

Certification Examination

Study Guide

Plant Maintenance Mechanical Technologist Grade III





Grade III Plant Maintenance Mechanical Technologist Study Guide

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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 we encourage you to identify and utilize the other resources in preparing for your next test.

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S e c t i o n 1

Introduction

The California Water Environment Association (CWEA) Technical Certification Program (TCP) is voluntary; its purpose is to educate, prepare, and test an individual's knowledge within six vocations.

- Plant Maintenance Technology (with two parallel specialties in Electrical/ Instrumentation and Mechanical Technology)
- Laboratory Analysis
- Collection System Maintenance Technology
- Environmental Compliance Inspection
- Industrial Waste Treatment Plant Operations
- Biosolids Land Application Management

CWEA also assists in educating and training wastewater treatment plant operators for the State of California Operator Certification Tests. Upon qualifying and successfully completing a test, an individual is certified in that specialty at one of the grade levels. Levels within a specialty designate technical knowledge for the apprentice, journey, and management levels. Tests are designed to demonstrate minimum competence for a particular grade.

The purpose of this study guide is to provide a description of the knowledge, skills, and abilities (KSA) needed to pass the test. Also included are questions designed to assess candidates' strengths and weaknesses relative to their present KSA. Finally, the study guide provides references used to refresh subject knowledge, or to learn more about particular subject areas not completely understood.

Typically there are two to five primary references for each specialty area, which need to be read and understood. Test questions are generally based on information contained in these references. Secondary references give more information and often provide a different approach to a subject, making it easier to understand.

This study guide is not a compendium of all that may be on the test, so successfully answering questions contained in this guide does not guarantee passing. To successfully pass the Grade III

Plant Maintenance Mechanical Technologist test, the reference materials presented in this study guide should be thoroughly understood.

This studyguide can best be used to help identify strengths and weaknesses and to identify material that may need further study. Comments and suggestions to improve the study guide are always welcome and appreciated. Good luck on the test!



S e c t i o n 2

Certification Program Information and Policies

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 National Organization for Competency Assurance (NOCA).

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 twice yearly in six different disciplines: 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.

The first committees were formed in 1975 to establish a voluntary certification program for water quality professionals specializing in disciplines other than plant operation. The Voluntary Certification Program (VCP) emerged with specialized certificate programs for Collection System Maintenance, 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 six vocational programs with a total of 22 individual certifications. About 2,000 applications are processed annually and currently over 5,500 certificates are held by individuals in California and neighboring states.

Certification Process

To become certified, *all applicants* must complete the Application for Technical Certification, pay the application fee, have suitable 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 subject matter experts for the respective vocation applied for. If approved, the applicant will receive an eligibility letter. If the application is rejected, the applicant will be notified and asked if warranted to supply more information.

After completion of the computer-based test and grading, applicants are mailed their official results. Those who pass the exam, are mailed certificates and wallet cards.

Test Administration

Test Dates and Sites

Tests are given throughout the year in California, Michigan, and Alaska (see Application for Technical Certification for test schedule. Applicants who are eligible to take the test will be mailed an acceptance letter with instructions on how to schedule their exam.



Section 2: Certification Program Information and Policies

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 may a candidate begin the exam. Candidates do not require to show their eligibility letters to enter the test site.

Test Security

All tests are computer-based. No reference material, laptop computers, or cameras are allowed in the test site. Candidates will have access to an on-screen calculator, however, candidates are welcome to bring their own pre-approved calculator (visit www.cwea.org/cert). Candidates are not allowed to take any notes from the test site. Candidates who violate test site rules may 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 (a letter stating that you wish to postpone), to postpone to the adjacent testing window. You may only reschedule your application once without a fee. Additional postponement will require a \$40 reschedule fee. There are no exceptions to this policy.

To cancel your application you must submit a written request (a letter stating you wish to cancel your application) to CWEA. The written request must be received at the CWEA office no later than two (2) weeks after the approved testing window. Full refunds, less the \$40 administrative fee, will be made within 4 weeks after the scheduled test date. There are no exceptions to this policy.

If you have a scheduled exam with our testing administrator, Pearson Vue, you must contact them 24 hours in advance to avoid losing your exam fee.

Test Result Notification

Test results are routinely mailed to certificate candidates approximately two weeks after the test date.

Results are never given over the phone. All results are confidential and are only released to the certificate candidate. There are no exceptions to this policy.

Issue of Certificate / Wallet Card

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

Certificate Renewal

All certificates are renewed 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 a penalty fee of 100 percent of the renewal fee. Certificate holders more than one year past due will need to retest to regain certification. Renewal notices are mailed to certificate holder's two months before the due date. It is the responsibility of certificate holders to ensure the certificate(s) remains valid. Continuing education will be required for renewal after 2001.

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.

Test Design and Format

Test Design

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

The Essential Duties and Test Content Areas for each certification were determined by a job analysis and meta-analysis of job specifications by two independent psychometric consulting firms.



Section 2: Certification Program Information and Policies

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 sub-committees, 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 written in the English language only.

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 format allows a greater content coverage for a given amount of testing time and improves competency measurement reliability. Multiple choice questions range in complexity from simple recall of knowledge to the synthesis and evaluation of the subject matter.

Test Pass Point

The basic minimum score required to pass all tests is 75 percent of possible total points. However, the score may be adjusted downward depending on test complexity. It should be assumed that the passing score is 75 percent and 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 judgments 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, re-classified, 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 regrade 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.



Section 2: Certification Program Information and Policies

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 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 by completing the Candidate Feedback review screen at the end of the exam. Candidate feedbacks will be evaluated and appropriate adjustments will be made to the test content. Candidates submitting feedback will not be contacted in regards to the appeal.

Eligibility Criteria For Taking The Test

The basic requirement is six years of full time work experience performing the Essential Duties of a Grade III Mechanical Technologist (listed below). You may also qualify by having four years of experience and holding a Grade II Plant Maintenance Certificate for two years, OR having four years of full-time experience and holding an (AA/AS) degree in a related field, OR having three years of full time experience and holding a Bachelor's (BA/BS), or higher, degree in a related field.

Eligibility criteria are summarized in Table 2-1. You may qualify by meeting either Education/ Experience Combination A, B, C, or D. If you do not meet any of the combinations of experience and education, then you do not qualify for Grade III.

Qualifying with Your Education

Holding a college degree, or its equivalent, in a field related to your vocation will reduce the number of years required to qualify for your test (see Table 2-1). Your degree must be in a field that is related to the certificate for which you are applying. If you are uncertain if your degree is related to your vocation, you should still include your degree information in your application. The Technical Certification Program Committee will determine if your degree qualifies. If it does not, you will be accepted for the next highest grade level for which you qualify. Associate's and Bachelor's degrees in technical fields are usually accepted. Degrees are evaluated on a case-by-case basis upon receipt of the application. College credit without a degree is not accepted unless it can be demonstrated that the credit is equivalent to a degree.

Table 2-1 Eligibility Criteria for Grade III Plant Maintenance Mechanical Technologist

| Combination | Education and Certificates | + Experience |
|---|---|--------------------------------|
| A | None | 6 full-time years in vocation* |
| B | Hold a Grade II Plant Maintenance Certificate for 2 years | 4 full-time years in vocation* |
| C | Hold an AA/AS degree in a related field | 4 full-time years in vocation* |
| D | Hold a BA/BS, or higher, degree in a related field | 3 full-time years in vocation* |
| * Experience must be in mechanical technology or other field closely related to water or wastewater plant mechanical maintenance. | | |



Section 2: Certification Program Information and Policies

Essential Duties

Grade III duties include the *Essential Duties* identified in the Study Guides for Grade II Plant Maintenance Mechanical Technologist and Grade I Plant Maintenance Technologist. In addition, the Grade III Plant Maintenance Mechanical Technologist *Essential Duties* include:

- Prepares receives and reviews assignments for the mechanical maintenance of potable water, wastewater, storm drainage, hydraulic power, chemical handling systems, and oxygen injection systems.
- Supervises, participates in, and reviews the work of staff responsible for maintenance of the wastewater treatment plant, including repair and installation of all hydraulic, pneumatic, and mechanical equipment.
- Participates in the development of policies and procedures; monitors work activities to ensure compliance with established policies and procedures and makes recommendations for changes and improvements to existing policies and procedures.
- Performs complex preventive mechanical maintenance.
- Performs complex corrective mechanical maintenance by troubleshooting cause of malfunction using visual inspection and precision measuring and testing instruments, and replacing or repairing broken parts such as gauges, gaskets, plugs, coils, wires, bearings, drive lines, valves, pistons, rings, crankshafts, and pumps.
- Rebuilds equipment by disassembling, cleaning, ordering replacement parts, repairing mechanical malfunctions, and re-assembling and testing.
- Carries out or assists in the planning and implementation of computer-based maintenance programs.
- Estimates materials, equipment, and personnel necessary for scheduled and emergency repairs and maintenance.
- Prepares and is responsible for time and equipment reports.
- Trains personnel in the proper operation of tools and equipment, chlorine and confined-space procedures, and safety practices.
- Responsible for adherence to safety orders and compliance with federal and Cal-OSHA regulations in all aspects of work.
- Coordinates work with other departments or agencies.
- Responsible for the administration of outside contract work.
- Assists in planning, developing, and implementing safety and training programs.



Section 2: Certification Program Information and Policies

- Coordinates work with other departments or agencies.
- Responsible for the administration of outside contract work.
- Assists in planning, developing, and implementing safety and training programs.



S e c t i o n 3

Skill Sets

This section describes the four practical skill sets that candidates should possess to pass the Grade III test. These include safety; tools and equipment; wastewater plant fundamentals; and maintenance supervision. Each skill set has subsections to further delineate skills.

Table 3-1, presented at the end of this section, cross-references each skill set with a specific chapter, section, and/or page of applicable references to assist the candidate in better understanding the subject matter.

| | | |
|-----------|----------|---------------|
| Skill Set | 1 | Safety |
|-----------|----------|---------------|

1.1 General

To successfully achieve a Grade III classification, Technologists should have the ability to recognize, identify, and anticipate hazards and hazardous situations encountered above and below ground in plant maintenance and operations. A full knowledge of safety procedures and prevention techniques is also needed. Technologists should be able to identify any potential safety problems and know how to control the situation and report potential safety problems appropriately to supervision.

Additionally, it is necessary to know, understand and recognize how to apply safety laws, rules, and regulations as they apply to Technologists, their co-workers, and the public. The ability to interpret and understand the worker right-to-know law is also necessary.

Candidates must have knowledge of techniques used in protecting their health and the health of those around them. This includes items such as: lifting and back safety, ergonomics, noise hazards, industrial housekeeping, working with heights, ladders and scaffolds safely, and traffic safety.

1.2 Confined Space

It is important to define what a confined space is and to understand its definition. Grade III candidates should know how to determine if a confined space is “permit required” or not. A strong knowledge of the confined-space permit process, entry procedures and rescue operations, as well as terminology, is necessary. It is important to be able to evaluate a confined space, make quick decisions, and inform supervision regarding entry requirements and/or modifications.

Knowledge and understanding of confined-space safety rules, requirements, and regulations, as well as accident/injury prevention techniques, is important. It is necessary to be aware of and understand the hazards and effects of working in confined spaces and what the Technologist’s responsibilities are in these situations. Candidates need to be able to recognize and evaluate confined-space safety equipment and its components, understand the proper function and operation of the various components, and determine use based on the situation.

1.3 Chemical and Biological Hazards

There are numerous chemical and biological hazards within the plant maintenance field that may be encountered on a daily basis. A strong knowledge of these substances and an understanding of their potential for hazard should be obtained. Technologists should have knowledge of the policies and procedures for prevention of and protection from these hazards. Grade III Technologists should know where to find appropriate personal protective equipment (PPE) and should know the fundamental safety precautions associated with chemical and biological hazards.

Grade III candidates should also know the requirements for labeling, storing, identifying, handling, transporting, and keeping proper records of hazardous materials.



Section 3: Skill Sets

1.4 Material Safety Data Sheets (MSDS)

Any hazardous chemical product used in the plant maintenance field has an MSDS. These sheets provide valuable information about potentially hazardous chemicals used on the job. Candidates should know what an MSDS is and understand its use. They should know the laws governing the MSDS and how to obtain one when necessary. They should be able to evaluate the MSDS program at the facility and modify or update it as necessary.

1.5 Lock Out/Tag Out (LO/TO)

It is necessary that all personnel working in plant maintenance have a firm understanding of LO/TO procedures. It is important to know the policies and procedures set forth by Cal-OSHA. Working knowledge of written requirements, application rules and regulations, removal requirements, and LO/TO terminology is required. Grade III candidates should also have the ability to evaluate a LO/TO procedure for accuracy and safety. They should be able to respond to problems and/or questions from all personnel involved in a confined-space entry. Candidates should also be aware of requirements for a LO/TO program as OSHA-mandated. They should be able to evaluate their current program for compliance and/or create one as necessary.

