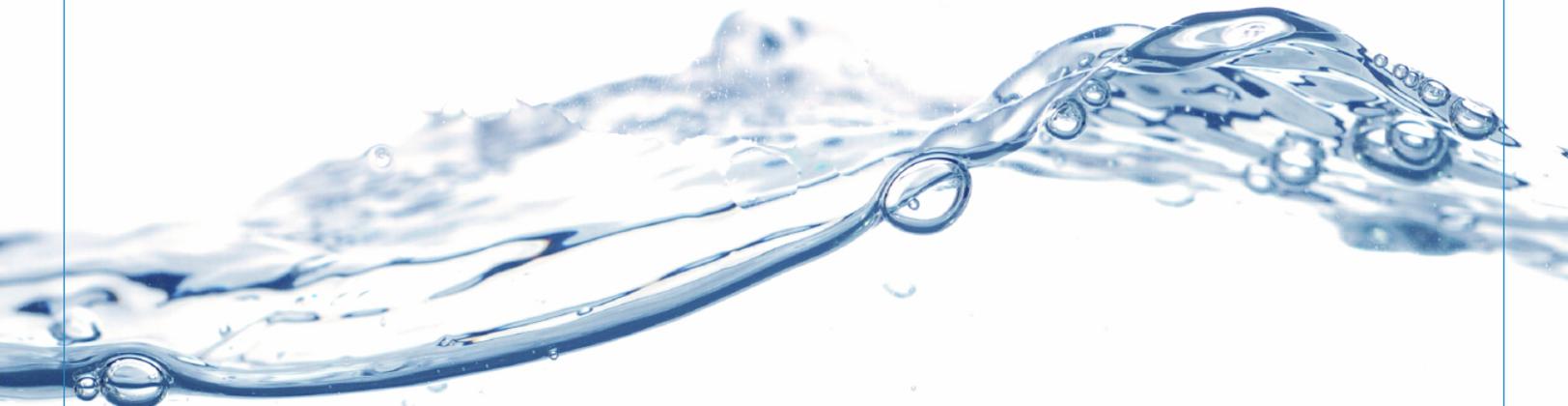




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A dynamic splash of clear water with numerous bubbles, moving from the left towards the right across the upper half of the page.

ABC

Association of Boards of Certification

Water Treatment **Need-to-Know** Criteria

*A Need-to-Know Guide when preparing for the
ABC Water Treatment Certification Examination.*

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Acknowledgement

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- Brian Thorburn, British Columbia (Chair)
- Gary Coleman, New Jersey
- Kim Dyches, Utah
- Ander Houlihan, Nova Scotia
- Bob Hoyt, Massachusetts
- Ken Kerri, California
- Chuck Kingston, Oregon
- Gerald Samuel, Alberta
- Scott Williams, Tennessee

Introduction

As part of the development of its certification exams, the Association of Boards of Certification (ABC) conducted a job analysis of water treatment operators in 2010. As part of this process, ABC conducted a national survey of water treatment operators. This *Need-to-Know Criteria* was developed from the results of ABC's 2010 water treatment operator job analysis.

How the *Need-to-Know Criteria* Was Developed

Review of Task Survey

The results of the 2010 task analysis survey were provided to the ABC Water Treatment V&E Committee. In the task analysis survey, operators rated job tasks and capabilities for frequency of performance and seriousness of inadequate or incorrect performance. These two rating scales were used because they provide useful information (i.e., how critical each task is and how frequently each task is performed) pertaining to certification. Of the 1192 individuals in the water treatment industry who completed the survey, 169 were class I operators, 254 were class II operators, 224 were class III operators, and 349 were class IV operators.

Analysis of Ratings

The composite criticality ratings and percentage of operators reporting that they performed the tasks were presented to the Water Treatment V&E Committee in January 2011 to begin development of the new *Need-to-Know Criteria*. V&E committee members were given the opportunity to retain tasks which did not meet decision criteria (a criticality value of at least 10.5, and a percent performing value of at least 50%) if a significant rationale could be provided for their importance on the examination. The V&E committee members were also given the opportunity to remove any tasks which met criteria on the survey but were deemed untestable or inappropriate for the water treatment certification examination. Final examination blueprint weights were calculated by summing the criticality values of all remaining tasks, and dividing the criticality value of each task by the grand total criticality value. Weights of individual tasks were summed for each core competency area to determine the proportion of the water treatment certification examination devoted to each core competency.

Core Competencies

The essential tasks and capabilities that were identified through this process are called the core competencies. The following pages list the core competencies for water treatment operators. The core competencies are clustered into the following job duties:

- Monitor, Evaluate, and Adjust Treatment Processes
- Laboratory Analyses
- Comply with Drinking Water Regulations
- Operate and Maintain Equipment
- Perform Security, Safety, and Administrative Procedures
- Evaluate Characteristics of Source Water

The level of knowledge (i.e., comprehension, application, analysis) required for each task is also identified in the following pages.

- **Comprehension** is the most basic level of understanding and remembering. Items written at the comprehension level require examinees to recognize, remember, or identify important ideas.
- Items written at the **application** level require examinees to interpret, calculate, predict, use or apply information and solve problems.
- Items written at the **analysis** level require examinees to compare, contrast, diagnose, examine, analyze, and relate important concepts.

The level of knowledge is a hierarchy from basic comprehension to analysis. The level of knowledge tested is cumulative. Therefore, tasks identified as application may include questions written at both the application and comprehension levels. Tasks identified as analysis may include questions written at the comprehension, application, and analysis levels.

About the Association of Boards of Certification

Established in 1972, the Association of Boards of Certification (ABC) is a non-profit member-driven organization dedicated to protecting public health and the environment by advancing the quality and integrity of environmental certification programs. ABC membership includes almost 100 certifying authorities, representing more than 40 states, nine Canadian provinces as well as several international programs. Existing solely for its members, ABC is the voice for the profession and serves as the conduit for information in an ever-changing industry.

Over 70 certification programs currently test approximately 35,000 operators and laboratory analysts annually through ABC's industry-leading Certification & Testing Services. Over 400,000 water and wastewater operators, laboratory analysts, and backflow prevention assembly testers have taken an ABC exam since the testing program began in 1982.

