1999 V2: 14
sprinkler systems, 2000 V3: 15
symbols for, 2004 V1: 13
vacuum cleaning tubing, 1999 V2: 269
SUR (surfaces), 2004 V1: 16
SURD (surfaces, dry), 2004 V1: 16
surface abrasions
corrosion and, 2004 V1: 146
grab bars, 2004 V1: 122
surface efficiency (SEFF), 2004 V1: 14
surface evaporation, 2000 V3: 121
surface fault slips, 2004 V1: 158
surface fires, 2000 V3: 19
surface-mounted pumps, 1999 V2: 245
surface runoff. *See* runoff
surface skimmers. *See* skimmers
surface-type sprinkler spray heads, 2000 V3: 101
surface water
as feed water for pure water systems, 1999 V2: 321
defined, 1999 V2: 282
discharge permits for, 2000 V3: 89

private water systems, 1999 V2: 239
pumps for, 1999 V2: 245
Surface Water Treatment Rule, 1999 V2: 316
surfaces (SUR, S)
dry (SURD), 2004 V1: 16
fixture materials, 2003 V4: 1
symbols for, 2004 V1: 16
wet (SURW), 2004 V1: 16
surge chambers, 2000 V3: 142, 143, 212
surge loads in wet-vented systems, 1999 V2: 45–46
surge pits, 2000 V3: 108, 109
surge pressure. *See* water hammer
surge tanks, 1999 V2: 27, 2000 V3: 137, 140
surges
in horizontal drains, 1999 V2: 5
pressure surges, 1999 V2: 35
swimming pool pumps, 2000 V3: 139
vacuum surges, 1999 V2: 35
surgical ceiling columns, 2000 V3: 57–58
surgical clean-up areas, 2000 V3: 32
surgical gas track systems, 2000 V3: 58–59
surgical instruments, 2000 V3: 59, 68
surgical scrub areas, 2000 V3: 32
surgical supply areas, 2000 V3: 32
surgical vacuum (SV), 2004 V1: 9
surveys in plumbing cost estimation, 2004 V1: 93
SURW (surfaces, wet), 2004 V1: 16
suspended equipment
fixed suspended equipment, 2004 V1: 164
vibration-isolated, suspended equipment, 2004 V1: 166
suspended metals in wastes, 2000 V3: 93
suspended piping, earthquake recommendations, 2004 V1: 162
suspended solids
defined, 1999 V2: 280
filtration, 1999 V2: 298
removing, 1999 V2: 294
total suspended solids, 1999 V2: 287–288
turbidity, 1999 V2: 282
suspended tanks, 2004 V1: 162
suspension, defined, 1999 V2: 280
sustainable design, 2004 V1: 263–267
Sustainable Sites design (LEED), 2004 V1: 263
SV (service) cast-iron soil pipe, 2003 V4: 27, 30–31
SV (surgical vacuum), 2004 V1: 9
swamp gas, 1999 V2: 284
sway bracing
acceptable types, 2004 V1: 187
horizontal loads for, 2004 V1: 185–186
lateral and longitudinal, 2004 V1: 181–182, 185–186
longitudinal and transverse, 2004 V1: 179, 180
potential problems, illustrated, 2004 V1: 189
sway in piping, 2004 V1: 162
swelling characteristics of soils, 1999 V2: 219
swimming pools
applying standards to reflecting pools, 2000 V3: 107
components and materials
backwash pits, 2000 V3: 143
cleaning equipment, 2000 V3: 146
filtration systems, 2000 V3: 131–137, 139–140, 143–144
fittings, 2000 V3: 137, 144, 145
flow indicators, 2000 V3: 142
gutters, 2000 V3: 142
heaters, 2000 V3: 144–145
ladders, 2000 V3: 145
main drains, 2000 V3: 143
piping, 2000 V3: 145
pumps, 2000 V3: 140–142
skimmers, 2000 V3: 142, 146
surge chambers, 2000 V3: 143
underwater lights, 2000 V3: 145
vacuum cleaning lines, 2000 V3: 144
valves and pumps, 2000 V3: 145–146
water heaters, 2000 V3: 138–139, 146
water supply and drainage, 2000 V3: 131
defined, 2004 V1: 30
design parameters, 2000 V3: 127–130
bathhouses, toilets, and showers, 2000 V3: 130
location, 2000 V3: 128
physical characteristics, 2000 V3: 128–130
size and capacity, 2000 V3: 127–128
disinfection, 2000 V3: 148–151
algaecides, 2000 V3: 150
aluminum sulfate, 2000 V3: 149–150
breakdown chlorination, 2000 V3: 149
calcium hypochlorite, 2000 V3: 148–149
chemical feeding equipment, 2000 V3: 150–151
chlorine gas, 2000 V3: 148
cleaning filters, 2000 V3: 150
cyanurates, 2000 V3: 149
filtration turnover rates, 2000 V3: 140
sodium hypochlorite, 2000 V3: 149
sulfuric acid, 2000 V3: 150
superchlorination, 2000 V3: 149
grate materials, 1999 V2: 15
heat loss retardants, 2000 V3: 150
indoor and outdoor pools, 2000 V3: 139
numbers of fixtures for, 2003 V4: 19
numbers of swimmers, 2000 V3: 127–128
overview, 2000 V3: 127
references, 2000 V3: 151
resources, 2000 V3: 151
sequestering agents, 2000 V3: 150
water chemistry, 2000 V3: 146–148
mineral deposits, 2000 V3: 147–148
pH values, 2000 V3: 147
water supply, 2000 V3: 131
Swimming Pools: A Guide to their Design and Operations, 2000 V3: 151
swing check valves, 1999 V2: 249, 2000 V3: 118
switch-gear rooms, 2000 V3: 73
SWRO (spiral wound modules), 1999 V2: 289, 309
SYGEF piping, 2000 V3: 48
symbols
fire protection, 2004 V1: 12–13
references, 2004 V1: 40
standardized plumbing and piping symbols, 2004 V1: 7–13
Synthesis phase in value engineering, 2004 V1: 213
synthetic fiber gas filters, 2000 V3: 250
synthetic resins, 1999 V2: 302
SYS (systems), 2004 V1: 16, 137
system descriptions in specifications, 2004 V1: 69, 88

system performance criteria in specifications, 2004 V1: 69, 88
Systeme International and d'Unites, 2004 V1: 32
systems (SYS)
  defined, 2004 V1: 137
  diagramming, 2004 V1: 231
  symbols for, 2004 V1: 16
  value engineering questions, 2004 V1: 213–214

T

t (metric tons), 2004 V1: 34
T STAT (thermostats), 2004 V1: 16
Ät, TD (temperature differences), 2004 V1: 16, 136
T (temperature). *See* temperature
T (tera) prefix, 2004 V1: 34
T (teslas), 2004 V1: 33
T (time). *See* time
T-Y fittings, 1999 V2: 61
tab, TAB (tabulation), 2004 V1: 16
table salt, 2000 V3: 150
tablespoons, converting to SI units, 2004 V1: 40
tabular take-off sheets, in cost estimations, 2004 V1: 94
tabulation (tab, TAB), 2004 V1: 16
take-off estimating method, cost estimating, 2004 V1: 94–95
Take the Guesswork out of Demineralizer Design, 1999 V2: 325
tamper switches, 2004 V1: 30
tamping fill
  leaching trenches, 1999 V2: 223
  sewers, 1999 V2: 16
  subsurface drainage pipes, 1999 V2: 102, 103
  water pipes, 1999 V2: 250
Tanaka, T., 1999 V2: 325
tangential-flow filtration, 1999 V2: 300, 308
tank-mounted product dispensers, 2000 V3: 168
tank-refilling acoustics, 2004 V1: 194
tank-type water closets, 2004 V1: 135–136
tank-type water heaters, 2004 V1: 129
tankless water heaters, 2004 V1: 129–130
tanks. *See also* septic tanks
  aboveground tanks, 2000 V3: 90–91, 165–169
    connections and access, 2000 V3: 166
    construction, 2000 V3: 165
    corrosion protection, 2000 V3: 165
    filling and spills, 2000 V3: 166–167
    leak prevention and monitoring, 2000 V3:167–168
    materials, 2000 V3: 165
    overfill prevention, 2000 V3:167
    product dispensing systems, 2000 V3:168
    tank protection, 2000 V3:169
    vapor recovery, 2000 V3:168
    venting, 2000 V3:167
  carbon dioxide extinguishing systems, 2000 V3: 20, 21
  cryogenic, 2000 V3: 62
  determining demand and capacity, 1999 V2: 151
  distilled water systems, 2000 V3: 46
  drinking water storage, 1999 V2: 247–248
  earthquake damage, 2004 V1: 161, 162
  earthquake protection, 2004 V1: 163–164, 188, 189
  fire-protection supplies, 2000 V3: 226
  gauges, 2000 V3: 166
  gravity tank systems, 1999 V2: 150–152
  hazardous waste incompatibilities, 2000 V3: 90, 91
  holding tanks
    for firefighting drainage, 1999 V2: 347
    for radioactive wastes, 1999 V2: 342
  hydropneumatic-tank systems, 1999 V2: 150
  kill tanks, 1999 V2: 344–345
  liquefied natural gas tanks, 1999 V2: 194
  liquid fuel tanks
    connections and access, 2000 V3: 156–157
    construction, 2000 V3: 156
    filling and spills, 2000 V3: 156–157
    installation, 2000 V3:172
    materials, 2000 V3: 155–156
    overfill prevention, 2000 V3: 158
    venting, 2000 V3: 157–158
  protection, 2000 V3:169
  settling tanks, 2000 V3: 93
  storage tanks defined, 2000 V3: 153
  suspended, 2004 V1: 164
  tank end deflection, 2000 V3: 172
  tank farms, 2004 V1: 150
  thermal expansion tanks, 1999 V2: 167
  tightness testing, 2000 V3: 161–162, 171, 2000 V3:172, 2000 V3: 172
  underground tanks, 2000 V3: 90–91
    illustrated, 2000 V3: 164
    liquid fuel tanks, 2000 V3: 155–158
  venting, 2000 V3: 157–158, 166, 2000 V3:167
  vibration isolation, 2004 V1: 205
  water storage tanks, 1999 V2: 239, 323–324, 2000 V3: 44
tannin in water, 2000 V3: 147
tapping illegally into water lines, 1999 V2: 115
tappings for cast iron radiators, 2000 V3: 179
taps
  large wet tap excavations, 2000 V3: 222
  pressure loss and, 2000 V3: 221
target areas in water closets, 2003 V4: 4
taste of drinking water, 1999 V2: 245, 316
TAU (transmissivity), 2004 V1: 16
taverns and bars, numbers of fixtures for, 2003 V4: 19, 22
taxes
  in labor costs, 2004 V1: 94
  in plumbing cost estimation, 2004 V1: 94
tc, TC (thermocouple), 2004 V1: 16
Tchobanoglous, George, 2000 V3: 125
TCPL (thermocouple), 2004 V1: 16
TD (temperature differences), 2004 V1: 16, 136
TD (turndown ratio), 1999 V2: 182
TDIF (temperature differences), 2004 V1: 16
TDS (total dissolved solids), 1999 V2: 288, 316
TE (temperature entering), 2004 V1: 16
teaspoons, converting to SI units, 2004 V1: 40
technetium 99, 1999 V2: 340
technology advances, value engineering and, 2004 V1: 212
Technology for the Storage of Hazardous Liquids, 2000 V3: 96
tectonic plates, 2004 V1: 156–158
tee-wyes, flow capacity and, 1999 V2: 4
tees (TEE), 2004 V1: 10, 16
Teflon, 1999 V2: 341, 2000 V3: 42