1.6 Personal Protective Equipment (PPE)

Technologists need to be aware of physical and chemical hazards not found in other fields and the PPE required for protection from these hazards. They need to be able to identify the different types of PPE available to them, understand how to properly use the PPE, and be able to evaluate a job for PPE requirements depending upon the work being accomplished and the associated hazards. They should also know how to obtain, distribute, care for, and properly store PPE.

1.7 Tool Safety

Technologists should be able to understand and anticipate the safety hazards associated with the hand and power tools used in plant maintenance. Technologists should be able to identify the needs of and train all staff. Some of the hazards candidates would be expected to know include: when a tool is being used incorrectly, how to identify a defective tool, when someone is using the wrong

tool for the job, how to identify an improperly maintained tool, and incorrect body positioning when using a tool.

1.8 Machinery Safety

Candidates should have a strong understanding of the safety hazards and precautions associated with working around and with machinery. They should be knowledgeable about the policies and procedures for prevention of and protection from these hazards.

Grade III candidates need to have knowledge of the safety items associated with machinery, why they are there, and their proper use. They should be familiar enough with the specifics of the safety features and procedures associated with the equipment to be able to train staff and make decisions based on this knowledge.

1.9 Electrical Safety

Grade III Technologists are required to have a good understanding of the safety hazards and precautions associated with working around and with electricity. Candidates should be knowledgeable about the policies and procedures for prevention of and protection from these hazards as set forth by NEC and OSHA. Technologists should also be well versed in first aid for electrical shock victims.

1.10 Fire Safety

Technologists should have a strong understanding of fires, including how they start, how they spread, and how they are put out. Grade III candidates need to be aware of and know how to recognize and rectify fire hazards. They should know the four classes of fires and which types of fire-fighting materials and actions are appropriate for each class. They must be able to recognize and properly use the fire-fighting equipment that is commonly available in a treatment plant or wastewater collection system.

1.11 Welding Safety

Technologists should have a strong understanding of the safety hazards and precautions associated with welding. Grade III candidates should be knowledgeable about the policies and procedures for prevention of and protection from such hazards as they relate to the different types of welding that occur in a wastewater system.



Candidates need to be aware of the safety hazards and required permits associated with hot (welding or cutting) work in a confined space. They need to be able to convey these hazards and policies to plant personnel and monitor the work for compliance.

1.12 Safety Program Administration

Technologists should be able to implement and administer a safety program that includes a written safety policy, safety goals, and procedures to ensure that the program is properly implemented.

| | | |
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| Skill Set | 2 | Tools and Equipment |
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2.1 Hand Tools and Equipment

Technologists must be able to correctly identify, select, know the proper use of, and be able to train entry-level personnel on the various hand tools and small equipment used in plant maintenance. Candidates need to be aware not only of normal hand tools and equipment, but also should have a working knowledge of all specialized tools and equipment used in plant and collection system maintenance.

It is important to understand the characteristics and operation of the various tools and equipment as they apply to the plant maintenance field. Candidates should be able to identify the various tool parts and equipment used in plant maintenance and have the ability to recognize and understand the inherent hazards, know when to exercise caution, and know the proper use of these tools.

Hand tools and light equipment that a Grade III Technologist must be familiar with include:

Measuring—tape measures, steel rules, calipers, vernier calipers, micrometers, thread gauges, and squares.

Pipefitting—pipe wrenches, saws, strap and chain wrenches, pipe vises, pipe cutters, tap and die sets, reamers, and tube flaring tools.

Plumbing—propane torches, tube benders, and cast iron pipe snapper and line clearing tools.

Electrical—EMT benders, knockout punches, fish tape, various special pliers, circuit testers, meggers, multi-meters, and amp meters.

Woodworking—saws, planes, scrapers, bits, chisels, levels, plumb bobs, hammers, and nails.

Metalworking—layout tools, rivets and riveting tools, metal-cutting chisels, hammers, metal-cutting snips, notchers, forming tools, hacksaws, vises, files, tap and die sets, and reamers.

Hoisting/Pulling—rope, wire rope, slings, sling hitches, block and tackle, chain falls and machine part pullers.

2.2 Power Tools and Light Equipment

It is important to correctly identify, select, know the proper use of, and train personnel on the various power tools and light equipment used in plant maintenance. Candidates should have a full understanding of the characteristics and proper application of the various power tools and light equipment used in the plant maintenance field. They should also have the ability to recognize and understand inherent hazards and exercise caution and proper use of power tools.

Candidates should also know how to perform basic field repair on power tools and light equipment and know when basic field repair will not suffice.

| | | |
|-----------|----------|-------------------------------|
| Skill Set | 3 | Mechanical Maintenance |
|-----------|----------|-------------------------------|

3.1 Maintenance Fundamentals

Technologists must understand the principles and purposes of the mechanical equipment found in a wastewater treatment plant and collection system. Also necessary, is the ability to understand the characteristics and mechanical theory behind this equipment.

Grade III candidates should be able to supervise/lead a maintenance staff and perform complex and advanced maintenance and repair on equipment found in a wastewater system, including installation, lubrication, adjustments, and preventative and proactive maintenance. Candidates need to have firm knowledge of and skills to accomplish: maintenance on or with bearings, carpentry, mechanical power transmission systems and components, hydraulics and pneumatics, fasteners, packing and seals, lubrication, lubrication systems, piping systems, tubing, alignment, gears, pumps, blowers, fans, screens, boilers, HVAC units, engines, motors and electrical systems.



Section 3: Skill Sets

Candidates must also be able to evaluate maintenance programs and procedures to ensure that generally accepted sound maintenance practices are being used.

3.2 Drawings and Prints

Technologists must be able to read, understand, interpret and work from mechanical drawings, plans, specifications, sketches and blueprints. Candidates should be able to readily identify schematic symbols, abbreviations, and terminology used in prints and drawings. They should also be able to understand the difference between and know when to use the different types of drawings and prints, including single line, double line, isometric, and orthographic. Technologists must be able to create shop drawings and mechanical drawings that are of such a nature that others will be able to understand the installation or modification.

Grade III technologists need to be able to assist managers in assessing jobs for materials, manpower, and correctness from the drawings and/or prints as provided. They also need to be able to troubleshoot a proposed installation or modification from mechanical drawings, plans, specifications, sketches and/or blueprints.

3.3 Shop Math

It is important for Grade III candidates to be able to perform the shop math necessary in the performance of the duties of a Mechanical Technologist. They should be familiar with the principals of and the basic formulas associated with mechanical and electrical maintenance, including unit conversion, percentage, Ohm's Law, power formulas, linear calculations, area, volume, basic geometry, volume-weight, flow rate, ratios, horsepower, thermal expansion, manpower, power cost, and chemical dosage.

Technologists need to possess the skills to use these principals and formulas to solve some of the more complex algebraic problems that sometimes arise during the performance of duties. This may include solving for the unknown, manipulation of formulas, and/or combining formulas to achieve the solution.

3.4 Metalworking

Technologists must possess the knowledge and skills to fabricate items out of metal and work on metal items associated with plant maintenance. Candidates should understand the principals of tools used on and how to work with structural steel, special alloys, and sheet metal.

Grade III candidates should be able to design patterns and fabricate projects out of sheet metal by cutting, forming, fastening, etc., using recognized methods and practices. They should be familiar with the different metals and alloys available and the terminology associated with metalworking, including heat transfer capabilities, resistance and susceptibility to different types of corrosion, and which metals are and are not compatible.

3.5 Machinery Installation

Technologists need to understand, use and inspect (for proper installation techniques) the machinery and equipment associated with plant and collection system maintenance. Candidates should know the terms, principals, tools, methods, hardware, and specifications used in establishing a proper foundation for the installation. They should know how to properly rig, in a safe manner, equipment in place. They also need to know proper alignment techniques, when and how to field balance, what pipe strain is, and how to check for and alleviate pipe strain.

Grade III Technologists need to be able to evaluate an installation procedure for correctness and inspect an installation as it is happening and after it is complete. They also need to be able to convey their findings, both orally and in report form, to appropriate personnel.

3.6 Welding

Grade III candidates need to have a firm understanding of four common welding practices: SMAW, GMAW, GTAW and OAW. They should understand the dangers and hazards associated with these types of welding and how to accomplish the work safely. They should be able to use at least one of the above-mentioned welding practices. They should also be able to evaluate a job to determine which welding practice is best suited. They need to be able to perform quality control evaluations on welding jobs and be able to train subordinates on proper welding techniques.



3.7 Troubleshooting

It is important that Technologists are able to diagnose the root cause of problems associated with maintenance equipment. Candidates need to be familiar with the failure modes of different types of equipment found in plants and collection systems. Using operational parameters, Technologists must be able to troubleshoot both mechanical and operational problems of the equipment and systems. They also must have the skills to troubleshoot a piece of equipment once it has been removed from service for maintenance.

Troubleshooting techniques include understanding: how different types of equipment failures influence operational parameters; how to use equipment parameters to evaluate the condition of equipment and possible pending failure modes; wear patterns on bearings and wearing rings; effects of pressure and temperature on equipment; faces of mechanical seals; and how to use information on a pump curve to determine if problems are mechanical or systems-related.

Technologists need to be able to assemble the proper team to conduct root cause analysis of a piece of equipment in accordance with specific indicators. This includes knowing what different trades can provide and what specialized tests may be required. A Grade III candidate needs to be able to put these troubleshooting skills to use not only in identifying the root cause of a problem, but also in recommending a course of action to rectify the situation.

3.8 Carpentry

Technologists must know the terminology, tools, techniques, and capabilities of the carpentry trade. They need to have the knowledge and skills necessary to understand the properties and capabilities of different types of wood and wooden structures, especially as they compare to other materials available. They need to be able to use this ability to determine the best material for each job.

Grade III candidates should have the knowledge and skills necessary to manufacture forms and structures out of timber and lumber. They should have the ability to understand the inherent hazards, exercise caution, and know how to safely accomplish tasks involving carpentry.

3.9 Piping Systems

Candidates should know how to maintain, install, inspect and repair piping systems. They should know and understand the terminology, tools, techniques and typical uses of the types of piping materials, valves and fittings used, including: PVC, cast iron, steel and ABS for materials; gate, globe, ball, butterfly, reducing, sustaining and knife for valves; ells, tees, reducers, unions, couplings, and wyes for fittings. They should also be able to calculate offset and roll for piping system installation or modification.

| | | |
|-----------|---|--|
| Skill Set | 4 | Communications, Customer Service, and Supervision |
|-----------|---|--|

4.1 Communications

It is very important to maintain effective communication with customers, co-workers, and supervisors. The ability to follow written and verbal instructions from supervision or management is necessary. Grade III Technologists need to be able to create the many different types of reports required by management. This requires being able to use many different writing styles such as technical writing, objective writing, subjective writing, report writing, and approval request writing. Reports that advanced-level technologists need to be able to research and prepare include: maintenance control; manpower usage; return on investment; budgetary; cost analysis; CMMS generated; daily, weekly, monthly and long term work; and root cause analysis.

Candidates should be able to establish and maintain effective working relationships with various personnel with whom they are required to interact. This includes knowledge of and ability to use theories of workplace interpersonal relations. Some of the techniques necessary to accomplish these tasks are effective listening, arbitration skills, maintaining balance between the requirements of both management and subordinates, and understanding and using sound supervision practices.



Section 3: Skill Sets

4.2 Training

Training is important to all organizations. Grade III candidates need to be aware of required and desired training necessary in plant maintenance. They should know what training is required by such agencies as: Department of Labor (DOL), National Institute of Safety and Health (NISH), and Occupational Safety and Health Administration (OSHA).

Technologists must be able to evaluate and identify the training needs of their facility using such indicators as size of the facility, availability of skilled craftsmen, attitude of labor, and policies of management.

Candidates need to be aware of the different types of training that are available and when to use each. Some of the types of training include: orientation, apprentice, multimedia, lecture, self-paced, on-the-job, outsource, safety, and computer-based.

Grade III candidates need to be familiar with terminology and techniques associated with training and training programs. These include: needs assessment; gap analysis; individual training plans; master training plan; knowledge, skills and abilities; lecture; mini-lecture; and exposure.

4.3 Planning and Scheduling

It is important that candidates have a strong knowledge of planning and scheduling functions as they pertain to plant maintenance. They need to understand the terminology and principals associated with planning and scheduling, such as time and manpower requirements, effective material planning, assets, backlog, workflow control, planned versus unplanned, special tools and equipment planning and scheduling, bill of materials, equipment history, materials inventory, and stores control systems.

Grade III candidates also need to be able to understand differences between and plan for expected and unexpected work, emergencies, and major overhaul/re-engineered projects.