ABC Vision

Promote integrity in environmental certification throughout the world.

ABC Mission

ABC is dedicated to advancing the quality and integrity of environmental certification programs.

ABC Objectives

- Promote certification as a means of protecting public health, the infrastructure, and the environment.
- Promote uniformity of standards and best practices in certification.
- Serve as the technical resource for certification entities.
- Facilitate the transfer of certification between certifying authorities.
- Serve the needs of our members.

ABC Water Treatment Certification Exams

The ABC water treatment certification exams evaluate an operator's knowledge of tasks related to the operation of water treatment systems. The ABC Water Treatment V&E Committee determined the content of each exam based on the results of the national task analysis survey. To successfully take an ABC exam, an operator must demonstrate knowledge of the core competencies in this document.

Four levels of certification exams are offered by ABC, with class I being the lowest level and class IV the highest level. The specifications for the exams are based on a weighting of the job analysis results so that they reflect the criticality of tasks performed on the job. The specifications list the percentage of questions on the exam that fall under each job duty. For example, 27% of the questions on the ABC class I water treatment exam relate to the job duty "Operate and Maintain Equipment." For a list of tasks and capabilities associated with each job duty, please refer to the list of core competencies on the following pages.

ABC Water Treatment Exam Specifications

Blueprint Area	Class I	Class II	Class III	Class IV
Monitor, Evaluate, and Adjust Treatment Processes	30%	28%	31%	31%
Laboratory Analyses	12%	13%	11%	11%
Comply with Drinking Water Regulations	12%	12%	11%	10%
Operate and Maintain Equipment	27%	26%	24%	25%
Perform Security, Safety, and Administrative Procedures	13%	16%	18%	18%
Evaluate Characteristics of Source Water	6%	5%	5%	5%

Monitor, Evaluate, and Adjust Treatment Processes	Class I	Class II	Class III	Class IV
Chemical Addition				
Chemical pretreatment	Comprehension	Comprehension	Application	Analysis
Chlorine dioxide disinfection	Analysis	Analysis	Analysis	Analysis
Chlorine gas disinfection	Analysis	Analysis	Analysis	Analysis
Corrosion control	Comprehension	Comprehension	Application	Analysis
Fluoridation	Comprehension	Analysis	Analysis	Analysis
Ozone disinfection	Comprehension	Comprehension	Application	Application
pH adjustment	Application	Application	Analysis	Analysis
Sodium hypochlorite disinfection	Analysis	Analysis	Analysis	Analysis
Ultraviolet disinfection	Comprehension	Comprehension	Application	Application

Monitor, Evaluate, & Adjust Treatment Processes Continued	Class I	Class II	Class III	Class IV
<i>Coagulation and Flocculation</i>				
Chemical coagulants	Comprehension	Application	Application	Analysis
Flocculation tanks	Comprehension	Application	Application	Analysis
Rapid mix units	Comprehension	Application	Application	Analysis
<i>Clarification and Sedimentation</i>				
Dissolved air flotation	Comprehension	Application	Application	Analysis
Inclined-plate sedimentation	Comprehension	Application	Application	Analysis
Sedimentation basins	Comprehension	Application	Application	Analysis
Tube sedimentation	Comprehension	Application	Application	Analysis
Up-flow solids-contact clarification	Comprehension	Application	Application	Analysis
<i>Filtration</i>				
Cartridge filters	Application	Application	Application	Application
Diatomaceous earth filters	Comprehension	Comprehension	Comprehension	Application
Direct filtration	Comprehension	Application	Application	Analysis
Gravity filtration	Comprehension	Application	Application	Analysis
Membranes (ultrafiltration, nanofiltration, reverse osmosis)	Application	Application	Application	Application
Microscreens	Comprehension	Comprehension	Application	Analysis
Pressure or greensand filtration	Application	Application	Application	Application
Slow sand filters	Comprehension	Application	Application	Analysis
<i>Residuals Disposal</i>				
Discharge to lagoons	N/A	N/A	Comprehension	Comprehension
Discharge to lagoons and then raw water source	N/A	N/A	Comprehension	Comprehension
Discharge to raw water	N/A	N/A	Application	Analysis
Disposal to sanitary sewer	N/A	N/A	Comprehension	Comprehension
Land application	N/A	N/A	Comprehension	Comprehension
Mechanical dewatering	N/A	N/A	Application	Analysis
On-site disposal	N/A	N/A	Comprehension	Comprehension

Monitor, Evaluate, & Adjust Treatment Processes Continued	Class I	Class II	Class III	Class IV
Residuals Disposal Continued				
Solids composting	N/A	N/A	Comprehension	Comprehension
Additional Treatment Tasks				
Aeration	Comprehension	Application	Application	Analysis
Backwash aids	Comprehension	Application	Application	Analysis
Coagulation aids	Comprehension	Application	Application	Analysis
Copper sulfate treatment	Application	Application	Application	Application
Electrodialysis	Comprehension	Comprehension	Comprehension	Application
Filter aids	Comprehension	Application	Application	Analysis
Ion-exchange/softening	Application	Application	Application	Application
Iron manganese/softening	Application	Application	Application	Application
Lime-soda ash softening	Comprehension	Comprehension	Application	Analysis
Packed tower aeration	Comprehension	Comprehension	Comprehension	Comprehension
Powdered activated carbon	Application	Application	Application	Application

Required Capabilities

Knowledge of:

- Analysis and interpretation
- Basic chemistry
- Chemical properties
- Drinking water treatment concepts
- General electrical principles
- Monitoring requirements
- Normal chemical range
- Physical science
- Principles of measurement
- Proper application of chemicals
- Proper chemical handling and storage

Ability to:

- Adjust chemical feed rates
- Adjust flow patterns
- Adjust process units
- Calculate dosage rates
- Confirm chemical strength
- Diagnose/trouble shoot
- Discriminate between normal and abnormal conditions
- Evaluate facility performance
- Evaluate process units
- Interpret data
- Maintain processes in normal operating condition
- Measure chemical weight/volume
- Perform basic math
- Perform physical measurements
- Perform process control calculations
- Prepare chemicals
- Recognize abnormal analytical results

