YOUR FREE READER'S COMPANION

The Distribution Operator Exam Cram Pack

A companion to The Water Distribution Operator Certification Study Guide · by Dale Rourke

Thanks for picking up the study guide. This companion is the part you carry with you: fold it into your notebook, tape it inside your truck, or read it in the parking lot before you walk in to test. It pulls the formulas, the highest-yield numbers, the main-disinfection tables, ten worked problems, and a fast recall quiz into a few pages you can drill in an afternoon. Every value here matches the book and the ABC and AWWA need-to-know. This is the distribution system, the network out in the ground, so the numbers are pressure and residual and main disinfection, not the treatment plant.

Most people who fail the distribution exam do not fail on theory. They fail on the math and on a handful of limits they never quite memorized. Get the pressure and pounds formulas automatic, know your 20 psi minimum, your 0.2 residual, your main-disinfection doses, and your cross-connection rules cold, and keep your units straight, and you have already answered most of the questions that sink everyone else. Carry this, drill it, and walk in calm. — Dale

Operator Math and Hydraulics Formula Sheet

Every formula you need, in one compact list. Keep your units straight: pressure in psi, head in feet, flow in gpm or MGD as the formula names, pipe diameter in inches for volume, feet for area.

Pressure and head (the distribution workhorse)

- Pressure (psi) = 0.433 x Head (ft)
- Head (ft) = 2.31 x Pressure (psi)
- 1 psi = 2.31 feet of head; 1 foot of head = 0.433 psi
- Elevation makes pressure: every 2.31 feet of elevation difference is 1 psi. A tank sitting higher than a customer delivers that head as pressure.

The pounds formula (chlorine for mains and tanks)

- Pounds per day = Concentration (mg/L) x Flow (MGD) x 8.34
- For a fixed volume (disinfecting a main or a tank): Pounds of chlorine = Dose (mg/L) x Volume (MG) x 8.34
- Less-than-pure product = Pounds of pure chlorine / (available strength as a decimal). For a liquid, gallons = pounds / 8.34.
- 8.34 is pounds per gallon of water, the anchor for every pounds question.

Pipe and tank volume

- Gallons per foot of pipe = 0.0408 x d squared (d in inches). An 8-inch main holds 0.0408 x 64 = 2.61 gallons per foot.
- Pipe volume (gallons) = 0.0408 x d squared (in) x Length (ft)
- Circular area = 0.785 x Diameter squared (ft2); 0.785 is pi divided by 4
- Cylindrical tank volume (gallons) = 0.785 x Diameter squared x Height x 7.48 (diameter and height in ft)
- Rectangular volume (gallons) = Length x Width x Depth (ft) x 7.48

Flow and velocity

- Q = A x V (flow = cross-sectional area x velocity). Area in ft2, velocity in ft/s gives Q in cfs.
- Velocity (ft/s) = Q / A
- Convert cfs to gpm: multiply by 448.8. Convert gpm to cfs: divide by 448.8.

Head loss and friction

- Head loss climbs with more flow and longer pipe, and falls with larger diameter and a higher C factor.
- C factor (Hazen-Williams roughness): new smooth pipe about 130 to 140; it drops as pipe ages, tuberculates, and roughens. A lower C means more friction and lost pressure.

- Total dynamic head (TDH) = elevation lift + friction (head) loss + any pressure head you must deliver.

Storage detention and water age

- Detention time = Volume / Flow. Keep volume and flow in matching units (gallons and gpm give minutes; gallons and gpd give days).

Pump hydraulics

- Water horsepower (WHP) = (Flow gpm x Head ft) / 3,960
- Brake horsepower (BHP) = WHP / Pump efficiency (decimal)
- Motor horsepower = BHP / Motor efficiency (decimal). Wire-to-water efficiency = pump eff. x motor eff.

Fire flow and hydrant test

- Pitot flow (gpm) = 29.8 x c x d squared x square root of P, where d is the outlet diameter in inches, P is the pitot pressure in psi, and c is the discharge coefficient (about 0.9 for a smooth, rounded outlet).
- Hydrant flow test reads three things: static pressure (no flow), residual pressure (while flowing), and pitot pressure at the flowing outlet.

