Mechanical Technologist
Grade II
2nd Edition

Study Guide
Certification Examination

New 2nd Edition
- Revised for 2015 tests.
- New KSA descriptions including KSA weighting.
- Expanded practice test and solutions.
- Searchable text optimized for electronic reading.

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Appendix A: You and Wastewater Math
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Important Notice: CWEA is pleased that you have purchased this book. We want to remind you that this book is one of many resources available to assist you and encourage you to identify and utilize the other resources in preparing for your next test.

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Section 1

Introduction

What to Expect From This Study Guide

The purpose of this study guide is to help certificate candidates understand what is expected of them on the certification test and to help them identify resources to assist in preparation for the test. It is not a comprehensive text on the wide variety of topics covered on the certification test. Successful candidates should expect to spend significant time reading and reviewing additional materials listed in this study guide along with any other materials available that can help them understand the subject matter of the test. In addition, successful preparation strategies include attending study sessions, participating in study groups, and completing relevant vocational and college courses. Ultimately, the amount of preparation required to pass the test depends on a candidate’s education, training, and work experience. After reviewing this study guide, you should be able to determine what you need to do to prepare for the test and how much time you will need (months are often required).

About the CWEA Certification Program

The California Water Environment Association (CWEA) Technical Certification Program (TCP) is either required or encouraged by many wastewater employers. Its purpose is to set a standard of the essential requirements for an individual to perform a given job safely and effectively, and to provide a measure of competency through certification testing. The certification test focuses on the Knowledge, Skills, and Abilities (KSAs) an individual must master to perform their job safely and effectively.

CWEA certifies personnel in six vocations:

- Plant Maintenance Technologist (with two parallel specialties of Electrical/Instrumentation, and Mechanical Technologist)
- Laboratory Analyst
- Collection System Maintenance Technologist
- Environmental Compliance Inspector
- Industrial Waste Treatment Plant Operator
- Biosolids Land Application Management

Upon qualifying and successfully completing the certification test, an individual becomes certified in that specialty at that grade level. Grade levels within a vocation designate technical knowledge for the entry-level, apprentice, journey, and management levels. More information about minimum qualifications can be found in the Candidate Handbook for your vocation available at www.cwea.org/cert or calling 510-382-7800.

Much of the CWEA mission is dedicated to providing education and training in all aspects of the wastewater industry including the KSAs of each certification vocation. CWEA is careful to separate its education and training activities from its certification activities to ensure that the educational focus is on the KSAs wastewater professional need to know to perform their jobs rather than being narrowly focused on just passing the certification test.
CWEA’s mission is to enhance the education and effectiveness of California wastewater professionals through training, certification, dissemination of technical information, and promotion of sound policies to benefit society through protection and enhancement of the water environment.
CWEA is a California Nonprofit Corporation, a Member Association of the Water Environment Federation (WEF), and a member of the Institute of Credentialing Excellence (ICE).

**Technical Certification Program History**

TCP was created to offer multilevel technical certification for individuals employed in the water quality field. Tests are written by vocational specialists and administered year round in six different vocations: Collection System Maintenance, Environmental Compliance Inspection, Laboratory Analysis, Plant Maintenance (Electrical/Instrumentation and Mechanical Technologist), Industrial Waste Treatment Plant Operation, and Biosolids Land Application Management.

CWEA first offered a certification program for wastewater treatment plant operators in 1937. The program was administered by CWEA until 1973 when the State of California assumed responsibility. During those 36 years, CWEA awarded 3,915 operator certificates.

CWEA established its Line Maintenance certification program in 1964. Eventually that would become the Collection System Maintenance certification program. In 1974 the first committees were formed to establish a voluntary certification program for water quality professionals specializing in disciplines other than plant operation. The following year the State Water Resources Control Board suggested that CWEA implement an industrial waste pretreatment certification program. TCP, then known as the Voluntary Certification Program or VCP, emerged in 1976 with specialized certificate programs for Plant Maintenance, Environmental Compliance Inspection, and Laboratory Analysis with certifications first issued in April 1976. In the 1980s, two more disciplines were added: Electrical/Instrumentation and Industrial Waste Treatment Plant Operator.

Today, CWEA offers certification in vocational programs with a total of 23 individual certifications. About 2,000 applications are processed annually and currently over 5,500 certificates are held by individuals primarily in California. CWEA also partners with other WEF Member Associations to offer certification in Michigan, Hawaii, and Missouri.

**Certification Process**

To become certified, all applicants must complete the Application for Technical Certification, pay the application fee, meet minimum qualifications regarding professional experience and education, and pass the computer-based test. Application instructions and fee schedules are listed on the application. After applications are received at the CWEA office, applicant information is compiled in a database, and reviewed by CWEA staff and experts in the field. If timing permits, staff will work with the applicant to resolve any incomplete applications. When approved, the applicant will receive an acceptance letter and test registration and scheduling instructions.
Immediately after completion of the computer-based test, a preliminary score and result will be given at the testing center. Occasionally, the official results may be adjusted from the preliminary results to resolve scoring issues. Official results are mailed to candidates. Those who pass the test are mailed certificates and blue wallet cards (also known simply as “blue cards”).

**Test Administration**

**Test Dates and Sites**

Tests are given throughout the year within four quarterly windows (see Application for Technical Certification for test schedule). Applicants who are eligible to take the test are mailed an acceptance letter with instructions on how to schedule their exam.

**Test Site Admission**

Certificate candidates are required to show at least one valid government issued photo identification (state driver’s license or identification, or passport). Only after positive identification has been made by the testing proctor can a candidate be allowed to take a CWEA cert test. Be sure the name on your acceptance letter matches your identification or you could be turned away at the test center. If your name does not match, contact the CWEA office immediately. Candidates are not required to show their eligibility letters to enter the test site.

**Test Security**

All tests are computer-based. No reference material, laptop computers, cameras or other personal items are allowed in the test site (see the test site policy at www.cwea.org/cbt). Candidates will have access to an on-screen calculator. However, candidates are welcome to bring their own calculator as long as it is on the list of approved calculators (visit www.cwea.org/cbt). Candidates are not permitted to take any notes from the test site. Candidates who violate test site rules will be asked to leave the site and may be disqualified from that test. All violations of test security will be investigated by CWEA and appropriate action will be taken.

**Test Rescheduling and Cancellation**

To reschedule your application, you must submit a written request stating that you wish to postpone to the adjacent testing window. You may only reschedule your application to the adjacent window once without a fee. Additional postponement will requires a reschedule fee. There are no exceptions to this policy.

To cancel your application you must submit a request to CWEA. The request must be received at the CWEA office no later than 2 weeks after the approved test window begins. Full refunds, less the administrative fee, will be made within 4 weeks after the scheduled test date. There are no exceptions to this policy.

If you already have a scheduled exam with our testing partner, Pearson VUE, and need to cancel your appointment, you must contact them two business days in advance to avoid losing your exam fee.

**Test Result Notification**

Official test results are routinely mailed to certificate candidates approximately two weeks after the test date. Results are never given over the phone, via fax or email. All results are confidential and are only released to the certificate candidate.
**Issue of Certificate/ Blue Wallet Card**

Certificates and blue wallet cards are issued to all candidates who pass the test. Certificates and blue wallet cards are mailed within three weeks after result notifications are mailed.

**Certificate Renewal**

All certificates are renewable annually. The first renewal is due one year from the last day of the month in which the certification test was held. Certificate renewals less than one year past due are subject to the renewal fee plus $25 late fee. Certificates more than two years past due are only renewable through retesting. Renewal notices are mailed to certificate holders two months before the due date. It is the responsibility of certificate holders to ensure the certificate(s) remains valid.

Every other year, certificates holders are required to submit 12 contact hours of education or training relevant to the certificate held. Continuing Education is required to help ensure that individuals certified by CWEA continue to be knowledgeable of technological advancements and regulatory requirements in the wastewater fields. Continuing education enhances the operation, maintenance and management skills of the certificate holders, and ensures the quality of wastewater treatment. This ultimately increases the ability and confidence of certificate holders and the credibility of the wastewater professions certified by CWEA.

**Accommodations for Physical or Learning Disabilities**

In compliance with the Americans with Disabilities Act, special accommodations will be provided for those individuals who provide CWEA with a physician’s certificate, or its equivalent, documenting a physical or psychological disability that may affect an individual’s ability to successfully complete the certification test. Written requests for special accommodations must be made with the test application along with all supporting documents of disability. Applicants requesting accommodations are encouraged to apply as early as possible to ensure sufficient time to process the request.

**Test Design and Format**

**Test Design**

All certification tests are designed to test knowledge and abilities required to perform the KSAs listed at the end of the section with minimal acceptable competence.

The KSAs were determined by a job analysis and meta-analysis of job specifications by experts in the filed under the guidance of test development specialists. The studies gathered data from on-site visits of over 31 water and wastewater agencies, interviews with 110 water and wastewater professionals, and analysis of more than 300 job specifications. All research was conducted under the guidance of the TCP Committee, vocational subcommittees, and CWEA staff. All test questions are designed to measure at least one area of knowledge or ability that is required to perform an essential duty.
**Test Delivery Mechanism**

All tests are computer-based format and are available in the English language only. Tests are delivered at Pearson VUE testing centers.

**Test Format**

All TCP tests are in multiple-choice format (see the sample test questions in this booklet for an example). The multiple-choice format is considered the most effective for use in standardized tests. This objective

**Test Pass Point**

The minimum score required to pass varies depending on the test and possible total points. The score may be adjusted downward depending on test complexity. It should be assumed that if the passing score is 75 percent candidates should try to score as high as possible on their test (in other words, always try for 100 percent). The pass point for each vocation and grade level is set independently. Also, each version, or form of a test will have its own pass point. Different versions are given each time the certification test is administered.

**How Pass Points are Set**

A modified Angoff Method is used to determine the pass point for each version of each test. The modified Angoff Method uses expert judgements to determine the test difficulty. The easier the test, the higher the pass point; similarly the more difficult the test, the lower the pass point.

The following is an outline of the modified Angoff Method (some details have been omitted):

1. A group of Subject Matter Experts (SMEs) independently rate each test question within a given test. The ratings are defined as the probability that an acceptably (minimally) competent person with the requisite education and experience will answer the question correctly. An acceptably (minimally) competent person is defined as someone who safely and adequately performs all job functions and requires no further training to do so.

2. The SMEs review each test question as a group. A consensus is reached for the rating of each test question. The SMEs also review comments submitted in writing by test-takers. Any test question that is judged to be ambiguous, has more than one correct answer, or has no correct answers is eliminated from the scoring process for that test. These test questions are then revised for future use, reclassified, or deleted from the test item bank.

3. After the data are refined, the final step is to calculate the mean, or average, of all the test question ratings. This becomes the overall pass point estimation.

**Why Use Modified Angoff?**

Each version of a given certification test uses questions from a test item bank. Each of these questions vary in difficulty. Because a different mix of questions is used in each test, the overall difficulty level is not fixed. Thus, it is important to make sure that the varying difficulty level is reflected in the pass point of each test to ensure that test results are reliable. Test reliability is concerned with the reproducibility of results for each version of a given test. In other words, for a test to be reliable it must yield the same result (pass or fail) for the same individual under very similar circumstances. For example, imagine taking a certain grade level test and passing it. Immediately after completing this test, a different version of the same grade level test is taken.
If the test is reliable, the same result will be achieved: pass. If a passing grade is not achieved, it is likely that the test is not a reliable measure of acceptable (minimal) competency.

By taking into consideration the difficulty of the test, the modified Angoff Method significantly increases the reliability of the test. Also, since each test is adjusted for difficulty level, each test version has the same standard for passing. Thus, test-takers are treated equitably and fairly, even if a different version of the test is taken.

There are other methods for setting pass points. However, for the type of tests administered by CWEA, the modified Angoff Method is the best and most widely used.

**Test Scoring**

All tests are electronically scored by Pearson VUE pending approval by CWEA. Most test items are valued at one point. Some test items requiring calculations are worth multiple points varying from two to five (possibly more). After tests are scored, total points are compiled and an overall score is calculated as the sum of all points earned on the test. If the overall score is equal to, or greater than the established pass point, the candidate has passed the test. Total points possible for each test varies, but the average is 100 points plus or minus 25.

**Item Appeals**

Candidates who wish to appeal a specific test item must do so during the test by completing the Candidate Comment Review Section during the exam. Item appeals will be evaluated and appropriate adjustments will be made to the test content. Candidates submitting comments will not be contacted in regards to the appeal.
Understanding The KSAs
The key to success on the CWEA certification test is understanding the KSAs and having adequate training, education, and experience in those KSAs. Each KSA describes the competencies required of an individual to successfully perform the essential duties of the job at grade level. Although the KSAs do not correspond precisely to every individual Grade I position description, they do reflect the core competencies and essential duties required of any Grade I Electrical/Instrumentation Technologist. The KSAs are developed from a job analysis that includes research of the essential duties at a representative cross-section of systems and facilities throughout California and other participating states.

This section outlines each KSA and includes descriptions of the general competencies, math competencies, and suggested reading for that KSA. Candidates are expected to understand the competencies described in this section and seek further educational opportunities to address those KSAs that have not been mastered. Although each candidate is encouraged to find educational opportunities that suit his or her needs best, typical educational opportunities include:

- On the job training
- Print or online training materials
- Manuals of practice, technical documents, regulations, etc.
- Mentoring
- Trade, vocational, or college courses
- Professional education sessions and seminar

Candidates seeking Environmental Compliance Inspector IV certification should review the KSAs presented in this section and seek to understand how they apply to everyday duties and responsibilities.

KSA Weight
KSA Weight is the approximate percent of the test content covered by a KSA. For example, a KSA with a weighting of 7% will have about 7% of all questions (or points) dedicated to that KSA, or 7% of the test is about that KSA. The KSA weight is approximate and shows the relative importance of a KSA compared to the other KSAs. The KSA weight on the actual certification test may vary slightly.

General Competencies and Math Competencies
Each KSA includes an expanded description of the competencies, tasks, and duties expected of certificate holders. Math Competencies describe the math, analytical, or calculation knowledge and skills that are expected of certificate holders. There are no specific “math” questions on the test, but questions in some KSAs require computational skills to complete. Like all other questions on the test, questions requiring math or computational skills are randomly distributed throughout the test.

Suggested Reading
The Suggested Reading lists some materials that are representative of each KSA. Each reference includes chapters, sections, or pages that are representative of the KSA. This is not an exhaustive list of sources relevant to the KSA and candidates are strongly encouraged to seek additional material that covers each KSA especially in those KSAs where the candidate is not adequately prepared.
KSA 201

Perform fabrication to maintain facilities and equipment using the following methods:

- multi-position welding with acetylene and arc welders
- knowledge of materials and tools to use

KSA201 General Competencies
A journey level Mechanical Technologist is expected to have a firm understanding and aptitude in regards to arc and oxy-acetylene welding. Knowledge of the materials and tools used in these processes is also needed.

This knowledge is usually gained through:
- apprenticeship trade schools
- military schools
- entry-level in-house training
- Regional Occupations programs

KSA201 Math Competencies
There are no math competencies for this KSA.

KSA201 Suggested Reading
- www.welding.com
KSA 202

With an understanding of engine operations and engine types, perform engine repair and maintenance such as:

- changing oil, belts, filters and spark plugs
- troubleshooting and performing corrections
- obtain hydrometer readings, oil and fuel samples and based on results interpret and correct

KSA202 General Competencies

A journey level Mechanical Technologist is expected to troubleshoot and perform discovered corrections in engine maintenance and operations. The technologist should be versed in obtaining:

- hydrometer readings
- changing oil
- changing belts
- replacing spark plugs
- replacing filters

The technologist should also know the importance of pulling oil and fuel samples and how to correct the faults they show.

This knowledge is usually gained through:

- apprenticeship trade schools
- military schools
- entry-level in-house training
- Regional Occupations programs

KSA202 Math Competencies

There is no specific math competency required for this KSA.