Laboratory Analysis	Class I	Class II	Class III	Class IV
Algae identification	Comprehension	Comprehension	Application	Application
Asbestos	Comprehension	Comprehension	Application	Application
Biological	Application	Application	Application	Application
Chemical	Comprehension	Application	Application	Application
Chlorine	Analysis	Analysis	Analysis	Analysis
Coliform bacteria	Application	Application	Application	Analysis
Complete chain-of-custody	Comprehension	Application	Application	Analysis
Corrosivity	Comprehension	Comprehension	Comprehension	Comprehension
Disinfectant by-products (THM/HAA)	Comprehension	Comprehension	Application	Analysis
Dissolved oxygen	Comprehension	Comprehension	Comprehension	Comprehension
Hexavalent chromium	Comprehension	Comprehension	Comprehension	Comprehension
Inorganic minerals	Comprehension	Comprehension	Comprehension	Comprehension
Jar test	Comprehension	Comprehension	Application	Analysis
Langelier Index	Comprehension	Analysis	Analysis	Analysis
Metals	Application	Application	Application	Application
Organics	Comprehension	Comprehension	Analysis	Analysis
pH	Application	Application	Analysis	Analysis
Physical parameters	Analysis	Analysis	Analysis	Analysis
Radiological parameters	Analysis	Analysis	Analysis	Analysis
Saturation Index	Comprehension	Comprehension	Comprehension	Comprehension
Solids	Comprehension	Comprehension	Comprehension	Comprehension
Streaming current analysis	Comprehension	Comprehension	Comprehension	Comprehension

Required Capabilities

Knowledge of:

- Basic chemistry
- Basic laboratory techniques
- Biological science
- Chemical properties
- Data collection
- Laboratory equipment
- Material Safety Data Sheet
- Monitoring requirements
- Normal characteristics of water
- Normal chemical range
- Personal protective equipment
- Pesticides

Ability to:

- Accurately transcribe data
- Communicate in writing
- Communicate verbally
- Determine what information needs to be recorded
- Follow written procedures
- Interpret data
- Measure chemical weight/volume
- Perform basic math
- Perform laboratory calculations
- Perform physical measurements
- Prepare chemicals

Required Capabilities Continued

Knowledge of:

- Physical science
- Principles of measurement
- Proper sampling procedures
- Quality control/quality assurance practices
- Safety procedures
- Standard methods

Ability to:

- Recognize abnormal analytical results
- Record information

Comply with Drinking Water Regulations	Class I	Class II	Class III	Class IV
40 CFR 141 Subpart A: General (definitions, coverage, variances and exemptions, siting requirements, and effective dates)	Comprehension	Comprehension	Application	Application
40 CFR 141 Subpart B: Maximum Contaminant Levels (arsenic, nitrate, turbidity)	Comprehension	Comprehension	Application	Application
40 CFR 141 Subpart C: Monitoring and Analytical Requirements (turbidity, coliforms, organic contaminants, organic contaminants)	Comprehension	Comprehension	Application	Application
40 CFR 141 Subpart D: Reporting and Recordkeeping Requirements	Comprehension	Comprehension	Application	Application
40 CFR 141 Subpart E: Special Regulations, Including Monitoring Regulations and Prohibition on Lead Use	Comprehension	Comprehension	Application	Application
40 CFR 141 Subpart F: Maximum Contaminant Level Goals and Maximum Residual Disinfectant Level Goals	Comprehension	Comprehension	Application	Application
40 CFR 141 Subpart G: National Primary Drinking Water Regulations: Maximum Contaminant Levels and Maximum Residual Disinfectant Levels	Comprehension	Comprehension	Application	Application
40 CFR 141 Subpart H: Filtration and Disinfection	Comprehension	Comprehension	Application	Application
40 CFR 141 Subpart I: Control of Lead and Copper	Comprehension	Comprehension	Application	Application

Comply with Drinking Water Regulations Continued	Class I	Class II	Class III	Class IV
40 CFR 141 Subpart K: Treatment Techniques	Comprehension	Comprehension	Application	Application
40 CFR 141 Subpart L: Disinfectant Residuals, Disinfection Byproducts, and Disinfection Byproduct Precursors	Comprehension	Comprehension	Application	Application
40 CFR 141 Subpart P: Enhanced Filtration and Disinfection Systems Serving 10,000 or More People	Comprehension	Comprehension	Application	Application
40 CFR 141 Subpart Q: Public Notification of Drinking Water Violations	Comprehension	Comprehension	Application	Application
40 CFR 141 Subpart S: Ground Water Rule	Comprehension	Comprehension	Application	Application
40 CFR 141 Subpart T: Enhanced Filtration and Disinfection Systems Serving Fewer Than 10,000 People	Comprehension	Comprehension	Application	Application
40 CFR 141 Subpart U: Initial Distribution System Evaluations	Comprehension	Comprehension	Application	Application
40 CFR 141 Subpart V: Stage 2 Disinfection Byproducts Requirements	Comprehension	Comprehension	Application	Application
40 CFR 141 Subpart W: Enhanced Treatment for Cryptosporidium	Comprehension	Comprehension	Application	Application
40 CFR 143: National Secondary Drinking Water Regulations	Comprehension	Comprehension	Application	Application

Required Capabilities

Knowledge of:

- Code of federal regulation
- Regulations
- Reporting
- Safe Drinking Water Act

Operate and Maintain Equipment	Class I	Class II	Class III	Class IV
<i>Evaluate Operation of Equipment</i>				
Check speed of equipment	Comprehension	Application	Application	Analysis
Inspect equipment for abnormal conditions	Comprehension	Application	Application	Analysis
Measure temperature of equipment	Comprehension	Application	Application	Analysis
Read charts	Application	Application	Application	Analysis
Read meters	Application	Application	Application	Analysis
Read pressure gauges	Application	Application	Application	Analysis
<i>Operate Equipment</i>				
Blowers and compressors	Application	Application	Application	Application
Chemical feeders	Analysis	Analysis	Analysis	Analysis
Computers (SCADA systems, HMI, etc.)	Application	Application	Application	Application
Drives	Application	Application	Application	Application
Electronic testing equipment	Application	Application	Application	Application
Engines	Application	Application	Application	Application
Gates	Application	Application	Application	Application
Generators	Application	Application	Application	Application
Hand tools	Application	Application	Application	Application
Hydrants	Application	Application	Application	Application
Hydraulic equipment	Application	Application	Application	Application
Instrumentation	Application	Application	Application	Application
Motors	Application	Application	Application	Application
Pneumatic equipment	Application	Application	Application	Application
Power tools	Application	Application	Application	Application
Pumps	Application	Application	Application	Application
Valves	Application	Application	Application	Application

