

Water Distribution Systems

Distribution Systems

The final link between the water source and the customer/consumer.

3 basic elements:

- 1. Treated water storage - ground, elevated, standpipes, hydropneumatic**
- 2. Pumping facilities**
- 3. Distribution network - piping, valves, hydrants, service connections, meters**

Operational Objectives

- ❖ Determine potential for degradation of water quality in distribution system
 - reliability
 - quality
 - quantity
 - vulnerability of distribution system
- ❖ Ensure sampling/monitoring plans conform with requirements & adequately assess water quality in distribution system

Types of Pipes

- ❖ Cast Iron (CIP) & Ductile Iron Pipe (DIP)
 - strength, load bearing capacity
 - DIP stronger, less rigid than gray CIP
 - ✓ both brittle, inflexible
 - heavy, subject to corrosion
 - flanged joints above-ground, bell/spigot & MJ below-ground
- ❖ Steel
 - lighter, easier to handle, more flexible than IP
 - very susceptible to corrosion
 - lower bearing strength, collapse under vacuum
 - jointing same as IP, threads

Types of Pipes (cont'd)

❖ Asbestos-Cement Pipe (ACP)

- less expensive, lighter, easier to install & tap than IP
- resists corrosion & tuberculation
- joined using sleeved couplings & O-rings
- health hazard (carcinogenic)
- brittle, cracks under trench loads, difficult to repair

❖ Plastic (PVC, HDPE)

- light, easy to install & repair
- unaffected by corrosion
- susceptible to thermal expansion (lengthwise)
- fragile – select backfill material

Backfill

- ❖ Type of material important
 - abrasive, sharp edges
 - sand
 - 1st lift - tamp when pipe half exposed
 - 2nd lift - again when pipe covered by ~6 inches
- ❖ Steel conduit sheath
 - protects pipe (esp. plastic) from vibration & stress loadings (under railroads, highways)
 - ✓ easier to repair, replace
- ❖ Metal tape, 12-ga insulated Cu wire
 - mark plastic line for metal detection
 - install after tamping 2nd lift, before refilling trench

Separation Distances

- ❖ Horizontal
 - 10 ft minimum
- ❖ Vertical – water over wastewater
 - 18 inches minimum
- ❖ Vertical – wastewater over water
 - water-tight casing around wastewater pipe
 - water line required to be at least 10 feet from either end of casing

**NEED TO REFER TO NMED REGULATIONS
AND LOCAL ORDINANCES FOR SPECIFIC
SEPARATION DISTANCES**

Line Cleaning

❖ Routine flushing

- SOP
- valve inspection & exercising
- hydrant inspection & operation
- dead ends

❖ Pipe pig

- bullet-shaped foam swab
- pushed through pipe using water pressure
- special launch sites
- extraction points

Line Repairs

❖ Line breaks

- disruption of service - PR
- water loss = revenue loss
- cross-contamination

❖ Detection

- observation
- report
- comparison between production and billing
- rapid drop in storage

Line Repairs (cont'd)

❖ 3 Steps

- leak location
- repair
- disinfection (repair or new construction)

❖ SOP's

- customer notification
- health & safety
- maintenance activities
- emergency repair call-outs
- recordkeeping

Disinfection of New & Repaired Lines

- ❖ AWWA Standard C-651 or 10-State Stds
- ❖ Flushing
 - minimum velocity – 2.5 fps
 - 2x pipe volume minimum
- ❖ Disinfect with chlorine
 - usually start with 50 mg/L dosage
 - target 5 mg/L residual 24 hours after dosage added
 - can increase dose to achieve residual with shorter contact time (critical line)
- ❖ Flush to remove chlorinated water
- ❖ Collect Bac-T sample(s)
- ❖ Customer meters and service lines

Valves

❖ Uses

- control flow (rate & direction) & pressure
- maintenance (isolation)
- vent

❖ General maintenance

- exercise at least 1x annually
- check for leaks – stem, stuffing box

❖ Maintenance data (GIS)

- map of system showing valve locations
- make, type & size
- operating status & # of turns to open/shut
 - ✓ valve stem indicator fully open ~25% diameter
 - ✓ ie., for 4" valve fully open = 1"
- exercise date(s)
- maintenance date(s)

Types of Valves

❖ Gate

- isolation
- NOT for flow control
- least friction loss when open

❖ Butterfly

- isolation
- easier to open than gates (1/4 turn)
- can be used to control flow

❖ Ball or plug

- similar to butterfly
- 2nd most common valve: corp & curb stops
- usually not used in sizes $>2\frac{1}{2}$ "

Types of Valves (cont'd)

❖ Check

- swing in horizontal; lift in vertical
- discharge side of pumps; foot valves

❖ Air release

- vent

❖ Globe

- stem is perpendicular to seat
- flow control

❖ Diaphragm, or hydraulic control valves

- uses water pressure acting on different surface areas
- springs add additional pressure on diaphragm so it fails in closed position

❖ Altitude

- closes when storage tank full
- req'd for systems that contain several tanks at different elevations

Uses of Valves (cont'd)

❖ Pressure reducing (PRV)

- set points to reduce & maintain steady pressure on downstream side of valve
- sized for min & max flows, or in pairs
- too low flow can cause water hammer

❖ Pressure relief

- provide protection against high pressures that may develop
- used in conjunction with PRV
- acts as by-pass, dump (Xconn potential)

❖ Pressure sustaining

- throttles flow to increase pressure

Hydrants

❖ Fire insurance rates

- 500-600 feet residential spacing
- minimum 6" lines
- dead ends
- operated every 6 months, flow tested annually

❖ Other uses

- flush, vent lines
- pressure & flow testing

❖ Wet barrel

- always pressurized; main valve at top

❖ Dry barrel – used in freezing conditions

- bottom main valve
- drain hole – potential cross-connection

Hydrants

❖ Flow color code ratings

- AA ≥ 1500 gpm – light blue
- A 1000-1499 gpm - green
- B 500-999 gpm - orange
- C < 500 gpm – red

❖ Nozzle coefficients

- A = 0.9-0.97
- B = 0.7
- C = 0.5-0.6

Services

- ❖ Corporation stop
 - “hot” or “wet” tap into pressurized water line
 - direct tap, saddle strapped to line
 - 45° angle from horizontal - protect from backhoe
- ❖ Service line
 - copper, PVC, PE
 - bend to allow flex if pipe settles or shifts
- ❖ Curb stop (copper shut-off valve)
 - located in easement for service isolation
 - meter stop can be used instead of curb stop
- ❖ Meters & service lines must be installed below frost line