KSA202 Suggested Reading

- Operation of Wastewater Treatment Plants; Volume II, Page 89
KSA 203  
Weight 8%

With a thorough knowledge of pump principles regarding centrifugal, positive displacement, and vacuum pumps, perform pump maintenance and repair with techniques and principles such as:

- servicing, lubricating, adjusting, maintaining and rebuilding pumps
- removal and installation of packing and mechanical seals
- read and interpret pump curves and efficiencies
- alignment techniques
- vibration analysis
- troubleshooting and performing corrections
- basic pump hydraulics
- complete proper installation and removal techniques
- identify the major components of a pump
- preventative and predictive maintenance

KSA203 General Competencies

A journey level Mechanical Technologist is expected to have a well defined knowledge base of: Centrifugal, Positive Displacement, and Vacuum Pump principles. The technologist should be experienced in performing pump maintenance and repair, to include:

- packing
- alignment
- vibration analysis
- troubleshooting
- identification
- installation
- removal

This knowledge is usually gained through:

- apprenticeship trade schools
- military schools
- entry-level in-house training
- Regional Occupations programs

KSA203 Math Competencies

There are no math competencies for this KSA.

KSA203 Suggested Reading

- *Operation of Municipal Wastewater Treatment Plants*; Manual of Practice-MOP 11, Page 43, Pg. 191 & Pg. 685
- *Operation of Wastewater Treatment Plants*; Volume 2, Pg. 64, 202, 234-237, 239, 244
KSA 204

Clean and repair wet wells with an understanding of methods such as:

- knowledge of proper coating
- repairing and maintenance of level control devices
- septic prevention
- odor control systems
- predictive and preventive maintenance

KSA204 General Competencies

A journey level Mechanical Technologist expected to perform predictive and preventative maintenance on wet wells. Familiarity with level control, septic prevention, and proper operation is a must.

This knowledge is usually gained through:

- apprenticeship trade schools
- military schools
- entry-level in-house training
- Regional Occupations programs

KSA204 Math Competencies

There are no math competencies for this KSA.

KSA204 Suggested Reading

- Operation of Wastewater Treatment Plants; Vol. II; 7th Edition; Maintenance, Plant Tanks and Channels; Page 335
KSA 205

With knowledge of pipelines and valves, perform maintenance and repair such as:

- change piping
- proficient pipe layout
- piping systems of galvanized, PVC, stainless steel, and copper tubing
- proper connecting techniques
- pipe inspection and repair
- modifying existing piping systems
- knowledge in application of valve, actuators types and associated repairs
- piping support systems
- expansion systems
- technics and devices used to stop/repair leaks

KSA205 General Competencies

A journey level Mechanical Technologist is expected to know how to measure, prepare, thread or glue piping systems of:

- PVC
- ABS
- Galvanized
- Stainless Steel
- Copper piping

Use of brazing tools, manual and power threading tools, and fitting knowledge is required. Further, the person should be able to identify different types of valves and understand their operation and application.

This knowledge is usually gained through:

- apprenticeship trade schools
- military schools
- entry-level in-house training
- Regional Occupations programs

KSA205 Math Competencies

There are no math competencies for this KSA.

KSA205 Suggested Reading

- Operation of Wastewater Treatment Plants; Vol. II, Pg. 81, 199 & 200
KSA 206

**Weight 7%**

Repair and maintain mechanical systems with knowledge of the operation, maintenance and repair of compressors and blowers and associated components such as:

- lubrication
- air receivers and tanks
- types of valves
- cooling systems
- troubleshooting and applying corrections
- control systems
- filtration systems
- predictive and preventive techniques
- vibration analysis

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**KSA206 General Competencies**

A journey level Mechanical Technologist is expected to have a firm grasp of pneumatic systems. Predictive and Preventative techniques are used often to ensure control, lubrication, and filtration systems are effective. Troubleshooting and applying corrections are also a big area of this KSA.

This knowledge is usually gained through:

- apprenticeship trade schools
- military schools
- entry-level in-house training
- Regional Occupations programs

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**KSA206 Math Competencies**

There are no math competencies for this KSA.

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**KSA206 Suggested Reading**

- [Operation of Wastewater Treatment Plants](#); Vol. II, Pg. 142 & 259
KSA 207

Weight 8%

Safely and effectively repair and maintain process equipment and related components with apprentice level knowledge of process equipment purpose and function such as:

- chemical feed systems and effects of delivered chemicals on associated equipment
- solids removal systems
- conveyance systems
- digesters and associated systems
- odor control systems
- aeration systems
- disinfection and de-chlorination
- filtration systems
- settling basins
- storage systems
- predictive and preventive maintenance

KSA207 General Competencies

A journey level Mechanical Technologist is expected to demonstrate knowledge of typical water and wastewater equipment. This equipment includes conveyors, digesters, heat exchangers, boilers, and chemical feed systems. A good understanding of odor systems, disinfection and de-chlorination systems is also necessary.

This knowledge is usually gained through:
- apprenticeship trade schools
- military schools
- entry-level in-house training
- Regional Occupations programs

KSA207 Math Competencies

There are no math competencies for this KSA.

KSA207 Suggested Reading

- Operation of Wastewater Treatment Plants, Vol. I & II, Pg. 41, 79 & 109
KSA 208

Perform shop mathematics and techniques to calculate or determine:

- efficiency of pumps and motors
- horsepower (brake and motor)
- flow rates
- volumes and area
- measurements
- drive ratios
- pressure

KSA 208 General Competencies

A journey level Mechanical Technologist is expected to demonstrate knowledge of mathematically calculating volumes, areas, flow rates, horsepower, drive ratios, and pressure.

This knowledge is usually gained through:

- apprenticeship trade schools
- military schools
- entry-level in-house training
- Regional Occupational Programs

KSA 208 Math Competencies

In this KSA, the math competencies needed are the ability to calculate or determine flow rates, horsepower, and efficiency of pumps. An understanding of how to calculate perimeter, volume, and area are also needed.

KSA 208 Suggested Reading

- Shaft alignment
KSA 209  
Weight 3%  

Safely and effectively repair and maintain equipment with a knowledge and understanding of electrical principles and practices including:

- Ohms Law
- voltage ratings
- motor identification
- battery principles

KSA209 General Competencies

A journey level Mechanical Technologist is expected to have a strong knowledge of electrical principles and terms. Identification of motor style and type is also needed.

This knowledge is usually gained through:

- apprenticeship trade schools
- military schools
- entry-level in-house training
- Regional Occupational Programs

KSA209 Math Competencies

There are no math competencies for this KSA.

KSA209 Suggested Reading

- Operation of Wastewater Treatment Plants; Vol. II, Pg. 162.
KSA 210

Repair and maintain mechanical systems while adhering to industry safety standards and regulations pertaining to CCR Title 8 or equivalent state regulations:

- lock tag verification (LTV) (Lockout/Tagout) and Blocking/Isolation
- confined space
- slip, trip and fall
- proper lifting
- trench safety
- crane safety
- vehicle safety
- tool safety
- stored energy
- electrical safety
- chemical safety
- wet well safety
- fire safety
- Safety Data Sheet (MSDS)
- gas detection systems
- proper use of PPE (Personal Protective Equipment)
- traffic control
- rigging safety
- NFPA 70E (National Fire Protection Association)
- IIP (Injury Illness Prevention)

KSA210 General Competencies

To spec pumps for given applications, a journey level Mechanical Technologist is expected to have a very strong background in lock out/tag out and all aspects of safety while on the job. The technologist should have a firm understanding of proper safety procedures while in a confined space, a trench, a crane, a vehicle, and in use of tools. A broad base of safety knowledge while working with chemicals, traffic, and electricity is also useful. The technologist should be comfortable and confident enough to lead others in safety.

This knowledge is usually gained through:
- apprenticeship trade schools
- military schools
- entry-level in-house training
- Regional Occupational Programs

KSA210 Math Competencies

There are no math competencies for this KSA.

KSA210 Suggested Reading

- Operation of Wastewater Treatment Plants; Vol. II, Pg. 355 & 357
KSA 211

Weight 4%

Participate in the lifting and moving of heavy machinery or equipment with knowledge and understanding of:

- crane operations
- rigging and lifting
- proper use of fork lifts
- use of proper hand signals
- A-frame use
- chain falls/come alongs (cable or chain puller)

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KSA 211 General Competencies

Journey level Mechanical Technologists are expected to be well versed in craning operations. Technologist should be aware of proper safety and hand signals. He or She should know how to properly use fork lifts and A-frames.

This knowledge is usually gained through:

- apprenticeship trade schools
- military schools
- entry-level in-house training
- Regional Occupational Programs

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KSA 211 Math Competencies

There are no math competencies for this KSA.

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KSA 211 Suggested Reading

- California Manual on Uniform Traffic Control Devices
KSA 212

Repair and maintain mechanical systems with the knowledge of proper use of tools such as:

- hand tools
- power tools
- machine/shop tools
- hydraulic/pneumatic tools
- measurement tools
- computers and systems
- understanding of ultra-sonic preventative maintenance equipment
- alignment and precision measurement tools

KSA212 General Competencies

Journey level Mechanical Technologists are required to have a wide based knowledge of a variety of tools that are applicable to the task. These include measurement, shop, hydraulic, power, and hand tools. The technologist should understand and apply principles of an average machine shop and know how to use alignment tools.

This knowledge is usually gained through:
- apprenticeship trade schools
- military schools
- entry-level in-house training
- Regional Occupational Programs

KSA212 Math Competencies

There are no math competencies for this KSA.

KSA212 Suggested Reading

- *Operation of Wastewater Treatment Plants*; Vol. II, Pg. 136
KSA 213

**Weight 5%**

*Apply appropriate construction methods and materials with a knowledge of facility maintenance, construction methods and materials, to perform apprentice level maintenance such as:*

- pipe fitting
- framing
- concrete forming, pouring, and finishing
- painting/coating
- heating and cooling systems
- plumbing and draining systems
- lighting and electrical
- knowledge of job estimation

---

**KSA213 General Competencies**

Journey level Mechanical Technologists should have a strong understanding of pipe fittings and how they are used. The person should know how to estimate the amount of paint, concrete, and lumber needed for a job. The person should know how to assemble the materials properly and follow through to the job's completion.

This knowledge is usually gained through:

- apprenticeship trade schools
- military schools
- entry-level in-house training
- Regional Occupational Programs

**KSA213 Math Competencies**

There are no math competencies for this KSA.

**KSA213 Suggested Reading**

- There are no specific suggested references for this KSA.
KSA 214  

Perform apprentice level maintenance and repair by interpreting and applying information from:

- designs and sketches
- written and verbal design instructions
- equipment specifications
- operations and maintenance service manuals
- diagrams
- schematics
- pump curve

KSA214 General Competencies
Journey level Mechanical Technologists are expected to understand the proper symbols when reading or drawing sketches and schematics. The candidate should be able to easily follow written and verbal instructions.

This knowledge is usually gained through:

- apprenticeship trade schools
- military schools
- entry-level in-house training
- Regional Occupational Programs

KSA214 Math Competencies
There are no math competencies for this KSA.

KSA214 Suggested Reading

- There are no specific suggested references for this KSA.
KSA 215
Establish and maintain effective working relationships with every person encountered in the workplace to help incorporate the concept of teamwork.

- planning and scheduling work with other team members
- promoting the agencies core values

KSA215 General Competencies
A Journey level Mechanical Technologists is expected to work together with other team members, when planning and scheduling work, to help promote the agencies core values.

This knowledge is usually gained through:
- apprenticeship trade schools
- military schools
- entry-level in-house training
- Regional Occupational Programs

KSA215 Math Competencies
There are no math competencies for this KSA.

KSA215 Suggested Reading
- Operation of Wastewater Treatment Plants; Vol. II; 7th Edition; Maintenance, Beware of Electricity; Page 373
KSA 216

Communicate clearly and concisely in English, both verbally and in writing with respect to:

- completing and accepting work orders
- purchase requests
- warehouse requisition
- accident reporting
- radio and telephone communication
- written and computerized records

KSA216 General Competencies

A Journey level Mechanical Technologists is expected to have a strong familiarity with the basic use of handheld radios and telephones. A firm grasp of computer use is needed to keep records and complete/accept work orders.

This knowledge is usually gained through:

- apprenticeship trade schools
- military schools
- entry-level in-house training
- Regional Occupational Programs

KSA216 Math Competencies

There are no math competencies for this KSA.

KSA216 Suggested Reading

- There are no specific suggested references for this KSA.
KSA 217

**Weight 7%**

Perform maintenance and repair with an apprentice level knowledge and understanding of power transmission equipment such as:

- types of drives
- gear and pulley ratios
- machine guards
- shafts
- alignment techniques
- types of couplings
- joints
- gear reduction systems

---

**KSA217 General Competencies**

Journey level Mechanical Technologists are expected to have a solid foundation in couplings, gears, pulleys, drives, and gear reduction. The technologist should know proper maintenance procedures for all of the above.

This knowledge is usually gained through:

- apprenticeship trade schools
- military schools
- entry-level in-house training
- Regional Occupational Programs

**KSA217 Math Competencies**

There are no math competencies for this KSA.

**KSA217 Suggested Reading**

- *Operation of Wastewater Treatment Plants*; Volume I & II Pg. 41 & 255.
- *Audel Mechanical Trades Pocket Manual*; 4th Ed.; Chain Drives; Page 191, 200 & 209
- *What is a Reduction Gear?*
Section 4
Test Preparation

This section provides tips on how candidates should prepare, information provided with the test, the types of questions likely to be on the test, and solutions to typical math problems.

Basic Study Strategy

To prepare adequately, candidates need to employ discipline and develop good study habits. Ample time to prepare for the test should be allowed. Candidates should establish and maintain a study schedule. One or two nights a week for one or two months should be sufficient in most cases. Spend one or more hours studying in quiet surroundings or in small groups of two or three serious candidates. Efforts should be directed to the test subject areas that are not being performed on a day-to-day basis.

While using this study guide, be sure to understand the KSAs and answers to all questions. Discuss test questions with others. Not only is this a good study technique, it is also an excellent way to learn.

Candidates should study at the certification level being sought after. There is no advantage to spending time studying material that will not be on the test. Refer to Section 3 for a description of the KSAs and reading assignments that cover the topics on the test.

It is not necessary, but certainly helpful, to memorize all formulas and conversion factors. A formula table is provided on the test to assist in this area. Tables 4-1 give the same formulas and conversion factors as those given on the test.

Candidates should obtain the primary reference and training material listed in Section 6. Any material not available at their workplace can be obtained from the sources listed in Section 6.

Multiple Choice Questions

All test questions are written in multiple-choice format. At first glance, the multiple-choice problem may seem easy to solve because so much information is given, but that is where the problem lies. The best answer must be chosen from the information provided. Here are some tips that may help solve multiple-choice questions.

1. Read the question completely and closely to determine what is being asked.

2. Read all the choices before selecting an answer.

3. Look for key words or phrases that often, but not always, tip off correct or incorrect answers:
Absolute Words
(Suspect as a wrong choice)

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<table>
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<tr>
<td>All</td>
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<td>Always</td>
<td>None</td>
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<tr>
<td>Totally</td>
<td>Completely</td>
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</table>

Limiting Words
(Often a correct choice)

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<tbody>
<tr>
<td>Few</td>
<td>Occasionally</td>
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<td>Some</td>
<td>Generally</td>
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<tr>
<td>Often</td>
<td>Usually</td>
</tr>
<tr>
<td>Many</td>
<td>Possible</td>
</tr>
</tbody>
</table>

4. Never make a choice based on the frequency of previous answers. If the last ten questions have not had a “b” answer, don’t arbitrarily select “b”. Instead use logic and reasoning to increase the chances of choosing the best answer.