Operate and Maintain Equipment Continued	Class I	Class II	Class III	Class IV
Perform Maintenance				
Backflow prevention devices	Application	Application	Application	Analysis
Blowers and compressors	Application	Application	Application	Application
Bulk chemical storage systems	Application	Application	Application	Analysis
Calibration of chemical feeders	Application	Application	Application	Analysis
Chemical feeders	Application	Application	Application	Application
Drives	Comprehension	Application	Application	Application
Electrical grounding	Comprehension	Application	Application	Application
Engines	Comprehension	Application	Application	Application
Gates	N/A	N/A	N/A	Comprehension
Generators	Comprehension	Comprehension	Comprehension	Comprehension
Hydrants	N/A	N/A	N/A	Comprehension
Hydraulic equipment	N/A	N/A	N/A	Comprehension
Instrumentation	Application	Application	Application	Application
Lock-out/tag-out	Application	Application	Application	Application
Motors	Application	Application	Application	Application
Pipes	Comprehension	Comprehension	Comprehension	Comprehension
Pneumatic equipment	Comprehension	Comprehension	Comprehension	Comprehension
Pumps	Application	Application	Application	Application
Treatment units	Comprehension	Application	Application	Application
Valves	Application	Application	Application	Application

Required Capabilities

Knowledge of:

- Facility operation and maintenance
- Function of tools
- General electrical principles
- HVAC equipment
- Hydraulic principles
- Internal combustion engines
- Lubricant and fluid characteristics
- Mechanical equipment
- Mechanical principles
- Operation and maintenance practices
- Personal protective equipment
- Pneumatics

Ability to:

- Adjust equipment
- Assign work to proper trade
- Calibrate equipment
- Communicate in writing
- Communicate verbally
- Diagnose/troubleshoot
- Differentiate between preventative and corrective maintenance
- Discriminate between normal and abnormal conditions
- Evaluate operation of equipment
- Monitor equipment

Required Capabilities Continued

Knowledge of:

- Process control instrumentation
- Proper lifting procedures
- Start up and shut down procedures
- Storage

Ability to:

- Operate safety equipment
- Order spare parts
- Organize information
- Perform general maintenance
- Perform general repairs
- Perform physical measurements
- Recognize unsafe work conditions
- Record information
- Report findings
- Translate technical language into common terminology
- Use hand tools

Perform Security, Safety, and Administrative Procedures	Class I	Class II	Class III	Class IV
Write/complete reports (state/provincial)	Comprehension	Application	Application	Analysis
Manage Facility				
Administer safety program	Comprehension	Comprehension	Comprehension	Comprehension
Develop budget	N/A	N/A	Comprehension	Comprehension
Respond to complaints	Analysis	Analysis	Analysis	Analysis
Respond to Emergencies				
Facility upset	Application	Application	Application	Application
Major spill response	Application	Application	Application	Application
Natural disasters	Comprehension	Application	Application	Analysis
System contamination	Analysis	Analysis	Analysis	Analysis
Safety Procedures				
Calibration of atmospheric testing devices	Application	Application	Application	Application
Chemical hazards and chemical spill response	Application	Application	Application	Application
Confined space entry	Analysis	Analysis	Analysis	Analysis

Perform Security, Safety, and Administrative Procedures Continued	Class I	Class II	Class III	Class IV
Safety Procedures Continued				
General safety and health	Analysis	Analysis	Analysis	Analysis
Pathogens	Application	Application	Application	Application
Personal protective equipment	Analysis	Analysis	Analysis	Analysis
Record Information				
Compliance	Application	Application	Analysis	Analysis
Corrective actions	Application	Application	Analysis	Analysis
Customer complaints	Application	Application	Application	Application
Facility operation	Application	Application	Application	Application
Laboratory	Comprehension	Application	Application	Analysis
Maintenance	Application	Application	Application	Analysis

Required Capabilities

Knowledge of:

- Arbitration procedures
- Building codes
- Disciplinary procedures
- Emergency plans
- Legislative process
- Local codes and ordinances
- Material Safety Data Sheet
- Personal protective equipment
- Potential causes of disasters in facility
- Potential impact of disasters on facility
- Principles of finance
- Principles of management
- Principles of public relations
- Principles of supervision
- Proper chemical handling and storage
- Proper lifting procedures
- Public administration procedures
- Recordkeeping policies
- Regulations
- Reporting requirements
- Retrieval
- Risk management
- Safety procedures
- Safety regulations

Ability to:

- Assess likelihood of disaster occurring
- Communicate in writing
- Communicate verbally
- Conduct meetings
- Conduct training programs
- Coordinate emergency response with other organizations
- Demonstrate safe work habits
- Determine what information needs to be recorded
- Develop a budget
- Develop a public relations campaign
- Develop a staffing plan
- Develop a work unit
- Evaluate employee performance
- Evaluate promotional materials
- Evaluate proposals
- Generate capital plans
- Generate long and short term plans
- Generate written safety procedures
- Identify potential safety hazards
- Negotiate contracts
- Operate safety equipment
- Perform impact assessments
- Prepare proposals
- Recognize unsafe work conditions
- Report findings
- Select safety equipment

Evaluate Characteristics of Source Water	Class I	Class II	Class III	Class IV
Algae control	Comprehension	Comprehension	Comprehension	Application
Bacteriological	Application	Analysis	Analysis	Analysis
Biological	Comprehension	Comprehension	Application	Application
Chemical	Comprehension	Comprehension	Application	Application
Chemical treatment (copper sulfate)	Application	Application	Application	Analysis
Identify and evaluate potential sources of source water contamination	Comprehension	Application	Analysis	Analysis
Monitor, evaluate, and adjust source water	Comprehension	Application	Analysis	Analysis
Physical	Comprehension	Comprehension	Application	Application
Stratification control	Comprehension	Comprehension	Application	Analysis

Required Capabilities

Knowledge of:

- Contaminants
- Hydrology
- Normal characteristics of water
- Watershed protection

Ability to:

- Communicate in writing
- Communicate verbally
- Discriminate between normal and abnormal conditions

References

The following are approved as reference sources for the ABC water treatment examinations. Operators should use the latest edition of these reference sources to prepare for the exam.