Service Meters

- ❖ Meters are the system 'cash register'
- ❖ Can also be used to encourage conservation
- ❖ Residential meters generate most revenue
 - 60% of revenue comes from 20% of meters
 - loss of revenue if not sized, maintained properly
 - under reading – recalibrate, repair, replace
 - over reading – customer leak
- ❖ Test schedule based on AWWA MOP22 meter testing standard:
 - 2" every 4 years; 3" every 3 years; 4" every 2 years
 - $\geq 6"$ annually
- ❖ Accuracy for residential meters is +/- 1.5%
- ❖ Larger meters (>2", commercial, industrial apps) can have accuracies up to +/- 4%

Types of Service Meters

❖ Positive displacement

- most common; applications up to 2"
- fill/empty cycle of calibrated chamber displaces disc (nutating) or oscillating piston
- disc or piston action transferred to head by gears or magnetic drives

❖ Turbine or rotor

- 5/8" and larger, low pressure applications
- dependable with relatively low head loss
- Water velocity proportional to turbine rotation
- turbine shaft connected to meter register
- multi-jet meters for low flow applications

Types of Service Meters (cont'd)

❖ Venturi

- high flow applications
- measures difference in pressure head at throat (conservation of energy, Bernoulli equation)
- low head loss; very dependable (no moving parts)

❖ Compound meter

- two-in-one meters
- displacement meter for low flows
- turbine meter for higher flows

Elimination of Water Loss

❖ Water loss limits

- $\leq 10\%$ acceptable
- 10-15% - some improvement needed
- $> 15\%$ unacceptable, serious problem

❖ Reasons for water loss

- inaccurate or non-working meters
- leaks
- illegal taps
- overflowing tank(s)

❖ Leak detection program

Leak Prevention & Detection

❖ Components

- selection of appropriate types of equipment – pipes, valves, hydrants, meters
- proper installation
- calibration (accuracy)
- maintenance and replacement
- calculation practices

HOW MUCH WATER IS LEAKING?

● SIZE OF HOLE	GALLONS WASTED PER MONTH *
● 1/32"	6,300
● 1/16"	25,000
● 1/8"	100,000
● 3/16"	225,000
● 1/4"	400,000

* @ 60 PSI

● FAUCET LEAKS:

- 60 DROPS PER MINUTE = 192 GALLONS PER MONTH
- 90 = 310 GALLONS PER MONTH
- 120 = 429 GALLONS PER MONTH

System Hydraulics

❖ Friction loss

- loss of energy – Bernoulli equation
- factors
 - ✓ pipe length, diameter
 - ✓ flowrate
 - ✓ “C” factor – coefficient of friction

❖ Water hammer, or pressure surge

- due to quickly stopping pipe flow
- the faster the stop, the bigger the surge
- rupture lines, lift hydrants
- open & close valves slowly (pump control valves)
- use thrust blocks

System Hydraulics (cont'd)

❖ Thrust blocks

- prevent joint leakage
- bends, elbows, tees, dead-ends
- thrust factors, $F = SF \times p \times A \times \sin(0.5 \times \theta)$
 - ✓ bend angle
 - ✓ pipe diameter
 - ✓ internal pressure
 - ✓ use 1.5-2 safety factor multiplier to account for surges
- size of block depends on surrounding soil type
 - ✓ hard clay can support up to 9000 #/ft²
 - ✓ soft clay can support up ~ 1000 #/ft²

Corrosion

- ❖ Attacks metal components of distribution system
 - causes rust, tubercles (knobby protuberances)
 - increases friction loss
 - can cause Pb, Cu problems (brass 7-11% Pb)
 - dissolved CO_2 or DO can cause corrosion
 - pH and alkalinity
- ❖ 2 tests to determine corrosion potential
 - calcium carbonate stability test, or precipitation potential
 - ✓ determines amount of CaCO_3 that will ppt
 - Baylis curve
 - ✓ family of pH/alkalinity curves
 - ✓ zones of no or corrosion potential

Other Types of Corrosion

❖ Galvanic

- 2 dissimilar metals in contact with each
- submerged in water
- generates electric current between metals
- plating leads to metal failure
- meter installations, service connections

❖ Electrolysis

- DC current through metal pipes
- discharges to ground
- metal plates from pipe to ground – failure point