temp., TEMP (temperatures). *See* temperature
TEMP. HW (tempered hot water), 2004 V1: 8
TEMP. HWR (tempered hot water recirculating), 2004 V1: 8
temperature (temp., TEMP, T)
acid wastes, 2000 V3: 40
bathtub water notes, 2004 V1: 119
cast iron radiators, 2000 V3: 180
compressed air systems and, 2000 V3: 211
conversion factors, 2004 V1: 37, 38
cooling air compressors, 2000 V3: 202
corrosion rates and, 2004 V1: 145
CPVC *vs.* PVC piping, 2003 V4: 62
deaeration water temperatures, 1999 V2: 294
dew points, 2000 V3: 201
feed water temperature and deposits, 1999 V2: 291, 312, 321–322
flue gas temperatures, 1999 V2: 178
high-temperature withstand for hot-water systems, 1999 V2: 166
hot-water properties, 1999 V2: 168
hot-water relief valves, 1999 V2: 166–167
hot-water temperatures, 1999 V2: 159, 161–165, 165, 2000 V3: 36, 45
maintenance hot-water temperatures, 1999 V2: 166
measurements, 2004 V1: 33
microbial control in water, 1999 V2: 312
mixed-water temperatures, 1999 V2: 159–160
natural gas, 1999 V2: 179, 180
non-SI units, 2004 V1: 34
operating hot-water temperatures, 1999 V2: 166
pipe expansion and contraction, 2004 V1: 3
PVC pipe and, 2003 V4: 62
rate of rise detection, 2000 V3: 13
scalding water, 1999 V2: 169–170
shower compartments, 2004 V1: 120, 2003 V4: 15
special-waste effluent, 1999 V2: 328
specific resistance and, 1999 V2: 286
sprinkler head ratings, 2000 V3: 17
storage tanks and piping, 2000 V3: 172
stratification, 2000 V3: 172
swimming pools, 2000 V3: 139
symbols for, 2004 V1: 16
temperature differences (TD,)t, TDIF), 2004 V1: 16, 136
temperature differentials, 2004 V1: 125–126
temperature entering (TE, TENT), 2004 V1: 16
temperature leaving (TL, TLEA), 2004 V1: 16
temperature stratification, 2000 V3: 172
thermal support systems and earthquakes, 2004 V1: 168
water heaters, 1999 V2: 157, 160
water vapor in air and, 2000 V3: 200–201
Temperature Limits in Service Hot Water Systems, 1999 V2: 170
temperature-pressure-relief valves (TPV), 2004 V1: 10, 1999 V2: 166, 167
temperature stratification, 2000 V3: 172
tempered water
defined, 2004 V1: 30
tempered hot water (TEMP. HW, TW), 2004 V1: 8
tempered hot water recirculating (TEMP. HWR, TWR), 2004 V1: 8
tennis courts, numbers of fixtures for, 2003 V4: 19
tensile strength
plastic pipe, 2003 V4: 60
PVC pipe and, 2003 V4: 62
Tension 360 bracing, 2004 V1: 169
tension problems in seismic protection, 2004 V1: 190
TENT (temperature entering), 2004 V1: 16
Tentative Provisions for the Development of Seismic Regulations for Buildings, 2004 V1: 183, 191
"tera" prefix, 2004 V1: 34
terminal elements, defined, 2004 V1: 137
terminal length, defined, 1999 V2: 1
terminal velocity
defined, 1999 V2: 1
stack capacities and, 1999 V2: 4
stack terminal velocity, 2004 V1: 3
terminal vents. *See* vent stack terminals
terminals, passenger, 2003 V4: 19
termites, 2000 V3: 116
tertiary treatment of gray water, 1999 V2: 28, 29
teslas, 2004 V1: 33
test block conditions in gas boosters, 1999 V2: 182
test fittings, 2000 V3: 195
test headers, 2004 V1: 12
test-method standards, 2004 V1: 66
test station cathodic protection, 2004 V1:151
testing
acoustic ratings of fixtures and appliances, 2004 V1: 194–195
cold-water systems, 1999 V2: 154
fountain piping systems, 2000 V3: 117
gaseous fire-suppression systems, 2000 V3: 24–25
hot-water relief valves, 1999 V2: 166
hydrants, 2000 V3: 4
hydraulic soil conditions, 1999 V2: 217–220
liquefied petroleum gas systems, 1999 V2: 197
liquid fuel systems, 2000 V3:170–172
medical-gas alarms, 2000 V3: 81
medical-gas systems, 2000 V3: 77–83
natural gas services, 2000 V3: 252, 253
percolation rates for soils, 1999 V2: 219–220
pipes for radioactive waste systems, 1999 V2: 342
plastic fixtures, 2003 V4: 2
swimming pools, 2000 V3: 131
tank tightness testing, 2000 V3: 161–162, 171, 2000 V3:172, 2000 V3: 172
urinal tests, 2003 V4: 9
water closet flushing, 2003 V4: 5–6
welders for radioactive pipe systems, 1999 V2: 342
wells, 1999 V2: 243
tetrafluoroethylene (TFE), 2003 V4: 48
text, abbreviations in, 2004 V1: 14–16
texture of soils, 1999 V2: 218
theaters
numbers of fixtures for, 2003 V4: 19, 21
vacuum calculations for, 1999 V2: 269
theft of backflow preventers, 1999 V2: 149
theoretical barometric pressure, 2000 V3: 200
theoretical standard atmospheric pressure, 2000 V3: 200
therapy pools, 2000 V3: 128

therm, converting to SI units, 2004 V1: 40
thermal conductivity (*k,* K)
measurements, 2004 V1: 33
plastic pipe, 2003 V4: 60
symbols for, 2004 V1: 16
thermal efficiency
defined, 2004 V1: 30, 136
water heaters and, 1999 V2: 169
thermal expansion
converting to SI units, 2004 V1: 39
hot-water systems and, 1999 V2: 167–168
plastic pipe thermal expansion, 1999 V2: 251
sanitary drainage systems, 1999 V2: 18
thermal expansion coefficients (TXPC), 2004 V1: 16
thermal expansion tanks, 1999 V2: 167
water pipes and, 1999 V2: 251–252
thermal expansion loops, 2004 V1: 162
thermal-hydraulic irrigation valves, 2000 V3: 103
thermal insulation thickness, 2004 V1: 127
thermal movement, sound insulation and, 2004 V1: 193
thermal resistance (*R,* R, RES), 2004 V1: 16
thermal-shock protection, 2004 V1: 120
thermal stability for hot-water systems, 1999 V2: 166
thermal-support systems, earthquakes and, 2004 V1: 168
thermocompression distillation, 1999 V2: 295–298
thermocouple (tc, TC, TCPL), 2004 V1: 16
thermodisc traps, 2000 V3: 182, 186
thermodynamic steam traps, 2000 V3: 182, 194
thermometers, 2004 V1: 10
thermoplastic pipes, 2003 V4: 58
thermoset plastic, 2000 V3: 155, 2003 V4: 58
thermostatic bellows, 2000 V3: 182
thermostatic-mixing shower valves, 2003 V4: 15, 18
thermostatic-mixing tub valves, 2003 V4: 16
thermostatic radiator vents, 2000 V3: 179
thermostatic steam traps, 2000 V3: 182, 186, 194, 196
thermostats (T STAT), 2004 V1: 16
thickness (thkns, THKNS, THK)
of soils, 1999 V2: 219
symbols for, 2004 V1: 16
Thickness Design, 2003 V4: 32
thinking outside the box, 2004 V1: 232
THK (thickness), 2004 V1: 16, 1999 V2: 219
thkns, THKNS (thickness), 2004 V1: 16, 1999 V2: 219
thousand circular mils (Mcm, MCM), 2004 V1: 16
thousand cubic feet (Mcf, MCF), 2004 V1: 16
thousand foot-pounds (kip ft, KIP FT, KIPFT), 2004 V1: 16
thousand pounds (kip, KIP), 2004 V1: 16
threaded end connections, 2004 V1: 23
threaded joints, 2004 V1: 167
threaded outlets, 1999 V2: 18
three-compartment sinks, 2003 V4: 11, 12
thresholds in shower compartments, 2004 V1: 120
throttling damper devices, 2000 V3: 144
throttling valves, 2000 V3: 118, 140, 144
thrust bearings, 2004 V1: 196
thrust blocks, 1999 V2: 250–251, 2000 V3: 231
tie-in tests, 2000 V3: 82
tie rods, 2000 V3: 229
“tight” piping systems, 2004 V1: 168
tightness testing, 2000 V3: 161–162, 171, 172
tiles in leaching trenches, 1999 V2: 221
time (T)
clean agent gas fire suppression, 2000 V3: 23
of concentration in runoff, 1999 V2: 97, 2000 V3: 244
in creativity checklist, 2004 V1: 234
intervals in hydraulic shock, 2004 V1: 6
in measurements, 2004 V1: 33
non-SI units, 2004 V1: 34
symbols for, 2004 V1: 16
time in pipes, 2000 V3: 244
time-temperature curves in fire tests, 2000 V3: 3
time delays
clean gas extinguishing systems, 2000 V3: 24
fountain relays, 2000 V3: 120–121
time history
computer analysis, 2004 V1: 186
earthquakes, 2004 V1: 159, 160
time switches for fountains, 2000 V3: 121
tin
corrosion, 2004 V1: 139
galvanic series, 2004 V1: 141
piping, 1999 V2: 122
tin-lined copper pipes, 2000 V3: 47
tipping prevention, 2004 V1: 189
tissue-culture rooms, 2000 V3: 45
titanium, 2004 V1: 141, 144, 2000 V3: 20
TL (temperature leaving), 2004 V1: 16
TLEA (temperature leaving), 2004 V1: 16
TOC (total organic carbon), 1999 V2: 288
toe clearance in toilet compartments, 2004 V1: 113, 114
toilet compartments. *See* water-closet compartments
toilet paper
dispensers, 2004 V1: 114
in septic tanks, 1999 V2: 231
toilets. *See also* water closets
composting, 2004 V1: 265
incinerating, 2004 V1: 265
tolerance, 2004 V1: 32
tons (TON)
converting to SI units, 2004 V1: 40
symbols for, 2004 V1: 16
tons of refrigeration (tons, TONS), 2004 V1: 16
tools
tool access in cleanouts, 1999 V2: 9
for vacuum cleaning systems, 1999 V2: 269–270
top coats, 2004 V1: 147
top-entry fittings in sovent systems, 1999 V2: 62
top-spud water closets, 2003 V4: 3, 8
torch testing, 2003 V4: 2
Toro Company, 2000 V3: 105
torque
conversion factors, 2004 V1: 35
converting to SI units, 2004 V1: 39
measurements, 2004 V1: 33
torrs, 1999 V2: 254
TOT HT (total heat), 2004 V1: 16
total (TOT), 2004 V1: 16
total alkalinity, 1999 V2: 283
total connected loads, 2000 V3: 50, 249, 253
total costs
defined, 2004 V1: 222
generalized, 2004 V1: 223