Technologists need to have a strong understanding of the work order system. They need to know what a work order is, how a work order system flows, the reporting aspect of a work order system, the communication required, and how to control the flow of the work order system. They also

need to be able to plan for both shift and non-shift work and know how to adjust a schedule to account for emergencies, vacations, and personnel calling in sick.

Grade III Technologists need to be able to understand and disseminate the advantages, disadvantages, and requirements of the different types of maintenance management systems available.

4.4 Laws and Regulations

Grade III technologists need to be aware of the laws and regulations that apply to wastewater maintenance, construction, repair, and operations. Candidates should be familiar with the various agencies that govern different aspects of plant maintenance. These include: Department of Labor (DOL), Equal Employment Opportunity Commission (EEOC), Environmental Protection Agency (EPA), Air Pollution Control District, State Water Resources Control Board (SWRCB), Regional Water Quality Control Boards (RWQCBs), Department of Health Services (DOH), and Occupational Safety and Health Administration (OSHA).

Candidates should know which agency is responsible for what part of the operation and how to contact appropriate agencies if necessary.

Grade III Technologists need to be familiar with the major laws and acts that affect wastewater maintenance including: Safe Drinking Water Act (SDWA), Resource Conservation and Recovery Act and its Amendment, Clean Water Act, and the Superfund Reactivation. They should know how the agencies' laws, codes, and acts are applied to the process of plant maintenance in areas such as hazardous materials, LO/TO, MSDS, employees' rights and responsibilities, management's rights and responsibilities, hiring and promotional practices, discipline, construction requirements, and safety.

Grade III candidates also need be aware of how plant equipment can affect the facility's ability to be in compliance with these laws and regulations.

4.5 Performance Evaluations

It becomes a responsibility of all plant personnel, as they move into the role of supervision or lead, to evaluate the performance of subordinates.



Grade III Technologists must be familiar with the terminology and techniques of the performance evaluation procedure. They should understand how to set the goals of the performance evaluation, using techniques such as traditional factors and determining weight of factors chosen. They should be familiar with what to evaluate. They should be able to establish standards that are fair and understandable. They should be able to understand the legal concerns of the performance evaluation, such as what can and cannot be in an evaluation and the employee's rights as they pertain to performance evaluations.

Candidates should know the different evaluation methods and when and how to use them. Some of these include: ranking or forced-distribution, checklist or forced-choice, critical-incident or narrative, behaviorally anchored rating scales, field-review, and the scale.

They also must be aware of the common pitfalls and errors in the evaluation process. Some of these include: the halo effect, rating the person instead of the performance, saving up for the evaluation, rating everyone the same, the rush job, comparisons, lack of standards for performance, rating according to recent events, and lack of proper documentation.

Candidates should remember that performance evaluation is a tool to be used to evaluate the entire performance of an employee. They should accent positives and discuss negatives with a plan for improvement; then follow up on any goals set or established during the performance evaluation.

4.6 Staff Selection

Grade III Technologists are considered to be part of supervision, whether that is as an actual supervisor or as a lead person. In these positions, they will be required to have a good knowledge of staffing requirements and the selection process.

One of the tasks expected is setting staffing requirements using parameters such as number of personnel required, forecast workloads, positions needed, budget considerations, backlog, and preventative maintenance requirements. Grade III Technologists must be familiar with the different organizational structures such as line, line-staff, functional, and geographical.

Candidates should understand the roles that the Supervisor and Personnel or Human Resources play in the selection process. Usually Personnel or Human Resources will be responsible for application creation, posting the job, recruiting, screening applications, and checking interview questions to test for validity. The Supervisor usually provides job descriptions and job specifications, conducts final interviews, makes the decisions, and informs the applicants of decisions.

Candidates should also be aware of the different selection devices available and know when to use them. These include directive interviews, non-directive interviews, applications, and testing.

Candidates should be aware of the pitfalls that can be encountered during the selection process and know how to avoid them. Some common pitfalls are: the halo effect, the rush job, comparisons, failure to follow sound interviewing principles, omitting pertinent information, asking questions in violation of discrimination laws, and hiring friends or relatives who do not qualify.



Section 3: Skill Sets

Table 3-1 Grade III Plant Maintenance Technologist

| Primary References ^a | | | | | | | |
|---------------------------------|---------------------------------|---|---|---|--|--|------------------------|
| No. | Skill Set | Millwrights and Mechanics Guide 4th Edition | Maintaining Wastewater Equipment Book 383 | Industrial Safety and Health Book 109.1 | Maintenance Engineering Handbook 5th Edition | Maintenance Managers Standard Manual 2nd Edition | Utility Management |
| 1 | Safety | | | | | | |
| 1.1 | General | | | Lessons 2, 3, 6, 11 and 12 | | 168–202 | Chapter 12 |
| 1.2 | Confined Space ^b | | | | | 184–185 | Chapter 12.3 |
| 1.3 | Chemical & Biological Hazards | | | Lesson 4 | | 186–188 | Chapter 12.2 |
| 1.4 | MSDS | | | Lesson 1 | | 188 | Chapter 12.2 |
| 1.5 | LO/TO | | | Lesson 7 | | 180 | |
| 1.6 | PPE | | | Lesson 3 | | 169, 174 | Chapter 12.2 |
| 1.7 | Tool Safety | | | Lessons 3 and 5 | | 170, 177–178 | |
| 1.8 | Machinery Safety | Chapter 21 | Lessons 1, 2 and 4 | Lesson 7 | | 179–180 | |
| 1.9 | Electrical Safety | | | | | 171, 188–189 | |
| 1.10 | Fire Safety | | | Lesson 10 | | 169–170, 186, 193–194 | |
| 1.11 | Welding Safety | | | | | 170, 180–181 | |
| 1.12 | Safety Program Administration | | | | | 171–172, 718–719 | Chapters 12.1 and 12.4 |
| 2 | Tools and Equipment | | | | | | |
| 2.1 | Hand Tools and Equipment | | Entire Book | | | 299–304 | |
| 2.2 | Power Tools and Light Equipment | Chapters 17, 27, and 28 | | | | 170, 305–306 | |

a. Complete reference information given in Section 6.

b. Read *Confined Space Entry, 1998 Edition*.



Table 3-1 Grade III Plant Maintenance Technologist

| Primary References ^a | | | | | | | |
|---------------------------------|--|---|---|---|--|--|--------------------|
| No. | Skill Set | Millwrights and Mechanics Guide 4th Edition | Maintaining Wastewater Equipment Book 383 | Industrial Safety and Health Book 109.1 | Maintenance Engineering Handbook 5th Edition | Maintenance Managers Standard Manual 2nd Edition | Utility Management |
| 3 | Mechanical Maintenance | | | | | | |
| 3.1a | Machinery Identification and Maintenance | Chapters 24 and 25 | Lesson 1, 2, 3, 4, and 5 | | 6.1–6.172, 8.1–8.138 | 377–385, 392–403 | |
| 3.1b | Bearings | Chapter 10 | | | 6.1–6.38 | 377–380 | |
| 3.1c | Fasteners | Chapters 12 and 13 | | | 8.134–8.135 | | |
| 3.1d | Mechanical Power Transmission | Chapters 3 through 8 | | | 6.43–6.80, 6.130–6.172 | | |
| 3.1e | Gears | Chapter 6 | | | 6.145–6.172 | 382–383 | |
| 3.1f | Hydraulics and Pneumatics | Chapter 26 | | | | 391–399 | |
| 3.1g | Packing and Seals | Chapter 9 | | | | 386–389 | |
| 3.2 | Drawings and Prints | Chapter 1 | | | | 141 | |
| 3.3 | Shop Math ^c | Chapters 2, 6, 16, 24, 26, and 28 | | | | | |
| 3.4 | Metalworking | Chapters 19 and 20 | | | | 635–653 | |
| 3.5 | Machinery Installation | Chapters 2 and 21; Chapter 8, pgs. 217–231 | | | | | |
| 3.6 | Welding | Chapter 23 | | | 11.1–11.94 | 665–675 | |

a. Complete reference information given in Section 6.

c. Also read *Applied Math for Wastewater Plant Operators*.



Section 3: Skill Sets

Table 3-1 Grade III Plant Maintenance Technologist

| Primary References ^a | | | | | | | |
|---------------------------------|--|---|---|---|--|--|--------------------------|
| No. | Skill Set | Millwrights and Mechanics Guide 4th Edition | Maintaining Wastewater Equipment Book 383 | Industrial Safety and Health Book 109.1 | Maintenance Engineering Handbook 5th Edition | Maintenance Managers Standard Manual 2nd Edition | Utility Management |
| 3.7 | Trouble-shooting | Chapter 4, pgs. 122-123; Chapter 21, page 734; Chapter 24, pgs. 871-872; Chapter 25, pgs. 910-915 | Lessons 1 through 5 | | 6.126-6.128, 7.96-7.98, 7.144 | 375-384, 390-391, 477-479, 485, 497 | |
| 3.8 | Carpentry | Chapter 16 | | | | 654-674 | |
| 3.9 | Piping Systems | Chapters 14 and 15 | | | 8.87-8.138 | 627-631 | |
| 4 | Communications, Customer Service, and Supervision | | | | | | |
| 4.1 | Communications | | | | 1.32-1.37 | 5-11, 144-145, 164, 245-248, 805-815 | Chapters 6, 7, and 8 |
| 4.2 | Training | | | | 1.16-1.17, 5.34-5.36 | 29-47, 701-702, 715, 793-795 | Chapters 5.52 and 10 |
| 4.3 | Planning and Scheduling | | | | 3.30-3.59 | 83-147, 202-203 | Chapters 3 and 4 |
| 4.4 | Laws and Regulations | | | | | 34-35, 40, 696-723 | Chapters 5.56 and 5.6 |
| 4.5 | Performance Evaluations | | | | 2.47-2.69 | | Chapter 5.5 |
| 4.6 | Staff Selection | | | | | 17-22, 77, 88, 122-123, 252, 264-269, 567-569, 653 | Chapters 5.1 through 5.4 |

a. Complete reference information given in Section 6.



Section 4

Test Preparation

This section provides tips on the how candidates should prepare for the test, information on the test question format and the math skills likely to be needed, and a table of equivalents and formulas.

Basic Study Strategy

To prepare adequately for the test, candidates need to employ discipline and develop good study habits. Ample time to prepare for the test should be allowed. Candidates should establish a study schedule and stick to it. 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.

It is especially important for candidates to obtain access to the reference materials listed under the Primary References heading in Section 6 of this study guide. Many of these materials are likely to be available in the work place and in technical libraries. Some references, such as codes and regulations, are available on-line as well. For a list of links to on-line resources, see the Certification Resource Links page on the CWEA website at www.cwea.org/tcp/resources.

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 of this study guide for topics that will be covered.

While using this study guide, be sure to understand the answers to all the sample and diagnostic test questions. It may also be helpful to use the skill set descriptions in Section 3 to devise additional questions for further study. Discuss the questions with others. Not only is this a good study technique, it is also an excellent way to learn.

It is not necessary, but it can certainly be helpful, to memorize all the formulas and equivalents used in working out the solutions for questions involv-

ing calculations. Table 4-1 lists many, but not all, of these formulas and conversion factors. When the test is administered, a sheet listing some, but not all, of the relevant formulas and equivalents will be provided as part of the test materials. So that candidates may determine which formulas and equivalents will actually be on the sheet included with the test booklet, copies of these sheets are provided on the CWEA website at www.cwea.org/tcp/resources. (The set of equivalents and formulas on the sheet provided with the test may not be exactly the same as the set included in Table 4-1.)

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 problems.

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)

| | | |
|---------|-------|------|
| Always | Never | None |
| Totally | All | |

Limiting Words

(Often a correct choice)

| | |
|-------|--------------|
| Few | Occasionally |
| Some | Generally |
| Often | Usually |
| Many | Possible |



Section 4: Test Preparation

Table 4-1 Plant Maintenance Mechanical Technologist

Equivalents and Formulas

1 cubic foot = 1,728 cubic inches

1 cubic foot of water = 7.48 gallons

1 cubic foot of water weighs 62.43 pounds

1 gallon of water weighs 8.34 pounds

1 day = 1,440 minutes

1 cubic foot/second = 449 gallons/minute

1 MGD = 694 gallons/minute

1 MGD = 1.55 cubic feet/second

1 psi = 2.31 feet of water

1 horsepower = 746 watts

1 horsepower = 42.45 BTU/minute

1 horsepower = 33,000 foot-pounds/minute

Coefficients of thermal expansion

= 0.00000633/°F for steel

= 0.00001/°F for brass

1 BTU = 778 foot-pounds

1 watt = 3.412 BTU/hour

1 kilowatt = 1000 watts

1 therm = 100,000 BTU

$\pi = 3.14$

Water horsepower = $\frac{\text{flow} \times \text{total head} \times \text{specific gravity}}{3960}$

Brake horsepower = $\frac{\text{flow} \times \text{total head} \times \text{specific gravity}}{3960 \times \text{efficiency}}$

Hydrostatic force = column area x column height x fluid density

Thermal expansion = coefficient of thermal expansion x length x ΔT

Flowing quantity = area x velocity

Power costs = $\frac{(\text{quantity} \times \text{watts} \times \text{hours})}{1000 \text{ watts/kilowatt}} \times \text{cost/kilowatt} \times \text{time}$

Perimeter

rectangle = 2 x (length + width)

Circumference

circle = π x diameter

Area

rectangle = base x height

triangle = $\frac{1}{2}$ (base x height)

circle = π x radius²

circle = 0.785 x diameter²

Volume

rectangular solid = length x width x height

triangular solid = $\frac{1}{2}$ (base x height x length)

cylinder = π x radius² x height

cylinder = 0.785 x diameter² x height

$\frac{\text{Big}}{\text{Little}} = \frac{\text{Fast}}{\text{Slow}}$

Energy = power x time

Efficiency = $\frac{\text{work output}}{\text{work input}}$



- 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.
- Reject answers that are obviously incorrect and choose from the remaining answers.