5. Reject answers that are obviously incorrect and choose from the remaining answers. For example, in the multiple-choice question, “Why are gasoline and volatile solvents objectionable when present in a sewer?”

   a. They produce an explosion hazard.
   b. They tend to cause solids to vaporize.
   c. They will coagulate floatables and cause stoppages.
   d. Because they float, the substances flow to plant headworks quicker.”

   In reviewing physical and chemical characteristics of gasoline and volatile solvents, the specific gravities of these substances are generally less than water and float to the surface. They are solvents for other similar industrial organic chemicals. Therefore, answer “b”, that proposes gasoline and volatile solvents cause solids such as sand, and grit to vaporize, is obviously an incorrect answer.

6. Make an educated guess. Never reconsider a choice that has already been eliminated. That means in the example above, answer “b” is out.

   Look for “key” phrases or words that give a clue to the right answer. For the example above, choices “c” and “d” discuss floatables and are potentially good answers. For answer “c”, chemical interaction of gasoline with floatables is not likely unless they are oil and grease. In such case, the solvent may disperse the oil and grease and reduce stoppages.

   Answer “a” and “d” remain and are both reasonable choices. However, the best answer must be selected. Answer “d” is true, but without knowing the explosive nature of gasoline and volatile solvents, the answer is only a fact. An explosive material in wastewater creates a condition that endangers the public, a potential loss of expensive facilities, and a hazard to operations and maintenance personnel. The best answer is “a”, they produce an explosion hazard.

7. Skip over questions that are troublesome. Mark these questions for later review.
8. When finished with the test, return to the questions skipped. Now think! Make inferences. With a little thought and the information given, the correct answer can be reasoned out.
9. Under no circumstances leave any question unanswered. There is no penalty for an incorrect answer. However, credit is given only for correct answers.

**NO ANSWER=WONG ANSWER**

10. Keep a steady pace. Check the time periodically.
11. Remember to read all questions carefully. They are not intended to be “trick questions”; however, the intent is to test candidates’ knowledge of and ability to understand the written languages of this profession.

**Math Problems**

Math problems on the certification tests are meant to reflect the type of work encountered in Collection System Maintenance. Although there is no specific math section on the test, many questions will require some calculations such as area, volume, ratios, and conversion of units. Although math is important on the test, do not neglect other parts of the KSAs and focus too much time on the math. Completing the math problems will be greatly simplified by using a calculator and the approach suggested in the following paragraphs.

**Calculators**

Approved calculators may be used during the test. See the approved calculator list at www.cwea.org/cbt. A screen calculator will also be available on the test similar to the standard calculator found on computers running Windows. The most important factor in effectively using a calculator is the candidates’ familiarity with its use prior to the time of the examination. Confidence in the calculator and a full understanding of how to properly operate it are a must. The best way to gain confidence is to obtain a calculator from the approved calculator list and use it frequently.

Completing the worksheets in this section as well as the sample problems at the various grade levels will improve proficiency. Additional use will also help. For example, calculate the gas mileage when filling a vehicle’s tank each time. Check the sales tax calculation on each purchase. Balance a checkbook, or check a paycheck. The calculator chosen should have large enough keys so that the wrong keys are not accidentally punched. Be certain there are new batteries in the calculator, or use a solar powered calculator with battery back up.

**Approach**

The solution to any problem requires understanding of the information given, understanding of what is being requested, and proper application of the information along with the appropriate equations to obtain an answer. Any math problem can be organized as follows:

*Given or Known.* All information provided in the problem statement that will be used to get the correct answer.

*Find.* A description of the answer that is being requested.

*Sketch.* If possible, sketch the situation described in the problem statement showing size and shape (dimensions).
Equation. The equation or equations that will be used to generate the listed answers

Assumption(s). Stated assumptions of key information needed to answer a math problem with missing information. This occurs frequently on higher-grade tests.

Answer. This is where the answer is clearly identified.

Advantages to using this approach to organize math problems are that it helps to organize thoughts, breaks the problem solution into a series of smaller steps, reducing chances of making an error.

Solutions
Solutions to math problems are like driving routes from Los Angeles to San Francisco: there are many different routes that can be taken. Some routes are shorter or less complicated than others. Only certain routes end up in San Francisco.

Solutions to sample problems given in this study guide are the most common solutions. If a solution that is different, but arrives at the correct answer is found, then that solution can be used.

Equivalents/ Formulas
A sample of the equivalents and formulas sheet from the examination is included in Table 4-1. Familiarity with each of the equivalents (conversion factors) and each of the formulas is important. Pay special attention to the units of measure that are used in the formulas. A correct answer will not be obtained unless the correct units of measure are used.

Check the units, arithmetic, and answer. So that:

1. The units agree.
2. The answer is the same when the arithmetic is repeated.
3. The answer is reasonable and makes sense.

Dimensional Analysis
When setting up an equation to solve a math problem, the trick is to have clearly in mind what units the answer should be in. Once the units have been determined, work backwards using the facts given and the conversion factors known or given. This is known as dimensional analysis, using conversion factors and units to derive the correct answer.

Remember, multiplying conversion factors can be likened to multiplying fractions. The denominator (the number on the bottom of the fraction) and the numerator (the number on the top of the fraction) cancel each other out if they are the same, leaving the units being sought after.

Example:

If a company runs a discharge pump rated at 50 gallons per minute all day, every day for a year, what is the discharge for the year in millions of gallons per year (MGY)?

Given: pump rating = \( \frac{50 \text{ gal}}{\text{min}} \)
Find: discharge = ____ MGY

Calculations: Convert gal/min to million gal/yr, convert gallons to million gallons, and minutes to years.

What is known about minutes and years? There are 60 minutes in an hour, 24 hours in a day, and 365 days in a year. Put that into an equation, and multiply each conversion factor so the unneeded units are cancelled out:

\[
\frac{50 \text{ gal}}{\text{min}} \times \frac{60 \text{ min}}{\text{hr}} \times \frac{24 \text{ hr}}{\text{day}} \times \frac{365 \text{ days}}{\text{yr}} \times \frac{1 \text{ MG}}{1,000,000 \text{ gal}} = 26.28 \text{ mgy}
\]

Sample Questions

The following sample math problems are intended to demonstrate unit conversion techniques. Although they are general wastewater problems, the questions may not be specific to any vocation.

1. How many gallons of water will it take to fill a 3 cubic foot container?

\[
3 \text{ cubic feet} \times \frac{7.48 \text{ gallons}}{\text{cubic foot}} = 22.4 \text{ gallons}
\]

2. If a gallon of gasoline weighs 7.0 pounds, what would be the weight of a 350-gallon tank full of gasoline?

\[
350 \text{ gallons} \times \frac{7.0 \text{ pounds}}{\text{gallon}} = 2,450 \text{ pounds}
\]

3. The rated capacity of a pump is 500 gallons per minute (GPM). Convert this capacity to million gallons per day (MGD).

\[
500 \text{ gpm} \times \frac{1 \text{ MGD}}{694 \text{ gpm}} = 0.72 \text{ MGD}
\]

4. A chemical feed pump is calibrated to deliver 50 gallons per day (GPD). What is the calibrated chemical feed in gallons per minute (GPM)?

\[
\frac{50 \text{ gal}}{\text{day}} \times \frac{1 \text{ day}}{24 \text{ hr}} \times \frac{1 \text{ hr}}{60 \text{ min}} = 0.035 \text{ GPM}
\]

5. A chemical feed pump delivers 50 mL per minute (mL/min). Determine the chemical feed in gallons per day (gpd).
6. A cyanide destruction process is designed to treat 30 pounds of cyanide per 24-hour operational day. How many pounds of cyanide can be treated during an 8-hour shift?

Math Skills

Successful candidates must be skilled in arithmetic and geometry. Candidates must be able to apply these skills to make calculations for work-related tasks such as excavation, stationing, pumping, determining flow rate, cost estimation, and any other job related math skill that may fall within the Skill Sets listed in Section 3. A thorough review of the types of mathematics required for the test is beyond the scope of this study guide. Consult an appropriate math text (see Section 6, References) if there is unfamiliarity with any of these specific math skills. Appendix A provides general strategies for approaching math problems, math anxiety, and resources for remedial study.

Arithmetic

Candidates should be able to perform and understand the following calculations either manually or with a calculator:

1. Addition and subtraction of whole numbers and fractions.
2. Multiplication and division of whole numbers and fractions.

Be prepared to apply these basic skills to work-related problems. The following example problem requires application of knowledge and application of basic arithmetic and the ability to convert units.

Example:

Determine the volume of a concrete slab that measure 150 feet long, 200 feet wide, and 3 inches thick. Express your answer in cubic yards.

First convert inches to feet:

\[
3 \text{ inches} \times \frac{1 \text{ foot}}{12 \text{ inches}} = 0.25 \text{ feet}
\]

Next, using the formula for volume given in Table 4-2, determine the volume of the concrete slab in cubic feet:

\[
\text{Vol} = \text{LW} \times \text{d}
\]

\[
\text{Vol} = 150 \text{ feet} \times 200 \text{ feet} \times 0.25 \text{ Feet}
\]

\[
\text{Vol} = 7,500 \text{ cubic feet}
\]
Finally, calculate the volume of concrete in cubic yards:

\[7,500 \text{ cubic feet} \times 1 \text{ cubic yard} = 27 \text{ cubic feet} \]
\[= 277.78 \text{ cubic yards}\]

**Geometry**
Candidates should be able to calculate circumference, find the area of a rectangle, circle, and the volume of a rectangular solid or a right cylinder. This problem requires application of knowledge and application of basic geometry, arithmetic, and the ability to convert units.

Example:

What is the area of a manhole that measures 40 inches in diameter? Express your answer in square feet.

First convert inches into feet.

\[40 \text{ inches} \times \frac{1 \text{ foot}}{12 \text{ inches}} = 3.33 \text{ feet}\]

Then calculate the area of the manhole using the formula for the area of a circle given in Table 4-2.

\[A = 0.785D^2\]
\[A = 0.785 \times 3.33 \text{ feet} \times 3.33 \text{ feet}\]
\[= 1,256 \text{ ft}^2\]

Area of manhole
\[= 8.71 \text{ square feet}\]
### Mechanical Technology Grade 1-4
Conversion Factors & Formulas

#### Section 4: Test Preparation

<table>
<thead>
<tr>
<th>Conversion Factor</th>
<th>Equivalent</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 cubic foot</td>
<td>1,728 cubic inches</td>
</tr>
<tr>
<td>1 cubic foot</td>
<td>7.48 gallons</td>
</tr>
<tr>
<td>1 cubic foot of water</td>
<td>62.43 pounds</td>
</tr>
<tr>
<td>1 gallon of water</td>
<td>8.34 pounds</td>
</tr>
<tr>
<td>1 cubic foot/second</td>
<td>448.8 gallons/minute</td>
</tr>
<tr>
<td>1 MGD</td>
<td>694 gallons/minute</td>
</tr>
<tr>
<td>1 horsepower</td>
<td>33,000 foot-pounds/minute</td>
</tr>
<tr>
<td>1 psi</td>
<td>2.31 feet of water</td>
</tr>
<tr>
<td>1 kilowatt</td>
<td>1000 watts</td>
</tr>
<tr>
<td>1 horsepower</td>
<td>746 watts</td>
</tr>
<tr>
<td>1 horsepower</td>
<td>42.45 Btu/minute</td>
</tr>
<tr>
<td>1 MGD</td>
<td>1.55 cubic feet/second</td>
</tr>
<tr>
<td>1 Btu</td>
<td>778 foot-pounds</td>
</tr>
<tr>
<td>1 watt</td>
<td>3.412 Btu/hour</td>
</tr>
<tr>
<td>1 thermal unit</td>
<td>100,000 Btu</td>
</tr>
</tbody>
</table>
| \( \pi \)         | Steel: 0.00000633/\(^\circ\)F  
                   | Brass: 0.000001/\(^\circ\)F |

### Formulas

#### Geometry

- **Circumference of a circle**: \( C = \pi \times \text{diameter} \)
- **Area of a triangle**: \( A_{\text{triangle}} = \frac{\text{base} \times \text{height}}{2} \)
- **Area of a circle**: \( A_{\text{circle}} = \frac{\pi}{4} \times \text{diameter}^2 \)
- **Area of a rectangle**: \( A_{\text{rectangle}} = \text{base} \times \text{height} \)
- **Area of a cylinder**: \( A_{\text{cylinder}} = \pi \times \text{radius}^2 \)
- **Volume of a rectangular solid**: \( V_{\text{rectangular solid}} = \text{length} \times \text{width} \times \text{height} \)
- **Volume of a cylindrical solid**: \( V_{\text{cylindrical solid}} = \frac{\pi}{2} \times \text{diameter}^2 \times \text{height} \)
- **Efficiency**: \( \text{Efficiency} = \frac{\text{work output}}{\text{work input}} \)
- **Energy**: \( \text{Energy} = \text{power} \times \text{time} \)

### Coefficients of thermal expansion

- **Thermal expansion**: \( \text{coeff. of thermal expansion} \times \text{length} \times \Delta T \)

### Hydrostatic force

- **Hydrostatic force**: \( \text{column area} \times \text{column height} \times \text{fluid density} \)

### Motor horsepower

- **Motor horsepower**: \( \frac{\text{flow} \times \text{head} \times \text{specific gravity}}{3960 \times \text{efficiency pump} \times \text{efficiency motor}} \)

### Brake horsepower

- **Brake horsepower**: \( \frac{\text{flow} \times \text{head} \times \text{specific gravity}}{3960 \times \text{efficiency}} \)

### 3 phase A

- **3 phase A**: \( \frac{746 \times \text{horsepower}}{1.732 \times V \times \text{efficiency} \times \text{power factor}} \)

### Efficiency

- **Brake horsepower**: \( \frac{\text{water horsepower}}{\text{efficiency}} \)

### Water horsepower

- **Water horsepower**: \( \frac{\text{flow} \times \text{total head} \times \text{specific gravity}}{3960} \)

### V = d / t
Section 5

Practice Test

This section provides a practice certification test to help certificate candidates become familiar with the test format and subject matter. The actual certification test is given on a computer at a secure testing site. The computer-based test (CBT) requires test takers to be able to use a computer mouse and some very basic keyboard functions. Candidates who have never taken a computerized test are strongly encouraged to try the online CBT demo to become familiar with the computerized test format before going to a test site. A CBT tutorial is also available to candidates just before they start their test. For more information about CBT and to try the CBT demo go to www.cwea.org/cbt.

The number of test questions on the actual certification test may range from about 90 to 130 questions (this practice test has over 50 questions). The time limit for the test is 3 hours. The computerized certification test can be paused for restroom breaks, but the 3-hour clock will not stop. A formula table very similar to Table 4-1 (Section 4) will be available as a window on the computer screen during the test. The format of the test questions on the computerized certification test is very similar to the multiple-choice questions given in this practice test. There are no fill-in or essay type questions given on the test. Most questions on the certification test are worth 1 point, however some can be worth up to 5 or more points depending on the level of difficulty or calculations required. No point values are given for questions on this practice test so the weighting will not precisely reflect that of the actual certification test. If answered correctly, candidates will earn the number of points given for a question. If a question is not answered correctly, then no points are awarded (there is no penalty for “guessing”). At the test site, calculators are limited to a list of approved calculators. A screen calculator, similar to the basic Windows computer calculator, is also available during the test and can be toggled between basic and scientific modes. For the list of allowable calculators see the Calculator Policy at www.cwea.org/cbt, or contact CWEA at 510-382-7800, or tcp@cwea.org.

The practice test includes a key after the end of the test. Some questions that require calculations include solutions that are given after the key. These are indicated on the key with “see solutions” to the right of the correct answer. Candidates are encouraged to find the solutions to all of the questions requiring calculations themselves.
Practice Test

Select the best answer for each item below.