total dissolved solids (TDS), 1999 V2: 288, 316, 2000 V3: 123
total dynamic head, 1999 V2: 245
total flooding systems
carbon dioxide systems, 2000 V3: 20
defined, 2004 V1: 26
dry-chemical extinguishing systems, 2000 V3: 19
total head, 1999 V2: 245
total heat (tot ht, TOT HT), 2004 V1: 16
total organic carbon (TOC), 1999 V2: 288
total pumping head, 1999 V2: 245
total suspended solids, 1999 V2: 287–288
total work force in vacuum systems, 1999 V2: 259
towers in standpipe systems, 2000 V3: 19
T&P valves (temperature and pressure relief), 1999 V2: 166, 167
TPV (temperature-pressure-relief valves), 2004 V1: 10, 1999 V2: 166, 167
trace elements in water, 1999 V2: 283–284
Trace Level Analysis of High Purity Water, 1999 V2: 325
tractor-type grates, 1999 V2: 11
traffic loads
automotive traffic and grates, 1999 V2: 11
cleanouts and, 1999 V2: 9
grates and strainers, 1999 V2: 10
trailer parks
septic tank systems for, 1999 V2: 231–232
sewers, 2004 V1: 30
transfer-type showers, 2004 V1: 121
transferring hazardous wastes, 2000 V3: 90
transition fittings, 2000 V3: 252
transmissibility, coefficient of (Q factor), 1999 V2: 101
transmission loss (sound), 2004 V1: 209
transmission of noise, 2004 V1: 199
transmissivity (TAU), 2004 V1: 16
transport trucks, 2000 V3: 61
Transportation Department. *See* U.S. Department of Transportation
transportation gas services, 2000 V3: 249
transverse bracing, 2004 V1: 167, 171, 191
transverse sway bracing, 2004 V1: 179
trap arms
defined, 1999 V2: 64
fixture vents and, 1999 V2: 38, 39
length of, 1999 V2: 50
trap primers, 1999 V2: 13–14
trap seals
controlling induced siphonage, 1999 V2: 40
defined, 2004 V1: 31, 1999 V2: 64
factors in trap seal loss, 1999 V2: 36
floor drains, 1999 V2: 10, 2003 V4: 17
maintaining, 1999 V2: 14
primer devices, 2003 V4: 17
reduced-size venting and, 1999 V2: 49
reducing trap seal losses, 1999 V2: 39–40
stack venting and, 1999 V2: 47
tests, 2003 V4: 5
trap siphonage and, 1999 V2: 35
vents and, 1999 V2: 36
trapeze
bracing pipes on trapeze, 2004 V1: 175, 178
potential problems in bracing, 2004 V1: 189
trapeziums, calculating area, 2004 V1: 4
trapezoids, calculating area, 2004 V1: 4
traps. *See also* trap seals
building traps, defined, 2004 V1: 19
condensate traps, 2000 V3: 193–195, 195, 196
defined, 2004 V1: 31
eliminating siphonage with vents, 1999 V2: 35
fixture traps and vents, 1999 V2: 40
piping arrangement steam classifications, 2000 V3: 182–186
roof drains, 1999 V2: 84
sink traps, 2000 V3: 42
special-waste drainage systems, 1999 V2: 328
steam traps, 2000 V3: 180–182
unvented traps, 1999 V2: 46
urinals, 2003 V4: 9
vents and, 1999 V2: 36
TRC (tubular modules in reverse osmosis), 1999 V2: 309, 310
treated water. *See also* water treatment
defined, 1999 V2: 280
from reverse osmosis, 1999 V2: 309
systems. *See* gray-water systems
Treating Cooling Water, 1999 V2: 325
treatment of black water, 1999 V2: 28, 227, 232–233
treatment of gray water, 1999 V2: 22, 23, 27–29, 28
treatment of oil in water, 1999 V2: 347–349
Treatment of Organic Chemical Manufacturing Wastewater for Reuse (EPA 600), 2000 V3: 96
treatment rooms
fixtures, 2000 V3: 35
health-care facilities, 2000 V3: 32
medical gas stations, 2000 V3: 51
medical vacuum, 2000 V3: 54
water demand, 2000 V3: 45
tree piping systems, 2000 V3: 16
tree-root problems in leaching trenches, 1999 V2: 222
trench drains
in chemical plants, 1999 V2: 346
defined, 2003 V4: 17
trenches. *See also* leaching trenches
absorption trenches, 1999 V2: 220
labor productivity rates, 2004 V1: 95–97
near water pipes, 1999 V2: 250
sanitary sewer services, 2000 V3: 234, 235
storage tank piping, 2000 V3: 172
in subsurface drainage, 1999 V2: 102–103
Tri-Services Manual, 2004 V1: 183
triage rooms, 2000 V3: 35
triangles
calculating area, 2004 V1: 4–5
exercise, 2004 V1: 232, 261
rule for sink location, 2003 V4: 12
tributary areas for runoff, 1999 V2: 97
trichloroethylene, 2000 V3: 70
trickle irrigation, 2000 V3: 103
trickling filters, 2000 V3: 95
triggering clean agent gas fire suppression, 2000 V3: 24
trihalomethanes, 1999 V2: 311
triplex air compressors, 2000 V3: 213
triplex vacuum pump arrangements, 1999 V2: 263
trisodium phosphate, 1999 V2: 13

TROs (tubular modules in reverse osmosis), 1999 V2: 309, 310
troughs for waterfalls, 2000 V3: 109
truss-type bracing, 2004 V1: 190
tsunamis, 2004 V1: 158
tub fillers, 2003 V4: 16
tube ozone units, 1999 V2: 313
tube washers, 2000 V3: 37
tuberculation, 2004 V1: 154
tubing
  joints, 1999 V2: 196
  liquefied petroleum gas, 1999 V2: 196
  vacuum cleaning hose capacity, 1999 V2: 270
  vacuum cleaning systems, 1999 V2: 269–270
tubular-bag separators, 1999 V2: 268
tubular modules in reverse osmosis, 1999 V2: 309, 310
tunnel chases for swimming pool piping, 2000 V3: 144
turbidity
  clarification of, 1999 V2: 294
  defined, 1999 V2: 282
  drinking water, 1999 V2: 316
  measuring, 1999 V2: 287–288
  removing, 1999 V2: 244
turbine pumps, 1999 V2: 246, 247
turbine water meters, 1999 V2: 115, 116, 117
turbo pumps, 1999 V2: 259
turbo-surgical instruments, 2000 V3: 59
turbulence
  defined, 2004 V1: 31
  measurements, 1999 V2: 41
  in rate of corrosion, 2004 V1: 145
  turbulent flow in pipes, 2004 V1: 2
turf imperviousness factors, 2000 V3: 243
turndown ratio (TD), 1999 V2: 182
turnover rates
  gutters and, 2000 V3: 142
  swimming pools, 2000 V3: 140
turrets, gas, 1999 V2: 177
TW (tempered hot water), 2004 V1: 8
twin-agent dry-chemical systems, 2000 V3: 20
twin-tower air dryers, 2000 V3: 207
two. *See also entries beginning with* double-, dual-, *or* multiple-
two-bed deionizing units, 2000 V3: 46
two-compartment septic tanks, 1999 V2: 229
two-compartment sinks, 2003 V4: 11, 12
two-family dwellings, numbers of fixtures for, 2003 V4: 20
two-pipe steam systems, 2000 V3: 178, 180–182, 185, 186–187
two-pipe venturi suction pumps, 1999 V2: 241
two-point vapor recovery, 2000 V3: 163
two-stage reduction, 1999 V2: 153
two-step deionization (dual-bed), 1999 V2: 302, 303
two-valve parallel pressure-regulated valves, 1999 V2: 153
two-word expressions of functions, 2004 V1: 225, 231
TWR (tempered hot water recirculating), 2004 V1: 8
TXPC (thermal expansion coefficients), 2004 V1: 16
Type 1 air compressors, 2000 V3: 65, 67
Type 2 air compressors, 2000 V3: 65
Type A gray-water systems, 1999 V2: 31–32
Type ACR/MED pipes, 2003 V4: 36
Type ACR pipes, 2003 V4: 36
Type B gas vents, 1999 V2: 213
Type B gray-water systems, 1999 V2: 31–32
Type B vent codes, 2004 V1: 43
Type B-W gas vents, 1999 V2: 213
Type DWV pipes, 2003 V4: 36, 45
Type G copper, 2003 V4: 36
Type K copper
  copper water tube, 2003 V4: 37
  dimensions and capacity, 2003 V4: 39–40
  fuel-gas piping, 1999 V2: 196
  lengths, standards, and applications, 2003 V4: 35
  medical gas tube, 2000 V3: 77, 2003 V4: 45
Type L copper
  cast in columns, 1999 V2: 68
  copper water tube, 2003 V4: 37
  dimensions and capacity, 2003 V4: 41–42
  fountains, 2000 V3: 119
  lengths, standards, and applications, 2003 V4: 35
  medical gas tube, 1999 V2: 196, 2000 V3: 77, 2003 V4: 45
  natural gas, 2000 V3: 254
  pool water heating and, 2000 V3: 122
  sizing, 1999 V2: 133
Type L gas vents, 1999 V2: 214
Type L vent codes, 2004 V1: 43
Type M copper
  copper water tube, 2003 V4: 37
  dimensions and capacity, 2003 V4: 43–44
  lengths, standards, and applications, 2003 V4: 35
Type OXY/ACR pipes, 2003 V4: 36
Type OXY, MED pipes, 2003 V4: 36
Type OXY/MED pipes, 2003 V4: 36