❖ Corrosive (acidic) soil

- external corrosion potential
- need to coat CIP and DIP

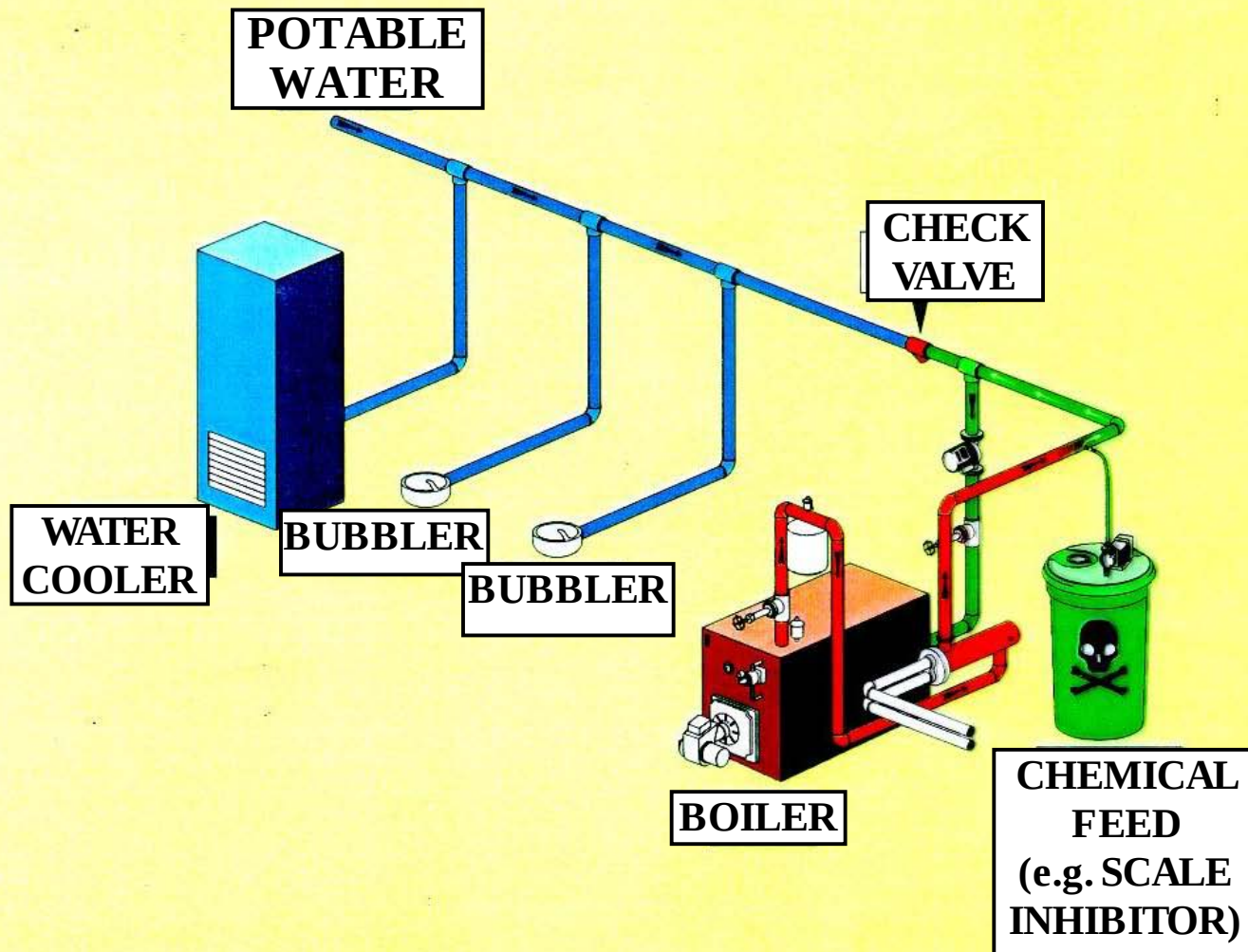
Cross Connections

- ❖ Any link between potable and non-potable water systems that allow contamination to enter the potable system
- ❖ Contaminants can enter the potable supply when the pressure in the non-potable system is greater than the pressure in the potable system
- ❖ This pressure differential causes 2 types of backflow –
 - back pressure backflow or back siphonage backflow
 - back pressure occurs when the non-potable system has a greater pressure than the potable system
 - back siphonage occurs when there is a vacuum in the potable system causing non-potable water to be siphoned into the potable system