Chlorine dose and demand

- Chlorine dose = Demand + Residual (all mg/L)
- Chlorine demand = Dose - Residual

Key conversion factors

Convert	Equals
1 cubic foot of water	7.48 gallons
1 gallon of water	8.34 pounds
1 cubic foot of water	62.4 pounds
1 psi	2.31 feet of head (1 foot of head = 0.433 psi)
1 foot of pipe, gallons	0.0408 x diameter squared (inches)
1 MGD	694 gpm = 1.55 cfs
1 cfs	448.8 gpm = 0.6463 MGD
1 day	1,440 minutes
1 percent	10,000 mg/L
1 acre-foot	43,560 ft3 = 325,829 gallons

Key Numbers to Memorize

The highest-yield values the exam loves. Learn them cold; they answer direct recall questions and set the sanity check for your math.

Pressure

- Minimum 20 psi at every service connection at all times, including during a fire flow. Below 20 psi the system can draw in contamination.
- Normal working pressure about 35 to 80 psi. Above roughly 80 psi, use a pressure-reducing valve.
- Water tower pressure: every 2.31 feet of tank height above the customer is 1 psi. A water level 115 feet up delivers about 50 psi at the base.

Disinfection residual in the distribution system

- Free chlorine entering distribution must be at least 0.2 mg/L; it cannot be undetectable.
- A detectable residual must be present in at least 95 percent of distribution samples each month.
- Chloramine systems carry a total chlorine residual and must watch for nitrification in warm water and dead ends (rising nitrite and nitrate, falling residual and pH). Booster chlorination at tanks and far ends holds the residual up.

Storage

- Storage serves three needs: equalizing (operational) demand, fire reserve, and emergency reserve.
- Turn tanks over so water does not age. Old water loses residual, forms disinfection byproducts, and can taste and smell bad. Avoid short-circuiting; use inlet and outlet arrangements that mix.
- Disinfect finished-water storage per AWWA C652 before returning it to service.

Cross-connection control and backflow

- Two ways backflow happens: backsiphonage (a vacuum or negative pressure upstream pulls water backward) and backpressure (a downstream source at higher pressure pushes water backward).
- Air gap is the best protection: a physical vertical gap of at least twice the pipe diameter, never less than one inch.
- Reduced-pressure principle assembly (RP or RPZ): high-hazard protection, testable, protects against both backsiphonage and backpressure.
- Double check valve assembly (DCVA): low-hazard, testable.
- Pressure vacuum breaker (PVB): backsiphonage only, common on irrigation.
- Backflow assemblies are tested at installation and at least annually.

Coliform and the Revised Total Coliform Rule (RTCR)

- Total coliform is an indicator and a treatment-technique trigger; E. coli carries the acute MCL.

- A positive sample triggers repeat samples and a Level 1 or Level 2 assessment to find and fix the cause.
- Collect samples at representative points on a written site plan; use dedicated sampling taps, not a hose or a hydrant.

Pipe materials and installation

- Common mains: ductile iron, PVC (AWWA C900), HDPE, and sometimes steel or concrete. Plastic pipe needs tracer wire so it can be located.
- Bury mains below the frost line on proper bedding.
- Restrain thrust at bends, tees, dead ends, reducers, and hydrants with thrust blocks or mechanical restraint. Pressure tries to push joints apart at every change of direction.
- Separation from sewers: at least 10 feet horizontal, and where they cross, 18 inches vertical with the water main on top.

Valves, hydrants, and water hammer

- Exercise valves and hydrants on a schedule so they work when you need them. Know which valves isolate which segment.
- NFPA 291 hydrant colors by available flow: light blue 1,500 gpm or more, green 1,000 to 1,499, orange 500 to 999, red less than 500 gpm.
- Water hammer comes from changing velocity too fast. Open and close valves slowly and start and stop pumps slowly. A dry-barrel hydrant must drain after use so it does not freeze.

Flushing

- Flush to remove sediment and biofilm and to restore residual. Aim for a scouring velocity of about 2.5 to 5 feet per second; unidirectional flushing pushes toward the higher end.
- Neutralize (dechlorinate) heavily chlorinated flush and disinfection water before it reaches a stream or storm drain.