Example

The straight line distance from the center of a circle to the outer edge is called the:

- diameter
- circumference
- chord
- radius

It is possible to reason out the answer by having some knowledge of geometry and studying the questions and the four provided answers. The question is asking for the name of a line or distance that is inside of the circle. Circumference is the distance around the outside of the circle, so this is an obvious incorrect answer.

- Make an educated guess.
Never reconsider a choice that has already been eliminated. This means that answer “b” should not be considered. Look for key phrases or words that give a clue to the right answer. Chord, answer “c,” chord refers to a straight line inside of the circle, but it does not necessarily go through the center of the circle, so this answer can be eliminated.
Answers “a” and “d” are distances that are measured as straight lines and either start or go through the center of a circle. The diameter goes through the center rather than starting from the center. Radius, answer “d” is the correct answer and is defined as the straight line distance from the center to the outer edge of a circle.
- Skip over questions that are troublesome. Mark these questions for later review.
- 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.

- Under no circumstances leave any question unanswered. There is no penalty for incorrect answers. However, credit is given only for correct answers.

NO ANSWER=WRONG ANSWER

- Keep a steady pace. Check the time periodically.
- 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 language of this profession.

Math Problems

Math problems on the certification tests are meant to reflect the type of work encountered in Plant Maintenance Mechanical Technology. 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. By far, the greatest number of applicants who fail the certification tests do so by failing to complete the math problems. Completing the math problems will be greatly simplified by using a calculator and the approach suggested in the following paragraphs.

Calculators

A scientific calculator may be used during the test; however, a four-function (add, subtract, multiply and divide) calculator is adequate for completing any of the certification tests. Additional functions (e.g., square root) are not necessary, but may be helpful in some situations. The most important factor in effectively using a calculator is the candidate’s 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 the calculator early and use it frequently.

Completing the sample problems in this section as well as the diagnostic test in Section 5 will improve proficiency. Additional use will also help. For example, calculate the gas mileage when filling a vehicle’s tank. 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



Section 4: Test Preparation

are not accidentally punched. Be certain there are new batteries in the calculator, or use a solar powered calculator with battery backup.

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

A listing of the equation or equations that will be used to generate the answer.

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, and reduces chances of making errors.

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 different solution arrives at the correct answer, then it can be used as well.

Equivalents and Formulas

Familiarity with the equivalents (conversion factors) and formulas in Table 4-1 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; and
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 = $50 \frac{\text{gal}}{\text{min}}$

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:

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



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.

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

$$3 \text{ cubic feet} \times 7.48 \frac{\text{gallons}}{\text{cubic feet}} = 22.4 \text{ gallons}$$

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

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

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

$$500 \text{ GPM} \times 1 \frac{\text{MGD}}{694 \text{ GPM}} = 0.72 \text{ MGD}$$

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

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

- A chemical feed pump delivers 50 mL per minute (mL/min). Determine the chemical feed in gallons per day (gpd).

$$\frac{50 \text{ mL}}{\text{min}} \times \frac{1 \text{ L}}{1000 \text{ mL}} \times \frac{1 \text{ gallon}}{3.785 \text{ L}} \times \frac{60 \text{ min}}{\text{hr}} \times \frac{24 \text{ hr}}{\text{day}} = 19 \text{ GPD}$$

- 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?

$$\frac{30 \text{ lbs CN}}{\text{day}} \times \frac{8 \text{ hr}}{\text{shift}} \times \frac{1 \text{ day}}{24 \text{ hr}} = 10 \text{ lbs CN/shift}$$

Math Skills

Grade III Technologists must be skilled in basic arithmetic, geometry, algebra, and trigonometry. Candidates should be able to apply such skills to make calculations for work-related tasks such as volume, flow rate, thermal expansion, pumping efficiency, ratio calculations for sheaves and gears, cost estimation, and other job-related mathematics that fall within the skill set subject areas discussed in Section 3.

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 specific math skill. Appendix A provides general strategies for approaching math problems and math anxiety, as well as resources for remedial study. Below are some examples of the types of math questions that a candidate should be able to quickly solve.

Arithmetic

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

- Addition and subtraction of whole numbers, fractions, and decimals.
- Multiplication and division of whole numbers, fractions, and decimals.

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

Example

Find the volume of water needed to fill a pipe 500 feet in length that has a 18-inch diameter. Express your answer in gallons.

First convert inches to feet:

$$\text{Diameter} = 18 \text{ inches} \times \frac{1 \text{ foot}}{12 \text{ inches}} = 1.5 \text{ feet}$$

Next calculate the volume:

$$\begin{aligned} \text{Vol} &= 0.785 \times \text{diameter}^2 \times \text{height} \\ &= 0.785 \times (1.5 \text{ ft})^2 \times 500 \text{ ft} \\ &= 883 \text{ cubic feet} \end{aligned}$$

Finally, calculate water volume in gallons:

$$\text{Vol} = 883 \text{ cubic feet} \times \frac{7.48 \text{ gallons}}{1 \text{ cubic foot}}$$

$$\text{Volume of water} = 6,605 \text{ gallons}$$



Section 4: Test Preparation

Algebra

Using basic algebra, candidates should be able to solve equations to determine information such as sheave or gear speed, or sheave diameter or number of gear teeth, given three of the four parameters.

Example

A motor operating at 1,760 RPM has a 10-inch sheave attached to it. What size sheave should you install on the pump to turn the pump at 1,100 RPM?

This is a ratio problem and using the formula below, you can solve for the sheave size.

$$\frac{\text{Big}}{\text{Little}} = \frac{\text{Fast}}{\text{Slow}}$$

Remember that to have the pump turn slower than the motor, the sheave on the pump must be larger than the sheave on the motor. Filling in the values:

$$\frac{? \text{ inch}}{10 \text{ inch}} = \frac{1,760 \text{ RPM}}{1,100 \text{ RPM}}$$

Using algebra and solving for the size of the big sheave:

$$\begin{aligned} ? \text{ inch} &= \frac{1,760 \text{ RPM}}{1,100 \text{ RPM}} \times 10 \text{ inch} \\ &= 16 \text{ inch} \end{aligned}$$

Geometry

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

Example

What is the volume of a cylindrical digester 145 feet in diameter and 15 feet in height? Express your answer in million gallons (MG).

First calculate the volume of the digester in cubic feet using the formula given in Table 4-1.

$$\text{Vol} = 0.785 \times \text{diameter}^2 \times \text{height}$$

$$\text{Vol} = 0.785 \times (145 \text{ ft})^2 \times 15 \text{ ft} = 247,569 \text{ ft}^3$$

Converting cubic feet to million gallons:

$$\begin{aligned} \text{Vol} &= 247,569 \text{ ft}^3 \times \frac{7.48 \text{ gal}}{\text{ft}^3} \times \frac{\text{MG}}{1,000,000 \text{ gal}} \\ &= 1.85 \text{ MG} \end{aligned}$$

Trigonometry

Candidates should be able to perform simple trigonometry calculations as they apply to determining bending offsets for conduit.

Example

To make a 15-inch offset, using 30° bends:

1. Use a trig table to find the cosecant of a 30° angle. It is 2.
2. Multiply 2 times the offset desired (which is 15 inches) to determine the distance between bend "B" and "C". The answer is 30 inches.



S e c t i o n 5

Diagnostic Test

Introduction

This section provides a diagnostic test to assist those studying for the Grade III Plant Maintenance Mechanical Technologist certification test in evaluating their current knowledge level about: safety; tools and equipment; maintenance, repair, construction, and inspection of wastewater treatment plants and collection systems; and communications and interpersonal relationships.

The example questions in the diagnostic test represent the type of knowledge that may be required to successfully pass the certification test. They are based generally on the information contained in the references listed in Section 6 of this study guide, and they are arranged according to the skill sets presented in Section 3. However, passing the diagnostic test does not guarantee passing the certification test.

Diagnostic test answers, the applicable skill sets, and selected solutions are presented at the end of this section. Candidates should take the diagnostic test, mark wrong answers, and record the skill sets for questions missed. Using Table 3-1, candidates should review the references to improve their knowledge of the subjects, especially in areas where they answered diagnostic test questions incorrectly.

| | | |
|-----------|----------|---------------|
| Skill Set | 1 | Safety |
|-----------|----------|---------------|

1. A confined space is described by Cal-OSHA as:
 - a. large enough to bodily enter and perform work; has limited or restricted means of entry or exit; and contains, or has the potential to contain, a hazardous atmosphere.
 - b. has limited or restricted means of entry or exit; contains, or has the potential to contain, a hazardous atmosphere; and is not designed for continuous human occupancy.
 - c. has limited or restricted means of entry or exit; large enough to bodily enter and perform work; and is not designed for continuous human occupancy.
 - d. large enough to bodily enter and perform work; is not designed for continuous human occupancy; and contains, or has the potential to contain, a hazardous atmosphere.
2. The only prescription eyeglasses that can be worn in an industrial setting are those approved by:
 - a. ANSI.
 - b. OSHA.
 - c. ISA.
 - d. EPA.



Section 5: Diagnostic Test

Skill
Set

2

Tools and Equipment

- Using a counter weight scale, you are required to use six disks to offset the weight of an object. If the disks are 10 inches in diameter, 1 inch thick, and made from steel that weighs 725 pounds per cubic foot, what is the weight of the object?
 - 197.5 lbs
 - 272.5 lbs
 - 395.2 lbs
 - 725 lbs
- The span of a belt-driven piece of equipment is described as:
 - the distance from the centerline of one shaft to the centerline of the other shaft.
 - the distance from the pitch line of one sheave to the pitch line of the other sheave.
 - the distance from where the belt loses contact with one sheave to the point where it contacts the other sheave.
 - the distance the belt travels in one revolution.
- The pitch of a screw thread is:
 - the angle included between the sides of the thread, measured in the axial plane.
 - the distance from a point on the screw thread to a corresponding point on the next thread.
 - the angle included between the side of a thread and the centerline, measured in the axial plane.
 - the distance a screw advances axially in one turn.
- What does the term "braided" refer to when applied to a pressure hose and/or fuel line?
 - Type of inner hose reinforcement
 - Type of material used for fluid contact
 - Method of connecting hose sections
 - Hose covering material

Skill
Set

3

Mechanical Maintenance

- Which of the following "trouble causes" would be associated with a pump that fails to discharge on start-up?
 - Leaks in the stuffing box
 - Excessive pump clearances
 - Lift too high
 - Air or vapor in the liquid
- The two main classifications of air compressors are:
 - positive-displacement and dynamic.
 - air-cooled and water-cooled.
 - reciprocating and rotary.
 - vane and piston.
- The main function of a lantern ring in a centrifugal pump is to:
 - apply sealing fluid to the stuffing box.
 - keep the packing straight and level.
 - provide cooling and lubrication.
 - properly align the packing in the stuffing box.
- The most common cause of mechanical seal failure is:
 - wrong type of seal.
 - dirty water.
 - vibration.
 - lack of maintenance.
- Preheated loads and vibrations applied over a long period will cause:
 - metal strain.
 - metal breakdown.
 - metal fatigue.
 - elastic breakdown.
- Which welding process produces the highest quality weld on stainless steel?
 - Oxyacetylene
 - Shielded metal-arc
 - Gas metal-arc
 - Gas tungsten-arc



