Table of Contents

Chapter | Introduction to CMOM |

- 1.1 Collection System Performance 2
- 1.2 Framework for Effective Collection Systems 5
- I.2.I Program Goals 7
- **1.2.2** Safety 7
 - 1.2.2.1 Collection System Hazards 9
 - 1.2.2.2 Injuries and Illnesses 11
 - 1.2.2.3 Equipment 19
- **1.2.3** Maintenance and Communication Responsibilities 20
 - 1.2.3.1 Communications and Notifications 211.2.3.2 Complaints and Public Relations 22
- 1.2.4 Legal Authority 22
- 1.2.5 Structures and Activities 23
 - 1.2.5.1 Maintenance Facilities and Equipment 23
 - 1.2.5.2 Collection System Map 23
 - 1.2.5.3 Timely, Relevant Information 24
 - 1.2.5.4 Routine Preventive Operation and Maintenance Activities 24
 - 1.2.5.5 Capacity Assessment 25
 - 1.2.5.6 Rehabilitation of Capacity and Structural Deficiencies 27
 - 1.2.5.7 Training 28
 - 1.2.5.8 Equipment and Replacement Parts Inventories 28
- 1.2.6 Design and Performance Standards 29
- 1.2.7 Monitoring, Measurement, and Modifications 29

1.3 Additional Resources 30

Chapter Review 31

Chapter 2 Lift Stations 33

2.1 Pumping Facilites 34

- 2.1.1 Location 34
- **2.1.2** Types of Lift Stations 35
 - 2.1.2.1 Submersible Lift Stations 36
 - 2.1.2.2 Suction Lift Stations 37
 - 2.1.2.3 Dry Pit Lift Stations 37
- **2.1.3** Lift Station Requirements 42 **2.1.3.1 Flow 49**
 - 2.1.3.2 Head 49

2.2 Lift Station Components 51

- **2.2.1** Wet Wells 52 2.2.1.1 Dimensions 52 2.2.1.2 Flow Distribution 54 2.2.1.3 Operating Levels 54 2.2.1.4 Access 56 2.2.1.5 Inlet Channel 56 2.2.1.6 Safety 57 2.2.1.7 Hardware 57 2.2.1.8 Electrical Systems 57 2.2.2 Bar Racks 58 2.2.3 Dry Pits 60 2.2.4 Electrical Systems 60 2.2.4.1 Power Transformers 61 2.2.4.2 Metering 61 2.2.4.3 Main Disconnect 61 2.2.4.4 Transfer Switch 61 2.2.4.5 Motor Control Center 64 2.2.4.6 110- and 220-Volt Loads 64
 - 2.2.4.7 Control Systems 65

2.2.5 Motors 65 2.2.5.1 Nameplate Data 68 2.2.5.2 Power Supply 71 2.2.5.3 NEMA Letter Designations 71 2.2.5.4 Enclosure 72 2.2.5.5 Motor Windings and Insulation 72 2.2.5.6 Altitude 73 2.2.5.7 Motor Mounting 73 2.2.5.8 Thermally Protected Motors 73 2.2.5.9 Service Factor 73 2.2.5.10 Motor Starting Devices and Methods 74 **2.2.6** Wet Well Level Measurement 77 2.2.6.1 Float Switches 78 2.2.6.2 Air Bubbler Systems 78 2.2.6.3 Electrode Sensor 79 2.2.6.4 Submersible Pressure Transducer 81 2.2.6.5 Ultrasonic Transducer 81 2.2.6.6 Other Controllers 81 2.2.6.7 SCADA Systems 82 2.2.7 Pumps 83 2.2.7.1 Centrifugal Pumps 85 2.2.7.2 Pump Layouts 85 2.2.7.3 Pump Components 88 2.2.7.4 Basic Pump Hydraulics 95 2.2.7.5 Sump Pump 98 2.2.8 Valves 98 2.2.8.1 Gate Valves 98 2.2.8.2 Plug Valves 100 2.2.8.3 Check Valves 101 **2.2.9** Ventilation and Auxiliary Equipment 103 2.3 New Lift Stations 105 **2.3.1** Plan Review 106 2.3.2 Reading Specifications 106 **2.3.3** Preliminary Assessment 107 2.3.4 Startup and Performance Verification 108 2.3.4.1 Pumps and Motors 108 2.3.4.2 Instrumentation and Controls 116 2.3.4.3 Screening and Grit Removal

Systems 117

2.4 Operation 118

- 2.4.1 Routine Inspections 118
- **2.4.2** Alarm Notifications 121

2.4.3 Odor Troubleshooting 122

2.5 Maintenance 124

- 2.5.1 Computerized Maintenance Management System 124
 2.5.1.1 CMMS Integration with SCADA Systems 127
- 2.6 Recordkeeping 129

Chapter Review 131

Chapter 3

- Equipment Maintenance 135
- 3.1 Maintenance Program 136
- 3.2 Lockout/Tagout Procedures 137

3.3 Electricity and Electrical Equipment 138

3.3.1 Understanding Electricity 140 3.3.1.1 Volts 140 3.3.1.2 Amps 140 3.3.1.3 Direct Current 141 3.3.1.4 Alternating Current 141 3.3.1.5 Power 142 3.3.1.6 Energy Requirements 143 3.3.1.7 Conductors and Insulators 143 **3.3.2** Meters and Testers 143 3.3.2.1 Multimeter 144 3.3.2.2 Ammeter 146 3.3.2.3 Megger 151 3.3.2.4 Ohmmeter 153 3.3.2.5 Motor Rotation Indicator 153 **3.3.3** Electrical System Equipment 153 3.3.3.1 Protective Devices 154 3.3.3.2 Fuses 156 3.3.3.3 Circuit Breakers 158 3.3.3.4 Ground 160 3.3.4 Motor and Supervisory Control Systems 164 3.3.4.1 Aluminum and Copper 165

3.4 Motors 166

- **3.4.1** Nameplate Data 168
- **3.4.2** Causes of Failure 168

3.4.3 Insulation 168

3.4.3.1 Increasing Resistance Value 169

3.4.4 Starters 169
3.4.5 Maintenance 179

3.4.5.1 Alignment 179
3.4.5.2 Correcting Rotation Direction 180
3.4.5.3 Allowable Deviations 180
3.4.5.4 Maximum Vibration Levels 182
3.4.5.5 Lubrication 182