Records and safety

- Keep bacteriological results at least 5 years and chemical results at least 10 years.
- Confined space oxygen must be 19.5 to 23.5 percent; test the air before you enter. Enter a flammable atmosphere only below 10 percent of the LEL.
- Slope, shore, or bench any trench deeper than 5 feet under a competent person; keep the spoil pile back from the edge.
- Chlorine gas is heavier than air and pools low; PEL is a 1 ppm ceiling and IDLH is 10 ppm; wear SCBA at or above the IDLH.

Main and Storage Disinfection Tables (AWWA C651 and C652)

New and repaired mains, and finished-water tanks, must be disinfected, flushed, and cleared by bacteriological sampling before they go into service. These are the methods and doses the exam tests.

New main disinfection methods (AWWA C651)

Method	Chlorine concentration	Contact time	Residual required at the end
Continuous feed	25 mg/L free chlorine	24 hours	at least 10 mg/L
Slug	100 mg/L free chlorine	3 hours (moving slug)	at least 50 mg/L
Tablet (calcium hypochlorite)	about 25 mg/L	24 hours minimum	detectable heavy residual

After the contact period

Step	What you do
Flush	Flush the heavily chlorinated water until the residual matches the rest of the system
Dechlorinate	Neutralize the discharge (sodium bisulfite, sodium sulfite, sodium thiosulfate, or ascorbic acid) before it reaches any waterway
Bacteriological clearance	Collect two consecutive sets of samples at least 24 hours apart; both must be free of total coliform before the main goes into service

Storage tank disinfection methods (AWWA C652)

Method	How it is done
Method 1	Fill the tank and chlorinate the full volume to about 10 mg/L, hold 24 hours
Method 2	Spray or brush all interior surfaces with a strong 200 mg/L chlorine solution, hold 30 minutes
Method 3	Chlorinate about 5 percent of the tank volume to roughly 50 mg/L, hold 6 hours, then fill to the operating level

Follow every tank disinfection with flushing, dechlorination of the discharge, and satisfactory bacteriological samples before returning the tank to service.

Ten Worked Math Problems

Cover the answer, work it on scratch paper, then check your setup against mine. The setup matters more than the arithmetic; if your setup is right, a calculator finishes the job.

1. Convert pressure to head. A gauge on a main reads 65 psi. How many feet of head is that?

Setup: Head = 2.31 x psi = 2.31 x 65 = 150.2 feet of head. (Going back: 150 ft x 0.433 = 64.95 psi.)

2. Pressure from an elevated tank. The water level in a standpipe sits 115 feet above a customer's meter. What static pressure does that deliver, ignoring friction?

Setup: Pressure = 0.433 x head = 0.433 x 115 = 49.8, about 50 psi.

3. Volume of a main in gallons. How much water does 2,000 feet of 8-inch main hold?

Setup: Gallons per foot = 0.0408 x 8 x 8 = 2.61. Volume = 2.61 x 2,000 = 5,222 gallons (about 5,220).

4. Chlorine to disinfect that main (continuous feed). Dose the 5,222-gallon main to 25 mg/L using 65 percent calcium hypochlorite (HTH). How much product?

Setup: Volume in MG = 5,222 / 1,000,000 = 0.005222 MG. Pure chlorine = 25 x 0.005222 x 8.34 = 1.09 lb. Product = 1.09 / 0.65 = 1.68 lb of HTH.

5. Velocity in a main. A 6-inch main carries 400 gpm. What is the velocity?

Setup: Q = 400 / 448.8 = 0.891 cfs. Area = 0.785 x 0.5 x 0.5 = 0.196 ft2. V = Q / A = 0.891 / 0.196 = 4.5 ft/s (a good flushing velocity).

6. Water age in storage. A 500,000-gallon tank passes an average of 150 gpm. What is the detention time?

Setup: Detention = Volume / Flow = 500,000 / 150 = 3,333 minutes = 55.6 hours, about 2.3 days. That is why low-demand tanks need active turnover.

7. Fire flow from a hydrant (pitot). A 2.5-inch smooth outlet (c = 0.9) reads a pitot pressure of 20 psi. What flow is that?

Setup: Q = 29.8 x c x d squared x square root of P = 29.8 x 0.9 x 6.25 x 4.47 = about 750 gpm.