Section 5: Diagnostic Test

7. A partially full 50-foot diameter, 30-foot tall cylindrical tank contains 293,740 gallons of water. What is the depth of the water in feet?
 - a. 2.0 feet
 - b. 15.7 feet
 - c. 20.0 feet
 - d. 25 feet
8. A steel plate is 12 feet square and $\frac{3}{4}$ inches thick. Assuming that steel weighs 565 pounds per cubic foot, how much does the steel plate weigh?
 - a. 424 lbs
 - b. 509 lbs
 - c. 848 lbs
 - d. 5,085 lbs
9. A steel bar 6.5 inches long is heated from 75°F to 250°F . What is the new length of the bar?
 - a. 6.4928 inches
 - b. 6.5006 inches
 - c. 6.5072 inches
 - d. 6.5170 inches
10. Water is flowing through a 24-inch diameter pipe at 2.5 feet per second. What is the flow rate in gallons per minute?
 - a. 3,525 GPM
 - b. 4,490 GPM
 - c. 5,260 GPM
 - d. 7,854 GPM
11. A 50 foot diameter tank is pumped from 70 feet down to 50 feet in 2.45 hours. What is the capacity of the pump in gallons per minute?
 - a. 267 GPM
 - b. 1,997 GPM
 - c. 4,895 GPM
 - d. 11,990 GPM
12. Crew A can pave 1,000 square feet in 4 hours, and Crew B can pave 800 square feet in 3 hours. How many square feet can be paved in 8 hours if the two crews are working together?
 - a. 514 sq ft
 - b. 2,136 sq ft
 - c. 4,136 sq ft
 - d. 5,140 sq ft
13. A piston-type positive displacement pump has a bore of $8\frac{3}{4}$ inches and a stroke of $10\frac{5}{16}$ inches. If it is being driven at 50 rpm, what is its flow rate in gallons per minute?
 - a. 134.2 GPM
 - b. 156.3 GPM
 - c. 170.9 GPM
 - d. 184.2 GPM
14. A motor operating at 1,760 RPM has a 10-inch sheave attached to it. The sheave is connected to a 16-inch sheave on the pump. At what RPM is the pump turning?
 - a. 110 RPM
 - b. 1,056 RPM
 - c. 1,100 RPM
 - d. 2,816 RPM
15. A 30-tooth gear is attached to pump that needs to operate at 500 RPM. If the motor operates at 750 RPM, how many teeth does its gear need?
 - a. 12
 - b. 20
 - c. 42
 - d. 45
16. A 1,760 RPM motor is attached to a gear box with a 3.52 to 1 ratio. What is the RPM of the pump attached to the other side of the gear box?
 - a. 500 RPM
 - b. 5,000 RPM
 - c. 6,000 RPM
 - d. 6,195 RPM



Section 5: Diagnostic Test

17. A running pump has a suction pressure of 15 psi and a discharge pressure of 135 psi. If the viscosity and bowl losses are 1.2 feet, what is the Total Dynamic Head?
- 270 feet
 - 272.2 feet
 - 311.8 feet
 - 346.5 feet
18. If an 85% efficient pump delivers 2,250 GPM at a TDH of 100 feet, what is the water horsepower?
- 42 Whp
 - 48.3 Whp
 - 56.8 Whp
 - 66.8 Whp

| | | |
|-----------|---|--|
| Skill Set | 4 | Communications, Customer Service, and Supervision |
|-----------|---|--|

- You have decided that it has become necessary that all plant personnel participate in housekeeping. There are many who have raised the objection that higher-paid workers should not waste time with housekeeping. Who is the first person/group that you need to convince in order for your plan to work?
 - The people required to do the work
 - The first line supervisors
 - Management
 - Your peers
- Permits to operate a wastewater treatment plant are issued by:
 - NPDES.
 - SWQCB.
 - RWQCB.
 - DOHS.

Test Answer Key

| | | |
|-----------|---|---------------|
| Skill Set | 1 | Safety |
|-----------|---|---------------|

| No. | Answer | Skill Set |
|-----|--------|-----------|
| 1 | c | 1.2 |
| 2 | a | 1.1c |

| | | |
|-----------|---|----------------------------|
| Skill Set | 2 | Tools and Equipment |
|-----------|---|----------------------------|

| No. | Answer | Skill Set |
|-----|--------|-----------|
| 1 | a | 2.1 |
| 2 | c | 2.2 |
| 3 | b | 2.1 |
| 4 | a | 2.2/3.0 |

| | | |
|-----------|---|-------------------------------|
| Skill Set | 3 | Mechanical Maintenance |
|-----------|---|-------------------------------|

| No. | Answer | Skill Set |
|-----|--------|-----------|
| 1 | d | 3.1 |
| 2 | a | 3.1 |
| 3 | a | 3.1 |
| 4 | b | 3.1 |
| 5 | d | 3.4 |
| 6 | c | 3.6 |
| 7 | c | 3.3 |
| 8 | d | 3.3 |
| 9 | c | 3.3 |
| 10 | a | 3.3 |
| 11 | b | 3.3 |
| 12 | c | 3.3 |
| 13 | a | 3.3 |
| 14 | c | 3.3 |
| 15 | b | 3.3 |
| 16 | a | 3.3 |
| 17 | b | 3.3 |
| 18 | c | 3.3 |



| | | |
|-----------|----------|--|
| Skill Set | 4 | Communications, Customer Service, and Supervision |
|-----------|----------|--|

| No. | Answer | Skill Set |
|-----|--------|-----------|
| 1 | c | 4.3 |
| 2 | c | 4.4 |

Selected Problem Solutions

| | | |
|-----------|----------|----------------------------|
| Skill Set | 2 | Tools and Equipment |
|-----------|----------|----------------------------|

- Using a counter weight scale, you are required to use six disks to offset the weight of an object. If the disks are 10 inches in diameter, 1 inch thick, and made from steel that weighs 725 pounds per cubic foot, what is the weight of the object?

This is a volume and conversion problem. After you find the volume of the cylinder, you use the given conversion factor to convert from volume (cu ft) to weight (lbs). Since there are six disks the height is:

$$6 \times 1 \text{ inch} \times \frac{1 \text{ ft}}{12 \text{ inches}} = 0.5 \text{ ft}$$

$$\begin{aligned} \text{Volume of a cylinder} \\ &= 0.785 \times \text{diameter}^2 \times \text{height} \end{aligned}$$

$$\text{Volume} = 0.785 \times (0.833 \text{ ft})^2 \times 0.5 \text{ ft}$$

$$\text{Volume} = 0.2724 \text{ ft}^3$$

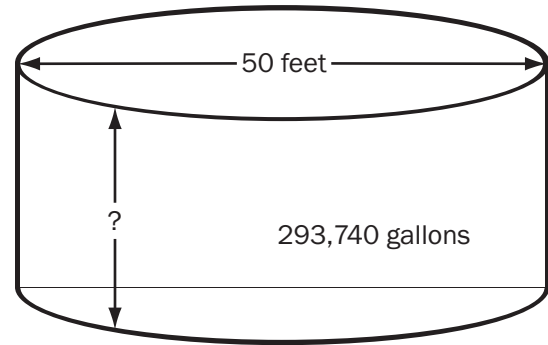
$$\text{Weight} = 0.2724 \text{ cu ft} \times \frac{725 \text{ lbs}}{1 \text{ cu ft}}$$

$$\text{Weight} = 197.5 \text{ lbs}$$

| | | |
|-----------|----------|-------------------------------|
| Skill Set | 3 | Mechanical Maintenance |
|-----------|----------|-------------------------------|

- A partially full 50-foot diameter, 30-foot tall cylindrical tank contains 293,740 gallons of water. What is the depth of the water in feet?

This is a volume problem; the shape is a cylinder. First draw a picture and label the known values.



$$\begin{aligned} \text{Volume of a cylinder} \\ &= 0.785 \times \text{diameter}^2 \times \text{height} \end{aligned}$$

$$\text{Height} = \frac{\text{Volume of cylinder}}{0.785 \times \text{diameter}^2}$$

$$\text{Height} = \frac{293,740 \text{ gallons}}{0.785 \times (50 \text{ ft})^2} \times \frac{1 \text{ cu ft}}{7.48 \text{ gal}}$$

$$\text{Height} = 20 \text{ feet}$$

- A steel plate is 12 feet square and 3/4 inches thick. Assuming that steel weighs 565 pounds per cubic foot, how much does the steel plate weigh?

This is a volume and conversion type of problem. After you find the volume of the rectangular solid, you use the given relationship to convert from volume (cu ft) to weight (lbs).

$$\text{Volume} = \text{length} \times \text{width} \times \text{height}$$

$$3/4 \text{ in} \times \frac{1 \text{ ft}}{12 \text{ inches}} = 0.0625 \text{ ft}$$

$$\text{Volume} = 12 \text{ ft} \times 12 \text{ ft} \times 0.0625 \text{ ft}$$

$$= 9.0 \text{ cu ft}$$

$$\text{Weight} = 9.0 \text{ cu ft} \times \frac{565 \text{ lbs}}{1 \text{ cu ft}}$$

$$\text{Weight} = 5,085 \text{ lbs}$$



Section 5: Diagnostic Test

9. A steel bar 6.5 inches long is heated from 75°F to 250°F. What is the new length of the bar?

The coefficient of thermal expansion for steel is 0.00000633/°F.

The new length is the amount of expansion plus the original length.

New Length = Thermal expansion + orig length

Thermal expansion = Coefficient of thermal expansion x length x ΔT

$$= 0.00000633/°F \times 6.5 \text{ in} \times (250°F - 75°F)$$

$$= 0.0072 \text{ inches}$$

$$\text{New Length} = 0.0072 \text{ in} + 6.5 \text{ in} = 6.5072 \text{ in}$$

10. Water is flowing through a 24-inch diameter pipe at 2.5 feet per second. What is the flow rate in gallons per minute?

This is a flow rate problem. As indicated in Table 4-1, the formula needed to determine flow rate is:

Flow = area x velocity

The cross-sectional area is the area of the circle as seen when the pipe is cut perpendicular to flow.

Area of a circle = 0.785 x diameter²

$$\text{Area} = 0.785 \times (2 \text{ ft})^2 = 3.14 \text{ ft}^2$$

Flow = Area x Velocity

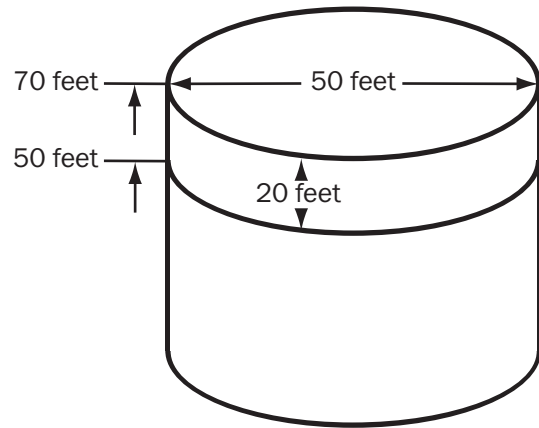
$$\text{Flow} = 3.14 \text{ ft}^2 \times 2.5 \frac{\text{ft}}{\text{sec}} = 7.854 \frac{\text{cu ft}}{\text{sec}}$$

$$\text{Flow} = 7.85 \text{ cfs} \times \frac{449 \text{ GPM}}{1 \text{ cfs}}$$

$$\text{Flow} = 3,525 \text{ GPM}$$

11. A 50 foot diameter tank is pumped from 70 feet down to 50 feet in 2.45 hours. What is the capacity of the pump in gallons per minute?

First draw a picture and label the known values.



In this problem you must understand what flow is and utilize the concept of flow rate. Flow rate is defined as volume per unit of time.

Therefore in this problem, Flow = volume/time, where the volume is a cylinder with a diameter of 50 feet and a height of 20 feet, and the time is 2.45 hours.

Volume of a cylinder

$$= 0.785 \times \text{diameter}^2 \times \text{height}$$

$$\text{Volume} = 0.785 \times (50 \text{ ft})^2 \times 20 \text{ ft}$$

$$\text{Volume} = 39,250 \text{ cu ft}$$

$$\text{Flow} = \frac{39,250 \text{ cu ft}}{2.45 \text{ hrs}} = 16,020 \text{ cu ft/hr}$$

$$\text{Flow} = 16,020 \frac{\text{cu ft}}{\text{hr}} \times \frac{7.48 \text{ gal}}{1 \text{ cu ft}} \times \frac{1 \text{ hr}}{60 \text{ min}}$$

$$\text{Flow} = 1997 \text{ GPM}$$

12. Crew A can pave 1,000 square feet in 4 hours, and Crew B can pave 800 square feet in 3 hours. How many square feet can be paved in 8 hours if the two crews are working together?

This is a manpower problem. You must know how to:

- Find how much work each crew can accomplish per hour.
- Add these values together.
- Multiply the number of hours they will work by the combined work per hour.

$$\text{Crew A: } \frac{1,000 \text{ sq ft}}{4 \text{ hr}} = 250 \text{ sq ft/hr}$$

$$\text{Crew B: } \frac{800 \text{ sq ft}}{3 \text{ hr}} = 267 \text{ sq ft/hr}$$

$$250 \text{ sq ft/hr} + 267 \text{ sq ft/hr} = 517 \text{ sq ft/hr}$$

$$8 \text{ hrs} \times 517 \text{ sq ft/hr} = 4,136 \text{ sq ft}$$



Section 5: Diagnostic Test

13. A piston-type positive displacement pump has a bore of $8 \frac{3}{4}$ inches and a stroke of $10 \frac{5}{16}$ inches. If it is being driven at 50 rpm, what is its flow rate in gallons per minute?