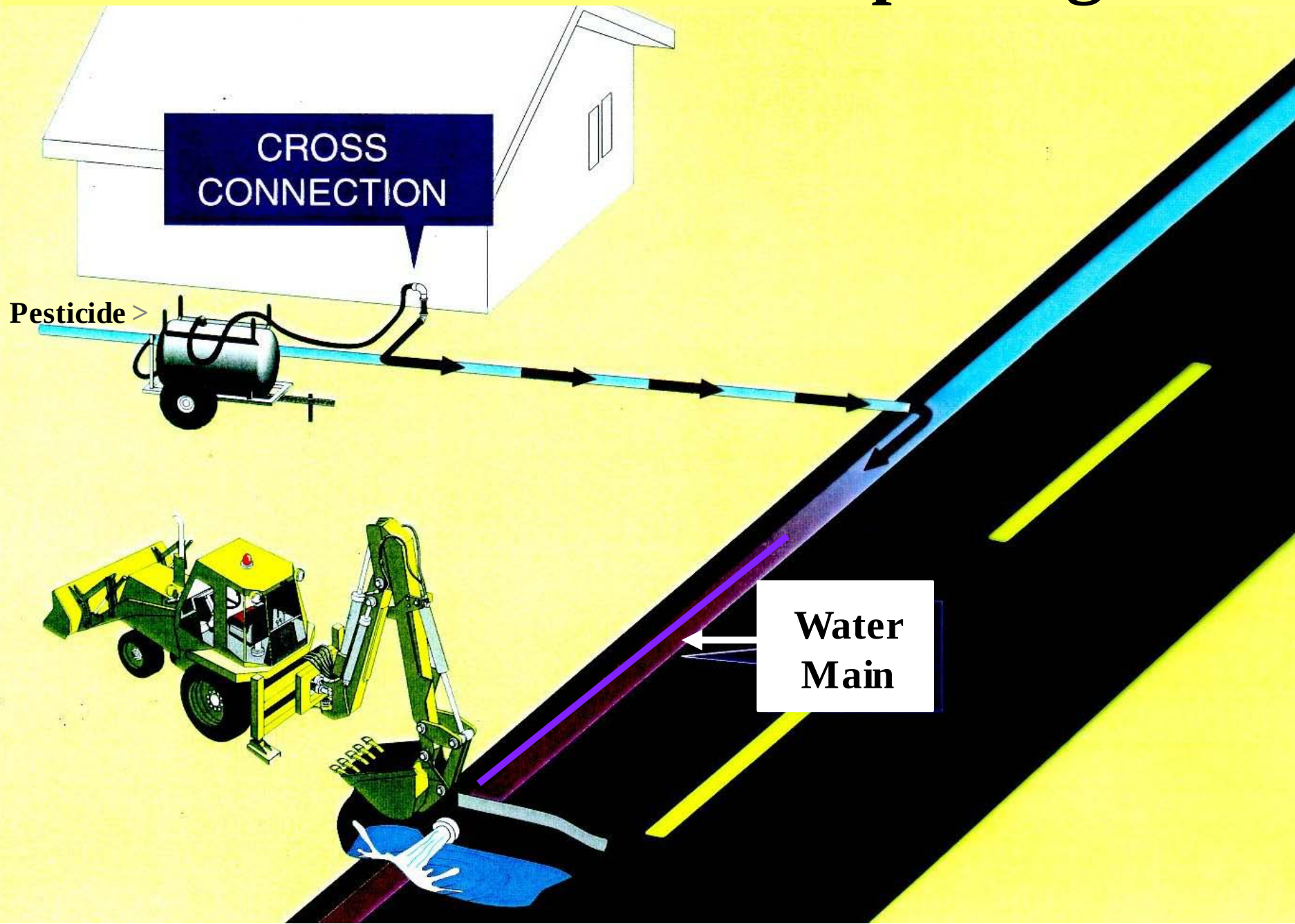
Examples

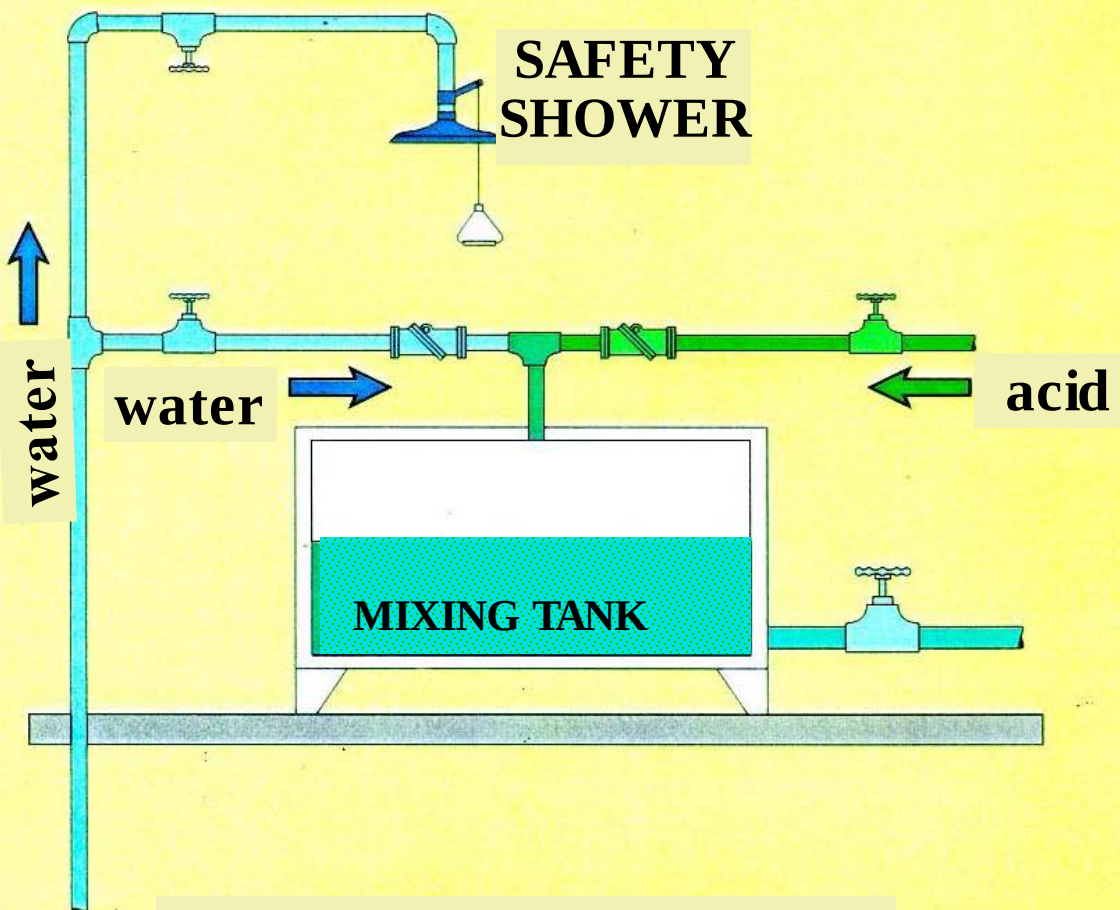
- ❖ Backwash drains – filters, softeners
- ❖ Ice, soft drink machines, HVAC, washing machines
- ❖ Chemical feed make-up & carrier water
- ❖ Split-feed (pre- & post-chlorination) system
- ❖ Water flush for pump bearings
- ❖ Fire hydrant drain lines
- ❖ Old wells
- ❖ Heating systems – make-up water, glycol
- ❖ Hose bibs, sinks
- ❖ Distribution system entry points
- ❖ Household residential boilers – huge danger
 - rarely serviced, poorly controlled