1. What does the term "arc length" refer to in arc welding?
   A. The voltage required to maintain an arc
   B. The amperage peak across the welding arc
   C. The length of time the arc is maintained during welding
   D. The distance from the end of the electrode to the surface of the work

2. When ARC (stick) welding in DC straight polarity welding:
   A. the work is the positive pole and the electrode is the negative pole.
   B. polarity switches back and forth at 60 cycles per second.
   C. the work is the negative pole and the electrode is the positive.
   D. a shielding gas is required.

3. What safety measure should be considered when chipping slag after stick welding?
   A. Take precautions against flying debris
   B. always use a stainless steel wire brush
   C. Use a beryllium hammer to avoid sparks
   D. Ise a ball-pen hammer

4. The tungsten electrode used to TIG welding is:
   A. sometimes used as a filler.
   B. consumed in the wire feed process.
   C. a non-filler electrode.
   D. used as an arc shield.

5. When MIG welding, which of the following is the proper shielding gas?
   A. Argon for welding stainless steel
   B. Carbon dioxide for penetrating welds on steel
   C. Triple-mix (helium+argon+carbon dioxide) when welding aluminum
   D. Carbon dioxide + helium when welding thin steel plates
6. Which is the best technique when plasma cutting?
   A. Bounce the work tip off the work piece to start the cut
   B. Hold the torch at a 60° angle to the work piece
   C. Use clean, dry, air
   D. Use the maximum air pressure available

7. Which of the following is the best description of a pressure head?
   A. It is equal to static head minus dynamic head.
   B. It is the amount of energy in water due to water pressure.
   C. It is the amount of energy in water due to velocity.
   D. It is equal to the static head plus dynamic head.

8. What is the source of most bearing failure?
   A. Excessive shaft speed
   B. Improper installation
   C. Under lubrication
   D. Some form of contamination entering the bearing

9. Of the following, what is the most likely cause of a pump to quickly become noisy and vibrate?
   A. Over lubrication
   B. Worn parts
   C. Loss of foundation bolts
   D. Cavitation

10. Which of the following is the most probable cause of an air compressor delivering below capacity?
    A. Inadequate lubrication
    B. Broken or worn valves
    C. Loose bearings
    D. Excessive crankshaft end display
11. Which is the best definition of friction, as it relates to machine components?
   A. The resistance to motion between two surfaces in contact.
   B. Heat created between two surfaces in contact.
   C. Degradation of lubrication between two surfaces in contact.
   D. Penetration of lubrication between two surfaces in contact.

12. Which of the following can cause cavitation in a centrifugal pump?
   A. Turbidity of mixture
   B. Restriction of suction piping
   C. Restriction of discharge
   D. A worn impeller

13. What can be assumed if a centrifugal pump sounds as if it is pumping rocks?
   A. The pump is excavating
   B. The pump is cavitating
   C. The pump is pumping sludge
   D. The pump is operating as designed

14. Which of the following pumps require priming?
   A. A centrifugal pump
   B. A rotary pump
   C. A reciprocating pump
   D. A gear pump

15. Which of the following defines the rated capacity of a pump?
   A. Electrical consumption and gallons per minute pumped
   B. Electronic consumption and velocity of flow
   C. Horsepower and velocity flow
   D. Gallons per minute pumped and pressure head
16. Closing the discharge valve on an electric motor driven centrifugal pump during pumping will cause the motor's amperage draw to:
   A. decrease.
   B. increase.
   C. remain unchanged.
   D. trip the circuit protection device.

17. What is the most common source of tripping a circuit breaker on an electrical motor driven centrifugal sewage pump?
   A. A plugged discharge line
   B. A plugged suction line
   C. Packing binding on the shaft
   D. Rags or debris binding the pump

18. An impeller in a centrifugal pump has become worn after use. For this pump the amount of energy used to pump the same amount of water as a new similar pump will be:
   A. erratic.
   B. increased.
   C. decreased.
   D. the same.

19. What is the advantage of a split mechanical seal compared to a cartridge mechanical seal?
   A. The seal can be installed without removing the pump.
   B. Seal water is not required.
   C. Packing glands are easier to adjust.
   D. Split in seal allows additional cooling.

20. What is used to adjust the clearance between the impeller and the wear ring in raw wastewater pumps?
   A. A flexible coupling
   B. A stuffing box
   C. A jack screws
   D. A ceramic seal
21. Which of the following is most true about shaft sleeves on raw wastewater pumps?
   A. They allow for replacement for the sleeve instead of the entire shaft.
   B. They are only used with mechanical seals.
   C. They are commonly made of Teflon.
   D. They eliminate the need to replace o-rings in mechanical seals.

22. In mounting a bearing, force should be applied to which ring?
   A. The ring that rotates in the application
   B. The ring that is stationary in the application
   C. The inner ring
   D. The outer ring

23. Lock-out, tag-out is not required to:
   A. clear a blocked pump impeller.
   B. replace a mechanical seal.
   C. collect vibrations data from a shaft bearing.
   D. adjust the tension on a v-belt.

24. In what conditions would you use an open or semi-open impeller pump?
   A. During high volume, low head applications
   B. During low volume, high head applications
   C. During chemical metering applications
   D. During grit removal applications

25. Internal leakage in a centrifugal pump with a closed impeller is restricted by the:
   A. wearing rings.
   B. casing.
   C. impeller shroud.
   D. impeller sleeve.
26. The main function of a pump stuffing box is to:
   A. prime the pump.
   B. protect the pump against leakage at the point where the shaft passes through the pump casing.
   C. provide a ball bearing race.
   D. house the shaft sealing device.

27. Which is the most common type of AC motor used at a treatment plant?
   A. A squirrel cage induction motor
   B. A wound rotor motor
   C. A synchronous motor
   D. A dual winding motor

28. Which of the following is most true when using packing for pump sealing?
   A. It should leak continuously
   B. It is superior because they do not cause shaft wear
   C. It should only need adjustment at installation
   D. They are designed to provide an additional point of shaft support

29. Which of the following is true about the flow capacity of pump?
   A. varies with the square of the speed \( Q_2/Q_1 = (N_2/N_1)^2 \)
   B. varies inversely with the speed \( Q_2/Q_1 = \frac{1}{N_2/N_1} \)
   C. varies directly with the speed \( Q_2/Q_1 = N_2/N_1 \)
   D. varies inversely with the square of the speed \( Q_2/Q_1 = \frac{1}{(N_2/N_1)^2} \)

30. Comminuter teeth should be set with how much clearance?
   A. .0005 in.
   B. .005 in.
   C. .05 in.
   D. .5 in.
31. A maintenance program consists of two major parts; performing tasks and:
   A. scheduling tasks.
   B. ordering renewal parts.
   C. equipment failure analysis.
   D. completing the paperwork.

32. In which circumstance would pneumatic ejectors be used for?
   A. Situations requiring pumping low flows containing large solids
   B. Situations requiring pumping high flows containing large solids
   C. Situations with excessive H₂S environments
   D. Situations with severe odor problems

33. Seal water is usually plumbed to pumps:
   A. with two stage impellers.
   B. in high head applications.
   C. pumping liquids containing grit.
   D. in high humidity environments.

34. Which of the following is true regarding incline screw pumps?
   A. They have pumping rates inversely proportional to submergence.
   B. They have operating efficiencies of 75-80%.
   C. They are susceptible to ragging.
   D. They are often used in high discharge head applications.

35. V-belts come in various letter designations ranging from "A" through "E". These letter designations identify which of the following?
   A. The belts cross section dimensions
   B. The maximum speed at which the belt can be used
   C. The maximum torque the belt will withstand
   D. The maximum temperature the belt can safely operate
36. What is dry ice used for at a pump shop?
   A. To expel a pump wear ring to ease installation
   B. To freeze the pump wear ring to ease installation
   C. To freeze shaft bearings to ease installation
   D. To expel oxygen from a crankcase before filling with oil

37. Which of the following best describes the efficiency of preventative maintenance for plant equipment?
   A. The accumulation and analysis of equipment performance data designed to schedule equipment repairs
   B. Timely response to equipment failure, returning equipment to service with a minimum of downtime
   C. Periodic inspection of facilities to discover developing defects that could lead to equipment failures
   D. Dependent upon just-in-time parts delivery

38. Which of the following is most true about predictive maintenance?
   A. Results in more downtime than preventative maintenance
   B. Costs less than preventative maintenance
   C. Ensure less downtime than breakdown maintenance
   D. Requires more spare parts on hand than breakdown maintenance

39. Which of the following could lead to water hammer in a piping system?
   A. Excessive flow
   B. Restriction of flow
   C. Slowly opening a valve
   D. Rapidly closing a valve

40. Which of the following valves will open or close with a 1/4 of a turn?
   A. A ball valve
   B. A gate valve
   C. A needle valve
   D. A diaphragm valve
41. Short pieces of pipe threaded on both sides are called:
   A. bushings.
   B. couplings.
   C. nipples.
   D. sleeves.

42. A pipe with many connection points to allow multiple flow operations is called a:
   A. gooseneck.
   B. multi-valve pipe.
   C. global valve.
   D. manifold.

43. Which of the following items must be replaced when connecting a new chlorine cylinder?
   A. Fiber washer
   B. Air and water regulator
   C. Needle valve seat
   D. Pressure regulator

44. What is the purpose of the low-pressure check valve on an anaerobic digester?
   A. To prevent air from being drawn into the gas piping by a vacuum condition in the digester
   B. To prevent the flame from going out
   C. To eliminate carbon dioxide from the digested gas
   D. To prevent gas leaks around the shaft seal

45. What are the typical settings for the pressure relief valve on an anaerobic digester? The pressure relief valve setting should:
   A. be lower than the setting for the cover mounted pressure and vacuum relief valve.
   B. be slightly higher than the setting for the cover mounted pressure and vacuum relief valve.
   C. be the same as the setting for the cover mounted vacuum relief valve.
   D. have 12-mm of water column above the lower pressure check valve (all other options are referring to a vacuum)
46. A Parshall flume is used to measure:
   A. liquid flows in an open channel.
   B. air flows in a heating system.
   C. water flow in a piping system.
   D. exhaust emissions.

47. What is the area of a triangle with a base of 15 feet and 4 inches and height of 8 feet and 9 inches?
   A. 67 square feet
   B. 68.5 square feet
   C. 134.1 square feet
   D. 137 square feet

48. The exterior walls of an open-top tank are to be painted. If the tank is 25 feet in diameter and 12 feet high, what is the total surface work area of the tank in square feet?
   A. 78.50 ft\(^2\)
   B. 113.04 ft\(^2\)
   C. 942.48 ft\(^2\)
   D. 1,356.48 ft\(^2\)

49. What is the area of a right triangle below?
   A. 60 square feet
   B. 67.5 square feet
   C. 120 square feet
   D. 135 square feet
50. Which of the following formulas correctly shows the relationship between absolute pressure and gauge pressure?
   A. absolute pressure + atmospheric pressure = gauge pressure
   B. absolute pressure + gauge pressure = atmospheric pressure
   C. absolute pressure = gauge pressure + atmospheric pressure
   D. absolute pressure = gauge pressure - atmospheric pressure

51. How much more water will a 6-inch diameter pipe carry compared to a 3-inch diameter pipe under the same conditions?
   A. 2 times
   B. 4 times
   C. 3 times
   D. 6 times

52. What is most true about the design of flame traps?
   A. It limits the distance a flashback can travel in the gas line.
   B. It must be located as far as possible from the source of combustion.
   C. They are designed to instantly shut down the flame in case of an emergency.
   D. They are subject to failure from condensation of water vapor in the gas.

53. Which of the following should be used for lifting objects with sharp edges at the contact points?
   A. A chain
   B. Leather
   C. a wire rope
   D. A webbed nylon

54. During a rigging operation, if the weight of an object is not known, how should the qualified rigger obtain the weight of the object?
   A. By referring to the equipment’s rigging documents
   B. By estimating
   C. By guessing
   D. By researching the weight on the web
55. You are asked to replace a long fluorescent bulb in the administrative building, where should you place the burnt out bulb while you install the new one?
   A. On the floor
   B. On your work cart
   C. Leaning against the nearest wall
   D. On the top of the ladder

56. Small by-pass lines are often furnished around large gate valves mainly to:
   A. direct the fluid in the event of the valve getting stuck.
   B. meter the flow of fluid.
   C. balance the pressure on the gate when the valve is being opened.
   D. permit the release of excess fluid.

57. What tool trues, cleans, and shapes a grinding wheel?
   A. Wheel Hone
   B. Wheel Sharpener
   C. Wheel Dresser
   D. Wheel Cutter

58. A thread chaser is likely to be used to:
   A. adjust die stocks.
   B. repair damaged threads.
   C. remove broken belts.
   D. flare tubing.

59. An electric hand tool, such as a drill, should never be lifted or carried by its service cord. Which of the following would be the primary reason this is true?
   A. The tool might swing and be damaged by striking some hard object.
   B. The cord might be pulled off its terminals and become short-circuited.
   C. The rubber covering the cord might overstretch.
   D. The tool might slip out of your hand because the cord is slick.
60. For a flow of 160 GPM, what is the pump efficiency?
   A. 25%
   B. 4.5%
   C. 60%
   D. 90%

61. Without overloading at any place on the figure above and not using the 1.15 safety factor, what HP motor would be required to meet the new operating condition?
   A. 150 HP
   B. 125 HP
   C. 100 HP
   D. The pump cannot make the new operating point. No motor will meet the conditions.

END OF PRACTICE TEST
Test Answer Key
The following tables show the correct answers for the test questions included in this study guide. The tables below show what section the answers are for, the correct answer, and the subsection the question refers to. If you marked a wrong answer to any of the diagnostic test questions, refer to the subsection listed and you will be able to find the correct reference material to study to help you correctly answer the question.

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58  B  212  
59  B  212  
60  C  214  
61  A  214

Selected Problem Solutions

48. The exterior walls of an open-top tank are to be painted. If the tank is 25 feet in diameter and 12 feet high, what is the total surface work area of the tank in square feet?

A. 78.50 ft²  
B. 113.04 ft²  
C. 942.48 ft²  
D. 1,356.48 ft²

Solution:

Area of Cylinder Wall = Circumference x Height  
Circumference = Diameter x 3.1416  
Circumference = 25 x 3.1416  
Circumference = 78.54

Height = 12 feet

78.54 x 12 = 942.48 sq. ft.
51. How much more water will a 6-inch diameter pipe carry compared to a 3-inch diameter pipe under the same conditions?

A. 2 times  
B. 4 times  
C. 3 times  
D. 6 times

Solution:

Length doesn't matter because question says same conditions. It's easiest to compare Area of the two.

Circle Area = Radius squared x Pi (3.1416)

---6 inch---
---3 inch---
3 inch squared x 3.1416 = 28.2744 sq. in
1.5 inch squared x 3.1416 = 7.0686 sq. in
28.2744 + 7.0686 = 4

28.2744 is 4 times bigger than 7.0686, so the 6-inch pipe will carry 4 times more than the 3-inch pipe.
Study Materials

The following section includes the titles and information of primary and secondary references for the Technologist. Because these references contain the majority of the information needed for the CWEA certification test, it is recommended that these references be obtained for personal use. They may also be obtained at a university library or possibly an employer’s library.

The Internet is also a valuable resource. However, when searching for material the source should be considered and your search information should be as targeted as possible to obtain the resource requested. If possible, you should target colleges, government agencies, public works agencies and similar trustworthy sources for your requests.