This is a flow rate problem where flow is defined as volume per unit of time.

The bore of the cylinder is the inside diameter. The stroke is the distance the piston moves from top to bottom, in other words, the height of the cylinder.

Flow = volume/time

Time = 1 minute

Volume pumped in 1 minute = Cylinder volume x 50 RPM

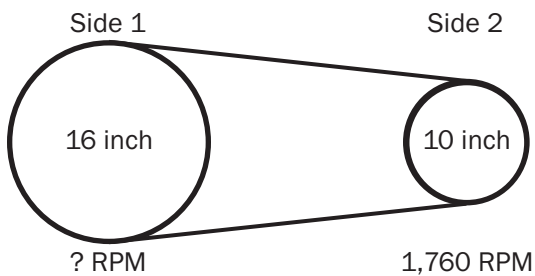
Volume of a cylinder
 = $0.785 \times \text{diameter}^2 \times \text{height}$
 = $0.785 \times \text{bore}^2 \times \text{stroke}$
 = $0.785 \times (0.7292 \text{ ft})^2 \times 0.8594 \text{ ft}$
 = 0.3587 cu ft

Volume pumped in 1 minute
 = cylinder vol x 50 RPM
 = 0.3587 cu ft x 50 RPM
 = 17.94 cu ft/min

Flow = $\frac{\text{volume}}{\text{time}} = \frac{17.94 \text{ cu ft}}{1 \text{ min}} \times \frac{7.48 \text{ gal}}{1 \text{ cu ft}}$

Flow = 134.2 GPM

14. A motor operating at 1,760 RPM has a 10-inch sheave attached to it. The sheave is connected to a 16-inch sheave on the pump. At what RPM is the pump turning?



This is a ratio problem. There are two ways to work this problem. The first is using the big/little=fast/slow formula. When using this formula, you must remember that the little sheave is the fast one and the big sheave is the slow one.

$$\frac{\text{Big}}{\text{Little}} = \frac{\text{Fast}}{\text{Slow}}$$

$$\frac{16 \text{ inch}}{10 \text{ inch}} = \frac{1,760 \text{ RPM}}{? \text{ RPM}}$$

$$? \text{ RPM} = 1,760 \text{ RPM} \times \frac{10 \text{ inch}}{16 \text{ inch}} = 1,100 \text{ RPM}$$

The second way to work a problem like this is to use a formula that does not require you to remember which is fast or slow. Everything on one side of the unit goes on one side of the equation and everything on the other side goes on the other side of the equation.

$$\text{RPM}_1 \times \text{Sheave } 1 = \text{RPM}_2 \times \text{Sheave } 2$$

$$? \text{ RPM} \times 16 \text{ in} = 1,760 \text{ RPM} \times 10 \text{ in}$$

$$? \text{ RPM} = \frac{1,760 \text{ RPM} \times 10 \text{ in}}{16 \text{ inch}}$$

$$\text{RPM} = 1,100$$

15. A 30-tooth gear is attached to pump that needs to operate at 500 RPM. If the motor operates at 750 RPM, how many teeth does its gear need?

First draw a picture and label the known values.



Both gears are drawn the same size because, when using this formula, you do not need to know which is larger. The formula will take care of that for you.

$$\text{RPM}_1 \times \# \text{ of Teeth}_1 = \text{RPM}_2 \times \# \text{ of Teeth}_2$$

$$750 \text{ RPM} \times ? \text{ teeth} = 500 \text{ RPM} \times 30 \text{ teeth}$$

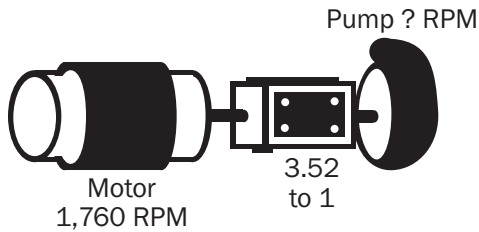
$$? \text{ teeth} = \frac{500 \text{ RPM} \times 30 \text{ teeth}}{750 \text{ RPM}}$$

$$? \text{ teeth} = 20 \text{ teeth}$$



Section 5: Diagnostic Test

16. A 1,760 RPM motor is attached to a gear box with a 3.52 to 1 ratio. What is the RPM of the pump attached to the other side of the gear box?



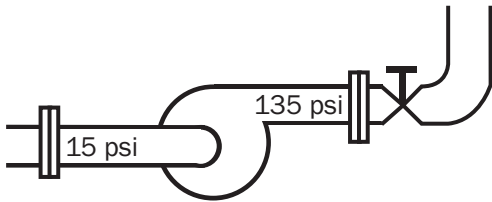
With this type of a ratio problem you must realize that the 3.52 to 1 ratio is, unless stated otherwise, the driver to the driven. Place a cross on your paper and place the 3.52 in the lower left hand part and the 1 in the lower right hand part. Put the RPM given over the appropriate side. Put the driver on the top left and the driven on the top right. Then set an equal sign between them and solve for the unknown.

$$\frac{1,760 \text{ RPM}}{3.52} = \frac{? \text{ RPM}}{1}$$

$$\frac{1,760 \text{ RPM}}{3.52} = ? \text{ RPM}$$

$$500 = \text{RPM}$$

17. A running pump has a suction pressure of 15 psi and a discharge pressure of 135 psi. If the viscosity and bowl losses are 1.2 feet, what is the Total Dynamic Head?



This problem requires that you understand what TDH is. Total Dynamic Head (TDH) represents the energy required to move the liquid at a given flow against a given pressure in a given system. The units for TDH are feet of liquid. Viscosity and bowl losses are part of the pump efficiency and do not affect the TDH calculations when you have dynamic discharge (pump running) and suction pressures.

$$\text{TDH} = (\text{Discharge psi} - \text{Suction psi}) \times 2.31 \text{ ft of H}_2\text{O/psi}$$

$$\text{TDH} = (135 \text{ psi} - 15 \text{ psi}) \times 2.31 \text{ ft of H}_2\text{O/psi}$$

$$\text{TDH} = 277.2 \text{ feet of H}_2\text{O}$$

18. If an 85% efficient pump delivers 2,250 GPM at a TDH of 100 feet, what is the water horsepower?

This is a straightforward water horsepower problem where the formula needed is:

$$\text{Whp} = \frac{\text{flow} \times \text{total head} \times \text{specific gravity}}{3960}$$

- Flow has to be in gallons per minute (GPM).
- Total head has to be in feet.
- Specific gravity is one (unity) unless otherwise given.

$$\text{Whp} = \frac{2250 \text{ GPM} \times 100 \text{ ft} \times 1}{3960}$$

$$\text{Whp} = 56.8$$



S e c t i o n 6

References

This section provides titles and information on primary and secondary references found useful in obtaining Grade III Plant Maintenance Mechanical Technologist certification. Because primary references contain most of the information needed for the certification test, it is recommended that candidates obtain access to them for personal use.

Many of these publications may be reviewed and purchased on-line from their publishers or from electronic book retailers. Others may be found in a wastewater treatment plant library or in a college or university library. In addition, see the CWEA Certification Resource Links page at www.cwea.org/tcp/resources for links to resources available on-line and any updates or changes to the information and URLs listed below.

Primary References

Maintenance Engineering Handbook, 5th Edition
Lindley R. Higgins, Dale P. Brautigam and
R. Keith Mobley (Editor)
ISBN 0070288119
Pub. Date: November 1994
McGraw-Hill Professional Publishing Group
800/262-4729
www.books.mcgraw-hill.com

Millwrights and Mechanics Guide, 4th Edition
Carl A. Nelson
ISBN 002588591X
Pub. Date: July 1989
Available online though various booksellers

Maintaining Wastewater Equipment, Book 383
Industrial Safety and Health, Book 109.1
Working with Metals
Arc Welding Practices
TPC Training Systems
750 Lake Cook Road
Buffalo Grove, IL 60089
800/837-8872, ext. 4060
www.tpctraining.com

Maintenance Manager's Standard Manual, 2nd Edition
Thomas A. Westerkamp
ISBN 0132437341
Pub. Date: April 1997
Available online through various booksellers

Utility Management
Office of Water Programs
California State University Sacramento
6000 J Street
Sacramento, CA 95819-6025
916/278-6142
www.owp.csus.edu

Confined Space Entry, 1998 Edition
Order No: P07115WW
Water Environment Federation
601 Wythe Street
Alexandria, VA 22314-1994
800/666-0206
www.wef.org

Applied Math for Wastewater Plant Operators
Joanne Kirkpatrick Price
ISBN 0877628092
CRC Press
800/272-7737
www.crcpress.com



Section 6: References

Secondary References

The information contained in the Primary References listed above provides a solid base of knowledge for the Technologist. Additional sources of information for Grade III candidates include:

Equipment Operation and Maintenance Manuals
Vendor Repair Manuals

Trade Magazines, paid for
Trade Magazines, free

(e.g., *Maintenance Technology*, *Plant Services*, *Pumps and Systems*, *Reliability Magazine*, *Valve Magazine*, and *Practicing Oil Analysis*)

Classes and Seminars

Additional recommended books for Technologists include:

Pump Handbook, 3rd Edition
Igor Karassik, Joseph Messina, Paul Cooper and Charles Heald
ISBN 0070340323
Pub. Date: September 2000
McGraw-Hill Professional Publishing Group
800/262-4729
www.books.mcgraw-hill.com

Piping Handbook, 7th Edition
Mohinder Nayyar
ISBN 0070471061
Pub. Date: October 1999
McGraw-Hill Professional Publishing Group
800/262-4729
www.books.mcgraw-hill.com

Centrifugal Pump Sourcebook
John W. Dufour and W. Ed Nelson
ISBN 0070180334
Pub. Date: 1992
The McGraw-Hill Companies
(Out of print, but can be found online through amazon or other online booksellers)

Pumps and Pumping, 7th Edition
Skeet Arasmith
ACR Publications
1298 Elm Street SW
Albany, OR 97321
800/433-8150
www.acrp.com

Machinery Failure Analysis and Troubleshooting

Volume 2
Heinz Bloch
ISBN: 088415662
Gulf Publishing Company
3301 Allen Parkway
Houston, TX 97019
713/529-4301
www.gulfpub.com

Math Test for Water and Wastewater Technology, 2nd Edition

Wright's Training
P. O. Box 515
Elmira, CA 92625
707/448-3659
Download form to order:
www.wrights-training.com

Audel Mechanical Trades Pocket Manual

Carl A. Nelson
ISBN 0025886657
Pub. Date: April 1990
Hungry Minds Inc. (formerly IDG Books)
909 Third Avenue
New York, NY 10022
800/755-7672
www.mtroubleshooting.com
Catalog # MTM-1025
Look under "Mechanical Trades"

Making Measurements-Course 104

Pneumatic Trouble Shooting-Course 310
TPC Training Systems
750 Lake Cook Road
Buffalo Grove, IL 60089
800/837-8872, ext. 4060
www.tpctraining.com

Management and Supervision for Working Professionals, Vols. I and II, 3rd Edition

Herman Koren
ISBN: 1566702038 and 1566702046
Pub. Date: December 1995
CRC Press
800/272-7737
www.crcpress.com



NEC 1999: National Electrical Code, (NFPA 70)
National Fire Protection Association
11 Tracy Drive
Avon, MA 02322
800-344-3555
www.nfpa.org

Supervisor's Guide to Safety and Health Programs
Water Environment Federation
601 Wythe Street
Alexandria, VA 22314
800/666-0206
www.wef.org

Supervision: Concepts and Practices of Management, 8th Edition
Raymond L. Hilgert and Edwin C. Leonard Jr.
ISBN 0-324-01389-2
Pub. Date: 2001
South-Western College Publishing
5101 Madison Rd.
Cincinnati, OH 45227-1490
800/543-0487
www.swcollege.com

Supervisory Management in the Water/Wastewater Field
Self-Study Course
Michigan State University
3535 Forest Rd.
Lansing, MI 48910
800/356-5705
www.vu.msu.edu
This self-study course uses *Supervision: Concepts and Practices of Management* (listed above) as a supporting textbook.



You and Wastewater Math

by Cheryl Ooten, Mathematics Professor, Santa Ana College, Ooten_Cheryl@rscsd.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 plane and solid geometry (area and volume problems). For specific kinds of math skills and problems you may encounter on the Grade III Plant Maintenance Technologist certification test, please review Sections 3, 4, and 5 of this study guide.

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.



Appendix A: You and Wastewater Math

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 Preparation 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:

- Technical Certification Training Classes and Annual Conferences
- CWEA Northern and Southern Regional Training Conferences
- CWEA Study Guides

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 are wanting to improve. Ask those managing other departments, agencies, or local professional organizations for help in getting the training you need.