3.4.6 Troubleshooting 183

3.5 Pumps 184

- 3.5.1 Centrifugal Pumps 187
- **3.5.2** Screw Pumps 193
- 3.5.3 Pneumatic Ejectors 195
- 3.5.4 Piston Pumps 197
- 3.5.5 Close-Coupled Pumps 198
- **3.5.6** Submersible Pumps 199
- **3.5.7** Trash Pumps 201
- **3.5.8** Diaphragm Pumps 203
 - 3.5.8.1 Pneumatic Pumps 205
- **3.5.9** Pump Components 206
 - 3.5.9.1 Impellers 207
 - 3.5.9.2 Shafts 210 3.5.9.3 Packing 213
 - 3.5.9.4 Mechanical Seals 218
 - 3.5.9.5 Bearings 221
 - 3.5.9.6 Direct-Coupled 225
 - 3.5.9.7 Belt-Driven 226
- 3.5.9.8 Flexible Shafting 228 3.5.10 Preventive Maintenance 229
- 3.5.10.1 Pump Controls 234

3.6 Compressors 234

3.7 Lubrication 237

- 3.7.1 Lubricant Properties 237
- **3.7.2** Schedule 239
- 3.7.3 Precautions 240
- **3.7.4** Procedures 240
- 3.7.5 Final Cleanup and Inspection 241

3.8 Records 241

3.8.1 Maintenance Scheduling with CMMS 243

3.9 Additional Resources 245

Chapter Review 246

Chapter 4 Rehabilitation 249

4.1 Program Development 250

- **4.1.1** Program Definition 250
- 4.1.2 Implementation 258

4.2 Evaluating Conditions 258

- 4.2.1 System Problems 258
- 4.2.2 Cross Bores 259
- **4.2.3** Flow Monitoring 260

4.2.3.1 Smoke and Dye Testing 267

4.2.4 Structural Aspects 270

4.3 Using the Data 275

- **4.3.1** Preliminary Statement of Needs 275
- 4.3.2 Cost Analysis 275
 - 4.3.2.1 Consequences of Failure 276
 - 4.3.2.2 Capital Costs of
 - Repair Alternatives 277
 - 4.3.2.3 Setting Priorities 278
- 4.3.3 Cost-Effectiveness Analysis 278

4.4 Methods of Rehabilitation 279

- 4.4.1 Excavation and Replacement 279
- 4.4.2 Chemical Grouting 283
- 4.4.3 Trenchless Technology 286
 - 4.4.3.1 Cured-In-Place Pipe 288
 - 4.4.3.2 Spray-On Lining 296
 - 4.4.3.3 Sliplining 297
 - 4.4.3.4 In-Line Replacement 300
 - 4.4.3.5 Deformed and Reshaped 301
- **4.4.4** Polyethylene Pipe Lining 302
 - 4.4.4.1 Preliminary Work 303
 - 4.4.4.2 Equipment 303
 - 4.4.4.3 Main Lines 303
 - 4.4.4 Service Laterals 307
 - 4.4.4.5 Sealing 309
 - 4.4.4.6 Thank the Public 309

- **4.4.5** Service Connections 310
 - 4.4.5.1 Infiltration Through Service Connections 310

4.5 Manholes 311

- 4.5.1 Chimney Seals 314
- 4.5.2 Coatings 317

Chapter Review 323

Chapter 5

Management 327

5.1 Managing Utilities 328

- 5.2 Planning 330
- 5.3 Organizing 331

5.4 Staffing 335

- 5.4.1 Workforce Analysis 335 5.4.1.1 Types of Crews 337
 - 5.4.1.2 Management and Support Staff 342
- **5.4.2** Qualifications Profile 346
- **5.4.3** Applications and the Selection Process 346
- 5.4.4 New Employee Orientation 350
- 5.4.5 Employment Policies and Procedures 351
 - 5.4.5.1 Probationary Period 351
 - 5.4.5.2 Compensation 351
 - 5.4.5.3 Training and Certification 352
 - 5.4.5.4 Performance Evaluation 353
 - 5.4.5.5 Dealing with Disciplinary Problems 356
 - 5.4.5.6 Example Policy: Harassment 358
 - 5.4.5.7 Labor Laws Governing Employer/ Employee Relations 363
 - 5.4.5.8 Personnel Records 364
- 5.4.6 Unions 364

5.5 Communication 365

- **5.5.1** Oral Communication 366
- **5.5.2** Written Communication 366

5.6 Conducting Meetings 369

5.7 Public Relations 370

- 5.7.1 Establish Objectives 370
- **5.7.2** Utility Operations 370
- **5.7.3** Mass Media 371
- 5.7.4 Being Interviewed 371
- **5.7.5** Public Speaking 372
- 5.7.6 Telephone Contacts 372
- 5.7.7 Consumer Inquiries 373
- **5.7.8** Facility Tours 374

5.8 Financial Stability 375

- 5.8.1 Measuring Stability 376
- **5.8.2** Rate Setting 377
- **5.8.3** Capital Improvement Program 378
- 5.8.4 Government Accounting Standards 380

5.9 Safety Program 381

- **5.9.1** Benefits 381
- **5.9.2** Establishing a Safety Program 382
- 5.9.3 Safety Meetings 385 5.9.3.1 Monthly Safety Meetings 386
- 5.9.4 Safety Committee 387
- **5.9.5** Written Safety Program 387
- **5.9.6** Program Policies and Standards 388
 - 5.9.6.1 Confined Space 389
 - 5.9.6.2 Hazardous Energy Control 395
 - 5.9.6.3 Personal Protective Equipment 402
 - 5.9.6.4 Records and Reporting 406

5.10 Security and Resilience 408

5.10.1 Emergency Preparedness 411

5.11 Collection System Evaluation 412

- 5.11.1 Flow Monitoring 412
- **5.11.2** Manhole Inspection 413
- **5.11.3** Pipeline Cleaning Related to I/I Reduction 414
- 5.11.4 Internal CCTV Inspection 414
- 5.11.5 Smoke Testing and Dyed Water Flooding 414
- 5.11.6 Performance Indicators 416

5.12 Level of Service 422

5.12.1 Economic Approach to Selecting Level of Service 423

5.13 CMOM Program 425 **5.13.1** Capacity Assurance 425 5.13.1.1 Rehabilitation 427 **5.13.2** Management 427 5.13.2.1 Organizational Structure 428 5.13.2.2 Training Program 448 5.13.2.3 Internal Communication 448 5.13.2.4 Customer Service 449 5.13.2.5 Information Management Systems 449 5.13.2.6 SSO Notification Program 452 5.13.3 Legal Authority 453 **5.13.4** Operation 454 5.13.4.1 Budgeting 454 5.13.4.2 Monitoring 456 5.13.4.3 Hydrogen Sulfide Monitoring and Control 457 5.13.4.4 Safety Program 458 5.13.4.5 Emergency Preparedness and Response 459 5.13.4.6 Hydraulic Modeling 461 5.13.4.7 Mapping 461 5.13.4.8 Construction 471 5.13.4.9 Lift Stations 472 5.13.5 Maintenance 473 5.13.5.1 Budgeting Maintenance 474 5.13.5.2 Proactive and Reactive Maintenance 474 5.13.5.3 Pipeline Cleaning 475 5.13.5.4 Parts and Equipment