Backflow from Backpressure

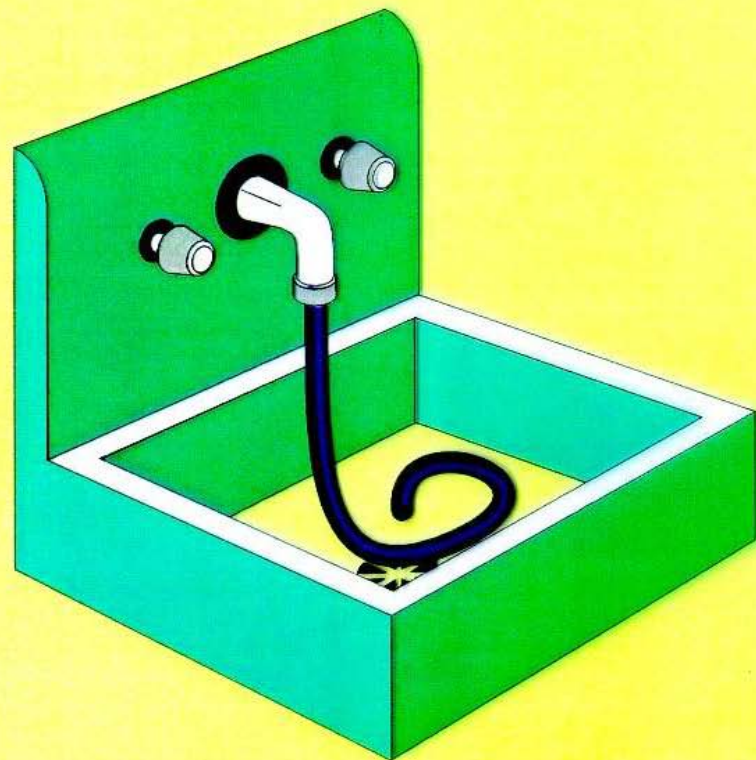


Backflow from Backsiphonage





Direct cross connection



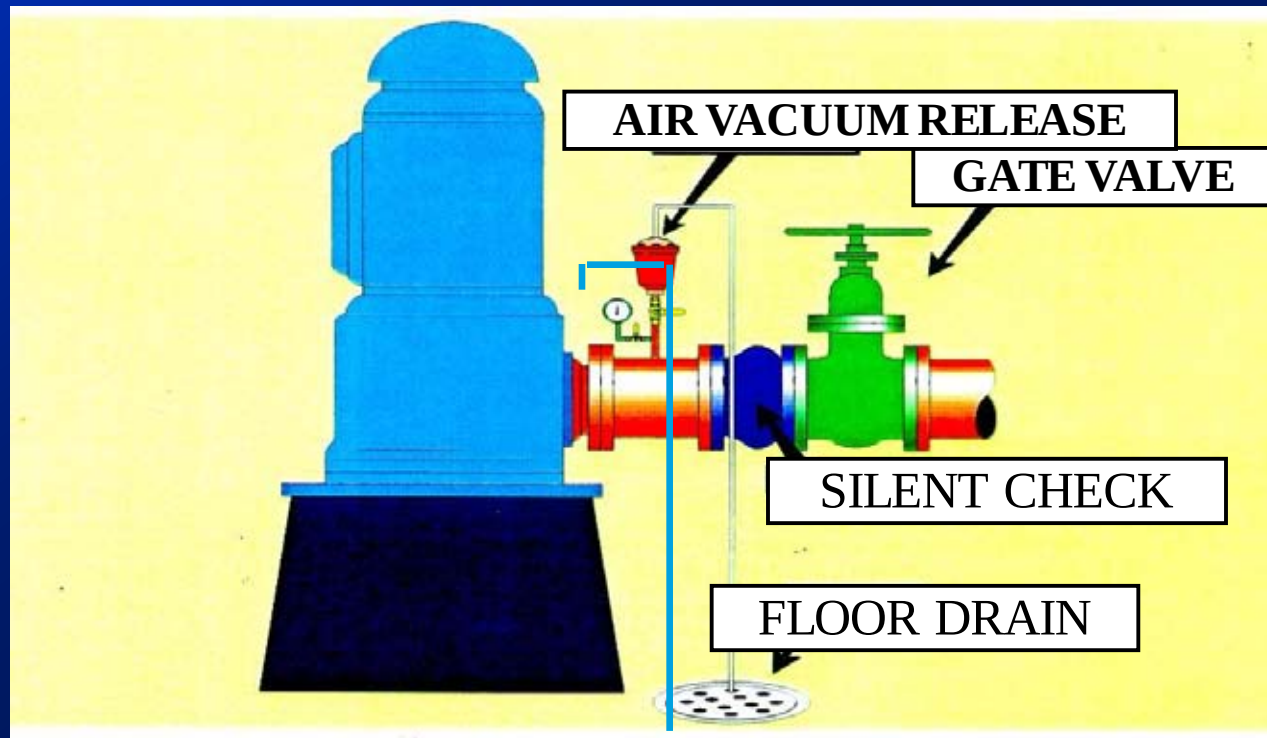
Indirect cross connection





Pumping Station Cross-connections

- ❖ Priming of raw water pumps with finished water
- ❖ Air relief valves piped directly to a drain

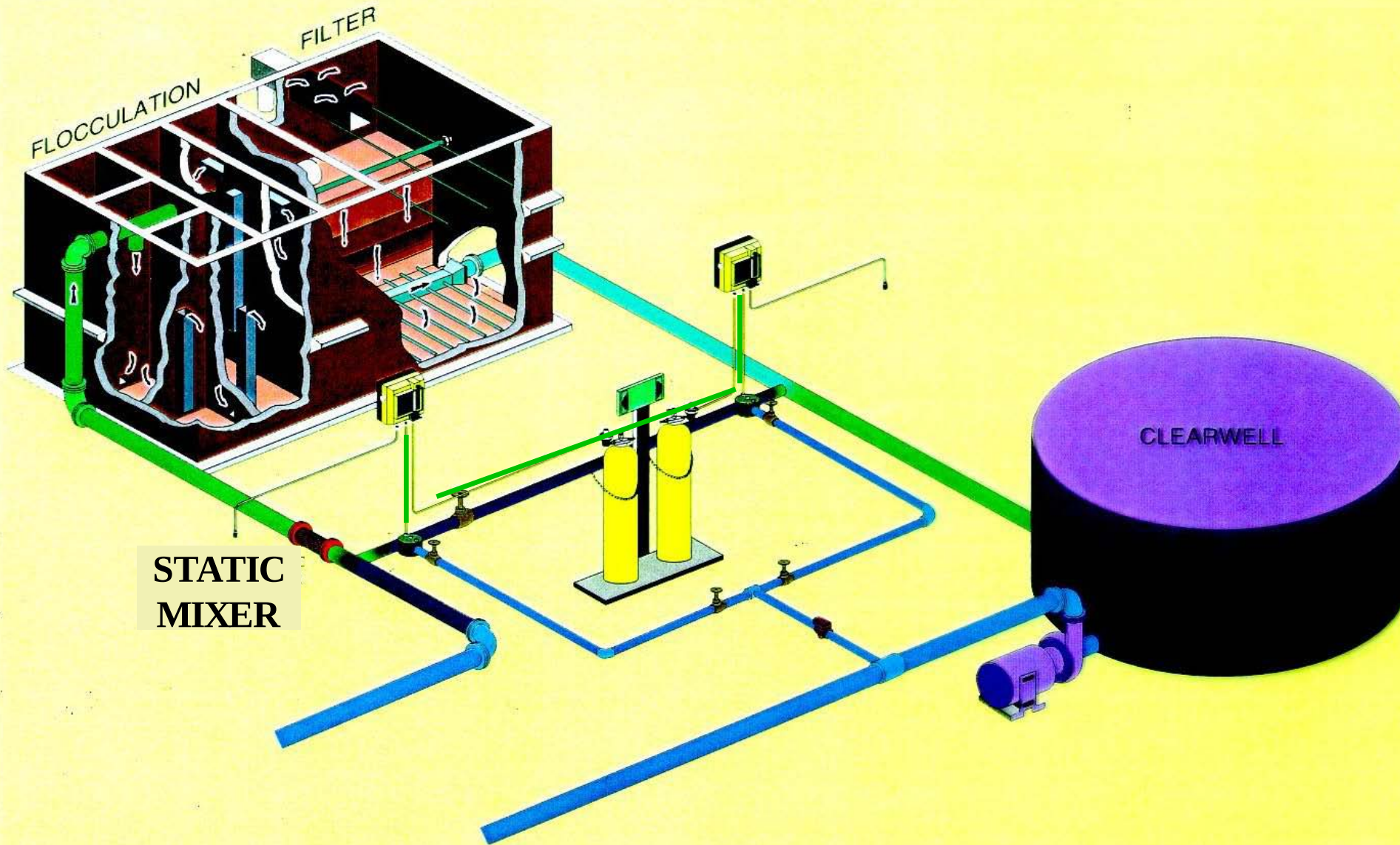


- ❖ Cooling water for an emergency generator submerged in a drain or returned to the potable supply