Study Materials Referenced in Section 3

- **California Manual on Uniform Traffic Control Devices**, (POCKET GUIDE)
  U.S. Department of Transportation, Federal Highway Administration

- **Mechanical Trades Pocket Manual 4th Edition**
  Thomas B. Davis, Carl A. Nelson, Audel

  Thomas B. Davis, Carl A. Nelson, Audel

- **Operation of Wastewater Treatment Plants, 7th Edition**
  Office of Water Programs, California State University Sacramento
  6000 J Street, Sacramento, CA 95819-6025, 916-278-6142  [www.owp.csus.edu](http://www.owp.csus.edu)

- **Operation of Municipal Wastewater Treatment Plants Manual of Practice No. 11**
  Water Environment Association

- **Shaft Alignment**
  Wikipedia article

- **What is a Reduction Gear?**
  Raunekk, Bright Hub Engineering

- [www.welding.com](http://www.welding.com)
Additional Study Materials

- 2012 WATCHBook: Work Area Traffic Control Handbook
  888-264-2665 www.bnibooks.com
  http://www.bnibooks.com/shopexd.asp?id=6471

- Condensed Hydraulic Data (POCKET GUIDE)
  Cornell Pump Company
  P.O Box 6334, Portland, OR 97228-6334, 503-653-0330 www.cornellpump.com

- Pocket Guide to Flanges, Fittings, and Piping Data
  http://www.amazon.com/Pocket-Guide-Flanges-Fittings-Piping/dp/088415310X

- Pocket Ref
  Thomas J. Glover, Sequioa Pub; 4th Edition
  http://sequoiapublishing.com/

- Pump Application Engineering, Hicks and Edwards,

- USA North’s California Excavation Manual (POCKET GUIDE)
  Underground Service Alert, USA North
  http://usanorth.org/calaw.pdf

  Office of Water Programs, CSUS
  6000 J Street, Sacramento, CA 95819-6025 916-278-6142
  www.calregs.com

- Valve & Actuator Technology
  Wayne Ulanski, McGraw-Hill

- Wastewater Operator Field Guide
  John M. Stubbart, William C. Lauer, Timothy J. McCandless, Paul Olson, American Water Works Association
  6666 W. Quincy Ave. Denver, CO 80235, 800-926-7337 www.awwa.org
Appendix A

You and Wastewater Math

By Cheryl Ooten, Santa Ana College  email: ooten-cheryl@rsccd.org

Example math problems found in Appendix A are representative of general wastewater math and are designed to illustrate a math problem solving strategy, not specific math skills. Examples given in this appendix may not be like the problems given on the test for your discipline. However, the problems are typical of types of problems you may encounter, including, but not limited to, basic algebra (solving one equation for one unknown), story problems, and geometry, (area and volume problems). For specific kinds of math skills and problems you may encounter on the Collection System Maintenance certification test, please review Sections 3, 4, and 5 of this study guide.

Section 1: Introduction

Now is the time for you to begin preparation for the math portion of your technical certification exam. This Appendix provides suggestions to take charge of:

- Your math skills
- Your attitudes toward math
- Your test-taking skills

By doing this, you can improve your performance in successfully completing the math questions on the certification exam.

Two Facts to Consider

First, since early childhood, you have used math mostly without giving it a second thought. Knowing your age, counting, comparing sizes and shapes, adding your money, and subtracting to get change are math skills.

You drive the streets judging distances, speeds, and times. You estimate if you can afford a vacation or a car and when you can retire. You compare volumes and areas as you build and do jobs around the work site. You even measure volume in putting toothpaste on your toothbrush. You use statistics as you watch sports and consider things like RBIs in baseball or field goal percentages in basketball. All of these are mathematical skills many people take for granted.

Second, if you think math is hard, please know that math becomes hard for everyone at some point. You are not alone. There are math problems that have been unsolved for hundreds of years even though they have been attempted by competent, well-informed mathematicians who may work at them for decades. Those are not the problems you need to work unless you are curious. When you work at your appropriate level, you find a combination of easy ideas and hard ideas.

You may get discouraged comparing your speed and understanding in math with others. Those people who appear to do math easily have, most likely, done those specific problems, or ones like them, many, many times.
You will want to study and progress at your “growing edge”—the skill level where you have a bit of discomfort with new material, but where you are not totally overwhelmed. You can expect challenges that trouble you, but that can be overcome. Instead of saying “I cannot do math,” decide now to begin learning enough math to make work and test-taking easier.

**Move Beyond the Math You Know**

To move beyond your routine skill level in math, consider the following points:

**You Have Skills.** You already have many math skills and can build on that base. It is best and easiest to build on what you already know.

**Basics are Important.** Going back over the basics of what you know will build confidence and help you progress and add new math skills to your ability to solve math problems.

**Math Progresses Logically.** There are many different areas of math and each builds on itself as well as on the others. If you cannot do a particular problem, it may be because you have missed something basic to that one area along the way. Working your way up slowly and cumulatively in math is the fastest way to gain skills.

**Words Count.** Each and every word and symbol in math means something. You need to find out those meanings and then practice them. If you do not know what “mgd” or “psi” means, or which units measure “flow”, it is harder to do problems involving them. It can seem like a foreign language.

**Brains are Unique.** Each individual brain is wired differently, causing each person to think and learn differently. The more you know about the way you as a specific individual learn, the more you will permit yourself to do what it takes to learn math. Some people need to do many written repetitions. Some need to walk or move around as they do math. Some need to talk out loud. Others need to draw pictures. Some need to work problems with other people. Some need to use words and some need to use symbols. In order to focus on how to move forward, think about what works for you or where learning has been difficult for you.

If you are an independent learner, you might find a basic math book at your library to work through on your own. You may be able to study with your own children to learn some math together or with your friends and colleagues. You may have an old math book you used a long time ago that could be helpful, and you may come to remember what you learned from it.

**Assessment Helps.** Assess your skill level honestly. Math placement tests are available at your local college and through private educational agencies to help you determine where your skills are and where you can best get help to make comfortable progress.

**You are Not Alone.** No one promises that math will always be easy or interesting for you. For most people, working on math is a challenge. Persevering and pushing personal limits allows you to experience the satisfaction of success.

**Get help when you get discouraged or experience confusion.** Remember this is just a momentary problem in a sequence of ideas that you are confronting. Do not buy into the myth that you have to do math alone. Do not believe it is demeaning for you to admit you do not understand. You can have fun if you lighten up as you progress. Working with others is an outstanding way to improve math skills.
Questions are Essential. Make a list of people with whom you feel comfortable discussing your math questions. They may be your colleagues, teachers, fellow students, friends, or family members—even your children. Do not ask just anybody; pick people who are helpful and positive or non-judgmental about your questions.

Mistakes Happen. Expect mistakes up front. As you learn anything new, you will make errors. Do not blame your mistakes on math itself! In any new endeavor you need to allow yourself to crawl before you can walk. Successful people in all fields know this. Trial and error is the basis of all learning.

You can learn more from your mistakes than from repeated successes. Making errors gives you feedback by showing you what you do not understand. Learn to value and accept those errors and use them to find out what areas of your learning need more work. Correct them and then move on with new knowledge.

Learning Math is Not a Competitive Game. Physicist Albert Einstein, politician Winston Churchill, and inventor Thomas Edison were all considered slow in school. Musical composer Ludwig Van Beethoven and scientist Louis Pasteur probably had learning disabilities. What all five certainly had was determination and patience to persevere. Only compete with yourself, pushing yourself forward, in learning math.

There is Hope for Those with Learning Disabilities. If you really have a hard time learning, you might ask your local college or a private learning specialist to assess you for a learning disability. Many colleges and universities do free testing and training for their students. You can also purchase this kind of assistance from private consultants. Much is now known about learning disabilities and how to help people who have them. Learning disabilities often become just learning differences as students learn to honor and use their own thinking and learning styles.

Math Success and Test-Taking Success are Not the Same. Many math students understand and can work math problems, but have difficulty in test-taking situations. It is possible to know math and still fail exams. These people may find Section 4 “Test-Taking Strategies” very helpful. Conscious practice of both math skills and test-taking skills can make a big difference in your score.

Resources are Available. Resources exist for all types of math. You will need to decide whether you will work on your math skills independently or with the help of some structure such as a math course or a tutor. Different strategies may work better at different stages in your progress.

Your local community college has inexpensive math courses. Some colleges even have math courses specifically for water and wastewater professionals. Professional organizations sponsor training conferences and seminars which include math courses specific to the field. Many agencies can provide in-house training and many agencies will provide individual help with all aspects of test taking.

Community Colleges. Community colleges offer several types of services including:

- Math Placement Testing
- Math Courses
- Water Utility Science Courses
- Math Anxiety Reduction Courses
- Testing and Training for those with Learning Disabilities
Professional Organizations. Organizations such as the California Water Environment Association (CWEA), American Water Works Association, and American Public Works Association also provide opportunities to practice your math skills and network with others:

- CWEA local section study sessions
- Technical Certification Training Classes and Annual Conferences
- CWEA Northern Regional Training Conferences
- CWEA Study Manuals

At Work. Ask for help and suggestions from others who have taken math courses or are skilled in the work area similar to the one you are trying to prepare or improve. Ask your supervisor for advice on how to prepare and how much time on the job you can have to prepare. Ask your supervisor to provide training classes for the areas that you want to improve. Ask those managing other departments, agencies, or local professional organizations for help in the training you need.

Materials. Any basic math book or instructional manual that you can beg, borrow, or buy, including:

- Courses from Office of Waste Programs, California State University, Sacramento, 6000 J Street, Sacramento, CA 95819.

Section 2: Practice Problem Solving Strategies

Wastewater math deals with only a handful of basic types of problems that involve moving liquids and semi-solids from place to place, and manipulating, storing, and treating these substances along the way.

So basically, understanding area, volume, slope, rates, concentrations, costs, and time elements that occur in wastewater treatment 24 hours per day, 365 days per year, pretty much covers what you need to know.

Units and Arithmetic

All wastewater math problems can be solved by simple arithmetic—adding, subtracting, multiplying, and dividing. You can become proficient with wastewater math by paying careful attention to the units in the problems as you write down your strategies, and then using a calculator to do the needed arithmetic. Make sure you use only a calculator that you can take into the test site (see www.cwwa.org/cbt for a list of approved calculators).

Units. Units such as cubic feet, gallons, gpm, and mgd are important in wastewater math problems. Paying attention to the units will tell you whether to multiply or divide. Also, the units will often help you know what numbers to multiply or divide.

Notice in each example that doing math operations on the units produces the correct units in the answer. Many people do the math on the units first to figure out the correct procedure before they ever do the math on the numbers.
**Multiplying.** Multiplying is important. There are several symbols for multiplication. They are •, x, and ( ).

For example,

\[ 2 + 3 = 2 \times 3 = (2)(3) = 6 \]

**Dividing.** Dividing is important to wastewater math because units often used such as mgd, cfs, ppm, gpm, psi, mg/L, gpd/sq.ft., and % are really division problems.

“Per” stands for “divided by”.

\[ \text{mgd} = \frac{\text{million gallons}}{\text{day}} \]

\[ \text{cfs} = \frac{\text{cubic feet}}{\text{second}} \]

\[ \text{ppm} = \frac{\text{parts}}{\text{million}} \]

\[ \text{gpm} = \frac{\text{gallons}}{\text{minute}} \]

\[ \text{psi} = \frac{\text{pounds}}{\text{square inch}} \]

\[ \text{mg/L} = \frac{\text{miligrams}}{\text{Liter}} \]

\[ \text{gpd/square foot} = \frac{\text{gallons/day}}{\text{square foot}} \]

\[ 10\% = \text{ten percent} = \frac{10}{100} \]
Example Problems

Example 1. Plant No. 1 measured a flow of 3.5 million gallons in half a day. If the peak flow (hydraulic) capacity of the plant is 8 mgd, is there need for concern?

Using the conversion factor:

\[
mgd = \frac{\text{million gallons}}{\text{day}}
\]

divide 3.5 million gallons by half a day.

\[
mgd = \frac{3.5 \text{ million gallons}}{0.5 \text{ day}} = 7 \text{ mgd}
\]

7 mgd is less than the peak flow capacity, 8 mgd. There is no need for concern yet.

Example 2.

a. Find the number of gallons in 10 cubic feet.

Since we can pour 7.48 gallons into a 1 cubic foot container, that means that 7.48 gallons = 1 cubic foot. We can use either factor:

\[
\frac{7.48 \text{ gal}}{1 \text{ cu ft}} \text{ or } \frac{1 \text{ cu ft}}{7.48 \text{ gal}}
\]

to convert cubic feet units into gallons or vice versa

\[
\frac{10 \text{ cu ft}}{1} \cdot \frac{7.48 \text{ gal}}{1 \text{ cu ft}} = (10 \text{ cu ft})(7.58 \text{ gal}) = 75.8
\]

Notice that using the first factor allows the unit “cu ft” to cancel out leaving the answer in gallons.

b. Find the number of cubic feet in 10 gallons. Notice that using the second factor allows the unit “gal” to cancel out leaving the answer in cubic feet.

\[
\frac{10 \text{ gal}}{1} \cdot \frac{1 \text{ cu ft}}{7.48 \text{ gal}} = (10 \text{ gal})(1 \text{ cu ft}) = 1.34 \text{ cu ft}
\]
You will notice how important it was in these examples to consider the units in deciding whether to multiply or divide by 7.48.

**Example 3.**

a. Find the detention time for a basin with 675,460 gal if the flow is 1,000,000 gal/day.

Flow is always a rate which is division. Units like gpd or cfs are both division.

The formula for the basin detention time is

\[
D_t = \frac{volume}{flow}
\]

\[
D_t = \frac{675,460 \text{ gal}}{1,000,000 \text{ gal/day}} = 0.675 \text{ days}
\]

b. Find the detention time for a 426 cubic foot basin if the flow is 1,000 cfs.

\[
D_t = \frac{426 \text{ ft}^3}{1,000 \text{ cfs}} = \frac{426 \text{ ft}^3}{1,000 \text{ ft}^3/\text{sec}} = 0.426 \text{ sec}
\]

**Example 4.**

Find the number of gallons of an 11% polymer needed to produce 100 gal of a 0.75% solution. Use the formula \(C_1V_1 = C_2V_2\) where \(C = \text{concentration or } \%\) and \(V = \text{volume}\).

You can let the volume you are looking for (i.e. the number of gal of 11% polymer) be represented by \(V_1\). Then \(C_1 = 11\%\) or 0.11, \(C_2 = 0.75\%\) or 0.0075, and \(V_2 = 100\) gal.

Using the formula \(C_1V_1 = C_2V_2\), you have \((0.11)(V_1) = (0.0075)(100)\)

Notice to find \(V_1\), you do the opposite of multiplying (i.e. dividing) by 0.11 on both sides. You then have

\[
\frac{(0.11)(V_1)}{0.11} = \frac{(0.0075)(100)}{0.11}
\]

and using a calculator, \(V_1 = 6.82\). So, the amount needed is 6.82 gal.

**Example 5.**

How many hours will it take to empty a 43,000 cubic foot tank if it empties at a rate of 2.7 cubic feet per second?

Notice that dividing 43,000 cubic feet by 2.7 cubic feet per second would make the cubic feet unit cancel out. This would give us the time in seconds. To convert seconds into hours, use the factors

\[
\text{time in hours} = \frac{\text{time in seconds}}{3600} = \frac{43,000}{2.7 \times 3600}
\]
The word is given below.

Notice how the units cancel out leaving the answer in hours.

$$\text{Time} = \frac{43,000 \text{ ft}^3}{2.7 \text{ ft}^3} \cdot \frac{1 \text{ min}}{60 \text{ sec}} \cdot \frac{1 \text{ hr}}{60 \text{ min}} = 4.42 \text{ hr}$$

Example 6.
Find the number of gallons of water in a rectangular basin 200 ft. long, 50 ft. wide, and 12 ft. deep.

First, find the volume of the rectangular basin by multiplying length by width by height. Volume = (200 ft)(50 ft)(12 ft) = 120,000 cubic feet or cu ft or ft[^3].

You now have a problem similar to Example 2. How many gallons are there in 120,000 cubic feet?