5.14 Additional Resources 478

Inventory 476

Chapter Review 479

Appendix A

Introduction to Basic Math for Operators 485

Introduction 486

Basic Concepts (Sections A.1–A.4) 487

A.1 Numbers and Operations 487

- A.I.2 Subtraction 487
- A.I.3 Multiplication 488
- A.I.4 Division 488
- A.2 Order of Operations 488
- A.2.1 More on Exponents 492
- A.3 Basic Algebra (Solving Equations) 492
- A.4 Percentages 495

Intermediate Concepts (Sections A.5-A.6) 498

A.5 Units 498

- A.5.1 Distance or Length 498
- A.5.2 Area 499
 - A.5.2.1 Surface Area of a Rectangle 499
 - A.5.2.2 Surface Area of a Triangle 500
 - A.5.2.3 Surface Area of a Trapezoid 501
 - A.5.2.4 Surface Area of a Circle 501
 - A.5.2.5 Surface Area of a Cylinder 502
 - A.5.2.6 Surface Area of a Cone 503
 - A.5.2.7 Surface Area of a Sphere 504
- A.5.3 Volume 504
 - A.5.3.1 Cube 505
 - A.5.3.2 Rectangular Prism 505
 - A.5.3.3 Triangular Prism 506
 - A.5.3.4 Cylinder 506
 - A.5.3.5 Cone 507
 - A.5.3.6 Sphere 507
- A.5.4 Mass and Weight 507
- A.5.5 Density, Specific Weight, and Specific Gravity 508
- A.5.6 Concentration 508
- A.5.7 Velocity and Flow Rate 510
- A.5.8 Force and Pressure 512
- A.5.9 Work, Head, and Power 517

A.6 Metric System 520

- A.6.1 SI Base Units 520
- A.6.2 Measures of Length 522
- A.6.3 Measures of Capacity or Volume 522
- A.6.4 Measures of Weight 522
- A.6.5 Temperature 523

Adv	anced Concepts (Sections A.7–A.8) 524
A.7	Pumps 524
A.7. I	Pressure 524
A.7.2	Work 525
A.7.3	Power 526
A.7.4	Horsepower 526
A.7.5	Head 530
A.7.6	Pump Characteristics 532
A.7.7	Evaluation of Pump Performance 534
	A.7.7.1 Capacity 534
	A.7.7.2 Efficiency 535
A.7. 8	Pump Speed–Performance Relationships 538
A. 7.9	Friction or Energy Losses 539
A.8	Analysis and Presentation of Data 543

A.8.1 Causes of Variations in Results 543 A.8.1.1 Water or Material Being Examined 544

A.8.1.2 Sampling 544 A.8.1.3 Testing 544 **.8.2** Controlling Variation 544 A.8.2.1 Reading Charts 546 **.8.3** Describing Data or Results 546 A.8.3.1 Graphs and Charts 547 A.8.3.2 Numerical Representation of Data 552 .8.4 Moving Averages 559 **.8.5** More Applications of Graphs 561 A.8.5.1 Volume of Sludge in a Digester 561 A.8.5.2 Tracking BOD Loading 564 **.8.6** Regression Analysis (Prediction Equations, Trends, and Correlations) 566 A.8.6.1 Correlations 571 Answer Key 573 Glossary 575 Index 601

Index

The letter f following a page number denotes a figure and the letter t following a page number denotes a table.

Α

Aboveground pump station with fiberglass-reinforced plastic enclosure, 40, 41 AC. See Alternating current (AC) Accident investigation and reporting, 459 Accountability, 331 Acrylamide grouts, 285-286 Acute health effect, 9 Aeration, 43 and oxygen injection, 122 systems, 55-56 Aerobic, 123 Air bubbler systems, 78–79 Air compressors, 19 Air gap, 92, 342 Air inversion system for service laterals, 290f Air release valve, 45, 46 Air-sensing (pneumatic) controllers, 79 Air testing crew, 341 Alarm floats, 57 Alarm notifications, 121-122 Algebra, 492-495 Alignment, 179-180 testing methods, 180, 181 Alternating current (AC), 65, 141-142 motor temperature limits, 170 Alternating current motors, 66 Altitude, 73 Aluminum, 154, 165-166 American National Standard for Industrial Head Protection (ANSI ISEA Z89.1), 405 Americans with Disabilities Act of 1990 (ADA), 335, 363 Ammeter, 146-151 Amperage, 140-143, 146, 147, 157, 200 Amperes (amps), 70, 140-142, 149-150, 160, 169 Amplitude, 141, 182 Anaerobic, 122 Anaerobic decomposition, 16 Anaerobic digestion, 44 Analog, 65 Annular space, 287 Anti-Friction Bearing Manufacturers' Association (AFBMA), 70 Anti-harassment policy checklist, 359f Appurtenances, 25, 311 Arithmetic mean/average, 552 Asset inventory, 456

Asset management, 2, 329 Authority, 331 Auto-transformer starting, 75 Auto-transformer-type reduced-voltage starters, 171–172 Awareness of the hazards associated with collection system, 11

В

Backfill compaction, 309 Backfilling, 294, 294f Backflow, 83, 262 Backflow device, 93, 342 Backflushing, 47 Backhoe, 303 Backsiphonage, 98 Bacteria, 13, 14 Baffle, 54 Balling crews, 341-342 Bar racks, 58-60 Bearings, 146, 188, 199, 221-225 Belt-driven, 226-228 Bites, 18 Block map, 468, 468f Blower, 57 Brake horsepower (BHP), 97, 527-528, 536-537 Brinelling, 221-223 Bucket machine crew, 338-339 Budgeting, 454-456 equipment repair and replacement fund, 456 maintenance, 474 Bypass, 58