U

U-factor (U), 2004 V1: 16
U, U (heat transfer coefficients), 2004 V1: 15
UF membranes, 1999 V2: 284
UFAS (Uniform Federal Accessibility Standard), 2004 V1: 105–106
UFC (Uniform Fire Code), 2000 V3: 154
Uhlig, Herbert H., 2004 V1: 154
UL listings
  address, 2004 V1: 59
  gas booster components, 1999 V2: 179
  hot-water components, 1999 V2: 166, 170
  list of standards, 2004 V1: 57
  pipe hangers, 2000 V3: 15
ULF. *See* ultra-low-flow water closets
ultra-high vacuum, 1999 V2: 254
ultra-low-flow fixture green building credits, 2004 V1: 264
ultra-low-flow water closets
  operation, 2004 V1: 135–136
  reduced-size venting and, 1999 V2: 19
  water usage rates, 2004 V1: 134–135
ultra-pure water systems, 1999 V2: 317
ultrafilters and ultrafiltration
  cross-flow filtration, 1999 V2: 300, 310–311
  membrane filters, 1999 V2: 308–311
  oil spills, 1999 V2: 347
Ultraviolet Disinfection in Biotechnology: Myth vs. Practice, 1999 V2: 325

ultraviolet radiation treatment of water, 1999 V2: 245, 311–312, 318, 323, 324
ultraviolet rays
chlorine and, 2000 V3: 149
PVC pipes, 2000 V3: 116
sterilization, 2000 V3: 47
swimming pool disinfection, 2000 V3: 150
unassisted creativity, 2004 V1: 232
unbalanced motors in pumps, 2004 V1: 196
unconsolidated aquifers, 1999 V2: 241
undamped mechanical systems, 2004 V1: 160
under-counter mounted lavatories, 2003 V4: 11
under-counter mounted sinks, 2003 V4: 12
under-film corrosion, 2004 V1: 154
under-floor areas, 2000 V3: 23
under-table waste and vent piping, 2000 V3: 42
underdrain systems in sand filters, 2000 V3: 132
underground building sanitary pipe codes, 2004 V1: 44
underground inspections, 2004 V1: 102–103
underground piping
acid-waste piping, 1999 V2: 334
cast-iron soil pipe, 2003 V4: 27
coatings, 2004 V1: 147
defined, 2004 V1: 31
fountains, 2000 V3: 116
glass pipe, 2003 V4: 47
materials for, 1999 V2: 14–15
medical gas piping, 2000 V3: 73
natural gas systems, 1999 V2: 176
storm-drainage systems, 1999 V2: 68
underground building sanitary pipe codes, 2004 V1: 44
water pipes, 1999 V2: 251
underground pressurized fuel delivery systems, 2000 V3: 162
underground site drainage, 1999 V2: 99–105
underground sprinklers, 2000 V3: 101
underground storage tanks (USTs)
codes and standards, 2000 V3: 154
defined, 2000 V3: 153
hazardous wastes, 2000 V3: 90
illustrated, 2000 V3: 164
liquid fuel storage tanks, 2000 V3: 155–158
connections and access, 2000 V3: 156–157
construction, 2000 V3: 156
filling and spills, 2000 V3: 156–157
leak detection and system monitoring, 2000 V3: 158–163
materials, 2000 V3: 155–156
overfill prevention, 2000 V3: 158
venting, 2000 V3: 157–158
product dispensing systems, 2000 V3: 163–165
dispenser pans, 2000 V3: 165
pressure dispensing, 2000 V3: 164
product dispensers, 2000 V3: 164–165
testing, 2000 V3:171
vapor recovery systems, 2000 V3: 163
underground suction fuel delivery systems, 2000 V3: 162–163
underwater lights, 2000 V3: 112, 121, 145
underwriters. *See* insurance carriers
Underwriters Laboratories, Inc. (UL)
address, 2004 V1: 59, 2000 V3: 97
gas booster components, 1999 V2: 179
hot-water components, 1999 V2: 166, 170
list of standards, 2004 V1: 57
pipe hangers, 2000 V3: 15
UL 58: Steel Underground Tanks for Flammable and Combustible Liquids, 2000 V3: 95
UL 142: Steel Above Ground Tanks for Flammable and Combustible Liquids, 2000 V3: 95, 154, 165
UL 2085: Fire Resistance, 2000 V3: 154
unemployment taxes, in labor costs, 2004 V1: 94
ungridded piping systems, 2000 V3: 16
uniform attack corrosion, 2004 V1: 142
Uniform Building Code (UBC), 2004 V1: 183, 191
Uniform Federal Accessibility Standard (UFAS), 2004 V1: 105–106
Uniform Fire Code (UFC), 2000 V3: 154
uniform flow
in horizontal drains, 1999 V2: 6–7
Manning formula, 2004 V1: 1
Uniform Plumbing Code, 1999 V2: 22, 34, 214, 2003 V4: 18
Uniformat specification system, 2004 V1: 64, 73
uninterrupted water supplies, 2000 V3: 43
uninterruptible gas services, 2000 V3: 249
unions (joins)
flanged, 2004 V1: 10
screwed, 2004 V1: 10
unions (labor), cost estimates and, 2004 V1: 98
unisex toilet rooms, 2003 V4: 18, 23
unit costs, in plumbing cost estimation, 2004 V1: 93
United States agencies and departments. *See* U.S. agencies and departments
United States Pharmacopoeia. *See* U.S. Pharmacopoeia (USP)
units (UNIT)
symbols for, 2004 V1: 16
units of measurement. *See* measurement units
universities. *See also* laboratories
diversity factor calculations for vacuums, 1999 V2: 263
natural gas piping, 1999 V2: 177
unknowns in value engineering presentations, 2004 V1: 258
unlined piping, 2003 V4: 26
unloading in air compressors, 2000 V3: 205
unobstructed reach for wheelchairs, 2004 V1: 111, 112
unoccupied buildings, conserving energy in, 2004 V1: 127
unrestricted areas (facilities with radiation), 1999 V2: 339
unsanitary, defined, 1999 V2: 64
untreated sewage, 2004 V1: 28
unvented traps (s traps), 1999 V2: 46
unventilated spaces and gas systems, 1999 V2: 176
upfeed risers, 2000 V3: 185
uplifting of buildings, 1999 V2: 99
upright sprinklers, 2004 V1: 13, 29, 30
upstream, defined, 2004 V1: 31
upward-tapered weirs, 2000 V3: 109
Urban Hydrology for Small Watersheds, 1999 V2: 114
urinals. *See also* water closets
accessibility design, 2004 V1: 116–117
acoustic ratings of, 2004 V1: 194
Energy Policy Act requirements, 2004 V1: 264
exclusion from gray-water systems, 1999 V2: 21
female, 2003 V4: 9

flushing requirements, 2003 V4: 10
gray water use, 2004 V1: 267, 1999 V2: 21, 25
health-care facilities, 2000 V3: 32, 33
installation requirements, 2003 V4: 9–10
minimum number for buildings, 2003 V4: 21–22
reducing flow rates, 2004 V1: 134–135
screening, 2003 V4: 10
specialty urinals, 2004 V1: 136
standards, 2003 V4: 2
testing, 2003 V4: 9
traps, 2003 V4: 9
types, 2003 V4: 8–9
typical use, 1999 V2: 25
ultra low flow, 2004 V1: 135–136
water fixture unit values, 2000 V3: 217
waterless, 2004 V1: 265, 2003 V4: 10
U.S. Architectural and Transportation Barriers Compliance Board (ATBCB), 2004 V1: 106, 107
U.S. Army Corps of Engineers
specifications, 2004 V1: 63
U.S. Army Corps of Engineers Manual, 1999 V2: 214
value engineering, 2004 V1: 211
U.S. competitive swimming meets, 2000 V3: 128
U.S. Department of Commerce, National Information Services, 1999 V2: 34
U.S. Department of Defense, 2004 V1: 161, 185, 191, 212–213
U.S. Department of Energy *Greening Federal Facilities,* 2004 V1: 134, 137
U.S. Department of Health and Environmental Control, 1999 V2: 170
U.S. Department of Health and Human Services, 2000 V3: 33
U.S. Department of Housing and Urban Development, 2004 V1: 105, 106
U.S. Department of the Army, 1999 V2: 114
U.S. Department of Transportation (DOTn), 2004 V1: 54, 58, 1999 V2: 194, 2000 V3: 88
U.S. Environmental Protection Agency
address, 2000 V3: 173
aggressiveness index, 1999 V2: 292
brass pipe standards, 2003 V4: 27
chemical waste system codes and, 1999 V2: 345
Effluent Guideline program, 2000 V3: 88–89
industrial waste water defined, 2000 V3:87
potable water treatment technologies, 1999 V2: 279
publications, 1999 V2: 238
EPA 440: The EPA Effluent Guidelines Series, 2000 V3: 96
EPA 600/2-79-130: Activated Carbon Process for Treatment of Wastewater Containing Hexavalent Chromium, 2000 V3: 96
EPA 600: Treatment of Organic Chemical Manufacturing Wastewater for Reuse, 2000 V3: 96
regulations, 2000 V3:88
Safe Drinking Water Act and, 1999 V2: 244
special waste drainage codes and, 1999 V2: 328
storage tank regulations, 2000 V3: 154
tank leak detection regulations, 2000 V3: 158
water consumption statistics, 2004 V1: 135
U.S. Federal Housing Administration, 2004 V1: 199
U.S. Federal Specifications (FS), 2004 V1: 25, 58
U.S. Food and Drug Administration, 1999 V2: 279, 321, 324, 328
U.S. General Services Administration, 2004 V1: 191, 199, 263, 1999 V2: 34
U.S. Government Printing Office
address, 2000 V3: 97
Clean Water Act, 2000 V3: 96
Code of Federal Regulations, 2000 V3: 96
Comprehensive Environmental Response, Compensation and Liability Act, 2000 V3: 96
Resource Conservation and Recovery Act, 2000 V3: 96
U.S. Green Building Council, 2004 V1: 263
U.S. Occupational Safety and Health Administration, 1999 V2: 333
U.S. Pharmacopoeia (USP)
USP nomographs, 1999 V2: 317
USP purified water, 1999 V2: 320, 321
water treatment standards, 1999 V2: 279
U.S. Public Health Service (USPHS), 1999 V2: 238, 2000 V3: 151
U.S. Veterans Administration, 2004 V1: 191
U.S. War Department, 1999 V2: 114
USACOE. *See* U.S. Army Corps of Engineers
usages in swimming pools, 2000 V3: 128
use factors
air compressors, 2000 V3: 206
compressed air systems, 2000 V3: 209
users in cost equation, 2004 V1: 223
USGBC (U.S. Green Building Council), 2004 V1: 263
USP. *See* U.S. Pharmacopoeia (USP)
USPHS. *See* U.S. Public Health Service (USPHS)
USTs. *See* underground storage tanks (USTs)
utilities. *See* site utilities
utility costs, lowering, 2004 V1: 128
utility gas. *See* fuel-gas piping systems
utility sinks, 2000 V3: 32
utility water treatment, 1999 V2: 313–314
UV (ultraviolet rays)
chlorine and, 2000 V3: 149
PVC pipes and, 2000 V3: 116
sterilization, 2000 V3: 47
swimming pool disinfection, 2000 V3: 150
UV treatment of water, 1999 V2: 245, 311–312, 318, 323, 324