Use the factor to convert cubic feet into gallons.

$$\text{volume} = \frac{120,000 \text{ cu ft}}{1} \cdot \frac{7.48 \text{ gal}}{1 \text{ cu ft}} = 897,600 \text{ gal}$$

Example 7.
A cylindrical tank is full to 3 feet below the top at 10 a.m. and empty at 4 p.m. If the tank is 50 ft. tall with a diameter of 70 ft., find the volume (in gal) of the liquid at 10 a.m. and the rate of flow from the tank in gal per minute.

For a math problem with many words, I recommend always first writing down what you are trying to find:

a. First, find the number of gal of water in the tank at 10 a.m.

b. Second, find the rate of flow in gal/min.

Drawing a sketch helps some people understand the problem and helps to keep track of the data.

I also like to write down and interpret the details that are given to me like:

- Full to 3 ft. below the top at 10 a.m.
- Empty at 4 p.m.
- Takes 6 hours to empty
The solution is presented in two parts.

a. First, to find the volume in gal at 10 a.m., use the formula for volume of a cylindrical tank which is \( V = (\text{area of the base}) \times (\text{height}) \).

To find the area of the base of the tank which is a circle, multiply 0.785 times the diameter squared.

So, the area of the base = 0.785(702) = 3,846.5 sq. ft.

The height at 10 a.m. is 47 ft. because the tank is filled to 3 ft. below the top.

Volume = (area of the base)(height) = (3846.5 ft\(^2\))(47 ft) = 180,785.5 ft\(^3\)

However, you want the volume in gal so use the factor \( \frac{7.48 \text{ gal}}{1 \text{ cu ft}} \) to convert.

Volume in gallons = \( \left(180,785.5 \text{ ft}^3\right) \left(\frac{7.48 \text{ gal}}{1 \text{ ft}^3}\right) = 1,352,275.54 \text{ gal} \)

b. Second, to determine the rate of flow in gallons per minute, divide the number of gallons by the number of minutes it took the tank to empty. It took 6 hours to empty. To convert 6 hours to minutes,

use 60 min = 1 hour or factors \( \frac{60 \text{ min}}{1 \text{ hour}} \) or \( \frac{1 \text{ hour}}{60 \text{ min}} \) to convert. You want the hour unit to cancel out, so you will use the first factor. The time becomes:

Rate of flow in gal per minute = \( \frac{1,352,275.54 \text{ gal}}{360 \text{ min}} = 3,756.32 \text{ gal per min} \)

### Section 3: Take Charge of Your Success

The key to progress with math is to consciously take charge of your thoughts and actions. Then, instead of letting math control you, you control math and you take charge of your success.

**Recommendations**

**Ask Questions.** Be active and assertive. Learning is not a spectator sport. You cannot learn well from the sidelines. Get involved. Work problems and keep asking questions until they become clear. In classes and seminars, ask questions on confusing procedures.

**Take It Easy.** When you get stuck working problems, hang in for a while and then take a break. Go back later, begin at the beginning with a clean sheet of paper and a different point of view. Just because you do not understand at first does not mean understanding will not come. Math learning requires time to settle into your brain. Being able to live with uncertainty for a while is a good math skill to have.
**Appendix A: You and Wastewater Math**

**Take It Easy.** When you get stuck working problems, hang in for a while and then take a break. Go back later, begin at the beginning with a clean sheet of paper and a different point of view. Just because you do not understand at first does not mean understanding will not come. Math learning requires time to settle into your brain. Being able to live with uncertainty for a while is a good math skill to have.

**Keep a List.** Write down your resources (books, tutors, people to answer questions, people who understand) so that you can consult them when you get discouraged. You are not alone. Find helpful people with whom you are comfortable. Form a network with others working toward the same goals as you.

**Find Yourself.** Discover your own unique ways of learning. Experiment with new ones. If a method does not work, find others. Ask different people how they learn math or do a problem. They will often feel honored and pleased that you asked them and you might get a breakthrough idea.

**Be Positive.** Listen to what you say to yourself inside your head. It is difficult to work well if you are saying, “I will never get this” or “I cannot do math.” Change those negative messages to neutral ones like “I have not learned this yet” or “I cannot do this particular problem yet.”

**Reward Yourself.** Acknowledge your progress—every little bit! Pat yourself on the back for each and every problem you work. Notice what you know now that is new that you did not know two weeks ago. Maybe even write it down to document your growth.

**Learn From Mistakes.** Remember that errors are part of the learning process. Pay attention to them and figure out where they happened and how to fix them.

**Keep It Real.** Be realistic with your expectations of yourself—your math level, your life commitments, and your time constraints. Do not beat yourself up for being a human being.

**Use Technology.** Learn to use a calculator and use it appropriately for calculations with large numbers and decimals. Be sure to use only an approved calculator for the test site (a list is available at www.cwec.org/cbt). Each brand of calculator is different so keep your manual for reference. Take spare batteries to exams.

**Start Easy.** Practice the easier math problems to warm up each time you begin your math study. This builds confidence and strengthens those math pathways in your brain.

**Write Out Problems.** You will be given a dry erase sheet to use at the test site. Practice math problems using scratch paper. Use this to think and do calculations.

**Promote Emotional Well Being.** Patience, self-care, and humor will make your math work so much easier. Your brain will work better too.

**Be Healthy.** You are making new connections in your brain as you practice math so sufficient sleep and healthy foods are important. Having fresh drinking water available and breathing fresh air also helps you think better.
Section 4: Test-Taking Strategies

There are many actions you can take before, during, and after exams that will improve your test-taking performance and outlook. Remember that math skills and test-taking skills are different from each other. This section will help you become conscious of your thoughts and actions regarding test preparation. Use these suggestions to take charge and approach your test confidently.

If you find yourself thinking negative thoughts about your coming exam, skip to the last section and read “Negative Thinking about Exams” first.

Before the Exam

Work Problems. Diligently prepare and practice. Repeat solving problems to gain speed and confidence. This takes work and time—sometimes many hours, even days. Going in to an exam with the knowledge that you have worked lots of problems boosts confidence. Prep time is invaluable.

Relax. Practice relaxation daily for about at least ten minutes using breathing. Sitting or lying comfortably, breathe slowly in through your nose counting to five and then out through your mouth counting to ten. If you feel dizzy, breathe normally for a while. Deep breathing activates chemicals in your body that help you relax and feel better. Any type of regular meditation, yoga, or slow stretching while breathing deeply can help facilitate your relaxation response. Practicing daily will help you control your adrenaline level during your exam. Using relaxation consciously during an exam frees up the thinking part of your brain. (Do not practice these deep breathing exercises while you are driving.)

Stay Active. Daily walks or biking or whatever aerobic exercise you use consistently prepares your body for your exam by relieving stress and keeping your state of mind positive. Your mind and your body are connected so tightly that they are nearly the same.

Rehearse. Do a dress rehearsal for your exam. Write or have someone assist you in writing a practice test with problems and questions that you think might be on the real exam. Take the practice test in this study guide in an environment as close to your testing situation and schedule as possible. Time it and then correct it to learn from your errors.

Plan Ahead. Plan ahead carefully so that you will get to the exam early—do not be in a rush. Know exactly how to get there and what you will wear so that you are comfortable. You might want to wear your “lucky” shirt or bring a photograph in your wallet of people who care about you and believe in you. WHATEVER you can do to increase your sense of comfort and security, do it. Ahead of time, pack a Testing-Taking Kit with sharp pencils, pens, a ruler, erasers, tissues or handkerchief, a bottle of water, extra calculator batteries, and anything else you think you might need that is allowed at the test.

Care For Your Body. Optimal food and rest are individual preferences. Plan these ahead of time. Some research has shown that a brisk walk before an exam has raised test results. Some research has shown that eating a few candies (not chocolate) right before an exam has raised test results. Protein appears to be essential for clear thinking. Be in charge of what happens to you before the exam. Do not let outside influences take charge of you for this little time before your test.
At the Exam

Do a Data Dump. Bring a short list of formulas or facts you find difficult to remember. Look at them before the test. Visualize them going into a holding tank in your brain. Practice making them subject to recall. You are not allowed to use notes on the exam, so be sure to put the list away so that your honesty is not questioned. When you start your test, quickly write these formulas or facts on your dry erase sheet. Now you do not have to expend any energy trying to recall them later when you need them.

Ignore Others. Ignore all of the other people at the test site—before, during, and maybe even after. Different people have different ways of dealing with their anxiety during tests (and remember, they are likely to be taking a completely different test than you). Some people get a little hyper and try to rub off their anxiety on everyone else. Do not take on someone else’s anxiety. Your test is not a competition so what other people do will not affect your score. Often the first person to leave an exam gets a very low score, while the last person to leave gets a very high score. Take your time. Pay no attention to other people’s behavior.

Breathe. When you feel stuck or tense, take a deep breath. Let it all go as you expel the air. (The more you have practiced relaxation and deep breathing before the exam, the more you will relax during the test.)

Take Time Out. Take short breaks during the exam to close your eyes, breathe deeply, and stretch your neck and arms. Massaging your temples, scalp, and the back of your neck will increase blood flow with oxygen to your brain to help you think better. A few isometric exercises can release tension too.

Use Your Subconscious Mind. If a problem makes no sense, read it and go on. Ideas will come to you as the problem sinks into your subconscious mind while you continue with the test.

Trust. Let each question reach into your mind for the answer. Remind yourself that you know everything you need to know for now.

Strategize. Do the easy problems and questions first. Make pencil marks by the questions to which you want to return.

Use Time Wisely. Do not work on one problem for a long time. Often a question further into the exam will act as a “key” to unlock a previous problem. Tell yourself that you have all of the time you need. Let go of the rest of your life during the exam. You can deal with all that later.

After the Exam, Let the Results Go. You have used a lot of energy and may be low and off balance. You may wish to pass up discussing the exam with others so you can take care of yourself. Going to the bathroom, drinking some water, and eating something can help you feel normal again. You may have set much of your life aside to prepare for this exam. Refresh yourself and get your life back. You can deal with the test results later when your priorities are in order again.

Negative Thinking About Exams

Here are negative thoughts math students often think before test-taking. Put a check mark by the examples familiar to you. Recognizing the distorted thinking in each example can help you change negative thoughts to neutral or positive ones. If you need more assistance with overwhelming negative thoughts, I recommend the book Feeling Good by David Burns (WholeCare, 1999).
“I Will Fail.” Unless you have a crystal ball and can see into the future OR unless you have made a definite plan NOT to prepare for the test OR unless you plan to “freeze up” during the exam, you have no way of knowing whether you will fail or not. Worrying about the future only takes energy from today.

“I Will Panic During the Test.” It is not uncommon to be excited. An exam is a process during which you will experience many thoughts, feelings, and body sensations. Actors get nervous, yet they still perform. If you do panic, let panic leave you. It will. No one dies from panicking during an exam.

Preparation by practicing problems, asking questions, and reviewing gives you confidence and skills that you need. Taking a dress rehearsal test and trying to panic can help you practice dealing with out-of-control feelings. Learning some relaxation techniques to use before and during the exam calms you and aids clear thinking. The more you prepare yourself ahead, the more you are in charge and feel relaxed.

“I Cannot Do Math.” Math is a very broad subject involving many different skills. If you can recognize shapes, tell time, and know where the front and back of a classroom are, you can already do math. There are many more math skills that you have and many that you do not have YET. There are also many that you will never choose to acquire. Instead of thinking so absolutely about math, find areas where you can grow and learn new skills instead of paralyzing yourself with this broad generalization.

“I Am Stupid.” Name calling is seldom productive. Occasionally you may feel stupid because you do not know something or you mess up. What really is happening is that you are being human and humans are not stupid. Educators recognize the need to change how everyone thinks about intelligence. They recognize that there are many different kinds of intelligence including:

- bodily/kinesthetic
- verbal/linguistic
- naturalist
- logical/mathematical
- visual/spatial
- interpersonal
- intrapersonal
- musical/rhythmic


You are a wonderful combination of these talents—not just an IQ number. IQ Tests are limited because they only measure a few types of intelligence and ignore the rest. We are not all the same and cannot possibly know all there is to know in every situation. Between now and the exam, there are many questions you can get answered as well as many new skills you can practice and master if you use the skills and intelligence that you have.

“I Will Forget Everything.” Forgetting does not mean something is gone from your mind forever. The right cue will often help you remember what you need to know. Your exam will be filled with cues—words and symbols—that will trigger formulas and ideas you have practiced.

Expecting to forget “everything” is foretelling the future and making a broad generalization. Even most people with amnesia caused by illness or injury do not forget “everything.” If you are extremely worried about your memory, The Great Memory Book by Karen Markowitz and Eric Jensen (The Brain Store, 1999) can be of assistance to you.
“Math Tests Are Tricky.” Math students who rely on memorizing the material rather than understanding it are usually the ones who think tests are tricky. You will use your memory to add to your understanding of how to do the math. Your math problems will contain many units such as mgd or ft$^3$ or psi. Learning how to skillfully convert back and forth between units of measure will take a lot of the trickiness away from your test problems. Practicing using your calculator will help too.

“There Is So Much I Do Not Know.” This will always be the case the rest of your life. It is the human condition. Taking a deep breath and finding the level where you can begin to learn will improve your feelings and your confidence.
Technical Terms

40 CFR 121-124: The federal storm water regulations for the permitting of municipalities and industries. Regulations define storm water terms, permitting, inspecting, and sampling requirements.

40 CFR 136: The regulations for sampling preservation and analyses of water, wastewater, and solid waste.

40 CFR 403: The federal regulations defining the elements of a pretreatment program, prohibited discharges, and the approval process for establishing a pretreatment program.

Acid: A compound which liberates hydrogen ions and has a pH below 7.

Alkalinity: The measurement of a sample's capacity to neutralize acid.

Approval Authority: The agency determining whether a pretreatment program contains the necessary elements to meet the intent of the Act.

Atomic Weight: The sum of the number of protons and the number of neutrons in the nucleus of an atom. Atomic weights of elements are found on periodic tables.

Base: A compound which liberates hydroxide ions and has a pH above 7.

Biochemical Oxygen Demand (BOD): The quantity of oxygen utilized in the biochemical oxidation of organic matter under standard laboratory procedures for five days at 20° Centigrade, usually expressed as a concentration (e.g., mg/L). BOD measurements are used to indicate the organic "strength" of wastewater.

Biological Treatment: A waste treatment process by which bacteria and other microorganisms break down complex organic or inorganic (e.g., ammonia) materials into simple, nontoxic, more stable compounds.

Categorical Industrial User (CIU): An industrial user (see IU definition below) that is conducting processes subject to a categorical standard promulgated by the U.S. EPA.

Centrifugal Pumps: Pumps using centrifugal force to convey liquid. Discharge will vary according to inlet and discharge pressure.

Chain-of-Custody: A legal record (which may be a series of records) of each person who had possession of an environmental sample, from the person releasing the sample, to the person who collected the sample, to the person who analyzed the sample in the laboratory, to the person who witnessed the disposal of the sample.

Chemical Oxygen Demand (COD): The amount of oxygen (expressed in mg/L) consumed from the oxidation of pollutants during a specific test. As such, COD is a measure of the oxygen-consuming capacity of the pollutants present in wastewater. The results of the COD test are not necessarily related to the BOD, because the chemical oxidant responsible for utilizing the oxygen may react with substances which bacteria do not stabilize.
Cipolletti Weir: A trapezoidal sharp-crested weir for measurement of liquid discharge in open channels.

Clean Water Act (CWA): Public law (PL 92-500) enacted in 1972, which sets the framework for the imposition of industrial wastewater control programs on municipalities and the regulation of industrial users. Sections 307(b) and (c) of the CWA set forth the authority for the U.S. EPA to establish pretreatment standards for existing and new sources discharging industrial wastewater to publicly owned treatment works (POTWs).

Composite Sample: A collection of individual samples obtained at regular intervals, based either on flow or time. The individual samples are combined proportionally.

Concentration Based Discharge Limits: Allowable concentration of a pollutant in wastewater discharges, usually expressed as a concentration (i.e., mg/L) in the discharge.