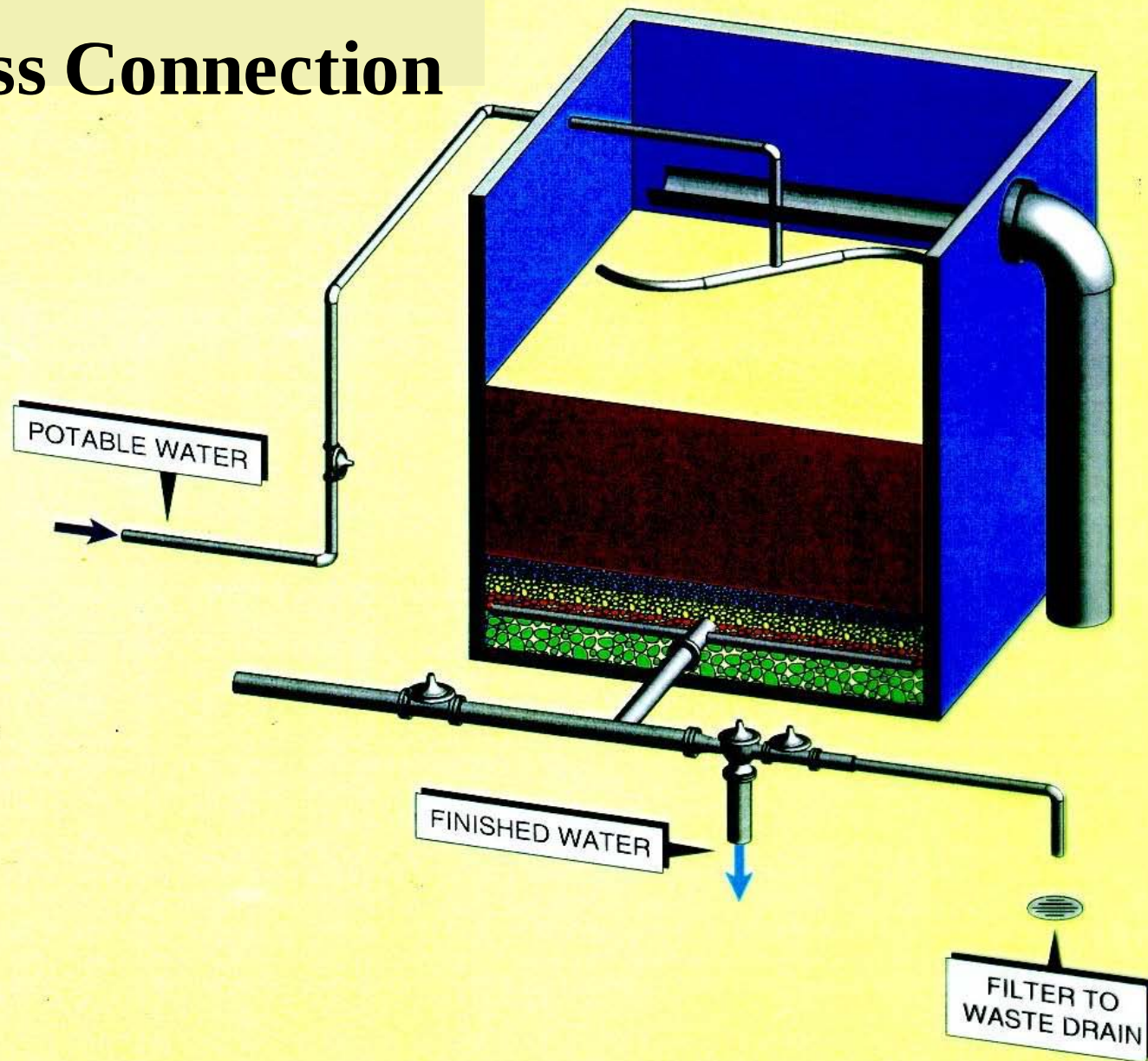
Air Release Valve Plumbed Directly to Drain