8. Pump horsepower. A booster pump moves 600 gpm against 180 feet of total dynamic head; the pump is 75 percent efficient and the motor 90 percent.

Setup: WHP = (600 x 180) / 3,960 = 27.3 HP. BHP = 27.3 / 0.75 = 36.4 HP. Motor HP = 36.4 / 0.90 = 40.4 HP.

9. Flushing an 8-inch main. What flow gives a 5 ft/s scouring velocity in an 8-inch main, and how many gallons to move three pipe volumes of a 1,500-foot run?

Setup: Q = A x V = 0.785 x 0.667 x 0.667 x 5 = 1.75 cfs = 784 gpm. Pipe volume = 0.0408 x 64 x 1,500 = 3,917 gallons; three volumes = 11,750 gallons; time = 11,750 / 784 = about 15 minutes.

10. Chlorine feed at a booster. A rechlorination station feeds 2.0 MGD. The chlorine demand is 1.2 mg/L and you want a 0.5 mg/L free residual. How many pounds per day?

Setup: Dose = Demand + Residual = 1.2 + 0.5 = 1.7 mg/L. Feed = 1.7 x 2.0 x 8.34 = 28.4 lb/day of chlorine.

Rapid-Fire Recall Quiz

Read the question, say the answer out loud, then uncover it. Do the whole set the night before and again the morning of. If you miss one, flag the chapter and reread that section.

Question	Answer
Feet of head per psi?	2.31
psi per foot of head?	0.433
Pressure equals what times head?	0.433 x head (ft)
Minimum pressure at every service connection?	20 psi at all times
Normal working pressure range?	About 35 to 80 psi
Above what pressure do you add a PRV?	About 80 psi
Pounds per day equals what?	mg/L x MGD x 8.34
What does 8.34 represent?	Pounds in one gallon of water
Gallons per foot of pipe?	0.0408 x diameter squared (inches)
Gallons in one cubic foot?	7.48
Free residual entering distribution?	At least 0.2 mg/L
Detectable residual in what share of samples?	At least 95 percent each month
Chloramine dead-end risk?	Nitrification
Chlorine dose equation?	Demand + Residual
Continuous-feed main dose and time?	25 mg/L for 24 hours
Continuous-feed residual at the end?	At least 10 mg/L
Slug-method dose and time?	100 mg/L for 3 hours
Slug-method residual at the end?	At least 50 mg/L
Bacteriological clearance for a new main?	Two sets, 24 hours apart, no coliform
Neutralize chlorinated flush water with?	Sodium bisulfite, sulfite, or thiosulfate
Two types of backflow?	Backsiphonage and backpressure
Best backflow protection?	Air gap
Air gap size?	Twice the pipe diameter, minimum 1 inch
High-hazard assembly?	Reduced-pressure principle (RP/RPZ)
Low-hazard assembly?	Double check valve (DCVA)
Backsiphonage-only device on irrigation?	Pressure vacuum breaker (PVB)
How often are backflow assemblies tested?	At least annually

Which coliform carries the acute MCL?	E. coli
A coliform positive triggers what?	Repeat samples and an assessment
Water and sewer horizontal separation?	At least 10 feet
Water and sewer crossing, vertical?	18 inches, water on top
Restrain thrust where?	Bends, tees, dead ends, hydrants, reducers
Locate plastic main with?	Tracer wire
Hydrant color for 1,500-plus gpm?	Light blue
Hydrant color for less than 500 gpm?	Red
Cause of water hammer?	Changing velocity too fast
Fix for water hammer?	Open and close valves and pumps slowly
Three purposes of storage?	Equalizing, fire, and emergency
Scouring flush velocity?	About 2.5 to 5 ft/s
Water horsepower equation?	(gpm x head) / 3,960
Total dynamic head is?	Elevation + friction + pressure head
Safe confined-space oxygen range?	19.5 to 23.5 percent
Shore or slope a trench deeper than?	5 feet
Chlorine gas IDLH?	10 ppm
Bacteriological record retention?	At least 5 years

That is the whole pack. Drill the formula sheet until the setups are automatic, memorize the limits, and trust your sanity checks. You have done the work. Walk in and pass. — Dale