С

Cable-attached controllers, 81 Call date, 379 Camera-packer, 311 Capacity assessment, 25–27 Capacity assurance plan, 26, 27 Capacity, management, operation, and maintenance (CMOM) program. *See* CMOM (capacity, management, operation, and maintenance) program Capacity measurement, 522 Capital improvement program, 378–380 Cardiopulmonary resuscitation (CPR), 392 Cast-in-place lift station

with an aboveground structure, 40, 45 plan view, 40, 44 section view, 40, 43 Cavitation, 51, 97-98, 190, 191, 208, 210 Celsius scale, 523 Central tendency, 552-556 Centrifugal pumps, 37, 85, 184, 187-193, 201. 532 Certification examinations, 352 Charts, 547-552 Check valves, 101-103 Chemical grouting, 317f Chemical oxygen demand (COD) test, 566-570 Chemical treatment crews, 339 Chimney seals, 314-317, 315f-317f Christy box, 308 Chronic health effect, 9 Circuit breakers, 37, 158-160 DC, 142 ground-fault, 139 motor, 156 resistance, 140 three-phase, 146 Clapper-type check valve, 103 Cleanout installation, in service laterals, 308-309 Cleanouts, 260 Close-coupled pumps, 86, 87, 198-199 Closed-circuit television crew, 340-341 CMMS. See Computerized maintenance management system (CMMS) CMOM (capacity, management, operation, and maintenance) program, 2, 5-6, 425-478 capacity assurance, 425-427 legal authority, 453-454 maintenance, 473-478 budgeting, 474 parts and equipment inventory, 476-478, 478f pipeline cleaning, 475-476 proactive and reactive, 474-475 management, 427-453 customer service, 449 information management systems, 449-452 internal communication, 448 SSO notification program, 452-453 training program, 448 operation, 454-473

CMOM program (continued) budgeting, 454-456 construction, 471-472 emergency preparedness and response, 459-461 hydraulic modeling, 461 hydrogen sulfide monitoring and control, 457-458 lift stations, 472-473 mapping, 461-471 monitoring, 456-457 safety program, 458-459 operators, 7 organizational structure, 428-447, 429f, 430t inspection and investigation section, 441-444, 446, 447f lift station operation and maintenance section, 438-441, 440f, 442f-446f repair and replacement section, 436–438, 437f service request response and preventive maintenance section, 431-436, 432f, 435f program goals, 7 program performance indicator, 30 Collection system, 250, 270 evaluation, 26, 412-422 dyed water flooding, 414-416 flow monitoring, 412-413 internal CCTV inspection, 414, 415f manhole inspection, 413-414 performance indicators, 416-422, 420f pipeline cleaning, I/I reduction, 414 smoke testing, 414–416 map, 23-24 performance, 2-5 equipment and tools, 19 factors, 3-4 hazards, 9-10 injuries and illnesses, 11-19 safety, 7-19 Color-coded work order schedule, CMMS, 125, 126 Combination air release and vacuum relief valve, 46-47 and cleanout manhole on force main, 46, 48f Combined collection system, 5 Combined sewer overflow (CSO), 2, 250 environmental effects of, 4 Comminutor, 58 installation, 58, 59 Communication, 21, 365-369 internal, 448 oral, 366 written, 366-369, 369t Competent person, 388t Complaints, 22 Compressors, 234-237 Computer-aided design (CAD), 257

Computerized data management system, 414 Computerized maintenance management system (CMMS), 20, 24, 119, 124-128, 144, 164, 241, 243-245, 257, 344, 450-452, 451f, 452f integration with SCADA systems, 127, 128 Concrete cut-off saws, 19 Conductors, 143, 149, 157-163, 178 Cone, volume of, 507 Confined space, 17, 37, 389-391 emergency rescue personnel, 393-395 non-permit, 391 permit required, 388t, 389-391 permit system, 391-392 training and education, 392, 393t tripod rescue and retrieval systems for, 394f Construction crew, 339 Continuous high-density polyethylene pipe, 297-298 Control systems, 65, 66 Contusions, 15 Copper, 165-166 Corbel/grade ring repair, 316f Corrective maintenance, 475 Correlation coefficient, 571–572 Corrosion, 3, 37, 154, 158, 161, 192, 213, 230, 270 Cost analysis, in rehabilitation program, 275-278 capital costs of repair alternatives, 277 consequences of failure, 276-277, 277t setting priorities, 278 Cost performance indicator, 418-419 Coverage ratio, 376, 377 Crew types, 337-342 Cross-connection, 229 CSO (combined sewer overflow), 2 environmental effects of, 4 Cube, 505 Cured-in-place pipe (CIPP), 287-296, 289f, 290f, 294f advantages, 291 inversion process, 291-295 limitations of, 291 winched cable placement, 295-296 Current, 140 Customer service, 449 Cycle, 141, 154, 183, 206, 236 Cylinder, volume of, 506

D

Dangerous air contamination, 389 DC. *See* Direct current (DC) Debris caught on bar rack, 58 Defective joint leak, 266f Delegation, 331 Density, 508 Depreciation, 379 Design and performance standards, 29 Detention time, 53 Dewater, 184 Diaphragm pumps, 203-205 pneumatic, 205-206 Digital, 65 Direct-coupled pumps and motors, 225-226 Direct current (DC), 65, 141, 144, 159 Diseases and modes of transmission, 14 Dispersion (spread), 556-559 Dot diagrams, 550 Double mechanical seal, 93 Double row thrust bearings, 88 Drawdown method, 302 Drowning, 19 Dry pit lift stations, 37-45 Dry pits, 60 Dry well, 35 Duplex submersible pumping station, 37, 38 Dyed water flooding, 269-270, 414-416 Dye testing, 269-270, 271f Dynamic heads, 49, 50

E

Eccentric plug valve, 100, 101 Electrical control panels, motors, ventilation equipment, 60 Electrical hazards, 19 Electrical system equipment circuit breakers, 158-160 fuses, 156-158 ground, 160-163 protective devices, 154-156 Electrical systems, 57, 60-65 Electricity and electrical equipment AC, 141-142 amps, 140-141 conductors and insulators, 143 DC, 141 energy requirements, 143 power, 142-143 volts, 140 Electrode sensors, 79-81 Electromotive force (EMF), 140-142 Electron, 140, 141, 243, 244 Emergency maintenance, 136, 475 EMF. See Electromotive force (EMF) Energy-isolating devices, 137, 138, 396, 399-400 Energy losses, 539-542, 540f, 541f Energy requirements, 143 Engine-driven pumps, 19 Engulfment, 389 Entrain, 44 Equal Employment Opportunity (EEO) Act, 335, 363 Equipment and replacement parts inventories, 28

Equipment maintenance alignment, 179-180 allowable deviations, 180-182 compressors, 234-237 electricity and electrical equipment, 138-143 lockout/tagout, 137-138 lubrication, 237-241 maximum vibration levels, 182-183 mechanical maintenance, 136 meters and testers, 143-153 records, 241-245 rotation direction, 180 schedules and plans, 136 troubleshooting, 183-187 Excavation, 18-19 Excavation and replacement method, 279-283, 280f-283f Exfiltration, 3, 261 Explosion-proof, 72 Explosions in collection systems, 15-16 External manhole chimney seal, 316, 316f Eye protection policy, 403-404, 403f