Split Feed Cross Connection



Surface Wash Cross Connection









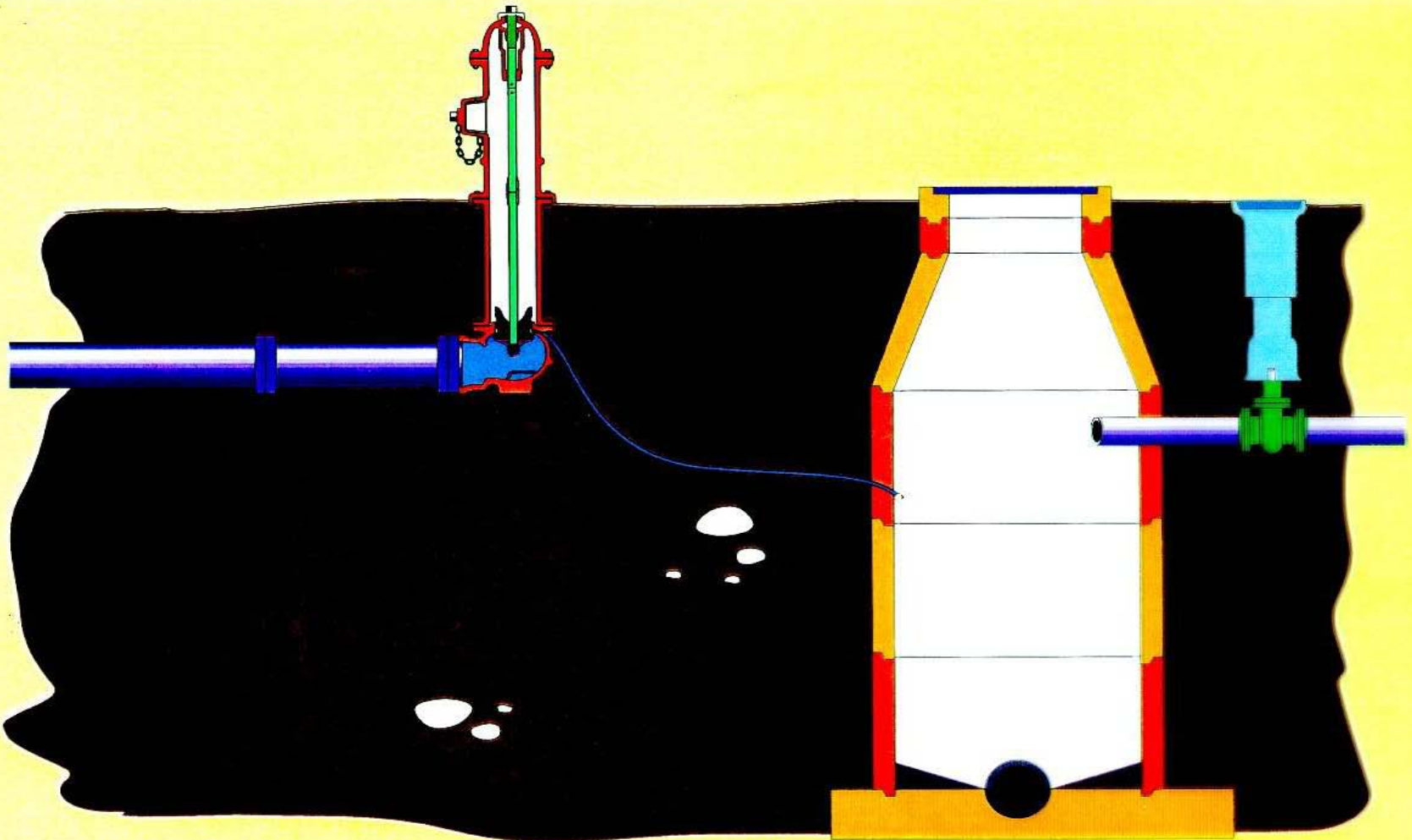


Clear Well or Storage Tank Overflow



Distribution System

Fire hydrant drain to sewer







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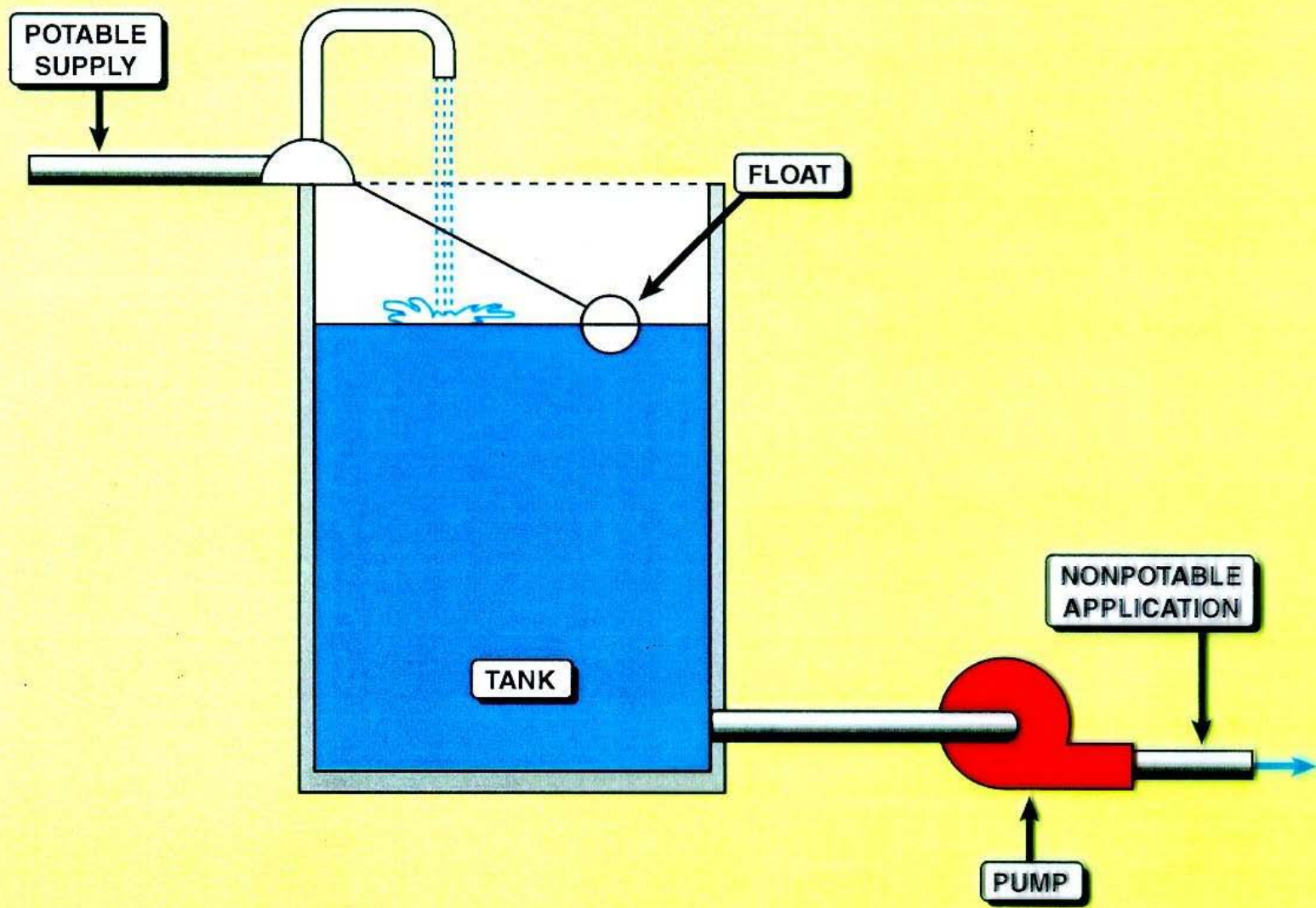


Protection Against Cross Connections

- ❖ Adequate distribution system pressures
- ❖ Air gap
- ❖ Atmospheric vacuum breakers (AVB)
 - includes hose bibb vacuum breakers
- ❖ Pressure vacuum breakers (PVB)
 - includes backflow preventer w/ intermediate atmospheric vent for ½" and ¾" lines
- ❖ Double check valve (DCV) assembly
- ❖ Reduced pressure zone (RPZ) backflow preventer
- ❖ Institutionalized X-conn control program

Air Gap

- ❖ Physical separation of the potable and nonpotable system by an air space
- ❖ Vertical distance between the supply pipe and the flood level rim should be two times the diameter of the supply line, but never less than 1”
- ❖ Used on a direct or inlet connection & for all toxic substances



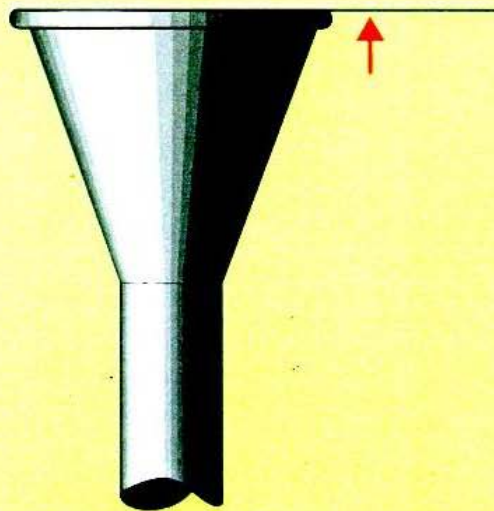
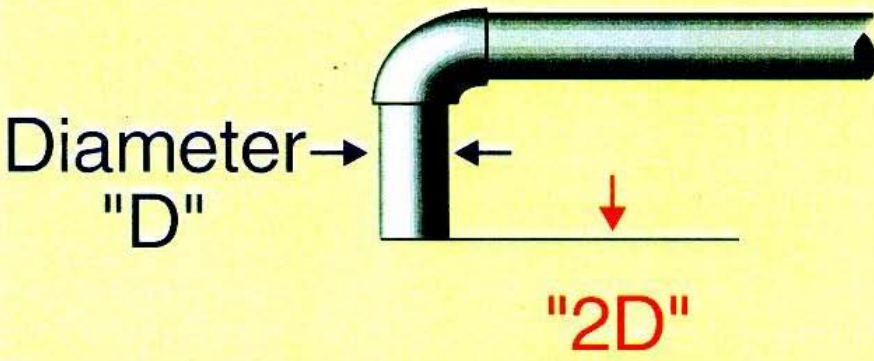
Air Gap