Materials

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

- Courses from Ken Kerri, Office of Water Programs, California State University, Sacramento, 6000 J Street, Sacramento, CA 95819
- Price, Joanne Kirkpatrick. *Basic Math Concepts for Water and Wastewater Plant Operators, 2nd Edition*. Lancaster, Pennsylvania: Technomic, 1991; currently CRC Press LLC.
- Smith, Richard Manning. *Mastering Mathematics: How to Be a Great Math Student*, 3rd Ed. Pacific Grove, CA: Brooks/Cole, 1998.
- Zaslavsky, Claudia. *Fear of Math*. New Brunswick, NJ: Rutgers University Press, 1994.

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



Appendix A: You and Wastewater Math

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.

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,

$$2 \bullet 3 = 2 \times 3 = (2)(3) = 6$$

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.”

$$\text{MGD} = \frac{\text{millions gallons}}{\text{day}}$$

$$\text{cfs} = \frac{\text{cubic feet}}{\text{second}}$$

$$\text{ppm} = \frac{\text{parts}}{\text{million}}$$

$$\text{GPM} = \frac{\text{gallons}}{\text{minute}}$$

$$\text{psi} = \frac{\text{pounds}}{\text{square inch}}$$

$$\text{mg/L} = \frac{\text{milligrams}}{\text{Liter}}$$

$$\text{GPD/square foot} = \frac{\text{gallons/day}}{\text{square foot}}$$

$$10\% = \text{ten percent} = \frac{10}{100}$$

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

$$\text{mgd} = \frac{\text{million gallons}}{\text{day}}$$

divide 3.5 million gallons by half a day.

$$\text{mgd} = \frac{3.5 \text{ million gallons}}{.5 \text{ day}} = 7 \text{ mgd}$$

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

$$\frac{10 \text{ cu ft}}{1} \times \frac{7.48 \text{ gal}}{1 \text{ cu ft}} = \frac{(10 \text{ cu ft})(7.48 \text{ gal})}{1 \text{ cu ft}}$$

$$= 74.8 \text{ gal}$$

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.

$$\frac{10 \text{ gal}}{1} \times \frac{1 \text{ cu ft}}{7.48 \text{ gal}} = \frac{(10 \text{ gal})(1 \text{ cu ft})}{7.48 \text{ gal}}$$

$$= 1.34 \text{ cu ft}$$

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:

$$Dt = \frac{\text{volume}}{\text{flow}}$$

$$Dt = \frac{675,460 \text{ gal}}{1,000,000 \text{ gal/day}}$$

$$= \frac{675,460 \text{ gal}}{1} \times \frac{\text{day}}{1,000,000 \text{ gal}} = 0.675 \text{ days}$$

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

$$Dt = \frac{426 \text{ cu ft}}{1,000 \text{ cfs}} = \frac{426 \text{ cu ft}}{1,000 \text{ cu ft/sec}}$$

$$= \frac{426 \text{ cu ft}}{1} \times \frac{\text{sec}}{1,000 \text{ cu ft}} = 0.426 \text{ sec}$$

Example 4

Find the number of gallons of an 11% polymer needed to produce 100 gallons of a 0.75% solution.

Use the formula $C_1V_1=C_2V_2$ where C=concentration or % and V=volume.

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

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 gallons.

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

$$\frac{1 \text{ min}}{60 \text{ sec}} \text{ and } \frac{1 \text{ hr}}{60 \text{ min}}$$

The work is given below. Notice how the units cancel out leaving the answer in hours.

$$\text{Time} = \frac{43,000 \text{ cu ft}}{2.7 \text{ cu ft/sec}} \times \frac{1 \text{ min}}{60 \text{ sec}} \times \frac{1 \text{ hr}}{60 \text{ min}}$$

$$= 4.42 \text{ hr}$$

Example 6

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

First, find the volume of the rectangular basin by multiplying length by width by height. $\text{Volume} = (200 \text{ ft})(50 \text{ ft})(12 \text{ ft}) = 120,000$ 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

$$\frac{7.48 \text{ gal}}{1 \text{ cu ft}}$$

to convert cubic feet into gallons.

$$\text{Volume} = \frac{120,000 \text{ cu ft}}{1} \times \frac{7.48}{1 \text{ cu ft}}$$

$$= 897,600 \text{ gal}$$



Appendix A: You and Wastewater Math

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 feet tall with a diameter of 70 feet, find the volume (in gallons) of the liquid at 10 a.m. and the rate of flow from the tank in gallons per minute.

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

- (1) First, find the number of gallons of water in the tank at 10 a.m.
- (2) 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

- a. First, to find the volume in gallons 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.

$$\begin{aligned}\text{So, the area of the base} &= 0.785(70^2) \\ &= 3,846.5 \text{ sq ft.}\end{aligned}$$

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

$$\begin{aligned}\text{Volume} &= (\text{area of the base})(\text{height}) \\ &= (3846.5 \text{ ft}^2)(47 \text{ ft}) = 180,785.5 \text{ ft}^3\end{aligned}$$

However, you want the volume in gallons so use the factor

$$\frac{7.48 \text{ gal}}{1 \text{ cu ft}}$$

to convert.

$$\begin{aligned}\text{Volume in gallons} &= 180,785.5 \text{ ft}^3 \times \frac{7.48 \text{ gal}}{1 \text{ ft}^3} \\ &= 1,352,275.54 \text{ gal}\end{aligned}$$

- 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 $60 \text{ min} = 1 \text{ hr}$ or factors

$$\frac{60 \text{ min}}{1 \text{ hr}} \text{ or } \frac{1 \text{ hr}}{60 \text{ min}}$$

to convert. You want the hour unit to cancel out, so you will use the first factor. The time becomes:

$$\frac{6 \text{ hrs}}{1} \times \frac{60 \text{ min}}{1 \text{ hr}} = 360 \text{ min}$$

Rate of flow in gal per minute =

$$\frac{1,352,275.54 \text{ gal}}{360 \text{ min}} = 3,756.32 \text{ gal per min}$$

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.

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. 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.

Use Paper.

Keep scratch paper available and expect to use it for your math work. You need empty space on paper 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.

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.)



Appendix A: You and Wastewater Math

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. Use questions from the diagnostic test in Section 5 of this study guide. Give yourself this practice test 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 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. If you are not allowed to use notes on the exam, be sure to put the list away so that your honesty is not questioned. When you receive your test, quickly write these formulas or facts on your exam paper. 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 exam—before, during, and maybe even after. Different people have different ways of dealing with their anxiety during tests. 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

This comes from the work of Howard Gardner. (Gardner, Howard. *Multiple Intelligences: The Theory in Practice*. New York: Basic Books, 1993.)

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.



Appendix A: You and Wastewater Math

“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 ft³ 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.



Glossary of Technical Terms

Absolute Viscosity: A measurement of the internal resistance, to shear, in a fluid.

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

Alloy Steel: Steel that owes its distinctive properties to elements other than carbon.

Alternating Current (AC): Electric current that periodically reverses its direction, rising from zero to maximum and returning to zero, then repeating the sequence in the opposite direction.

Ambient Temperature: The temperature of the surrounding medium, usually to be referred to as the temperature of the air surrounding a structure or operating device.

Angular Misalignment: Shafts with the axis concentric but not parallel.

Assembly: The joining together of two or more piping components by bolting, welding, caulking, brazing, soldering, cementing or threading into their installed location as specified by the engineering design.

Ball Joint: A joint that permits universal rotational movement in a piping or mechanical system.

Base Metal: The metal to be welded, brazed, soldered or cut. It is also referred to as the parent material.

Bearings: A bearing, in the mechanical terms used by millwrights and mechanics, is a support for a rotating shaft.

Bearing, Guide (Sleeve): The primary function of a guide bearing is to support and align members having sliding or reciprocating motion.

Bearing, Radial: The function of radial bearings is to support loads that act radially. These are loads acting at right angles to the shaft centerline.

Bearing, Thrust: The thrust bearing supports or resists loads that act axially. They may be termed endwise loads because they act parallel to the centerline, towards the shaft ends.

Blank Flange: A flange that is not drilled but is otherwise complete.

Blind Flange: A drilled flange used to close the end of a pipe. It is also known as a *dead end*.

Brazing: A metal joining process wherein coalescence is produced by the use of a nonferrous filler material having a melting point above 800°F but lower than that of the parent material. The filler metal is melted, distributed between closely fitted surfaces of a joint by capillary action, and adheres to the parent materials forming the weld.

Calipers: Adjustable instruments composed of two straight or curved legs joined at the top by a hinge. They are used to transfer measurements from a measuring tool to the work piece or from the work piece to the measuring tool.

Caliper, Vernier: The vernier caliper is designed to measure with greater accuracy than an ordinary caliper. The greater accuracy is possible because of the special vernier scale attached to the index line. It can measure with an accuracy of 0.001 of an inch and has separate scales, one for inside measurements and one for outside measurements.

Cast Iron: A generic term used for the family of high carbon-silicon-iron casting alloys including gray, white, and ductile iron.

Cavitation: The forming and collapsing of vapor bubbles from a low pressure to high pressure in a pumped fluid. This causes noise and may cause damage. Vapor bubbles are formed when the liquid falls below its vapor pressure at ambient temperature.

Celsius: The international name for the centigrade scale of temperature, on which the freezing point of water is 0°C and the boiling point is 100°.

Centrifugal Force: The force that causes rotating bodies to move away from the center of rotation.



Appendix B: Glossary of Technical Terms

Centrifugal Pump: A pump consisting of an impeller on a rotating shaft that is in a casing having a suction connection and a discharge connection. The rotating impeller creates pressure by the velocity derived from centrifugal force.

Circuit Breaker: A switch device that allows manual or automatic interruption of an electrical current by tripping a switch to isolate a circuit or electrical equipment from the power source.

Clean Water Act (CWA): The federal Clean Water Act 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 sets the authority for the U.S. EPA to establish pretreatment standards for existing and new sources discharging industrial wastewater to POTWs.

Conductor: Any material that will transmit electric current readily, such as wire or cable, busbar, liquid electrolyte, etc.

Coupling (piping): A sleeve used to connect two pipes.

Coupling (pump): A mechanical device usually fabricated of synthetic material, used to connect the ends of the motor shaft and the pump shaft.

Critical Speed: The speed of a rotating element at which resonance (natural frequency) occurs. It can destroy the rotating mass as the uncontrolled vibration level increases.

Density: The density of a substance is defined as the mass of the substance per unit volume. It is expressed in a variety of units.

Efficiency: The ratio between useful work performed and the energy expended in producing it. It is the ratio of output power divided by the input power.

End-suction Pump: A centrifugal pump with the suction and discharge ports located at right angles to each other.

Expansion Joint: A flexible piping component that absorbs thermal and/or terminal movements.

Fahrenheit: A temperature scale in which 32° marks the freezing point, and 212° the boiling point, of water.

Fatigue: The tendency for any material to fail structurally due to repeated cyclic stress at considerably less than its design strength.

Filter: A device which removes solid material from a liquid.

Filter Efficiency: The ability, expressed as a percent, of a filter to remove a specified artificial contaminant at a given concentration under specified test conditions.

Flash point: The temperature at which a liquid must be heated under specified conditions of the test method to give off sufficient vapor to form a mixture with air that can be ignited momentarily by a specified flame.

Flow: The movement of a stream of water or other fluid from place to place.

Flow Rate: The volume, mass or weight of a fluid passing through any conductor per unit of time.

Flux: A material used to dissolve, prevent accumulation of, or facilitate removal of oxides and other undesirable substances during welding, brazing or soldering.

Frequency: The number of cycles in a time period (usually one second). Alternating current frequency is expressed in cycles per second, termed Hertz (Hz).

Friction: The resistance to motion between two surfaces in contact.

Friction Head: The pressure expressed in pounds per square inch or feet of liquid needed to overcome the resistance to flow in the pipe and fittings.

Galvanizing: A process by which the surface of iron or steel is covered with a layer of zinc.

Gas Metal Arc Welding (GMAW): An arc welding process that employs a continuous solid filler metal (consumable) electrode. Shielding is obtained entirely from an external supplied gas or gas mixture. (Some methods of this process have been called MIG or CO₂ welding.)

Gas Tungsten Arc Welding (GTAW): An arc welding process that employs a tungsten (non-consumable) electrode. Shielding is obtained from a gas or gas mixture. Pressure may or may not be used and filler metal may or may not be used. (This process has sometimes been called TIG welding. When shielding is obtained by the use of an inert gas such as helium or argon, this process is called *inert-gas tungsten arc welding*.)



Gauge, Pressure: A device for registering the pressure of solids, liquids or gases. It may be graduated to register pressure in any units desired.

Gearbox or Reducer: A machine of different diameter gears, which connects the prime mover drive shaft to a driven piece of equipment and reduces the speed of the driven unit.