Confined Space: A space which has limited openings for entry and exit, has unfavorable natural ventilation which could contain or produce dangerous air contaminants (or create an atmosphere of oxygen deprivation), and which is not intended for continuous employee occupation. A permit may be required under OSHA to enter a confined space.

Control Authority: The agency responsible for implementing a pretreatment program.

Conventional Pollutants: Those pollutants which are usually found in domestic, commercial or industrial wastes (such as suspended solids or biochemical oxygen demand) that POTWs are designed to treat.

Density: The relationship between weight and volume, e.g., grams per cubic centimeter or pounds per gallon.

Detention Times: The residence time of wastewater undergoing treatment in a treatment unit such as a clarifier or tank. Minimum detention times are required for settling, chemical treatment, and biological treatment.

Doppler Flow Meter: A device that measures the velocity of a liquid by measuring the change in frequency between a wave source and the meter.

Electroplating: The process of applying a thin metal coating to the surface of a substrate by electrodeposition of dissolved metal in a plating solution.

Flow Equalization: Temporary storage of wastewater flow to provide more uniform flow or waste characteristics for treatment or discharge.

Flume: A specially shaped open channel flow section with an area and/or slope that is different from that of the channel.

Grab Sample: A sample which is taken from a wastestream without regard to the flow in the wastestream, and over a period of time not to exceed 15 minutes.

Holding Time: The maximum time allowed between when a sample is taken and when it must be analyzed in the laboratory, in accordance with standard preservation, storage, and analytical procedures.

Dissolved Sulfide (H2S): Produced by the biological reduction of sulfate and organic matter under anaerobic (oxygen-free) conditions. Dissolved sulfide can combine with hydrogen to form hydrogen sulfide gas. H2S gas is potentially hazardous to sewer maintenance workers.
**Industrial User (IU):** Any non-domestic source which introduces pollutants into a POTW.

**Industrial Wastewater:** Any non-domestic wastewater (excluding storm water).

**Magnetic Flowmeter:** A flowmeter that creates a magnetic field across a pipe flowing full, in which the liquid acts as a conductor to measure the velocity and flow in the pipe.

**Mass Based Limits:** Discharge limits based on allowable dry weight of pollutant, usually expressed in pounds per day (lbs/day).

**Mass Emission Rate:** The rate of discharge of the dry weight of a pollutant in wastewater or air, expressed in lbs/day or kilograms per day (kg/day).

**Material Safety Data Sheets (MSDS):** Sheets providing information about manufactured chemicals, as required by the Hazard Communication Rule.

**Molarity:** Moles per liter; a measure of concentration.

**Mole:** An Avogadro's number of something.

**Molecular Weight:** The sum of the atomic weights of all atoms making up a molecule.

**National Pollutant Discharge Elimination System (NPDES):** The federal permitting program designed to control all discharges of pollutants from point sources into U.S. waterways, as required under the CWA.

**National Prohibited Discharge Standards:** Prohibitions, applicable to all nondomestic dischargers, regarding the introduction of pollutants into POTWs as set forth in 40 CFR 403.5.

**Neutralization:** Addition of an acid or alkali (base) to a liquid to cause the pH of the liquid to move toward a neutral pH of 7.0.

**Normality:** A measure of the concentration of a solution.

**Oxidation-Reduction:** Reactions involving the transfer of electrons, with oxidation being the loss of electrons and reduction being the gain of electrons. ORP, or oxidation-reduction potential, is a qualitative measure of the state of oxidation in metal waste treatment systems. ORP is used to control the chemical addition to optimize the oxidation of compounds such as cyanide or reduction of metals such as hexavalent chromium.

**Parshall Flume:** An open channel flow-measuring device with a constricted throat that produces a head or water depth that is related to discharge.

**Pass-Through:** The passage of untreated pollutants through a POTW which could violate applicable water quality standards or NPDES effluent limitations.

**pH:** The negative logarithm of the hydrogen ion (H+) concentration; the measure of the relative acidity or alkalinity of a solution on a scale from 0 (acidic) to 14 (basic).

**Pollutants of Concern (POC):** Compounds in wastewater that pose a potential threat to the POTW or its ability to comply with environmental standards.
**Positive Displacement Pumps:** Pumps that use pistons, diaphragm action, etc., to convey liquid. The discharge rate of these pumps does not vary with inlet or outlet pressure.

**Pretreatment Standard:** Any regulation promulgated by the EPA in accordance with Sections 307(b) and (c) of the Clean Water Act, applying to a specific category of industrial users and providing limitations on the introduction of pollutants into POTWs. This term includes BMPS, the prohibited discharge standards under 40 CFR 403.5, and local limits [per 40 CFR 403.3 (j)].

**Precipitation:** Part of a treatment process that takes dissolved pollutants out of solution to form a precipitate that can be removed by filtration or settling.

**Printed Circuit Board:** A circuit for electronic apparatus made by depositing conductive material, usually copper, on an insulating surface.

**Process-Inhibition:** The concentration of a pollutant that will reduce the effectiveness or efficiency of a biological treatment process in the POTW.

**Publicly Owned Treatment Works (POTW):** A treatment works which is owned by a state, municipality, city, town, special sewer district, or other publicly owned and financed entity, as opposed to a privately owned (industrial) treatment facility. This definition includes any devices and systems used in the storage, treatment, recycling and reclamation of municipal sewage or industrial wastes of liquid nature. It also includes sewers, pipes and other conveyances only if they convey wastewater to a POTW treatment plant. The term can also mean the municipality (public entity) which has jurisdiction over the indirect discharges to and the discharges from such a treatment works.

**Settling:** The treatment process by which settleable or floatable solids are removed from wastewater by gravity separation in a tank or other vessel.

**Sludge Quality Standard:** Allowable concentration or mass of a pollutant in POTW sludge, or biosolids, used for land application, found in 40 CFR 503.

**Specific Gravity:** (1) The weight of a particle, substance, or chemical solution in relation to the weight of an equal volume of water. Water has a specific gravity of 1.000 at 4°C (39°F). (2) The weight of a particular gas in relation to an equal volume of air at the same temperature and pressure. Air has a specific gravity of 1.0. Chlorine, as a gas, has a specific gravity of 2.5.

**Total Suspended Solids (TSS):** Residue (expressed as mg/L) that is removed from a wastewater sample by a standard laboratory filtration procedure.

**Turbine Meter:** A positive displacement meter with an internal turbine turned by the water flow. Flow is proportional to the turbine rotation speed.

**V-notch Weir:** A triangular sharp-crested weir for measurement of liquid discharge in open channels.

**Volatile Solvents:** A solvent that is capable of being evaporated or changed to a vapor at relatively low temperatures.

**Weir:** A dam built across an open channel over which liquid flows, usually through some type of opening or notch.
Wet Well: A compartment or tank in which wastewater is collected. The suction pipe of a pump may be connected to the wet well or a submersible pump may be located in the wet well.

Worker Right-to-Know Laws: Legislation that requires employers to inform employees of the possible health effects resulting from contact with hazardous substances. At locations where this legislation is in force, employers must provide employees with information regarding any hazardous substances that they might be exposed to under normal working conditions or reasonably foreseeable emergency conditions resulting from workplace conditions. OSHA’s Hazard Communication Standard (HCS) (29 CFR Part 1910.1200) is the federal regulation. There are also state statutes that are called Right-to-Know Laws.

Management and Supervision Terms

Ability: The quality of being able to perform; a natural or acquired skill or talent.

Accident: Unplanned or uncontrolled event in which action or reaction of an object, material, or person results in personal injury.

Accountability: Non-assigned liability for the manner in which an organizational obligation held by a member is discharged, either personally or by subordinates.

Active listening: Conscious process of securing information through full attention, intent listening, and alert observation.

Affirmative Action: In-company program designed to remedy current and future employment inequities. Americans with Disabilities Act (ADA): Prohibits employment discrimination based on a person’s mental or physical disability.

Appraisal interview: Meeting held between a supervisor and an employee to review performance rating and, using the evaluation as a basis, to discuss overall quality of work performed, and methods of improvement, if necessary.

Arbitration: Labor dispute or employee grievance settlement by an impartial umpire selected through mutual agreement by organization and worker’s union.

Attrition: Reduction in a work force due to natural events and causes, (e.g., retirement, death, resignation), as opposed to planned reductions (e.g., discharges, layoffs, early retirement).

Authority: The power needed to do a specific job, or to carry out one’s responsibilities, usually handed down from immediate bosses or superior.

Body language: Nonverbal body movements, facial expressions and/or gestures that project or reveal underlying attitudes and sentiments.

Budget: Plan, or forecast, especially of allowable expenses in operation of a department.

Budgetary control: Planning and reporting system incorporating standards for operating conditions and results, as well as costs and expenses, within a single document.

Certification Exam: An examination administered by a state or professional association that candidates take to indicate a level of professional competence.
Chain-of-Command: Formal channels in an organization that distributes authority from top down.

Code of Federal Regulations (CFR): A publication of the United States Government that contains all of the proposed and finalized federal regulations, including environmental.

Collective bargaining: Process of give-and-take engaged in by management and collective employees representatives to reach formal, written agreement about wages, hours, and working conditions.

Communication process: Giving and receiving information and understanding, such as between a supervisor and an employee, leading to a desired action or attitude.

Computerized Maintenance Management System (CMMS): A computerized system to assist with the effective and efficient management of maintenance activities through application of computerized elements including: work orders, routine standard jobs, bills of materials, application parts, and lists of numerous other features.

Competition: Relatively healthy struggle among individuals or organizational groups to excel in striving to meet mutually beneficial goals.

Conflict: Disruptive clash of interests, objectives, or personalities, between individuals or groups within an organization.

Control: To exercise authoritative influence over; the authority or ability to manage and/or direct.

Cost-benefit analysis: Technique for weighing pros and cons of alternative actions, in which both intangible benefits as well as costs are assigned dollar values.

Cost variance report: Listing of allowable expenses compared with actual expenses incurred.

Decision-making: Part of the problem-solving process that entails evaluation of alternative solutions and a choice of an effective action.

Delegation: The act in which authority is given to another person in the organization to accomplish a specific job.

Differential treatment: The act of treating a minority or protected group member differently from other applicants or employees.

Discipline: Imposition by management—in such a manner as to encourage more constructive behavior—of a penalty on an employee for infraction of a rule, regulation, or standard.

Discrimination: Managerial action or decision based on favoring or disfavoring one person or group member over another on the basis of race, color, ethnic or national origin, sex, age, handicap, Vietnam era war service, or union membership.

Division of work: Principle that performance is more efficient when a large job is broken down into smaller, specialized tasks.
Appendix B: Glossary

**Due process**: Employee's legal entitlement to a fair hearing, usually before an impartial party and with appropriate representation, before discipline can be meted out.

**Employee turnover**: Measure of how many people come to work for an organization and do not remain employed by that organization, for whatever reason.

**Ergonomics**: Study of how workers react to their physical environment; used in design of more comfortable and productive workstations.

**Equal Employment Opportunity (EEO)**: System of organizational justice, stipulated by law, that applies to all aspects of employment; intended to provide equal opportunity for all members of the labor force.

**Feedback**: Process of relaying measurement of actual performance back to an individual or unit, so that action can be taken to correct, or narrow, the variance.

**Gantt Chart**: Chart that enables a planner to schedule tasks in the most productive sequence, and that also provides a visual means for observing and controlling progress.

**Geographical Information System (GIS)**: An integrated system of computer hardware, software, and trained personnel linking topographic, demographic, utility, facility, images, and other resource data that are geographically referenced.

**Grievance**: Job-related complaint stemming from an injury or injustice, real or imaginary, suffered by an employee, for which relief or redress from management is sought.

**Grievance procedure**: Formalized, systematic channel for employees to follow in bringing complaints to the attention of management.

**Hazard**: Potentially dangerous object, material, condition, or practice present in the workplace, to which employees must be alert and from which they must be protected.

**Hostile Work Environment**: Conditions such as harassment, offensive speech, or unwelcomed conduct, that create an abusive, antagonistic, or inhospitable work place.

**Information Management System (IMS)**: System comprised of data processing devices, programs, and people that collects, analyzes, exchanges, and delivers information to an organization in such a manner as to aid managers in making decisions.

**Information**: Dates, past or present facts, observations, or conclusions, collected in numbers and words that have been selected, arranged, and analyzed (processed) to make them useful for a specific human (managerial) activity.

**Injury Illness Prevention Plan**: Plan required by California Senate Bill (SB) 198 to establish, implement, and maintain an effective program helping assure employee safety while on the job. It includes eight elements: management assignments and responsibilities, safety communications system with the employees, system assuring employee compliance with safe working practices, scheduled inspections and compliance system, accident investigation, health and safety training and instruction, and record-keeping and documentation.
**Injury Illness Prevention Plan**: Plan required by California Senate Bill (SB) 198 to establish, implement, and maintain an effective program helping assure employee safety while on the job.

**It includes eight elements**: management assignments and responsibilities, safety communications system with the employees, system assuring employee compliance with safe working practices, scheduled inspections and compliance system, accident investigation, health and safety training and instruction, and record-keeping and documentation.

**Job breakdown analysis**: Segmentation of a job into key elements, or steps, which require an employee to perform, induce, or supervise an action that advances work toward completion.

**Job evaluation**: Systematic technique for determining job worth, compared with other jobs in an organization.

**Just cause**: Reason for a disciplinary action that is accurate, appropriate, well founded, deserved and meets the test of prior notification of unacceptable behavior and its penalty.

**Knowledge**: Information that can be learned from reading, listening to an expert, or keenly observing a situation; often a prerequisite to skill development.

**Management**: Process of obtaining, deploying, and utilizing a variety of essential resources in support of an organization’s objectives.

**Management by objectives (MBO)**: Planning and control technique where supervisors and their immediate superiors agree on goals to be attained and/or standards to be maintained.

**Management development**: Systematic program for improving the knowledge, attitudes, and skills of supervisors and managers.

**Management principles**: Set of guidelines established for carrying out the management process.

**Management process**: General sequence of five unique functions—planning, organizing, staffing, directing or activating, and controlling—provided by managers for any organization.

**Manager**: An individual who plans, organizes, directs, and controls work of others in an organization.

**Material Safety Data Sheets (MSDS)**: Sheets providing information about manufactured chemicals, as required by the Hazard Communication Rule (HCR).

**Mentor**: Knowledgeable, often influential, individual who takes an interest in, and advises, another person concerning that person’s career.

**Morale**: Measure of the extent of voluntary cooperation—as well as the intensity of desire—to meet common work goals, as demonstrated by an individual or work group.

**Motivation**: Process that impels someone to behave in a certain manner in order to satisfy highly individual needs.

**Networking**: Informal process of getting to know, and create confidence among others who—through mutual exchange—help advance one’s career.
**Non-managerial employees**: Workers who receive direction from managers, who perform specific, designated tasks, and who are responsible only for their own performance.

**Organizing**: Deciding who does what work and delegating authority to the appropriate person.

**Organization**: Structure derived from systematically grouping tasks to be performed, and from prescribing formal relationships that strengthen the ability of people to work together more effectively.

**Performance appraisal**: Formal and systematic evaluation of how well a person performs work and fills an appropriate role in the organization.

**Penalty**: Punishment or forfeiture imposed as discipline by management on an employee.

**Personality**: An individual’s unique way of behaving and of interpreting events and the actions of others.

**PERT Chart**: Graphic technique for planning a project in which a large number of tasks must be coordinated, by showing the relationship between tasks and critical bottlenecks that may delay progress towards completion.

**Policies**: Broad guidelines, philosophy, or principles which management establishes and follows in support of organizational goals.

**Procedures**: Methods, prescribed by management, for the proper and consistent forms, sequences, and channels to be followed by individuals and units of an organization.