F

Face protection, 403-404 Fahrenheit scale, 523 Falling objects, 12 Fall protection equipment, 56 Falls from ladders, 11-12 Family and Medical Leave Act (FMLA), 335, 363 Financial stability, 375-380 capital improvement program, 378-380 Governmental Accounting Standards Board (GASB), 380 rate setting, 377-378 stability measurement, 376-377 Fire hazards, 19 Fire point, 238 Fixed gas detection sensors, 103 Fixtures and alarm floats, 57 Flammability testing, 406 Flash point, 238 Flexible shafting, 228-229 Flexibly coupled, horizontally mounted centrifugal pump, 85 Flexibly coupled, vertically mounted centrifugal pump, 86 Flexibly shafted vertical pump, 86, 87 Float (control), 46 Float switches, 78 Flooding, performance indicators, 417 Flows, pump capacities, 49 Flushing crews, 341-342 Force main, 34 Friction, 539-542, 540f, 541f Friction loss, 51, 96 Fuses, 156-158

G

Gas detection alarm notification system, 104 Gate valves, 98-100 Geographic information systems (GIS), 257, 462, 469-470, 469f Geometric mean, 555-556 Global positioning satellite (GPS), 462 Governmental Accounting Standards Board (GASB), 380 Grade, 297 Graphs, 547-552 applications of, 561-566 tracking BOD loading, 564-566 volume of sludge in digester, 561-563 Gravity flow, 3, 34, 184 Grid coordinate system, 465f Ground, 160-163 Ground-fault circuit interrupter (GFCI), 61 Groundwater measurement, 263 Grouting, 287

н

Hand-off-auto (HOA) switch, 176 Harassment, 358-363, 359f, 360f Harassment reporting system and investigations checklist, 360f Hard hat policy, 405, 405f Hardware, 57 Hazard communication, 382, 383t Hazardous energy control, 395-402, 395f employee training, 401 periodic inspections, 401-402 Head of water, 43 Head protection, 404-406, 405f Head, 190 Health effect acute, 9 chronic, 9 Hearing protection, 19 Hertz (Hz), 61, 141 High-velocity cleaner (HVC), 19, 53, 305 High-velocity cleaner crew, 338 Histograms, 547-549 HMI. See Human-machine interface (HMI) Hobas pipe, 298 Homeland Security Advisory System, 410 Horizontal motors, 179 Horizontal squirrel cage induction motor, 66, 68, 166, 167 Horsepower, 526-530 Human-machine interface (HMI), 64, 164 touch panels, 64 HVC (high-velocity cleaner), 19, 53, 305 Hydraulic cleaning, 476 Hydraulic cleaning machine, 53 Hydraulic modeling, 461 Hydraulic models, 261 Hydrogen sulfide monitoring and control, 457-458

L

Impellers, 49, 95, 187-190, 195, 204, 207 - 211types, 208 Impeller vane tip or discharge cavitation, 97 Induction motor, 66 Industrial waste inspectors, 15 Infections, 13-15 Infectious diseases, 13-15 Infiltration, 3, 250, 260 by service connections, 310-311 Infiltration/inflow (I/I), 4, 25, 49, 258, 260, 267f, 412 Information management systems, 449-452 Ingestion, 13 Inlet channel of larger stations, 56 In-line replacement, 300-301 pipe displacement, 300 pipe removal, 301 Insect, 18 Inspection crews, 340 Insulation, 168-169 ambient operating temperature, 169 classes or levels of insulation, 168-169 hot-spot allowance, 169 resistance value, 169 temperature rise, 169 Insulators, 143 Internal CCTV inspection, 414, 415f Internal communication, 448 Internal manhole chimney seal, 314-316, 315f Inversion lining, 311 Invert, 54 Iron salts addition, 123

J

Jackscrew for external shaft adjustment, 88

L

Labor laws governing employer/employee relations, 363-364 Lacerations and contusions, 15 Lateral-launch technology, 260 Laterals, 259 Lateral surface area, 502 Lead, 141 Legal authority, 22-23 Length measurement, 522 Level-sensing technology, 77 Life-cycle costing, 278 Lift stations, 136, 140, 153, 155, 159, 166, 177, 220, 243 access, 56 alarm notifications, 121-122 components, 51-105

Lift stations (continued) electrical problems, 121 location and design of, 34-35 maintenance, 124-128 maintenance schedule, 442-447 malfunctioning instruments, 121 mechanical failure, 121 new stations, 105-117 odor troubleshooting, 122-123 operation, 118-123 operation and maintenance crew, 340 performance indicators, 421-422 pumping facilities, 34-51 recordkeeping, 129-130 requirements, 42-51 routine inspections, 118-121 types of, 35-42 wet well inlet with automatic bar screen and bypass channel, 58, 60 Lockout, 19, 395, 395f devices, 396, 398f warning tags, typical, 399f Lockout/tagout, 109, 137-138 procedures, 19 Lubrication, 182-183 chart, 239 final cleanup and inspection, 241 precautions, 240 procedures, 240-241 properties, 237-238 schedule, 239

M

Magnetic starters, 171, 172 application of, 171, 172 maintenance, 178 troubleshooting guide, 173-176 wiring diagram of 3-phase magnetic starter, 171-173 Main disconnect switch, 61 Main line, 269 Main line multiple leaks, 266f Main panel, 64 Maintenance facilities and equipment, 23 Maintenance, pump station auxiliary systems, 446f electrical systems, 442f motors, 445f piping, 446f pumps, 444f supervisory control systems, 443f valves, 445f Management CMOM programs, 425-478 collection system evaluation, 412-422 dyed water flooding, 414-416 flow monitoring, 412-413 internal CCTV inspection, 414, 415f manhole inspection, 413-414 performance indicators, 416-422, 420f

pipeline cleaning, I/I reduction, 414 smoke testing, 414-416 communication, 365-369 oral, 366 written, 366-369, 369t conducting meetings, 369 financial stability, 375-380 capital improvement program, 378-380 Governmental Accounting Standards Board (GASB), 380 rate setting, 377-378 stability measurement, 376-377 level of service, 422-424, 424f economic approach to, 423-424 organizing, 331-334, 332f, 333t planning, 330-331 public relations, 370-375 being interviewed, 371 consumer inquiries, 373-374, 373f establish objectives, 370 facility tours, 374-375 mass media, 371 public speaking, 372 telephone contacts, 372 utility operations, 370-371 safety program, 381-408 benefits, 381-382, 382t, 383t confined space, 389-391 establishment, 382-385 hazardous energy control, 395-402, 395f monthly safety meetings, 386, 386t personal protective equipment, 402-406 program policies and standards, 388-408 records and reporting, 406-408, 407f safety committee, 387 safety meetings, 385-386 written document, 387-388, 388t security and resilience, 408-412 emergency preparedness, 411-412 staffing, 335-365 applications and selection process, 346-350, 348t-349t employment policies and procedures, 351-364 new employee orientation, 350 qualifications profile, 346 unions, 364-365 workforce analysis, 335-345 utilities, 328-330, 329t Mandrel, 29, 197, 215, 472 Manholes, 251, 270-271, 311-321, 312f, 313t, 314t, 462-463 channel, 311 chimney seals, 314-317, 315f-317f coatings, 317-321, 318f-321f frame, 311 inspection, 413-414 invert, 311