American Water Works Association (AWWA)

- Principles and Practices of Water Supply Operations Series:
 - *Water Sources*
 - *Water Treatment*
 - *Water Transmission and Distribution*
 - *Water Quality*
 - *Basic Science Concepts and Applications*

- Other AWWA References:
 - *Water Quality and Treatment*
 - *Water System Security, A Field Guide*

To order, contact:

American Water Works Association
6666 W Quincy Ave
Denver CO 80235
Web site: www.awwa.org
Phone: (800) 926-7337
Fax: (303) 347-0804
E-mail: custsvc@awwa.org

Association of State Drinking Water Administrators (ASDWA) and National Rural Water Association (NRWA)

- *Security Vulnerability Self Assessment Guide for Small Drinking Water Systems*

To order, contact:

ASDWA
1401 Wilson Blvd Ste 1225
Arlington VA 22209
Web site: www.asdwa.org
(available online in PDF format; select Security," then "Training and Tools")
Phone: (703) 812-9505
Fax: (703) 812-9506
E-mail: info@asdwa.org

California State University, Sacramento (CSUS) Foundation, Office of Water Programs

- *Water Treatment Plant Operation, Volumes I and II*
- *Manage for Success*

To order, contact:

Office of Water Programs
California State University, Sacramento
6000 J St
Sacramento CA 95819-6025
Web site: www.owp.csus.edu
Phone: (916) 278-6142 (916) 278-6142
Fax: (916) 278-5959
E-mail: wateroffice@owp.csus.edu

$$\text{Alkalinity, as mg CaCO}_3/\text{L} = \frac{(\text{Titrant Volume, mL}) (\text{Acid Normality}) (50,000)}{\text{Sample Volume, mL}}$$

$$\text{Amps} = \frac{\text{Volts}}{\text{Ohms}}$$

$$\begin{aligned} * \text{Area of Circle} &= (.785) (\text{Diameter}^2) \\ &= (\pi) (\text{Radius}^2) \end{aligned}$$

$$\text{Area of Cone (lateral area)} = (\pi) (\text{Radius}) \sqrt{\text{Radius}^2 + \text{Height}^2}$$

$$\text{Area of Cone (total surface area)} = (\pi) (\text{Radius}) (\text{Radius} + \sqrt{\text{Radius}^2 + \text{Height}^2})$$

$$\text{Area of Cylinder (total exterior surface area)} = [\text{Surface Area of End \#1}] + [\text{Surface Area of End \#2}] + [(\pi) (\text{Diameter}) (\text{Height or Depth})]$$

$$* \text{Area of Rectangle} = (\text{Length}) (\text{Width})$$

$$* \text{Area of a Right Triangle} = \frac{(\text{Base})(\text{Height})}{2}$$

$$\text{Average (arithmetic mean)} = \frac{\text{Sum of All Terms}}{\text{Number of Terms}}$$

$$\text{Average (geometric mean)} = [(X_1) (X_2) (X_3) (X_4) (X_n)]^{1/n} \quad \text{The } n\text{th root of the product of } n \text{ numbers}$$

$$\text{Chemical Dry Feeder Calibration, lbs/day} = \frac{(\text{Dry Chemical Collected, grams}) (60 \text{ min/hr}) (24 \text{ hr/day})}{(454 \text{ grams/lb}) (\text{Time, min})}$$

$$\text{Chemical Feed Pump Setting, \% Stroke} = \frac{\text{Desired Flow}}{\text{Maximum Flow}} \times 100\%$$

$$\text{Chemical Feed Pump Setting, mL/min} = \frac{(\text{Flow, MGD}) (\text{Dose, mg/L}) (3.785 \text{ L/gal}) (1,000,000 \text{ gal/MG})}{(\text{Liquid, mg/mL}) (24 \text{ hr/day}) (60 \text{ min/hr})}$$

$$\begin{aligned} \text{Circumference of Circle} &= (\pi) (\text{Diameter}) \\ &= 2 (\pi) (\text{Radius}) \end{aligned}$$

$$\text{Composite Sample Single Portion} = \frac{(\text{Instantaneous Flow}) (\text{Total Sample Volume})}{(\text{Number of Portions}) (\text{Average Flow})}$$

$$\text{CT Calculation} = (\text{Disinfectant Residual Concentration, mg/L}) (\text{Time, min})$$

$$\begin{aligned} \text{Degrees Celsius} &= (\text{Degrees Fahrenheit} - 32) (\frac{5}{9}) \\ &= \frac{(\text{°F} - 32)}{1.8} \end{aligned}$$

$$\begin{aligned} \text{Degrees Fahrenheit} &= (\text{Degrees Celsius}) \left(\frac{9}{5}\right) + 32 \\ &= (\text{Degrees Celsius}) (1.8) + 32 \end{aligned}$$

$$\text{Detention Time} = \frac{\text{Volume}}{\text{Flow}} \quad \text{Units must be compatible}$$

$$\text{*Electromotive Force (EMF), volts} = (\text{Current, amps}) (\text{Resistance, ohms}) \quad \text{or} \quad E = IR$$

$$\text{*Feed Rate, lbs/day} = \frac{(\text{Dosage, mg/L})(\text{Capacity, MGD})(8.34 \text{ lbs/gal})}{\text{Purity, \% expressed as a decimal}}$$

$$\text{Feed Rate, gal/min (Fluoride Saturator)} = \frac{(\text{Plant capacity, gpm}) (\text{Dosage, mg/L})}{18,000 \text{ mg/L}}$$