GPD: The rate of flow of a fluid measured in U.S. gallons per day.

GPM: The rate of flow of a fluid measured in U.S. gallons per minute.

Hazardous Waste: Any waste material that is potentially damaging to environmental health due to toxicity, ignitability, corrosivity, chemical reactivity or other reasons.

Head: The height of a column or body of fluid above a given point expressed in linear units. Head is often used to indicate gauge pressure. Pressure is equal to the height times the density of the fluid.

Head Loss: The decrease in pressure of a fluid flowing through a passage (pipe, for example), attributable to the friction between the fluid and the passage walls.

Header: A pipe or fitting to which a number of branch pipes are connected.

Heat Exchanger: A device that transfers heat through a conducting wall from one fluid to another.

Horsepower: A unit for measuring the power of motors or the rate of doing work. One horsepower equals 33,000 foot-pounds of work per minute (550 foot-pounds per second) or 746 watts.

Hot Taps: Branch piping connections made to operating pipelines, mains or other facilities while they are in operation.

Hydrogen Sulfide(H₂S): A toxic and lethal gas produced in sewers and digesters by anaerobic decomposition. Detectable in low concentrations (%) by its characteristic “rotten egg” odor. It deadens the sense of smell in higher concentrations or after prolonged exposure. Respiratory paralysis and death may occur at concentrations as low as 0.07% by volume of air.

Hypochlorination: The use of sodium hypochlorite (NaOCl₂) for disinfection.

Impact Test: A test to determine the behavior of materials when subjected to high rates of loading, usually in bending, tension or torsion. The quantity measured is the energy absorbed in breaking the specimen by a single blow, as in Charpy or Izod tests.

Impeller: A rotating set of vanes designed to impel rotation of a mass of fluid.

Instrumentation: The use of technology to control, monitor or analyze physical, chemical or biological parameters.

Kinematic Viscosity: The ratio of the absolute viscosity to the mass density. In the metric system, kinematic viscosity is measured in stokes or square centimeters per second.

Lantern Ring: A ring in line with a port in a stuffing box which provides sealing fluid. The sealing fluid also lubricates and cools the packing.

Manifold: A conductor that provides multiple connection ports.

Manometer: An instrument for measuring pressure. It usually consists of a U-shaped tube containing a liquid, the surface of which moves proportionally in one end of the tube with changes in pressure in the liquid in the other end.

Mechanical Seal: A seal placed on the pump shaft to prevent air from entering the pump and water from leaking from the pump along the shaft.

Megger: An extended ohmmeter used to measure the electrical resistance of motor insulation.

Meter: An instrument for measuring some quantity, such as the rate of flow of liquids, gases, or electric currents.

Methane (CH₄): A colorless, odorless, flammable, gaseous hydrocarbon present in natural gas and formed by the anaerobic decomposition of organic matter, or produced artificially by heating carbon monoxide and hydrogen over a nickel catalyst.

MGD: The rate of flow of a fluid measured as one million U.S. gallons per day.

Micrometer: A micrometer is a type of caliper that is used for accurate measurements to 0.0001 inch. It works by keeping track of the advance of a fine-pitch screw through any number of complete turns or a fraction of a turn.



Appendix B: Glossary of Technical Terms

Nipple: A piece of pipe less than 12 inches in length which may be threaded on both ends or one end and provided with ends suitable for welding or a mechanical joint. Pipe over 12 inches long is considered cut pipe.

Nondestructive Examination or Inspection: Inspection by methods which do not destroy the item, part, or component to determine its suitability for use.

NPDES Permit: National Pollutant Discharge Elimination System permit is the regulatory agency document issued by either a federal or state agency which is designed to control all discharges of pollutants from point sources into U.S. waterways. NPDES permits regulate discharges into navigable waters from all point sources of pollution, including industries, municipal wastewater treatment plants, sanitary landfills, large agricultural feedlots, and return irrigation flows.

NPSH: Net positive suction head is a measure of the pressure at the suction side of the pump, including atmospheric pressure and vapor pressure of the liquid being pumped.

Orifice: An opening with a closed perimeter in a plate, wall, or partition through which water may flow; generally used for the purpose of measurement or control of such water.

Orifice Plate: A plate containing an orifice. In pipes, the plate is usually inserted between a pair of flanges and the orifice is smaller in area than the cross section of the pipe.

Packing: Specially prepared material placed in a stuffing box around the pump shaft. The packing prevents air from entering the pump and water from leaking from the pump along the shaft.

Parallel Misalignment: Shafts with the axis parallel but not concentric.

Parts per million (PPM): The number of weight or volume units of a minor constituent present with each 1 million units of a solution or mixture.

Pipe: A closed conduit which diverts or conducts a fluid or gas from one location to another.

Pipe Diameter: The nominal or commercially designed inside diameter of a pipe.

Pressure: The force per unit area, usually expressed in pounds per square inch.

Pressure, Atmospheric: Pressure exerted by the atmosphere at any specific location. Sea level pressure is approximately 14.7 pounds per square inch absolute.

Pressure, Differential: The difference in pressure between any two points of a system or component.

Pump: A mechanical device for causing flow, for raising or lifting water or other fluid, or for applying pressure to fluids.

Pump Curve: A curve or curves showing the interrelationship of speed, dynamic head, capacity, brake horsepower, and efficiency of a pump.

Pump Efficiency: The ratio of energy converted to useful work to the energy applied to the pump shaft, or the energy difference in the water at the discharge and suction nozzles divided by the power input at the pump shaft.

Pumping Head: The sum of the static head and friction head on a pump discharging a given quantity of water.

RPM: Revolutions per minute; the means of measuring the rotational speed of machinery.

Spatter: In arc and gas welding, the metal particles expelled during welding that do not form part of the weld.

Specific Gravity: The ratio of the weight of a given volume of material or liquid to the weight of an equal volume of water.

Stainless Steel: An alloy of steel having unusual corrosion-resisting properties, usually imparted by nickel and chromium.

Static Head: The difference in distance from the surface of the suction level to the surface of the discharge level, generally given in feet.

Static Suction Head: The vertical distance from the source of supply, when its level is above the pump, to the centerline of the pump.

Suction Head: The head at the inlet to a pump; or the head below atmospheric pressure in a piping system.

Stuffing Box: A cavity and closure for a sealing device.

Tack Weld: A small weld made to hold parts of a weldment in proper alignment until the final welds are made.



Tolerance: The amount by which any characteristic (dimensional, electrical, physical or mechanical) may vary from that specified.

Torque: The rotating force produced by a motor. The units of torque may be expressed as foot-pounds, inch-pounds (English system) or newton-meter (metric system).

Total Dynamic Head: A measure (in feet) of the energy a pump must supply to move the desired amount of water.

Vacuum: Pressure less than atmospheric pressure. It is usually expressed in inches of mercury (in. Hg) as referred to the existing atmospheric pressure.

Valve: A device which controls fluid flow direction, pressure or flow rate.

Valve Actuator: The valve part(s) through which force is applied to move or position flow-directing elements.

Vertical Turbine Pump: A centrifugal pump, commonly a multistage diffuser, in which the pump shaft is mounted vertically.

Viscosity: In flowing liquids, the internal friction or internal resistance to relative motion of the fluid particles with respect to each other.

Water Hammer: A banging or hammering noise caused by a pressure wave oscillating in a closed conduit and rebounding off the closures at each end.

Wear Ring: A replaceable cylindrical ring usually made of bronze and pressed into the pump casing between the high- and low-pressure sides of the rotating impeller.



Glossary of Management and Supervision Terms

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.

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 supervisor 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: Gradual 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.



Appendix C: Glossary of Management and Supervision Terms

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 power 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.

Due process: Employee's legal entitlement to a fair hearing, usually before an impartial party and with appropriate representation, before discipline can be metered 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 are severe or persuasive enough to 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 the best possible decisions.



Appendix C: Glossary of Management and Supervision Terms

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.

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.



Appendix C: Glossary of Management and Supervision Terms

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.

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 factors—such as interesting and challenging work, full use of one's capabilities, or recognition for achievement—are provided.

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.



Appendix C: Glossary of Management and Supervision Terms

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.



A p p e n d i x D

Common Acronyms and Abbreviations

| | | | |
|------------------|--|-----------------|---|
| AA | atomic absorption | CFR | Code of Federal Regulations |
| AC power | alternating current | cfs | cubic feet per second |
| AC | acre | CH ₄ | Methane |
| AF | acre-feet | CIU | Categorical Industrial User |
| AF | acre-foot (feet) | CM | common mode |
| AFY | acre-foot per year | CMOM | Capacity Management, Operations, and Maintenance |
| AMSA | Association of Metropolitan Sewerage Agencies | COD | chemical oxygen demand |
| ANSI | American National Standards Institute | CPU | central processing unit |
| APHA | American Public Health Association | CRWA | California Rural Water Association |
| AS | activated sludge | CSP | confined-space permit |
| ASCE | American Society of Civil Engineers | CT | current transformer |
| ASME | American Society of Mechanical Engineers | CWA | Clean Water Act |
| ASTM | American Society for Testing and Materials | CWEA | California Water Environment Association |
| AWT | advanced wastewater treatment | DAF | dissolved air flotation |
| AWWA | American Water Works Association | DO | dissolved oxygen |
| BECP | Business Emergency and Contingency Plan | DOHS | California Department of Health Services |
| BNR | biological nutrient removal | DV/DT | ($\Delta V/\Delta T$) The change in voltage per change in time. |
| BOD ₅ | biochemical oxygen demand after 5 days | DWF | dry weather flow |
| BTU | British thermal unit | DWR | Department of Water Resources |
| C | Celsius | EIS | Environmental Impact Statement |
| Cal-OSHA | California Occupational Safety and Health Act | EMF | electromotive force or voltage |
| Cal-EPA | California Environmental Protection Administration | EPA | U.S. Environmental Protection Agency |
| CBOD | carbonaceous biochemical oxygen demand | F | Fahrenheit |
| CCE | carbon chloroform extract | F/M | food to microorganism ratio |
| CCR | California Code of Regulations | ft | feet (foot) |
| cf | cubic feet (foot) | ft ² | square foot |
| | | ft ³ | cubic feet |
| | | FTU | formazin turbidity unit |
| | | GAC | granular activated carbon |



Appendix D: Common Acronyms and Abbreviations

| | | | |
|------------------|---|-------|--|
| gal | gallon | min | minute |
| GFI | ground fault interrupter | MIS | Manufacturing Information System |
| GPD | gallons per day | mL | milliliter |
| GPM | gallons per minute | MLSS | mixed liquor suspended solids |
| GTAW | gas tungsten arc welding | MLVSS | mixed liquor volatile suspended solids |
| H ₂ S | hydrogen sulfide | MMI | Man Machine Interface |
| HCP&ERP | Hazard Communications Program and Emergency Response Plan | MOP | Manual of Practice |
| hp | horsepower | MPN | most probable number |
| HPLC | high-performance liquid chromatography | MS | mass spectrometer |
| Hz | Hertz | MSDS | Material Safety Data Sheets |
| IC | ion chromatograph | MTBF | mean time between failures |
| ICP | inductively coupled plasma | MTTR | mean time to repair |
| IEEE | Institute of Electrical and Electronics Engineers | N | normal |
| IIPP | Injury and Illness Prevention Plan | NEC | National Electrical Code |
| IML | Interface Management Language | NEMA | National Electrical Manufacturers Association |
| JTU | Jackson Turbidity Unit | NEPA | National Environmental Policy Act |
| K | Kilo, a prefix meaning 1,000 | NM | Normal Mode |
| KVA | kilovolt amperes | NOCA | National Organization for Competency Assurance |
| kw | kilowatt | NOD | nitrogenous oxygen demand |
| kwh | kilowatt hour | NPDES | National Pollutant Discharge Elimination System |
| L | liter | NPSH | net positive suction head |
| lb | pound | NTU | nephelometric turbidity unit(s) |
| M | Mega, a metric prefix meaning 1,000,000 | O&M | operation and maintenance |
| m | meter | OCT | Operator Certification Test (State of California) |
| M | mole or molar | OMR | operations, maintenance, and replacement |
| MA | millamps | OOC | Office of Operator Certification (SWRCB) |
| MBAS | methylene blue active substance | OSHA | Occupational Safety and Health Administration/Act |
| MCL | maximum contaminant level | OTE | oxygen transfer efficiency |
| MCLG | maximum contaminant level goal | P | Pico, a metric prefix meaning one millionth of a millionth, or one trillionth (10 ⁻¹²) |
| MCRT | mean cell residence time | PC | personal computer |
| MDL | method detection limit | | |
| MG | million gallons | | |
| mg | milligram | | |
| mg/L | milligrams per liter | | |
| MGD | million gallons per day | | |



Appendix D: Common Acronyms and Abbreviations

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



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 we encourage you to identify and utilize the other resources in preparing for your next test.

Your comments, questions, and suggestions are welcome.



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