**Productivity**: Measure of efficiency that compares operational output value with cost of resources used.

**Progressive Discipline**: Providing increasingly harsh penalties for substandard performance or broken rules, as the condition continues or the infraction is repeated.

**Quid pro quo**: An equal exchange or substitution; e.g., as applied to sexual harassment, when a supervisor threatens to fire or not promote an employee if they do not provide sexual favors in return.

**Regulations**: Special rules, orders, and controls set forth by management, restricting the conduct of units and or individuals within an organization.

**Reprimand**: Severe expression of disapproval or censure by management of an employee, usually written as well as oral, and retained in an employee’s personal file.

**Responsibilities**: Those duties one is held accountable for.

**Responsibility**: Duty or obligation to perform a prescribed task or service or attain an objective.

**Retributive**: Punishment inflicted as vengeance.

**Reverse discrimination**: Notion that implementation of affirmative action deprives qualified members of non-protected groups of their rightful opportunities.

**Satisfaction**: State that exists when motivating needs—such as interesting and challenging work, full use of one’s capabilities, or recognition for achievement—are met.
**Schedules:** Detailed assignments dictating how facilities, equipment, and/or individuals are used, according to times and dates, in accomplishment of organizational objectives.

**Sexual Harassment:** Unwanted sexual advances, requests for sexual favors, or other visual, verbal, or physical conduct of a sexual nature, which is conditioned upon an employment benefit, unreasonably interferes with an individual's work performance, or creates an offensive work environment.

**Skill:** The capacity to perform a job related action by blending relevant knowledge and physical or perceptual ability.

**Specification:** Collection of standardized dimensions and characteristics pertaining to a product, process, or service.

**Stereotype:** Characterization of an individual on the basis of a standardized, oversimplified view of characteristics believed to be held in common by a group to which the individual is assumed to belong.

**Supervisor:** Manager who is in charge of, and coordinates, activities of a group of employees engaged in related activities within a department, section, or unit of an organization.

**Suspension:** Temporary removal by management of an employee privilege (such as the right to report to work and receive pay for it) until proper actions have been determined and imposed.

**Time budget:** Charting technique for planning the systematic distribution of a supervisor's time.

**Theory X:** Negative approach to human relations in which a supervisor presumes most people don't like to work and thus need to be pushed or threatened.

**Theory Y:** Positive approach to human relations whereby a supervisor presumes that, given meaningful work, most people will try hard to achieve, especially when there is an opportunity to improve their self-regard.

**Tolerance:** Permissible deviation, or variance, from a standard.

**Type A individual:** Person characterized by high standards of achievement and an urgency to attain them, who is especially susceptible to stress.

**Unfair labor practices:** Practices engaged in by management or labor unions that are judged by federal labor law to be improper, especially when they interfere with the right to organize or when they discriminate against labor union activities.

**Unity of Command:** Principle that each individual should report to only one boss.

**Unity of Direction:** Principle that there should be a single set of goals and objectives that unites the activities of everyone in an organization.

**Variance:** Gap, or deviation, between actual performance, condition, or result and a standard of expected performance, condition, or result.

**Warning:** A reprimand so worded as to give formal notice to an employee that repetition of a particular form of unacceptable behavior will draw a penalty.

**Worker's compensation:** Financial reparations or awards granted by an employer to an employee who has suffered an on-the-job injury or illness that is judged to have permanently restricted the employee's earning capacity.
Acknowledgement/Credit: Many of the terms and definitions found in this glossary have been taken from the 6th Edition of *What Every Supervisor Should Know*, by L. Bittle and J. Newstrom. These definitions are reproduced, in part or in whole, with permission of The McGraw-Hill Companies. Most of the remaining terms and definitions have been taken from the 1st Edition of *Utility Management: A Field Study Training Program*, prepared by L. Lindsay for the California State University Sacramento Foundation. These definitions are copyrighted and reproduced by permission of the Office of Water Programs, CSUS.
### Appendix C

#### Common Acronyms and Abbreviations

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AA</td>
<td>atomic absorption</td>
</tr>
<tr>
<td>AC</td>
<td>alternating current</td>
</tr>
<tr>
<td>AC</td>
<td>acre</td>
</tr>
<tr>
<td>AF</td>
<td>acre-foot (feet)</td>
</tr>
<tr>
<td>AFY</td>
<td>acre-foot per year</td>
</tr>
<tr>
<td>AMSA</td>
<td>Association of Metropolitan Sewerage Agencies</td>
</tr>
<tr>
<td>ANSI</td>
<td>American National Standards Institute</td>
</tr>
<tr>
<td>APHA</td>
<td>American Public Health Association</td>
</tr>
<tr>
<td>AS</td>
<td>activated sludge</td>
</tr>
<tr>
<td>ASCE</td>
<td>American Society of Civil Engineers</td>
</tr>
<tr>
<td>ASME</td>
<td>American Society of Mechanical Engineers</td>
</tr>
<tr>
<td>ASTM</td>
<td>American Society for Testing and Materials</td>
</tr>
<tr>
<td>AWT</td>
<td>advanced wastewater treatment</td>
</tr>
<tr>
<td>AWWA</td>
<td>American Water Works Association</td>
</tr>
<tr>
<td>BECP</td>
<td>Business Emergency and Contingency Plan</td>
</tr>
<tr>
<td>BMP</td>
<td>Best Management Practice</td>
</tr>
<tr>
<td>BMR</td>
<td>Baseline Monitoring Report</td>
</tr>
<tr>
<td>BNR</td>
<td>biological nutrient removal</td>
</tr>
<tr>
<td>BOD5</td>
<td>biochemical oxygen demand after 5 days</td>
</tr>
<tr>
<td>BTU</td>
<td>British thermal unit</td>
</tr>
<tr>
<td>C</td>
<td>Celsius</td>
</tr>
<tr>
<td>Cal-OSHA</td>
<td>California Occupational Safety and Health Act</td>
</tr>
<tr>
<td>Cal-EPA</td>
<td>California Environmental Protection Administration</td>
</tr>
<tr>
<td>CBOD</td>
<td>carbonaceous biochemical oxygen demand</td>
</tr>
<tr>
<td>CCE</td>
<td>carbon chloroform extract</td>
</tr>
<tr>
<td>CCR</td>
<td>California Code of Regulations</td>
</tr>
<tr>
<td>cf</td>
<td>cubic feet (foot)</td>
</tr>
<tr>
<td>CFR</td>
<td>Code of Federal Regulations</td>
</tr>
<tr>
<td>cfs</td>
<td>cubic feet per second</td>
</tr>
</tbody>
</table>
Appendix C: Common Acronyms and Abbreviations

CH4  Methane
CIU  Categorical Industrial User
CM  common mode
CMOM  Capacity Management, Operations, and Maintenance
COD  chemical oxygen demand
CPU  central processing unit
CRWA  California Rural Water Association
CSP  confined-space permit
CT  current transformer
CWA  Clean Water Act
CWEA  California Water Environment Association
DAF  dissolved air flotation
DO  dissolved oxygen
DOHS  California Department of Health Services
DV/DT  (V/T) The change in voltage per change in time.
DWF  dry weather flow
DWR  Department of Water Resources
EIS  Environmental Impact Statement
EMF  electromotive force or voltage
EPA  U.S. Environmental Protection Agency
ERP  Enforcement Response Plan or Emergency Response Plan
F  Fahrenheit
F/M  food to microorganism ratio
ft  feet (foot)
ft²  square foot
ft³  cubic feet
FTU  formazin turbidity unit
GAC  granular activated carbon
gal  gallon
GFI  ground fault interrupter
GPD  gallons per day
GPM  gallons per minute
GTAW  gas tungsten arc welding
Appendix C: Common Acronyms and Abbreviations

H2S hydrogen sulfide
HCP&ERP Hazard Communications Program and Emergency Response Plan
Hp horsepower
HPLC high-performance liquid chromatography
Hz Hertz
IC ion chromatograph
ICE Institute for Credentialing Excellence (formerly NOCA)
ICP inductively coupled plasma
IEEE Institute of Electrical and Electronics Engineers
IIPP Injury and Illness Prevention Plan
IML Interface Management Language
JTU Jackson Turbidity Unit
K Kilo, a prefix meaning 1,000
KVA kilovolt amperes
kw kilowatt
kwh kilowatt hour
L liter
lb pound
M Mega, a metric prefix meaning 1,000,000
m meter
M mole or molar
MA millamps
MBAS methylene blue active substance
MCL maximum contaminant level
MCLG maximum contaminant level goal
MCRT mean cell residence time
MDL method detection limit
MG million gallons
mg milligram
mg/L milligrams per liter
MGD million gallons per day
min minute
MIS Manufacturing Information System
Appendix C: Common Acronyms and Abbreviations

- **mL**: milliliter
- **MLSS**: mixed liquor suspended solids
- **MLVSS**: mixed liquor volatile suspended solids
- **MMI**: Man Machine Interface
- **MOP**: Manual of Practice
- **MPN**: most probable number
- **MR&R**: Monitoring and Reporting Requirements
- **MS**: mass spectrometer
- **MSDS**: Material Safety Data Sheets
- **MTBF**: mean time between failures
- **MTTR**: mean time to repair
- **N**: normal
- **NEC**: National Electrical Code
- **NEMA**: National Electrical Manufacturers Association
- **NEPA**: National Environmental Policy Act
- **NM**: Normal Mode
- **NOD**: nitrogenous oxygen demand
- **NPDES**: National Pollutant Discharge Elimination System
- **NPSH**: net positive suction head
- **NTU**: nephelometric turbidity unit(s)
- **O&M**: operation and maintenance
- **OCT**: Operator Certification Test (State of California)
- **OES**: Office of Emergency Services
- **OMR**: operations, maintenance, and replacement
- **OOC**: Office of Operator Certification (SWRCB)
- **OSHA**: Occupational Safety and Health Administration/Act
- **OTE**: oxygen transfer efficiency
- **P**: Pico, a metric prefix meaning one millionth of a millionth, or one trillionth (10^-12)
- **PC**: personal computer
- **PCB**: polychlorinated biphenyls
- **pH**: potential of hydrogen
- **P&ID**: piping and instrumentation diagram
Appendix C: Common Acronyms and Abbreviations

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>PID</td>
<td>proportional gain, integral action time and derivative action time</td>
</tr>
<tr>
<td>PLC</td>
<td>Programmable Logic Controller</td>
</tr>
<tr>
<td>POTW</td>
<td>Publicly Owned Treatment Works</td>
</tr>
<tr>
<td>PPB</td>
<td>parts per billion</td>
</tr>
<tr>
<td>PPE</td>
<td>Personal Protective Equipment</td>
</tr>
<tr>
<td>PPM</td>
<td>parts per million</td>
</tr>
<tr>
<td>prct</td>
<td>percent</td>
</tr>
<tr>
<td>psi</td>
<td>pound per square inch</td>
</tr>
<tr>
<td>PSIA</td>
<td>pounds per square inch absolute</td>
</tr>
<tr>
<td>PSID</td>
<td>pounds per square inch differential</td>
</tr>
<tr>
<td>PSIG</td>
<td>pounds per square inch gage</td>
</tr>
<tr>
<td>PVC</td>
<td>polyvinyl chloride (pipe)</td>
</tr>
<tr>
<td>QA/QC</td>
<td>quality assurance/quality control</td>
</tr>
<tr>
<td>RAS</td>
<td>return activated sludge</td>
</tr>
<tr>
<td>RBC</td>
<td>rotating biological contactor</td>
</tr>
<tr>
<td>RCP</td>
<td>reinforced concrete pipe</td>
</tr>
<tr>
<td>RFI</td>
<td>Radio Frequency Interference</td>
</tr>
<tr>
<td>RMS</td>
<td>root mean square</td>
</tr>
<tr>
<td>RTD</td>
<td>resistance temperature device</td>
</tr>
<tr>
<td>RWQCB</td>
<td>Regional Water Quality Control Board (State of California)</td>
</tr>
<tr>
<td>SCADA</td>
<td>Supervisory Control and Data Acquisition</td>
</tr>
<tr>
<td>SCR</td>
<td>semiconductor (or silicon) controlled rectifier</td>
</tr>
<tr>
<td>SD</td>
<td>standard deviation</td>
</tr>
<tr>
<td>SDI</td>
<td>sludge volume index</td>
</tr>
<tr>
<td>sec</td>
<td>second</td>
</tr>
<tr>
<td>SI</td>
<td>System Internationale D’Unites (metric units)</td>
</tr>
<tr>
<td>SMR</td>
<td>Self-Monitoring Report</td>
</tr>
<tr>
<td>SS</td>
<td>suspended solids</td>
</tr>
<tr>
<td>SSO</td>
<td>sanitary sewer overflow</td>
</tr>
<tr>
<td>SVI</td>
<td>sludge volume index</td>
</tr>
<tr>
<td>SVR</td>
<td>sludge volume ratio</td>
</tr>
<tr>
<td>SWRCB</td>
<td>(California) State Water Resources Control Board</td>
</tr>
<tr>
<td>TAC</td>
<td>Technical Advisory Committee</td>
</tr>
<tr>
<td>Acronym</td>
<td>Definition</td>
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<td>---------</td>
<td>------------</td>
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<tr>
<td>TC</td>
<td>total carbon</td>
</tr>
<tr>
<td>TCP</td>
<td>Technical Certification Program</td>
</tr>
<tr>
<td>TDS</td>
<td>total dissolved solids</td>
</tr>
<tr>
<td>TF</td>
<td>trickling filter</td>
</tr>
<tr>
<td>THD</td>
<td>total harmonic distortion</td>
</tr>
<tr>
<td>TIC</td>
<td>total inorganic carbon</td>
</tr>
<tr>
<td>TMDL</td>
<td>total maximum daily load</td>
</tr>
<tr>
<td>TOC</td>
<td>total organic carbon</td>
</tr>
<tr>
<td>TOD</td>
<td>total oxygen demand</td>
</tr>
<tr>
<td>TS</td>
<td>total solids</td>
</tr>
<tr>
<td>TSS</td>
<td>total suspended solids</td>
</tr>
<tr>
<td>TU</td>
<td>turbidity unit</td>
</tr>
<tr>
<td>m</td>
<td>micro, a metric prefix meaning one millionth</td>
</tr>
<tr>
<td>UPS</td>
<td>uninterruptible power supply</td>
</tr>
<tr>
<td>USB</td>
<td>universal serial bus</td>
</tr>
<tr>
<td>USEPA</td>
<td>United States Environmental Protection Agency</td>
</tr>
<tr>
<td>V</td>
<td>volt</td>
</tr>
<tr>
<td>VAC</td>
<td>volts of alternating current</td>
</tr>
<tr>
<td>VCP</td>
<td>vitrified clay pipe</td>
</tr>
<tr>
<td>VFD</td>
<td>variable frequency drive</td>
</tr>
<tr>
<td>VOC</td>
<td>volatile organic chemicals</td>
</tr>
<tr>
<td>VOM</td>
<td>volt Ohm meter</td>
</tr>
<tr>
<td>VSR</td>
<td>volatile solids reduction</td>
</tr>
<tr>
<td>VSS</td>
<td>volatile suspended solids</td>
</tr>
<tr>
<td>W</td>
<td>watt</td>
</tr>
<tr>
<td>WAN</td>
<td>wide area network</td>
</tr>
<tr>
<td>WDO/WDR</td>
<td>Waste Discharge Order/Waste Discharge Requirement</td>
</tr>
<tr>
<td>WEF</td>
<td>Water Environment Federation</td>
</tr>
<tr>
<td>WRP</td>
<td>water reclamation plant</td>
</tr>
<tr>
<td>WWF</td>
<td>wet weather flow</td>
</tr>
<tr>
<td>WWTF</td>
<td>wastewater treatment facility</td>
</tr>
<tr>
<td>WWTP</td>
<td>wastewater treatment plant (same as POTW)</td>
</tr>
<tr>
<td>yr</td>
<td>year</td>
</tr>
</tbody>
</table>