V

v, V (valves). *See* valves
V (specific volume). *See* specific volume
V (velocity of uniform flow), 2004 V1: 1
V (velocity). *See* velocity
V (vents). *See* vents and venting systems
V (volts). *See* volts
v/v (volume to volume), 1999 V2: 285
VA (volt amperes), 2004 V1: 16
vac, VAC (vacuum). *See* vacuum
vacation pay, in labor costs, 2004 V1: 94
vacuum (vac, VAC)
defined, 2004 V1: 31, 1999 V2: 253
perfect vacuum, 2000 V3: 200
surgical use, 2000 V3: 57
symbols for, 2004 V1: 8, 16

vacuum breakers. *See* backflow preventers
vacuum cleaning systems, 1999 V2: 266–277. *See also* vacuum systems
  cleanouts, 1999 V2: 276
  codes and standards, 1999 V2: 266
  components, 1999 V2: 266–269, 268
  friction losses, 1999 V2: 272–274, 274
  inlet locations and spacing, 1999 V2: 269
  piping, 1999 V2: 269
  separators, 1999 V2: 275–276
  simultaneous operators, 1999 V2: 269
  sizing exhausters, 1999 V2: 272, 274–275
  swimming pools, 2000 V3: 145, 146
  types, 1999 V2: 266
Vacuum Cleaning Systems, 1999 V2: 277
vacuum condensate pumps, 2000 V3: 189
vacuum deaerators, 1999 V2: 294, 295
vacuum diatomaceous earth filtration, 2000 V3: 132, 135, 136, 139
vacuum levels
  defined, 1999 V2: 253–254
  in exhauster sizing, 1999 V2: 274
vacuum producers (exhausters), 1999 V2: 266–269, 270, 272, 274–275
vacuum product dispensers, 2000 V3: 163, 168
vacuum pumps, 1999 V2: 259, 263–264, 2000 V3: 49, 70, 71
vacuum relief valves, 2004 V1: 31
Vacuum Sewage Collection, 1999 V2: 238
vacuum sewers, 1999 V2: 226
vacuum sources, 1999 V2: 259–261, 262, 263–264
Vacuum Sources, 1999 V2: 277
vacuum steam units, 2000 V3: 188, 189
vacuum systems, 1999 V2: 266–277. *See also* vacuum cleaning systems
  altitude adjustments, 1999 V2: 257
  cast iron radiators, 2000 V3: 180
  codes and standards, 1999 V2: 262
  color coding, 2000 V3: 56
  fundamentals, 1999 V2: 253–254
  introduction, 1999 V2: 253
  laboratory systems, 1999 V2: 262–266, 2000 V3: 37–39
  leakage, 1999 V2: 265, 267
  Level 1 defined, 2000 V3: 85
  Level 3 defined, 2000 V3: 86
  medical gas system switches, 2000 V3: 72
  medical vacuum
    design checklist, 2000 V3: 49–50
    diversity factors, 2000 V3: 75
    laboratory outlets, 2000 V3: 37–39
    number of stations, 2000 V3: 50, 51–52
    oral surgery equipment, 2000 V3: 39
    patient vacuum, 2000 V3: 85
    peak demand, 2000 V3: 55
    piping systems, 2000 V3: 54, 68–70
  operating pressure steam classification, 2000 V3: 178
  operating pressures, 2000 V3: 175
  piping, 1999 V2: 262, 2000 V3: 74, 79
  pressure drop, 1999 V2: 258
  pressure measurement, 1999 V2: 254–256
  pump curves, 1999 V2: 258
  references, 1999 V2: 277
  sizing, 1999 V2: 262–266, 2000 V3: 74, 79
  surges, 1999 V2: 35
  swimming pools, 2000 V3: 144
  time to reach rated vacuum, 1999 V2: 257–258
  vacuum-pressure gauges, 1999 V2: 260
  vacuum reservoirs, 1999 V2: 262
  vacuum sources, 1999 V2: 259–261, 262, 263–264
  velocity calculations, 1999 V2: 258–259
  work forces, 1999 V2: 259
valence, 1999 V2: 280, 281, 302
value, defined, 2004 V1: 213–214
Value Engineering Change Proposals (VECP), 2004 V1: 260
Value Engineering Job Plan (VEJP), 2004 V1: 214
value engineering (VE)
  arguments against, 2004 V1: 232
  checklists
    creativity worksheets, 2004 V1: 233–234
    detail/product/material specification checklists, 2004 V1: 220
    evaluation checklists, 2004 V1: 237–238
    function definitions forms, 2004 V1: 225–227, 228
    functional evaluation worksheets, 2004 V1: 243–251
    idea development and estimated cost forms, 2004 V1: 241–242
    idea evaluation worksheets, 2004 V1: 243, 253
    project information checklists, 2004 V1: 215–220
    project information sources checklists, 2004 V1: 221
    questions checklists, 2004 V1: 213–214
    recommendation worksheets, 2004 V1: 258, 259
  compared to cost fitting, 2004 V1: 258
  contract document clauses, 2004 V1: 258, 260
  cost information, 2004 V1: 222–225
  creativity process, 2004 V1: 231–235
  defined, 2004 V1: 211
  elements of, 2004 V1: 214–225
  Evaluation phase, 2004 V1: 235–243
  Function Analysis phase, 2004 V1: 224–243
  Functional Development sketches, 2004 V1: 237, 239–240
  Gut Feel Index, 2004 V1: 254
  Information phase, 2004 V1: 214–222
  job plan phases, 2004 V1: 213
  overview, 2004 V1: 211–212
  pre-recommendation questions, 2004 V1: 254–257
  purpose, 2004 V1: 211–212
  qualitative results, 2004 V1: 212
  Recommendation/presentation phase, 2004 V1: 257–258
  results of, 2004 V1: 261
  Risk Guides, 2004 V1: 254, 257
  salesmanship in, 2004 V1: 257
  science of, 2004 V1: 258–260
  second creativity, cost, and evaluation analysis, 2004 V1: 254
  teams, 2004 V1: 212
  value changes, 2004 V1: 212–213
  "value" defined, 2004 V1: 213–214
valve-in-head irrigation, 2000 V3: 101
valve-per-sprinkler method of irrigation, 2000 V3: 100, 101

valved zones in irrigation systems, 1999 V2: 26
valves (v, V, VLV). *See also specific types of valves*
acoustic problems, 2004 V1: 197
acoustic ratings, 2004 V1: 194
automatic shutdown, 2000 V3: 90
battery-controlled, 2004 V1: 135
closing quickly, 1999 V2: 131
codes and standards, 2004 V1: 43
compressed air systems, 2000 V3: 210
domestic pressure drops and, 2000 V3: 221
fountains, 2000 V3: 116–119, 118–119
friction loss in, 1999 V2: 128
head loss and, 2000 V3: 115
infectious waste systems, 1999 V2: 345
irrigation systems, 2000 V3: 103–104
medical air compressors, 2000 V3: 66
medical gas control valves, 2000 V3: 71–72
pure water systems, 1999 V2: 324
in risers, 2004 V1: 10
sizing natural gas fittings, 1999 V2: 184
sulfuric acid and, 1999 V2: 332
swimming pools, 2000 V3: 145–146
symbols for, 2004 V1: 16
testing in medical gas systems, 2000 V3: 81
vacuum systems, 2000 V3: 70
valve flow coefficients, 2004 V1: 14
in yard boxes (YB), 2004 V1: 10
vandalism
backflow preventers, 1999 V2: 149
dressing rooms, 2000 V3: 130
fasteners on grates and strainers, 1999 V2: 11
protecting against, 1999 V2: 19
vane-type water-flow indicators, 2000 V3: 9, 10
VAP (vapor pressure), 2004 V1: 15
vap pr, VAP PR (vapor pressure), 2004 V1: 15
vap prf, VAP PRF (vaporproof), 2004 V1: 16
vapor-compression distillation, 1999 V2: 295–298
vapor operating pressure, 2000 V3: 175
vapor pressure, 2004 V1: 15
vapor recovery systems
aboveground tank systems, 2000 V3:168
classifications, 2000 V3: 154
hazardous wastes, 2000 V3: 90
testing, 2000 V3: 171
underground tank systems, 2000 V3: 163
vapor system pressure, 2000 V3: 175–178
vaporizers, 2000 V3: 61
vaporproof (vap prf, VAP PRF), 2004 V1: 16
vapors, hazardous
acid wastes and, 1999 V2: 332, 333
atmospheric tank venting and, 2000 V3: 157–158
contamination in compressed air, 2000 V3: 201
hydrocarbons, 2000 V3: 154
monitoring, 2000 V3: 160, 162
vapor pockets, 2000 V3: 172
VOCs, 1999 V2: 284
var, VAR (variables), 2004 V1: 16
variable air volume (VAV), 2004 V1: 16
variable-speed drivers, 2000 V3: 25
variables (var, VAR), 2004 V1: 16
varnishes in septic tanks, 1999 V2: 230
vaults
dry pumps in, 2000 V3: 115
pools and fountains, 2000 V3: 111
VAV (variable air volume), 2004 V1: 16
VECP (Value Engineering Change Proposals), 2004 V1: 260
vegetable oil, 1999 V2: 10
vehicular traffic
grates and, 1999 V2: 11
leaching trenches and, 1999 V2: 223
VEJP (Value Engineering Job Plan), 2004 V1: 214
vel., VEL (velocity). *See* velocity
velocity (vel., VEL, V). *See also* dynamic pressure
acoustic pump problems, 2004 V1: 197
cold-water systems, 1999 V2: 121–122
conversion factors, 2004 V1: 37
counterflow piping designs, 2000 V3: 178
defined, 2004 V1: 31
earthquakes, 2004 V1: 159
flow from outlets, 2004 V1: 6
hydraulic shock, 2004 V1: 6
intake air in compression systems, 2000 V3: 212
liquid fuel piping, 2000 V3:170
measurements, 2004 V1: 33
non-SI units, 2004 V1: 34
open-channel flow, 2004 V1: 1
in rate of corrosion, 2004 V1: 145
self-scouring velocity in sewers, 2000 V3: 232
site storm drainage, 1999 V2: 98
sizing method for pipes, 1999 V2: 131
steam systems, 2000 V3: 175
storm water in ditches, 2000 V3: 248
symbols for, 2004 V1: 16
terminal velocity, defined, 1999 V2: 1
vacuum cleaning systems, 1999 V2: 270–272
vacuum systems, 1999 V2: 258–259
water hammer and, 2004 V1: 198, 1999 V2: 144
water supply piping and, 1999 V2: 249
wind (w vel., W VEL), 2004 V1: 16
velocity head (h), 2004 V1: 5
vent connectors, defined, 1999 V2: 214
vent gases, defined, 1999 V2: 214
vent pipes
cast-iron soil pipe, 2003 V4: 27
glass pipe, 2003 V4: 47
vent stack terminals
defined, 1999 V2: 35–36, 64
liquefied petroleum gas, 1999 V2: 197
natural gas, 1999 V2: 177
vent stacks
air in, 1999 V2: 2
defined, 2004 V1: 31, 1999 V2: 64
vent headers, 1999 V2: 45
vent systems codes, 2004 V1: 43
ventilated sleeves and gas piping, 1999 V2: 176
ventilation
oxygen storage areas, 2000 V3: 63
swimming pools, 2000 V3: 129
ventilators, 2000 V3: 74
vents and venting systems (V, vent, VENT). *See also* vent stack terminals; vent stacks
1-pipe steam systems, 2000 V3: 179–180
aboveground tank systems, 2000 V3:167