precast concrete manhole, 312f precast manhole defects, 313t vent, 311 Manning's Formula for simpler systems, 27 Mapping, CMOM programs coordinates, 464-466, 465f geographic information systems, 469-470, 469f preparation and revision, 470-471 type and size of, 467-468, 467f, 468f Mass media, 371 Master maps, 467 Math for operators, 486 algebra, 492-495 analysis and presentation of data, 543-572 causes of variations in results, 543-544 controlling variation, 544-546 graph, applications of, 561-566 graphs and charts, 547-552 moving averages, 559-561 numerical representation, 552-559 regression analysis, 566-572 metric system, 520-524 capacity/volume measurement, 522 length measurement, 522 SI unit system, 520-521 temperature, 523-524 weight measurement, 522-523 numbers and operations, 487-488 addition, 487 division, 488 multiplication, 488 subtraction, 487-488 order of operations, 488-492 percentages, 495-498 pumps, 524-542 capacity of, 534-535 characteristics, 532-534 efficiency of, 535-538 friction/energy losses, 539-542, 540f, 541f head, 530-532 horsepower, 526-530 performance evaluation, 534-538 power, 526 pressure, 524-525 pump speed-performance relationships, 538-539 work, 525 units, 498 area, 499-504 concentration, 508-509 density, 508 distance/length, 498-499 force and pressure, 512-517 head, 518-519 mass and weight, 507 power, 519-520 specific gravity, 508 specific weight, 508 velocity and flow rate, 510-512

volume, 504-507 work, 517 Mechanical seals, 92-94, 218-221 cost-effective installation, 220-221 Median, 553, 554 Meg, 153 Megger, 151-153 Megohm, 152, 159, 169 Meniscus, 545 Mercury float switch for pump control, 81.82 Metering, 61 Metering flumes, 11-12 Metric system, 520-524 capacity/volume measurement, 522 length measurement, 522 SI unit system, 520-521 temperature, 523-524 weight measurement, 522-523 Microprocessor-controlled siliconcontrolled rectifiers (SCRs), 76, 77 Misalignment variations, 180, 181 Mode, 553 Motor and supervisory control systems, 164-166 Motor contactor operation, 177, 178 Motor control center (MCC), 64, 66 Motor enclosure, 72 Motor horsepower, 528 Motor insulation materials, 171 Motor mounting, 73 Motor rotation indicator, 153 Motors, 65-77, 108-116 failure causes, 168 insulation, 168-169 machine mounting configurations, 73 nameplate data, 168 types, 66, 67 Motor starter with microprocessor control, 76, 77 Motor starting devices and methods, 74-77 Motor windings and insulation, 72-73 Mounted pump in suction lift station, 37, 39 Moving averages, 559-561 Multimeter, 144-146

Ν

Nameplate data, 68–70, 140, 146, 168 Nameplate voltages, 71 National Association of Sanitary Sewer Contractors (NASSCO), 273 National Pollutant Discharge Elimination System (NPDES), 425 National Pollutant Discharge Elimination System permit (NPDES permit), 2 National Terrorism Advisory System (NTAS), 410 Nationwide accident and injury figures, 11 NEMA code letter designations, 71–72 Net positive suction head (NPSH), 97–98 New lift stations, 105-117 instrumentation and controls, 116-117 plan review, 106 preliminary assessment, 107-108 reading specifications, 106-107 screening and grit removal systems, 117 startup and performance verification, 108-117 Night flow isolation, 265 Nitrate addition, 122 Nonfatal injuries, water and wastewater treatment plant and systems operators, 11 Non-permit confined space, 391 Normal distribution, 549 Notifications, 21 NPDES permit (National Pollutant **Discharge Elimination System** permit), 2 Numerical representation of data, 552-559

0

Occupational Safety and Health Administration (OSHA), 18, 118, 137, 139, 162 Odor troubleshooting, 122-123 Ohm, 140, 141 Ohmmeter, 153 On-the-job training (OJT), 448 Open, closing, and closed eccentric plug valve, 100, 101 Open, drip-proof (ODP) motor enclosures, 72 Open impellers, 207 Operating ratio, 376 Operation and maintenance (O&M), 330 Operation and maintenance (O&M) programs, 257 Operation and maintenance schedule, 119 Operator injuries, 11, 12 Operator training and certification, 8 Oral communication, 365-369 Organizational structure, CMOM programs, 428-447, 429f, 430t inspection and investigation section, 441-444, 446, 447f lift station operation and maintenance section, 438-441, 440f, 442f-446f repair and replacement section, 436-438, 437f service request response and preventive maintenance section, 431-436, 432f, 435f Organizational structures, activities, and program requirements, 23-28 Organizing, 328 Orifice, 46 OSHA. See Occupational Safety and Health Administration (OSHA)

OUCH principle, 350

Outside screw and yoke valve, 100 Oxygen deficiency, 17–18, 57 Oxygen enrichment, 17–18

Ρ

Packing, 90-92, 213-218 hooks, 213 requirement, 214 shaft failure, 216-218 used/worn set of, 216 Paper screening, 347 Parasites, 15 Part winding motors and starters, 74-75, 173 Pathogens, 4 Peak demand in a multiple-pump station, 61 Percentages, 495-498 Performance indicators, 29-30, 416-422, 420f Performance rating, 420-421 Permit-required confined spaces, 388t, 389 Personal flotation device (PFD), 19 Personal protective equipment (PPE), 402-406 eve protection policy, 403-404, 403f face protection, 403-404 head protection, 404-406, 405f pH adjustment, 122, 123 Phase wound induction motor, 66 Piezometer, 263 monitoring well installation, 264f Pigs, 436 Pipe bursting, 287, 300 Pipe displacement method, 300 Pipe insertion, 297-300, 299f Pipeline Assessment and Certification Program (PACP), 273 Pipeline cleaning, 475-476 I/I reduction, 414 Pipeline insertion machine (PIM), 300 Pipeline rehabilitation crew, 339-340 Pipe removal method, 301 Piston pumps, 197-198 Planning, 328 Planning preventive maintenance, 24 PLC. See Programmable logic controllers (PLCs) Plug valves, 100, 101 Pneumatic bubbler system, 79, 80 Pneumatic ejectors, 195, 196 Point source leak, 265f Poisonous and toxic gases, 16-17 Poly pigs, 436 Polyethylene pipe lining, 302-309 equipment, 303 main lines, 303-307, 304f-307f preliminary work, 303 sealing, 309 service laterals, 307-309, 308f thank the public, 309