$$\text{Feed Rate, lbs/day (Fluoride)} = \frac{(\text{Dosage, mg/L}) (\text{Capacity, MGD}) (8.34 \text{ lbs/gal})}{(\text{Available Fluoride Ion, \% expressed as a decimal}) (\text{Purity, \% expressed as a decimal})}$$

$$\text{Filter Backwash Rise Rate, in/min} = \frac{(\text{Backwash Rate, gpm/ft}^2) (12 \text{ in/ft})}{7.48 \text{ gal/ft}^3}$$

$$\text{Filter Drop Test Velocity, ft/min} = \frac{\text{Water Drop, ft}}{\text{Time of Drop, min}}$$

$$\text{Filter Flow Rate or Backwash Rate, gpm/ft}^2 = \frac{\text{Flow, gpm}}{\text{Filter Area, ft}^2}$$

$$\text{Filter Yield, lbs/hr/ft}^2 = \frac{(\text{Solids Loading, lbs/day}) (\text{Recovery, \% expressed as a decimal})}{(\text{Filter Operation, hr/day}) (\text{Area, ft}^2)}$$

$$\text{*Flow Rate, cfs} = (\text{Area, ft}^2) (\text{Velocity, ft/sec}) \quad \text{or} \quad Q = AV \quad \text{Units must be compatible}$$

$$\text{*Force, lbs} = (\text{Pressure, psi}) (\text{Area, in}^2)$$

$$\text{Gallons/Capita/Day} = \frac{\text{Volume of Water Produced, gpd}}{\text{Population}}$$

$$\text{Hardness, as mg CaCO}_3\text{/L} = \frac{(\text{Titrant Volume, mL})(1,000)}{\text{Sample Volume, mL}} \quad \text{Only when the titration factor is 1.00 of EDTA}$$

$$\text{Horsepower, Brake (bhp)} = \frac{(\text{Flow, gpm}) (\text{Head, ft})}{(3,960) (\text{Pump Efficiency, \% expressed as a decimal})}$$

$$\text{Horsepower, Motor (mhp)} = \frac{(\text{Flow, gpm}) (\text{Head, ft})}{(3,960) (\text{Pump Efficiency, \% expressed as a decimal}) (\text{Motor Efficiency, \% expressed as a decimal})}$$

$$\text{*Horsepower, Water (whp)} = \frac{(\text{Flow, gpm}) (\text{Head, ft})}{3,960}$$

$$\text{Hydraulic Loading Rate, gpd/ft}^2 = \frac{\text{Total Flow Applied, gpd}}{\text{Area, ft}^2}$$

$$\text{Hypochlorite Strength, \%} = \frac{\text{Chlorine Required, lbs}}{(\text{Hypochlorite Solution Needed, gal}) (8.34 \text{ lbs/gal})} \times 100\%$$

$$\text{Leakage, gpd} = \frac{\text{Volume, gallons}}{\text{Time, days}}$$

$$\text{*Mass, lbs} = (\text{Volume, MG}) (\text{Concentration, mg/L}) (8.34 \text{ lbs/gal})$$

$$\text{*Mass Flux, lbs/day} = (\text{Flow, MGD}) (\text{Concentration, mg/L}) (8.34 \text{ lbs/gal})$$

$$\text{Milliequivalent} = (\text{mL}) (\text{Normality})$$

$$\text{Molarity} = \frac{\text{Moles of Solute}}{\text{Liters of Solution}}$$

$$\text{Normality} = \frac{\text{Number of Equivalent Weights of Solute}}{\text{Liters of Solution}}$$

$$\text{Number of Equivalent Weights} = \frac{\text{Total Weight}}{\text{Equivalent Weight}}$$

$$\text{Number of Moles} = \frac{\text{Total Weight}}{\text{Molecular Weight}}$$

$$\text{Reduction in Flow, \%} = \left(\frac{\text{Original Flow} - \text{Reduced Flow}}{\text{Original Flow}} \right) \times 100\%$$

$$\text{Removal, \%} = \left(\frac{\text{In} - \text{Out}}{\text{In}} \right) \times 100\%$$

$$\text{Slope, \%} = \frac{\text{Drop or Rise}}{\text{Distance}} \times 100\%$$

$$\text{Solids, mg/L} = \frac{(\text{Dry Solids, grams}) (1,000,000)}{\text{Sample Volume, mL}}$$

$$\text{Solids Concentration, mg/L} = \frac{\text{Weight, mg}}{\text{Volume, L}}$$

$$\text{Specific Gravity} = \frac{\text{Specific Weight of Substance, lbs/gal}}{\text{Specific Weight of Water, lbs/gal}}$$

$$\text{Surface Loading Rate or Surface Overflow Rate, gpd/ft}^2 = \frac{\text{Flow, gpd}}{\text{Area, ft}^2}$$

$$\text{Three Normal Equation} = (N_1 \times V_1) + (N_2 \times V_2) = (N_3 \times V_3) \quad \text{Where } V_1 + V_2 = V_3$$

$$\text{Two Normal Equation} = N_1 \times V_1 = N_2 \times V_2 \quad \text{Where } N = \text{normality, } V = \text{volume or flow}$$

$$\text{Velocity, ft/sec} = \frac{\text{Flow Rate, ft}^3 / \text{sec}}{\text{Area, ft}^2}$$

$$= \frac{\text{Distance, ft}}{\text{Time, sec}}$$

$$\begin{aligned} \text{*Volume of Cone} &= (1/3) (.785) (\text{Diameter}^2) (\text{Height}) \\ &= (1/3) [(\pi) (\text{Radius}^2) (\text{Height})] \end{aligned}$$

$$\begin{aligned} \text{*Volume of Cylinder} &= (.785) (\text{Diameter}^2) (\text{Height}) \\ &= (\pi) (\text{Radius}^2) (\text{Height}) \end{aligned}$$

$$\text{*Volume of Rectangular Tank} = (\text{Length}) (\text{Width}) (\text{Height})$$

$$\text{Watts (AC circuit)} = (\text{Volts}) (\text{Amps}) (\text{Power Factor})$$

$$\text{Watts (DC circuit)} = (\text{Volts}) (\text{Amps})$$

$$\text{Weir Overflow Rate, gpd/ft} = \frac{\text{Flow, gpd}}{\text{Weir Length, ft}}$$

$$\text{Wire-to-Water Efficiency, \%} = \frac{\text{Water Horsepower, hp}}{\text{Power Input, hp or Motor hp}} \times 100\%$$

$$\text{Wire-to-Water Efficiency, \%} = \frac{(\text{Flow, gpm}) (\text{Total Dynamic Head, ft}) (0.746 \text{ kW/hp})}{(3,960) (\text{Electrical Demand, kilowatts})} \times 100\%$$