acid-waste systems, 1999 V2: 332, 334, 2000 V3: 39
arterial vents, 1999 V2: 52
atmospheric tank venting, 2000 V3: 167
chemical-waste systems, 1999 V2: 346
chimney heights, 1999 V2: 178
circuit and loop venting, 1999 V2: 43–44
combination waste and vent systems, 1999 V2: 45–46
common vents, 1999 V2: 41
confluent vents, 1999 V2: 51
duct seismic protection, 2004 V1: 155
ducts in clean agent gas fire suppression, 2000 V3: 23
end venting, 1999 V2: 41
factors in trap seal loss, 1999 V2: 36
fire-suppression drainage and, 1999 V2: 347
fixture units, 1999 V2: 40–41
fixture vents, 1999 V2: 37–39
flash tanks, 2000 V3: 195
force mains, 2000 V3: 241
glossary of terms, 1999 V2: 64
gravity vents for gas appliances, 1999 V2: 178
infectious waste systems, 1999 V2: 345
introduction, 1999 V2: 35
laboratory waste and vent piping, 2000 V3: 42
loop venting, 2004 V1: 31, 1999 V2: 64
main vents, 2000 V3: 184
manholes, 2000 V3: 236, 239
natural gas appliance vents, 1999 V2: 177–178
offsets, 1999 V2: 44–45
oil separators, 1999 V2: 349
Philadelphia system, 1999 V2: 46, 47, 48
purposes, 1999 V2: 35
radiators, 2000 V3: 178, 184
reduced-size venting, 1999 V2: 49, 53, 54
references, 1999 V2: 65
relief vents, 1999 V2: 44, 45
septic tank vents, 1999 V2: 231
sewer vents, 1999 V2: 35
sizes and lengths, 2004 V1: 3, 1999 V2: 41–43, 50–63
sovent systems, 1999 V2: 46–47, 54–63
special-waste drainage systems, 1999 V2: 328
storm-drainage stacks, 1999 V2: 67
suds venting, 1999 V2: 36–37, 39
sumps, 1999 V2: 105
symbols for, 2004 V1: 8, 16
testing, 2000 V3: 171
traps and trap seals, 1999 V2: 36, 39–40
underground liquid fuel tanks, 2000 V3: 157–158
vent headers, 1999 V2: 45
vented inlet tees in septic tanks, 1999 V2: 228
waste anesthetic gas management, 2000 V3: 71
wet vents, 1999 V2: 43, 49
venturi action in pools, 2000 V3: 108
venturi-meters, 2004 V1: 197
venturi suction pumps, 1999 V2: 241
verbs in function analysis, 2004 V1: 224, 225, 231
vert., VERT (vertical). *See* vertical
vertical (vert., VERT), 2004 V1: 16
vertical filters, 2000 V3: 131
vertical forces, 2004 V1: 189
vertical leaders, 1999 V2: 85–88, 109
vertical pipes, 2004 V1: 31
vertical pressure media filters, 1999 V2: 300
vertical risers for vacuum systems, 1999 V2: 269
vertical seismic load, 2004 V1: 184
vertical shaft turbine pumps, 2004 V1: 24
vertical stacks
calculating terminal velocity and length, 2004 V1: 3
defined, 2004 V1: 31
fittings, 1999 V2: 1
flow in, 1999 V2: 1–2
hydraulic jumps and, 1999 V2: 2
loading tables, 1999 V2: 4
maximum fixture-unit values, 1999 V2: 4, 5
multistory stacks, 1999 V2: 5
pneumatic pressure in, 1999 V2: 2
sizing, 1999 V2: 5, 6
sovent systems, 1999 V2: 57
stack capacities, 1999 V2: 3–5
storm-drainage stacks, 1999 V2: 67
vertical turbine pumps
fire pumps, 2000 V3: 25
illustrated, 1999 V2: 246
private water systems, 1999 V2: 245
shallow wells, 1999 V2: 247
swimming pool pumps, 2000 V3: 140, 142
VFR (volumetric flow rates), 2004 V1: 16
viable-count essays, 1999 V2: 282
vibrating fill above sewers, 1999 V2: 16
vibration and vibration isolation
defined, 2004 V1: 209
earthquakes
earthquake vibration periods, 2004 V1: 160
floor-mounted equipment, 2004 V1: 164–166
isolators and, 2004 V1: 206
piping and, 2004 V1: 168
suspended equipment, 2004 V1: 166
equipment vibration criteria, 2004 V1: 202
fixtures, isolating, 2004 V1: 205, 207
natural or free vibration, 2004 V1: 160
noise and vibration control, 2004 V1: 199–200
piping, 2004 V1: 168. *See also* water hammer
pumps, 2004 V1: 205, 208
static deflection for pump vibration, 2004 V1: 205
types of vibration control devices, 2004 V1: 203–206
vibration isolation mounts, 2004 V1: 162, 163
vibration isolators, 2004 V1: 199
video equipment, 1999 V2: 10
vinyl coatings, 2004 V1: 147
viruses in feed water, 1999 V2: 282, 311–313
viscosity (visc, VISC, MU)
calculating values of, 2004 V1: 2
defined, 2000 V3: 154
measurements, 2004 V1: 33
symbols for, 2004 V1: 16
visitors' facilities, numbers of fixtures for, 2003 V4: 20, 21
visualization in function analysis, 2004 V1: 227
vitreous china fixtures, 2000 V3: 33, 2003 V4: 1, 2
vitrified clay piping, 1999 V2: 122, 346, 2000 V3: 245, 2003 V4: 49, 56–57
vitrified sewer pipes, 2004 V1: 31
VLV (valves). *See* valves
VOCs (volatile organic compounds), 1999 V2: 284, 292, 2000 V3: 154, 163
vol., VOL (volume). *See* volume

volatile liquids, 1999 V2: 13, 347–349
volatile organic compounds (VOCs), 1999 V2: 284, 292, 2000 V3: 154, 163
volcanoes, 2004 V1: 156
volts (V, E, VOLTS)
  decomposition potential defined, 2004 V1: 152
  measurement conversions, 2004 V1: 33
  symbols for, 2004 V1: 16
  volt amperes (VA), 2004 V1: 16
volume (vol., VOL)
  calculating, 2004 V1: 3–5
  conversion factors, 2004 V1: 37
  flow rate measurements, 2004 V1: 33, 1999 V2: 255
  gas particles, 2000 V3: 199
  non-SI units, 2004 V1: 34
  symbols for, 2004 V1: 16
volume to volume (v/v), 1999 V2: 285
volumetric flow rates (VFR), 2004 V1: 16
vortexes
  anti-vortex grating, 2000 V3: 110
  in drains, 1999 V2: 38
  from pumps, 2004 V1: 197
  from sumps, 2004 V1: 197
vp, VP (dynamic pressure or velocity), 2004 V1: 15

W

W, W (humidity ratios), 2004 V1: 15
W (walls). *See* walls
W (waste sewers), 2004 V1: 8
W (watts). *See* watts
W/m K (watts per meter per kelvin), 2004 V1: 33
w vel., W VEL (velocity, wind), 2004 V1: 16
w/w (weight to weight), 1999 V2: 285
wading areas, 2000 V3: 128
wafer butterfly valves, 1999 V2: 268
WAG (waste anesthetic gases), 2000 V3: 70–71
WAGD (waste anesthetic-gas disposal), 2000 V3: 57, 70–71, 86
wages, in labor costs, 2004 V1: 94
waiting rooms, 2000 V3: 32
WAL (walls). *See* walls
wall azimuth (WAZ), 2004 V1: 14
wall carriers, 2003 V4: 6
wall cleanouts (WCO), 2004 V1: 11
wall-hung lavatories, 2003 V4: 11
wall-hung urinals, 2003 V4: 10
wall-hung water closets, 2003 V4: 4, 6
wall hydrants (WH), 2004 V1: 10, 12
wall-mounted medical gas stations, 2000 V3: 58
walls (W, WAL)
  piping and acoustic design, 2004 V1: 195–196
  symbols for, 2004 V1: 16
  wall penetrations of pipes, 2004 V1: 201
wander, 2004 V1: 22, 190
ward rooms, 2000 V3: 34
warehouses, numbers of fixtures for, 2003 V4: 20, 21
warm-up loads
  automatic heat-up systems, 2000 V3: 196
  equations, 2000 V3: 195
  steam piping, 2000 V3: 187, 191, 192
warning systems (medical gas), 2000 V3: 72–73
  area alarms, 2000 V3: 72
  master alarms, 2000 V3: 72
  testing, 2000 V3: 81
warranty section in specifications, 2004 V1: 70, 90
Warren, Alan W., 1999 V2: 114
wash basins. *See* sinks and wash basins
wash-down urinals, 2003 V4: 9
wash-down water closets, 2003 V4: 3
washing floors with gray water, 1999 V2: 22
washing machines. *See* laundry systems and washers
washout urinals, 2003 V4: 9
washout water closets, 2003 V4: 3
waste, defined, 2004 V1: 31
waste anesthetic-gas disposal, 2000 V3: 57, 70–71, 86
waste brines, 1999 V2: 231, 307
waste-disposal units. *See* food waste grinders
waste fitting standards, 2003 V4: 2
waste grinders, 2000 V3: 32
waste-heat usage, 2004 V1: 131–134, 266
waste-heat vaporizers, 2000 V3: 61
waste oil (WO), 2004 V1: 8, 2000 V3: 154
waste oil vents (WOV), 2004 V1: 8
waste or soil vents. *See* stack vents
waste pipes, 2004 V1: 31, 2003 V4: 27
waste sewers (W), 2004 V1: 8
waste streams
  evaluation, 2000 V3: 90
  segregating, 2000 V3: 94
Wastewater Engineering: Treatment, Disposal, and Reuse, 2000 V3: 125
Wastewater Engineering: Treatment/Disposal/Reuse, 1999 V2: 238
wastewater heat recovery, 2004 V1: 133
wastewater management. *See also* gray-water systems; private sewage-disposal systems
  green building technologies, 2004 V1: 264
  individual aerobic wastewater treatment, 1999 V2: 232–233
  industrial wastewater treatment. *See* industrial wastewater treatment
  reclaimed and gray water systems, 2004 V1: 135, 1999 V2: 27–29
  swimming pools, 2000 V3: 131
WAT (watts). *See* watts
water (WTR). *See also* water analysis; water chemistry
  as seal liquid in liquid ring pumps, 1999 V2: 260
  asbestos concrete piping, 2003 V4: 26
  clarity, 2000 V3: 135
  contamination in compressed air, 2000 V3: 201
  density, 1999 V2: 116
  kinematic viscosity, 1999 V2: 121
  oil-water separation, 2000 V3: 93
  portable fire extinguishers, 2000 V3: 27
  potable amounts present, 2004 V1: 263
  samples of, 1999 V2: 155
  subsurface water, 1999 V2: 99–105
water absorption, plastic pipe and, 2003 V4: 60
water analysis
  aggressiveness index, 1999 V2: 292
  codes and standards, 1999 V2: 279
  example report, 1999 V2: 286
  introduction, 1999 V2: 284–285
  pH, 1999 V2: 285, 291