Polyvinyl chloride (PVC), 287 Portable pump installation, 201 Positive displacement pump, 84, 203, 206 Potential energy, 517 Power, 142-143 Power and control center for a lift station, one line riser diagram, 61, 63 Power, definition of, 526 Power factor, 142, 143, 145, 167 Power rodding crew, 338 Power supply, 71 Power transformers, 61 Precast concrete manhole, 312f Precast manhole defects, 313t Predictive maintenance, 124, 136 Preemployment inquiries, 348t-349t Prefabricated factory lift station, 40, 42 Present worth, 379 Pressure, 524–525 Pressure head, 49-51, 518-519 Pressure-sensing controllers, 79 Pretreatment facility, 15 Preventive maintenance, 2, 3, 98, 124, 136, 137, 165, 173, 210, 229-234, 474-475 Preventive maintenance program, 330 Primary resistor starting, 75 Prime, 192 Proactive maintenance, 2, 3, 124, 474-475 Probe injection method, 285 Procurement, 477, 478f Programmable logic controllers (PLCs), 64, 65, 66, 164, 177 Protective devices, electrical, 154-156 Publicly owned treatment works (POTW), 446 Public relations program, 22 Pumping facilities, 34-51 location and design, 34-35 requirements, 42-51 types of, 35-42 Pump layouts, 85-88 Pumps, 108-116, 524-542 bearings, 146, 188, 199, 221-225 backflow, 83 capacity of, 112, 113, 115, 534-535 cavitation, 54 centrifugal, 37, 85, 184, 187-193, 201, 532 characteristics, 532-534 close-coupled, 198-199 components, 88-95 bearings, 221-225 belt-driven, 226-228 direct-coupled pumps and motors, 225-226 flexible shafting, 228-229 impellers, 207–210 mechanical seals, 218-221 packing, 213-218 shafts, 210-212

controls, 234

diaphragm, pneumatic, 205-206 efficiency of, 535-538 friction/energy losses, 539-542, 540f, 541f head, 530-532 head-capacity calibration, 110, 111 horsepower, 526-530 hydraulic concepts, 95-98 performance evaluation, 534-538 piping layout, 83 piston, 197-198 pneumatic ejectors, 195, 196 power, 526 pressure, 524-525 preventive maintenance, 229-234 pump speed-performance relationships, 538-539 screw, 193-194 submersible, 199-200 trash, 201-204 types of, 84 work, 525 Pump shaft, 94-95 Pump shaft sleeves, 211, 212 Pump speed-performance relationships, 538-539 Pump stations, 64 Pump suction and discharge isolation gate valves, 98 Pump with automatic discharge connection, 37, 39 PVC-coated conduit, 57

Q

Quick Response (QR) code, 126

R

Rainfall-derived infiltration and inflow (RDII), 261 Rainfall-induced infiltration (RII), 26-27 Rainfall simulation techniques, 414-416 Range, definition of, 548 Raw wastewater, 43-44 Raw wastewater pump impellers, 95 Reactive maintenance, 124, 136, 474-475 Recordkeeping, 129-130 Records amperage, 147 CMMS maintenance scheduling, 243-245 equipment service card and service record card, 241, 242 Rectangular prism, 505–506 Reduced-voltage starting methods and devices, 74 Regression analysis, 566-572 Rehabilitation capacity assurance, 427 chemical grouting, 283-286, 283f, 285f, 286f

data usage, 275-279 capital costs of repair alternatives, 277 consequences of failure, 276-277, 277t cost analysis, 275-278 cost-effectiveness analysis, 278, 279f preliminary statement of needs, 275 setting priorities, 278 evaluating conditions, 258-274 cross bores, 259-260, 259f flow monitoring, 260-270, 262f-269f structural aspects, 270-274, 272f, 274t system problems, 258-259 excavation and replacement, 279-283, 280f-283f manholes, 311-321, 312f, 313t, 314t chimney seals, 314-317, 315f-317f coatings, 317-321, 318f-321f precast concrete manhole, 312f precast manhole defects, 313t methods of, 279-311 polyethylene pipe lining, 302-309 equipment, 303 main lines, 303-307, 304f-307f preliminary work, 303 sealing, 309 service laterals, 307-309, 308f thank the public, 309 program development, 250 implementation, 258 program definition, 250-258, 251f-257f service connections, 310-311 infiltration through, 310-311 trenchless technology, 286-302, 288t cured-in-place pipe (CIPP), 288-296, 289f, 290f, 294f deformed and reshaped, 301-302 in-line replacement, 300-301 sliplining, 297-300, 299f spray-on lining, 296-297, 296f Rehabilitation of capacity and structural deficiencies, 27-28 Repair crew, 339 Representative sample, 543 Resistance, 140, 141, 148, 152-154, 157, 168-170 Responsibility, 11 Revolutions per minute (rpm), 70 Right-angle gear drive, 109 Right-To-Know laws, 386t Robot drilling tools, 285f Rod-attached controllers, 81 Rodents, 18 Roll-down method, 302 Rope-attached controllers, 81 Rotating part of machine, 66 Rotor, 66 Routine preventive operation and maintenance activities, 24-25 Rungs on fixed manhole accesses, 12 Rural Utilities Service (RUS), 380

S

Safe Drinking Water Regulations, 380 Safety data sheet (SDS), 395 Safety program, 381-408 benefits, 381-382, 382t, 383t CMOM programs, 458-459 confined space, 389-391 emergency rescue personnel, 393-395 permit required, 389-391 permit system, 391-392 training and education, 392, 393t tripod rescue and retrieval systems for, 394f establishment, 382-385 hazardous energy control, 395-402, 395f employee training, 401 periodic inspections, 401-402 monthly safety meetings, 386, 386t personal protective equipment, 402-406 eve protection policy, 403-404, 403f face protection, 403-404 head protection, 404-406, 405f program policies and standards, 388-408 records and reporting, 406-408, 407f safety committee, 387 safety meetings, 385-386 written document, 387-388, 388t Safety vest policy, 402f Sanitary sewer overflow (SSO), 2, 5, 250 environmental effects of, 4 SCADA system (supervisory control and data acquisition system), 65, 170, 243, 261 software and hardware elements, 82-83 Scatter plots, 550-552 Screw pumps, 193-194 Seat belt policy, 402f Section maps, 467, 467f Segmental sliplining, 298 Sensor placement, 116, 117 Septic, 56 Septic conditions, 17 Septicity, 52, 56 Service connections in rehabilitation, 310-311 infiltration through, 310-311 Service factor, 70, 73 Service laterals, 307-309, 308f cleanout installation, 308-309 tee saddle installation, 309 Service request response crew, 337-338 Set point, 65 Sewer, 250 Sewer mains, 265 Sewer sausage, 310-311 Sewer system evaluation survey (SSES), 26, 258, 412 Sexual harassment, 358-359 Shafts, 94-95, 210-212 Shaft sleeves, 94, 211 Shape files, 469