Abbreviations:

cfs	cubic feet per second
DO	dissolved oxygen
ft	feet
g	grams
gpd	gallons per day
gpg	grains per gallon
gpm	gallons per minute
hp	horsepower
hr	hour
in	inches
kW	kilowatt
lbs	pounds
mg/L	milligrams per liter
MGD	million gallons per day
mL	milliliter
min	minute
ppb	parts per billion
ppm	parts per million
psi	pounds per square inch
Q	flow
SS	settleable solids
TTHM	total trihalomethanes
TOC	total organic carbon
TSS	total suspended solids
VS	volatile solids

Conversion Factors:

1 acre	= 43,560 square feet
1 acre foot	= 326,000 gallons
1 cubic foot	= 7.48 gallons
	= 62.4 pounds
1 cubic foot per second	= 0.646 MGD
1 foot	= 0.305 meters
1 foot of water	= 0.433 psi
1 gallon	= 3.79 liters
	= 8.34 pounds
1 grain per gallon	= 17.1 mg/L
1 horsepower	= 0.746 kW
	= 746 watts
	= 33,000 ft lbs/min
1 mile	= 5,280 feet
1 million gallons per day	= 694 gallons per minute
	= 1.55 cubic feet per second (cfs)
1 pound	= 0.454 kilograms
1 pound per square inch	= 2.31 feet of water
1 ton	= 2,000 pounds
1%	= 10,000 mg/L
π or pi	= 3.14159

Alkalinity Relationships:

All Alkalinity expressed as mg/L as CaCO₃

Result of Titration	Hydroxide Alkalinity	Carbonate Alkalinity	Bicarbonate Concentration
P = 0	0	0	T
P < 1/2 T	0	2P	T - 2P
P = 1/2 T	0	2P	0
P > 1/2 T	2P - T	2(T - P)	0
P = T	T	0	0

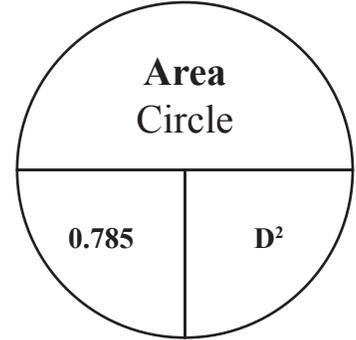
Key: P – phenolphthalein alkalinity T – total alkalinity

***Pie Wheels:**

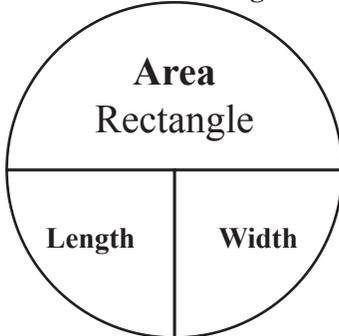
- To find the quantity above the horizontal line: multiply the pie wedges below the line together.
- To solve for one of the pie wedges below the horizontal line: cover that pie wedge, then divide the remaining pie wedge(s) into the quantity above the horizontal line.

Given units must match the units shown in the pie wheel.

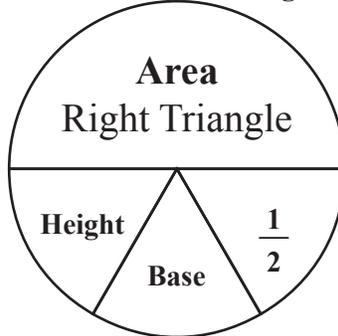
Area of Circle



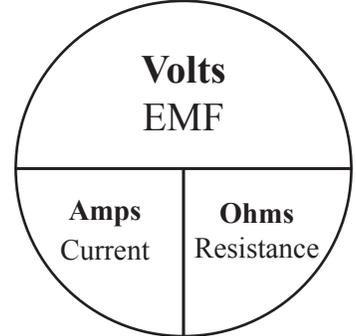
Area of Rectangle



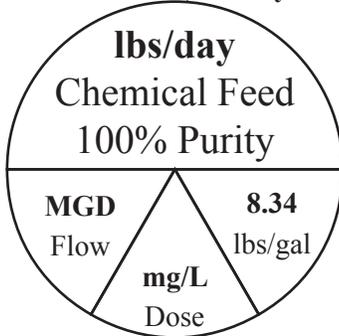
Area of Right Triangle



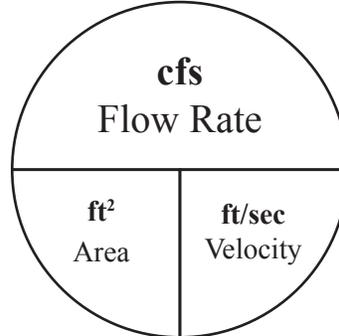
Electromotive Force (EMF), volts



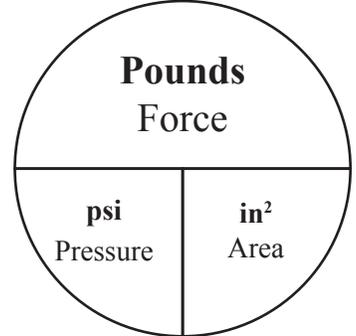
Feed Rate, lbs/day



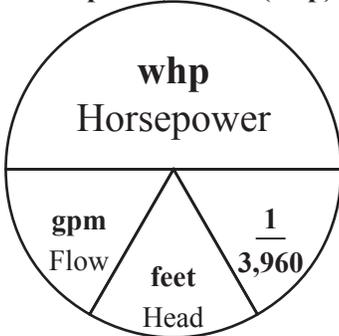
Flow Rate, cfs



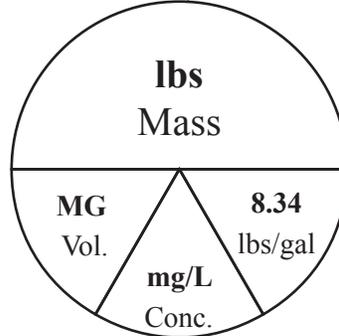
Force, pounds



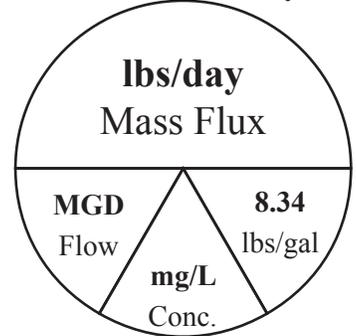
Horsepower, Water (whp)