predicting water deposits and corrosion, 1999 V2: 290–292
references, 1999 V2: 325
Ryzner stability index, 1999 V2: 292
silt density index, 1999 V2: 288–289
specific conductance, 1999 V2: 287
total dissolved solids, 1999 V2: 288
total organic carbon, 1999 V2: 288
total suspended solids, 1999 V2: 287–288
water chemistry
elements, acids, and radicals in water, 1999 V2: 281
heat loss retardants, 2000 V3: 150
introduction, 1999 V2: 280–284
mineral deposits, 2000 V3: 147–148
pH values, 2000 V3: 147
pools and fountains, 2000 V3: 123
sequestering agents, 2000 V3: 150
swimming pools, 2000 V3: 146–148
water impurities, 1999 V2: 280–284
water-closet compartments
accessibility, 2004 V1: 113–116
ambulatory-accessible toilet compartments, 2004 V1: 114
kitchen areas, 2000 V3: 36
patient rooms, 2000 V3: 34
single-occupant unisex toilet rooms, 2003 V4: 18, 23
spacing, 2003 V4: 6–7
swimming pool bathhouses, 2000 V3: 130
trap primers in, 1999 V2: 13
water-closet flanges, 2003 V4: 6
water closets (WC). *See also* urinals
accessibility design, 2004 V1: 113–116
acoustic design, 2004 V1: 200
acoustic ratings of, 2004 V1: 194
bolts, 2003 V4: 6
composting toilets, 2004 V1: 265
conserving water in, 1999 V2: 232
dual flush, 2004 V1: 265
Energy Policy Act requirements, 2004 V1: 264
exclusion from gray-water systems, 1999 V2: 21
fixture-unit loads, 1999 V2: 3
flushing performance testing, 2003 V4: 5–6
flushing systems, 2003 V4: 6–8
gray water usage, 2004 V1: 267, 1999 V2: 21, 25
in health-care facilities, 2000 V3: 32, 33, 34
incinerators, 2004 V1: 265
installation requirements, 2003 V4: 6–7
minimum numbers of, 2003 V4: 18–22
mounting, 2003 V4: 4
rates of sewage flows, 1999 V2: 237
reducing flow rates, 2004 V1: 134–135
seats, 2003 V4: 5
shapes and sizes, 2003 V4: 4–5
sovent systems, 1999 V2: 59, 62
specimen-type, 2000 V3: 35
standards, 2003 V4: 2, 6
types of, 2004 V1: 135–136, 2003 V4: 3–4
typical use, 1999 V2: 25
ultra-low-flow, 2004 V1: 135–136, 1999 V2: 19
water conservation, 2004 V1: 135–136
water fixture unit values, 2000 V3: 217
water column (wc), 2003 V4: 5
Water Conditional Manual, 1999 V2: 325
water conditioning. *See also* water purification; water softeners; water treatment
defined, 1999 V2: 279
water-conditioning or treating devices, 2004 V1: 31
water conservation. *See* conserving water
water consumption tests, 2003 V4: 5, 9
water-cooled after-coolers, 2000 V3: 202
water coolers
access to, 2004 V1: 109–112
gray-water output, 1999 V2: 25
health-care facilities, 2000 V3: 32
public areas in health-care facilities, 2000 V3: 33
standards, 2003 V4: 2
types, 2003 V4: 14
wheelchair space around, 2004 V1: 112
water damage
sprinkler systems, 2000 V3: 2
swimming pool bathhouses, 2000 V3: 130
water deposits, 1999 V2: 289, 290–292
Water Distributing Systems for Buildings, 1999 V2: 155
water-distribution pipes and systems. *See also* cold-water systems; hot-water systems
acoustic design, 2004 V1: 195–196
codes, 2004 V1: 45
defined, 2004 V1: 31
pipe codes, 2004 V1: 45
water supply and distribution symbols, 2004 V1: 12
water supply systems, 2004 V1: 31
weight of water-filled pipes, 2004 V1: 184
Water Efficiency design (LEED), 2004 V1: 263–264
water-flow indicators, 2000 V3: 9, 10
water for injection (WFI), 1999 V2: 317, 320, 321, 324
water glass, 2004 V1: 151
water hammer
acoustic control of, 2004 V1: 201
air locks, 2004 V1: 201
controlling water hammer, 1999 V2: 132, 143
counterflow piping designs, 2000 V3: 178
defined, 2004 V1: 31, 1999 V2: 131–144
flow velocity and, 2004 V1: 198
fountains and, 2000 V3: 116
fuel dispensers, 2000 V3: 170
shock intensity, 1999 V2: 132
sizing of arresters, 1999 V2: 143–144
steam systems, 2000 V3: 189, 190, 191
swimming pool pumps, 2000 V3: 139
symbols on arresters, 1999 V2: 143
system protection and control, 1999 V2: 132, 143–144
velocity and, 1999 V2: 121
water hammer arresters (WHA)
acoustic design in water pipes, 2004 V1: 195
as protection and control, 1999 V2: 132
codes, 2004 V1: 43
defined, 2004 V1: 31
flow velocity and, 2004 V1: 198
shock absorbers, 2004 V1: 198, 201
sizing, 1999 V2: 143–144
symbols, 2004 V1: 10, 1999 V2: 143
water heaters. *See also* hot-water systems
avoiding standby losses, 2004 V1: 127
booster water heaters, 2004 V1: 126, 129, 1999 V2: 160

codes, 2004 V1: 43
condensation use, 2004 V1: 267
conserving energy, 2004 V1: 124–125, 127
earthquake damage, 2004 V1: 162
earthquake protection, 2004 V1: 162, 163
explosions, 1999 V2: 157
gas water heaters, 2004 V1: 129
heat recovery, 1999 V2: 158
high-efficiency, 2004 V1: 265
instantaneous, 2004 V1: 265
locations of, 2004 V1: 129
mineral deposits and, 2000 V3: 147
overview, 1999 V2: 160–165
point-of-use booster heaters, 2000 V3: 45
recovering heat from water heaters, !1999 V2: 158
reflecting pools and fountains, 2000 V3: 112, 121–122
step heaters, 2000 V3: 144
stratification in water heaters, 1999 V2: 160, 165
swimming pools, 2000 V3: 138–139, 144–145, 146
temperature, 1999 V2: 157, 160
thermal efficiency, 1999 V2: 169
types of systems, 2004 V1: 129–134
water impurities
alkalinity, 1999 V2: 282–283
analysis and measurement, 1999 V2: 284–289
biological fouling, 1999 V2: 289, 316
dissolved gases, 1999 V2: 284
hardness, 1999 V2: 283
microorganisms, 1999 V2: 282
specific resistance, 1999 V2: 285–287
suspended solids, 1999 V2: 282
treatment methods, 1999 V2: 292–313
volatile organic compounds, 1999 V2: 284
water levels
in pools, 2000 V3: 112
sensors, 2000 V3: 124
water-level dependent spray jets, 2000 V3: 119
water-level independent spray jets, 2000 V3: 119
water mains
age and size, 2000 V3: 8
copper pipe, 2003 V4: 34, 35
defined, 2004 V1: 31
fire-protection connections, 2000 V3: 225, 227
inspection checklist, 2004 V1: 103
pressure and, 2000 V3: 216
sprinkler systems, 2000 V3: 3
water makeup. *See* makeup water systems
Water Management: A Comprehensive Approach for Facility Managers, 1999 V2: 34
water management plans, 2004 V1: 134–135
water meters
domestic water meters, 1999 V2: 115–116
estimating sewage disposal from, 1999 V2: 233
flow-pressure loss averages, 1999 V2: 117
friction losses, 1999 V2: 127
irrigation, 2000 V3: 105
locations for, 2000 V3: 217
loss of pressure, 1999 V2: 123
pressure losses, 2000 V3: 224
water motor gongs, 2000 V3: 9, 10
water, oil, and gas (WOG) pressure rating, 2000 V3: 210
water pipes. *See* cold-water systems; hot-water systems; water-distribution pipes and systems
water pressure
booster-pump system, 1999 V2: 152
excess water pressure, 1999 V2: 152–154
gravity-tank systems, 1999 V2: 150–152
hydropneumatic-tank systems, 1999 V2: 150
inadequate water pressure, 1999 V2: 149–152
pressure-regulating devices, 1999 V2: 122
water hammer and, 1999 V2: 144
water purification
central purification equipment, 1999 V2: 323–325
codes and standards, 1999 V2: 279, 317
feed water, 1999 V2: 320
high-purity water, 2000 V3: 46
methods, 2000 V3: 46–47
pharmaceutical systems, 1999 V2: 320
polishers and, 1999 V2: 308
pure-water systems defined, 1999 V2: 279
references, 1999 V2: 325
specific resistance of pure water, 1999 V2: 286
system design, 1999 V2: 321
water impurities, 1999 V2: 280–284
water quality
Clean Water Act, 2000 V3: 88
grades of laboratory water, 1999 V2: 317
gray-water systems, 1999 V2: 33
introduction, 1999 V2: 244
references, 1999 V2: 325
water-resistivity meters, 1999 V2: 286
water-reuse systems. *See* gray-water systems
water rise tests, 2003 V4: 5
water risers, 2004 V1: 31
water-seal self-scouring traps, 1999 V2: 36
water-service pipes, defined, 2004 V1: 31
water slides, 2000 V3: 128
water softeners
earthquake damage, 2004 V1: 162
hardness of water, 1999 V2: 283
ion-exchange, 1999 V2: 300
leakage, 1999 V2: 308
pressure losses and, 1999 V2: 125
pure water systems, 1999 V2: 323
types of, 1999 V2: 244, 307–308
utility water, 1999 V2: 314
waste brines, 1999 V2: 231
water sports, 2000 V3: 128
Water Spray Fixed Systems for Fire Protection (NFPA 15), 2000 V3: 2, 29
water-spray systems, 2000 V3: 13
water-storage tanks
earthquake damage, 2004 V1: 162
fire-protection water supply, 2000 V3: 232
pipe installation, 1999 V2: 250–252
piping, 1999 V2: 249–250
pressure regulators, 1999 V2: 248–249
private water systems, 1999 V2: 239
types of, 1999 V2: 247–248
water-air ratio in tanks, 1999 V2: 150
water levels in, 1999 V2: 151, 248