Shear pin, 138 Shims, 209 Shoring, 18-19 Short cycling of the pump motors, 55 Single pump control, schematic (ladder) diagram, 176, 177 SI unit system, 520-521 Sleeves. 188 Sliplining, 287, 297-300, 299f continuous high-density polyethylene pipe, 297-298 segmental sliplining, 298 spiral wound, 298-300, 299f Slips, 11-12 Smart Data Infrastructure for Wet Weather Control and Data Support, 83 Smoke testing, 267-269, 268f, 269f, 414-416 Smoke testing crew, 341 Snake bites, 18 Solid-state reduced-voltage starters, 172 Solid-state soft start controls, 76 Spare parts inventory tracking, 127 Specific gravity, 508 Sphere, volume of, 507 Spiral wound sliplining technique, 298-300, 299f Split stuffing box, 91 Spray-on liners, 287 Spray-on lining, 296-297, 296f Squirrel cage induction motors, 74 SSES (sewer system evaluation survey), 26 SSO. See Sanitary sewer overflow (SSO) SSO notification program, 452-453 SSO Response Plan (SSORP), 434 Staffing, 335-365 applications and selection process, 346-350, 348t-349t employment policies and procedures, 351-364 compensation, 351-352 dealing with disciplinary problems, 356-357 harassment, 358-363, 359f, 360f labor laws governing employer/ employee relations, 363-364 performance evaluation, 353-356, 354f-355f personnel records, 364 probationary period, 351 training and certification, 352-353 new employee orientation, 350 qualifications profile, 346 unions, 364-365 workforce analysis, 335-345 crew types, 337-342 management and support staff, 342-345, 343f Stairways, 56 Standard deviation, 559 Standard galvanized conduits and fittings, 57 Standard maintenance procedures (SMPs), 448

Standard operating procedures (SOPs), 448 Standby power generators, 19 Starters, 169-179 Starting methods comparison, 74 State plane system, 464 State revolving fund (SRF) programs, 380 Static heads, 49, 50 Station sign-in log, 119, 120 Stator, 67 Stator construction, 166 Steel tape-attached controllers, 81 Stem-and-leaf plots, 550 Stoppage performance indicator, 417-418 Stormwater, 270 Strains/ruptures, 18 Stretches, 265 Structural and hydraulic problems, 26 Stuffing boxes, 90, 91 Submergence, 54, 55 Submersible lift stations, 36-38 Submersible pressure transducers, 81 Submersible pump motors, 67 Submersible pumps, 199-200 Submersible-style pumps, 110 Suction cavitation, 97 Suction head, 49 Suction lift, 35, 189 Suction lift stations, 37, 39 Sump pump, 98 Supervisory control and data acquisition (SCADA) system, 65, 170, 243, 261 software and hardware elements, 82-83 Surcharge, 25 Surcharged collection system, 250 Surface area circle, 501-502 cone, 503-504 cylinder, 502-503 rectangle, 499-500 sphere, 504 trapezoid, 501 triangle, 500-501 Swing check valve, 101, 102 Synchronous motors, 66 System evaluation and capacity assurance plan, 27 System performance, 475

Т

Tagout, 395, 395f devices, 396 procedure, 19 Tailgate safety meetings, 385 Tee saddle installation, 309 Temperature, 523–524 Thermally protected motors, 73 Three-phase power from the MCC, 67 Total dynamic head (TDH), 49, 96, 112, 114, 532 Totally enclosed, fan-cooled (TEFC) motor enclosures, 72 Toxic/explosive gases, 16-17, 137 Toxic substance, 53 Traffic incidents, 18 Training, safety and best practices, 28 Transfer switch, 61, 64 Trash pumps, 201-204 Trenchless rehabilitation methods, 284, 286-302, 288t cured-in-place pipe (CIPP), 288-296, 289f, 290f, 294f deformed and reshaped, 301-302 drawdown method, 302 roll-down method, 302 in-line replacement, 300-301 pipe displacement, 300 pipe removal, 301 sliplining, 297-300, 299f continuous high-density polyethylene pipe, 297-298 segmental sliplining, 298 spiral wound, 298-300, 299f spray-on lining, 296-297, 296f Trench shoring, 18-19 Triangular prism, 506 Troubleshooting, 183-187 Trunk sewer, 34 Two-stage piston compressor, 234, 235 Typical static groundwater gauge installation, 264f

U

Ultrasonic level transducers, 81 Ultraviolet (UV), 9 Units, 498 area, 499–504 concentration, 508–509 density, 508 distance/length, 498–499 force and pressure, 512–517 head, 518–519 mass and weight, 507 power, 519–520 specific gravity, 508 specific weight, 508 velocity and flow rate, 510–512 volume, 504–507 work, 517 Utility safety programs and procedures, 8

V

Vacuum relief valve, 46, 47 Valves, 98-103 Variable frequency drives (VFDs), 64, 66, 164 Variable-speed pumps, 56 Variable-speed systems in lift stations, 67 V-belt drive pulleys, 226, 227 Velocity head, 95 Ventilation and auxiliary equipment, 103-105 Viruses, 14-15 Viscosity, 238 Voltage, 19, 61, 140 Volt alternating current (VAC) source, 65 Volt direct current (VDC) source, 65 Volts, 140 Volume, 504–507 Volume measurement, 522 Volute, 78, 187 Vortexing, 55

W

Wastewater agency, 2 Wastewater and combined collection systems, 5 Wastewater collection systems, 3, 5, 250, 256f, 429f

Wastewater lift stations, 35, 118 Wastewater maintenance, 373f Water hammer, 44, 45 Water horsepower (WHP), 527, 536 Water pollution control regulatory agency, 21 Water quality monitoring, 456-457 Watts, 142 Wear rings, 88, 90 Weight measurement, 522-523 Wet well level measurement, 77-83 Wet wells, 11-12, 35 cycle times, 52 dimensions, 52-54 electrical systems, 57 flow distribution, 54 hardware, 57 inlet channel of larger stations, 56 lift station access, 56 operating levels in a lift station, 54-56 operator access, 52, 54 safety procedures and equipment, 57 Winched cable placement, 295-296 Wire-to-water efficiency, 528, 537-538 of a pumping system, 115, 116 Workforce analysis, staffing, 335-345 crew types, 337-342 management and support staff, 342-345, 343f Workplace hazards, preventive measures for, 9, 10 Written communication, 366-369, 369t Wye-delta motor and starters, 75, 173

X

xy or x-y plots, 550-552

Z

Zerk fittings (or grease fittings), 88