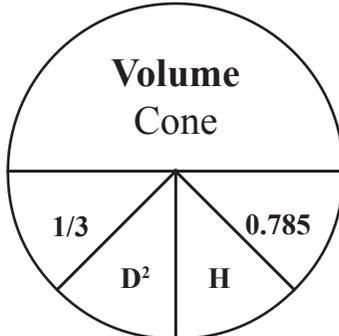
Mass, lbs



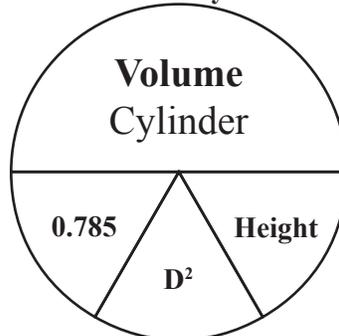
Mass Flux, lbs/day



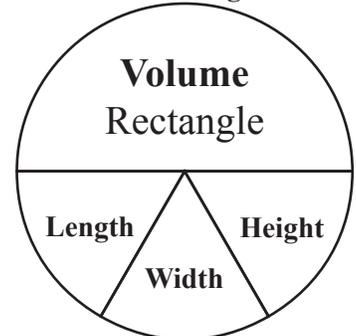
Volume of Cone



Volume of Cylinder



Volume of Rectangular Tank



ARKANSAS WATER TREATMENT LICENSE – MATHEMATICS STUDY GUIDE

The key to studying for the math portion of the license exam begins with the formula sheet. The formula sheet should serve as a guide to the type of questions that will be encountered on the exams. By using the formula sheet and the California text practice questions, a better understanding of the required math should be made more apparent.

The following is a list of math categories that relate to the formula sheet. Examples of some problems have been noted for study. The examples shown **do not** depict the only application that each formula may be used. These examples can be utilized to see how some formulas are executed. All formulas and examples may not be included. You may also find other examples of problems on your own.

In the “EXAMPLE” Column of the table below, “A” denotes sample problems located in the Arithmetic Appendix and “Ch” denotes chapter of the treatment books. The numbers are the chapter and/or section of that part of the treatment books.

FORMULA TOPIC	CSUS BOOK	EXAMPLE
Alkalinity	Treatment II	A.32 example # 14
Area of Circle	Treatment I	A.23 Circle
Area of Cylinder	Treatment I	A.24 Cylinder
Area of Rectangle	Treatment I	A.21 Rectangle
Area of Triangle	Treatment I	A.22 Triangle
Average (arithmetic mean)	Treatment II	A. 36
Average (Quarterly), ug/L	Treatment II	A.53 example # 24
Average (Running Quarterly Annual), ug/L	Treatment II	A.53 example # 25
Chemical Dry Feeder Calibration, lbs/day	Treatment I	A.131 example # 6
Chemical Feed Pump Setting, % Stroke	Treatment I	A.131 example # 5
Chemical Feed Pump Setting, mL/min	Treatment I	A.131 example # 3
Circumference of Circle	Treatment I	A.23 Circle
Degrees Celsius	Treatment I	A.139 example #43
Degrees Fahrenheit	Treatment I	A.139 example #44
Detention Time	Treatment II	A.30 example # 3
Discharge Rate	Treatment I	A.86 example c
Efficiency	Treatment I	A.86
Electromotive Force (E.M.F), volts	Treatment II	Ch 18.114
Feed Rate, (Dosage), lbs	Treatment I	A.131 example # 12
Feed Rate (Dosage), lbs/day	Treatment II	A.131 example # 2
Feed Rate, lbs/day (Fluoride)	Treatment II	Ch 13.12 example # 2
Feed Rate, gal/min (Fluoride Saturator)	Treatment II	Ch 13.12 example # 9
Filter Backwash Rise Rate, in/min	Treatment I	A.135 example #30
Filter Drop Test Velocity, ft/min	Treatment I	A.135 example #23
Filter Flow Rate or Backwash Rate, gpm/sq ft	Treatment I	A.135 example # 27
Flow Rate, cfs	Treatment I	A.71
Force, pounds	Treatment I	A.6
Hardness, as mg CaCO ₃ /L	Treatment I	Ch. 11.5.G
Horsepower, Brake (bhp)	Treatment I	A.83
Horsepower Brake	Treatment I	A.86
Horsepower, Motor (mhp)	Treatment I	A.84
Horsepower, Water (whp)	Treatment I	A.86
Hydraulic Loading Rate	Treatment I	A.134 example #19
Hypochlorite Strength, %	Treatment I	A.136 example #37
Motor Efficiency, %	Treatment I	A.86
Motor Power Input	Treatment I	A.83
Pump Capacity, gpm	Treatment I	A.86.1. Capacity
Pump Efficiency %	Treatment I	A.86.2. Efficiency

ARKANSAS WATER TREATMENT LICENSE – MATHEMATICS STUDY GUIDE

Surface Loading Rate, gpd/sq ft	Treatment I	A.155 example # 27
Velocity, ft/sec	Treatment I	A.135 example # 23
Volume of Cone	Treatment I	A.33 Cone
Volume of Cylinder	Treatment I	A.32 Cylinder
Volume of Rectangular Tank	Treatment I	A.30 Rectangle
Watts (DC circuit)	Treatment II	Ch 18.115
Weir Overflow Rate	Treatment I	A.134 example # 21
Wire to Water Efficiency, %	Treatment I	A.86