water-supply systems. *See* cold-water systems; domestic water supply; fire-protection systems; hot-water systems; private water systems; water-distribution pipes and systems; wells
Water Systems for Pharmaceutical Facilities, 1999 V2: 325
water tables
underground storage tanks and, 2000 V3: 155
wells, 1999 V2: 241–243
Water Tanks for Fire Protection, 1999 V2: 247
water temperature
bathtub water notes, 2004 V1: 119
deaeration water temperatures, 1999 V2: 294
feed water temperature and deposits, 1999 V2: 291, 312, 321–322
high-temperature withstand for hot-water systems, 1999 V2: 166
hot-water properties, 1999 V2: 168
hot-water relief valves, 1999 V2: 166–167
hot-water temperatures, 1999 V2: 159, 161–165, 165, 2000 V3: 36, 45
maintenance hot-water temperatures, 1999 V2: 166
mixed-water temperatures, 1999 V2: 159–160
operating hot-water temperatures, 1999 V2: 166
reflecting pools and fountains, 2000 V3: 108
scalding water, 1999 V2: 169–170
shower compartments, 2004 V1: 120, 2003 V4: 15
swimming pools, 2000 V3: 129, 139
water heaters, 1999 V2: 157, 160
water toys, 2000 V3: 128
water treatment
aeration, 1999 V2: 292–294
aluminum sulfate, 2000 V3: 149–150
boiler feed water, 1999 V2: 314–315
clarification, 1999 V2: 294
codes and standards, 1999 V2: 279
cooling towers, 1999 V2: 315–316
corrosion inhibitors, 2004 V1: 151
deaeration, 1999 V2: 294–295
dealkalizing, 1999 V2: 295
decarbonation, 1999 V2: 295
defined, 1999 V2: 279
distillation, 1999 V2: 295–298
drinking water, 1999 V2: 316–317, 318
filtration, 1999 V2: 298, 300
fountains and pools, 2000 V3: 107, 112, 122–124
ion-exchange and removal, 1999 V2: 300–308
membrane filtration and separation, 1999 V2: 300, 308–311
microbial control, 1999 V2: 311–313
references, 1999 V2: 325
swimming pools, 2000 V3: 130, 140, 146
utility water treatment, 1999 V2: 313–314
water impurities, 1999 V2: 280–284
water purification, 1999 V2: 317–325
water softening, 1999 V2: 307
Water Treatment for HVAC and Potable Water Systems, 1999 V2: 325
Water Use in Office Buildings, 1999 V2: 34
Water: Use of Treated Sewage on Rise in State, 1999 V2: 34
Water-Use Reduction Credit, 2004 V1: 264
Water Uses Study, 1999 V2: 34
water utility letters, 2000 V3: 216
water vapor in air, 2000 V3: 200–201, 201
water wells. *See* wells
waterborne radioactive waste (radwaste), 1999 V2: 337
waterfall aerators, 1999 V2: 293
waterfalls, 2000 V3: 108, 109
waterfront facilities, 1999 V2: 147
waterless urinals, 2004 V1: 136, 265, 2003 V4: 10
waterproof manholes, 2000 V3: 236, 239
waterproofing drains, 1999 V2: 17, 79
watertight joints, 2003 V4: 26
watt-hours (Wh, WH), 2004 V1: 16
watts (W, WAT)
converting to SI units, 2004 V1: 40
measurement conversions, 2004 V1: 33
symbols for, 2004 V1: 16
W/m K (watts per meter per kelvin), 2004 V1: 33
wave actions in water (tsunamis), 2004 V1: 158
wave pools, 2000 V3: 128
wax ring seals, 2003 V4: 6
WAZ (wall azimuth), 2004 V1: 14
wb, WB (wet bulbs), 2004 V1: 16
Wb (webers), 2004 V1: 33
wbt, WBT (wet-bulb temperature), 2004 V1: 16
wc (water column), 2003 V4: 5
WCO (wall cleanouts), 2004 V1: 11
WD (wind). *See* wind
wdir, WDIR (wind direction), 2004 V1: 16
weak-base regeneration, 1999 V2: 302, 305
weakly-acidic resins, 1999 V2: 308
weakly-basic resins, 1999 V2: 308
weather conditions, 2004 V1: 98, 2000 V3: 100, 105, 165, 219
webers, 2004 V1: 33
weep holes, 1999 V2: 17, 2000 V3: 144, 2003 V4: 15
weight (wt, WT)
clean agent gas fire containers, 2000 V3: 23
horizontal loads of piping, 2004 V1: 184
piping, earthquake protection and, 2004 V1: 167
in seismic force calculations, 2004 V1: 183
swimming pool filtration equipment, 2000 V3: 140
symbols for, 2004 V1: 16
weight loss in corrosion, 2004 V1: 144
weight to weight (w/w), 1999 V2: 285
weighted evaluations in value engineering, 2004 V1: 243
weighted runoff coefficients, 1999 V2: 97
weirs
flow rates, 2000 V3: 109
materials, 2000 V3: 146
sizing, 1999 V2: 93
swimming pools, 2000 V3: 142
water return in, 2000 V3: 119–120
waterfall rates and, 2000 V3: 108
welded steel piping, 2003 V4: 48
welding
clearance for, 2003 V4: 25
corrosion and, 2004 V1: 146
earthquake protection techniques, 2004 V1: 167
problems in seismic protection, 2004 V1: 190
weld decay defined, 2004 V1: 154
welded fittings, 2004 V1: 24
welded joints in radioactive waste systems, 1999 V2: 341

well screens, 2000 V3: 119–120
wells
  bored wells, 1999 V2: 241
  driven wells, 1999 V2: 241
  dug wells, 1999 V2: 240
  equilibrium equations for wells, 1999 V2: 242–243
  fire-protection connections, 2000 V3: 225
  gray-water irrigation systems and, 1999 V2: 26
  hydraulics of, 1999 V2: 241
  initial operation and maintenance, 1999 V2: 252
  introduction, 1999 V2: 240
  irrigation usage, 2000 V3: 105
  jetted wells, 1999 V2: 241
  matching water storage to pump flow, 1999 V2: 248
  monitoring fumes, 2000 V3: 162
  monitoring groundwater, 2000 V3: 162
  pipe installation, 1999 V2: 250–252
  protection of, 1999 V2: 243
  pumps, 1999 V2: 245–247
  swimming pool supplies, 2000 V3: 131
  system equipment, 1999 V2: 245–250
  water demand and, 1999 V2: 243–244
  water quality, 1999 V2: 244–245
wet-alarm valve risers, 2000 V3: 9, 10
wet-bulb temperature (wbt, WBT), 2004 V1: 16
wet bulbs (wb, WB), 2004 V1: 16
wet-cast pipe, 2003 V4: 32
wet floors in chemical plants, 1999 V2: 346
wet gas, 2000 V3: 250
wet-niche pool lighting, 2000 V3: 145
wet-pipe systems, 2004 V1: 29, 2000 V3: 9
wet pits, 2000 V3: 142
wet returns, 2000 V3: 179
wet standpipes, 2004 V1: 30
wet surfaces, 2004 V1: 16
wet-tap excavations, 2000 V3: 222
wet vacuum-cleaning systems (WVC)
  defined, 1999 V2: 266
  illustrated, 1999 V2: 276
  pitch, 1999 V2: 277
  separators, 1999 V2: 268
  symbols for, 2004 V1: 9
wet venting
  bathroom groups, 1999 V2: 43
  combination waste and vent systems, 1999 V2: 45–46
  defined, 2004 V1: 31, 1999 V2: 64
  illustrated, 1999 V2: 49
Weymouth formula, 2004 V1: 7, 1999 V2: 183, 190, 191, 198–209
WFI (water for injection), 1999 V2: 317, 320, 321, 324
WH (wall hydrants), 2004 V1: 10, 12
Wh, WH (watt-hours), 2004 V1: 16
WHA (water hammer arresters). *See* water hammer arresters
What Future Role for Pressure Sewers?, 1999 V2: 238
wheel loads in pipe selection, 2003 V4: 26
wheelchairs
  adult-sized, dimensions, 2004 V1: 108
  anthropometrics for wheelchairs, 2004 V1: 109
  approaches and reaches, 2004 V1: 110
  clear space for, 2004 V1: 109
  toilet and bathing rooms, 2004 V1: 112–113
wheeled fire extinguishers, 2000 V3: 19, 27
WHEN relationship, 2004 V1: 230
whirlpool bathtubs, 2003 V4: 16
White, George Clifford, 1999 V2: 155
Whitney, Eli, 2004 V1: 231
WHY logic path, 2004 V1: 230, 231, 258
WI (width), 2004 V1: 16
wide seepage beds, 1999 V2: 225
width (WI), 2004 V1: 16
wind (WD)
  direction (wdir, WDIR), 2004 V1: 16
  effect on irrigation sprinklers, 2000 V3: 102
  fountains and, 2000 V3: 115, 120–121
  gas appliances and, 1999 V2: 178
  reflecting pools and, 2000 V3: 108
  speed and heat loss, 2000 V3: 121
  symbols for, 2004 V1: 16
  velocity, 2004 V1: 16
  vent stack terminals and, 1999 V2: 36
  wind pressure (wpr, WPR, WP, WPRES), 2004 V1: 16
withstand for hot-water systems, 1999 V2: 166
WO (waste oil), 2004 V1: 8
WOG (water, oil, and gas pressure rating), 2000 V3: 210
wood shrinkage, protecting against, 1999 V2: 19
wood stave piping, 1999 V2: 122
Woodcock, J.J., 1999 V2: 34
word processing of specifications, 2004 V1: 71–72
work
  conversion factors, 2004 V1: 35
  converting to SI units, 2004 V1: 39
  defined, 2004 V1: 61
  measurements, 2004 V1: 33
work change directives, 2004 V1: 63
work functions in value engineering, 2004 V1: 225, 243
working deionizers, 1999 V2: 301, 302
working hours, in cost estimation, 2004 V1: 98
working pressure
  fuel gas, 1999 V2: 212
  in pipe selection, 2003 V4: 26
  relief valves and, 1999 V2: 167
  vacuum systems, 1999 V2: 259, 262
workmanship standards, 2004 V1: 66
workmen's compensation, in labor costs, 2004 V1: 94
worksheets. *See* checklists and forms
worst case possibilities, radiation and, 1999 V2: 341
worth, defined, 2004 V1: 213
WOV (waste oil vents), 2004 V1: 8
WP (wind pressure), 2004 V1: 16
wpr, WPR (wind pressure), 2004 V1: 16
WPRES (wind pressure), 2004 V1: 16
wrapped piping
  plastic-wrapped steel piping, 1999 V2: 196
  sound damping, 2004 V1: 196, 201–202
  wrapped storm piping, 1999 V2: 68
wrist blades on faucets, 2000 V3: 33
written amendments, 2004 V1: 63
Wrought Copper and Copper Alloy Solder-Joint Pressure Fittings, 2003 V4: 37
Wrought Copper and Wrought Copper Alloy Solder-Joint Drainage Fittings, 2003 V4: 45
Wrought Copper Braze Fittings, 2003 V4: 45
wrought iron piping, 1999 V2: 122, 176, 196

wt, WT (weight). *See* weight
WVC (wet vacuum cleaning). *See* wet vacuum-cleaning systems
wyes
  avoiding suds formation, 1999 V2: 37
  sovent systems, 1999 V2: 61
  water closet installation, 2003 V4: 6–7
Wyly, R.S., 1999 V2: 4, 19, 65

X

x-ray areas, 2000 V3: 39, 51
x-rays, 1999 V2: 337
X#A (compressed air). *See* compressed air (A, X#, X#A)
XH (extra heavy) cast iron soil pipe, 2003 V4: 29–30
XH (extra heavy) cast-iron soil pipe, 2003 V4: 27
XP explosion-proof construction, 1999 V2: 179
XP junction boxes, 1999 V2: 179
XPAN (expansion. *See* expansion

Y

y (years), 2004 V1: 16, 34
y-type strainers, 2000 V3: 116
yards (yd, YD)
  converting to SI units, 2004 V1: 40
  symbols for, 2004 V1: 16
yards and lawns
  lawn imperviousness factors, 2000 V3: 243
  lawn sprinkler supply (LS), 2004 V1: 8
  sprinkler systems (irrigation)
    lawn sprinklers, 1999 V2: 121
  storm-drainage systems and, 1999 V2: 67
  yard cleanouts (CO), 2004 V1: 11
YB (valves in yard boxes), 2004 V1: 10
yd, YD (yards), 2004 V1: 16, 40
year-round pools, 2000 V3: 129
years (yr, YR), 2004 V1: 16, 34
Yeh, K.L., 1999 V2: 325
yellow brass, 2004 V1: 144
yoke vents, 2004 V1: 31
Young, Virgil E., 2000 V3: 105
yr, YR (years), 2004 V1: 16, 34
Yrjanainen, Glen, 1999 V2: 114

Z

z, Z (zones), 2004 V1: 16, 183
Zelmanovich, Y., 1999 V2: 325
zeolite process, 1999 V2: 244
zeolites, 1999 V2: 302
zero-flow potential, 2004 V1: 153
zero governors, 2000 V3: 251
zeta potential, 1999 V2: 294
zinc
  anodes, 2004 V1: 150
  corrosion, 2004 V1: 139
  electromotive force series, 2004 V1: 144
  galvanic series, 2004 V1: 141
zirconium, 2000 V3: 20
ZN (zones), 2004 V1: 16, 183
zone valves, 2000 V3: 49, 71
zones (z, Z, ZN)
  in seismic force calculations, 2004 V1: 183
  symbols for, 2004 V1: 16