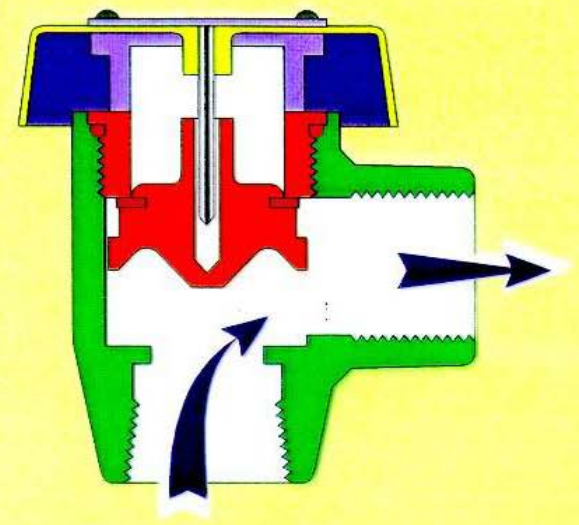
Atmospheric Vacuum Breaker

- ❖ Incorporates atmospheric vent in conjunction with a check valve
- ❖ Supply of potable water seals off vent
- ❖ Negative pressure in supply line permits check valve to seal the orifice
 - at the same time the vent opens allowing air to enter the system to break the vacuum
- ❖ Can be used where the vacuum breaker is never subjected to back pressure & is installed on discharge side of the last control valve above the usage point
- ❖ Can not be used under continuous pressure – check valve tends to ‘modulate’ permitting backflow
- ❖ Low hazardous application only

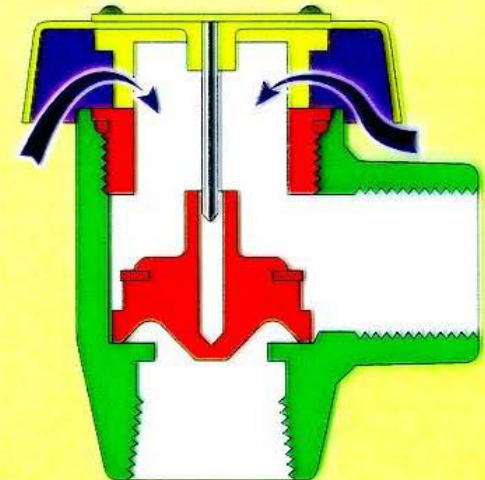
Protection



Air Gap



Flow condition



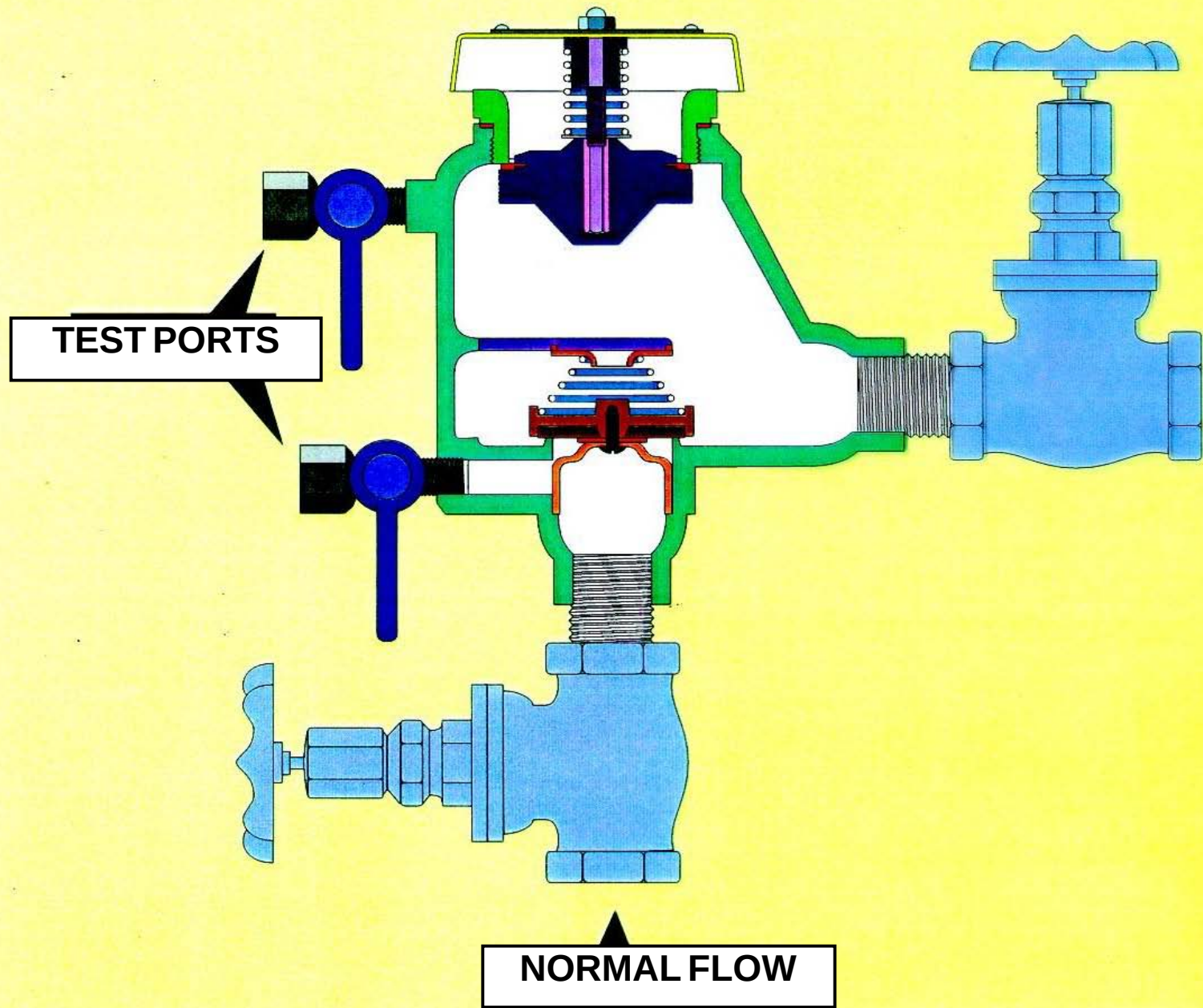
Non flow condntions

Atmospheric Vacuum Breaker

Pressure Vacuum Breaker

- ❖ Assembly consisting of an inlet valve with a spring loaded poppet, a spring loaded check valve, 2 test cocks and 2 shut off valves
- ❖ For use in pressurized systems
- ❖ Operates only when vacuum occurs
- ❖ Designed to operate for extended periods under continuous pressure
- ❖ Should not be subjected to back pressure
- ❖ Must be installed a minimum of 12" above highest outlet
- ❖ Must be tested annually
- ❖ Can be used for intermediate/high hazard applications where air gap not possible

Pressure Vacuum Breaker



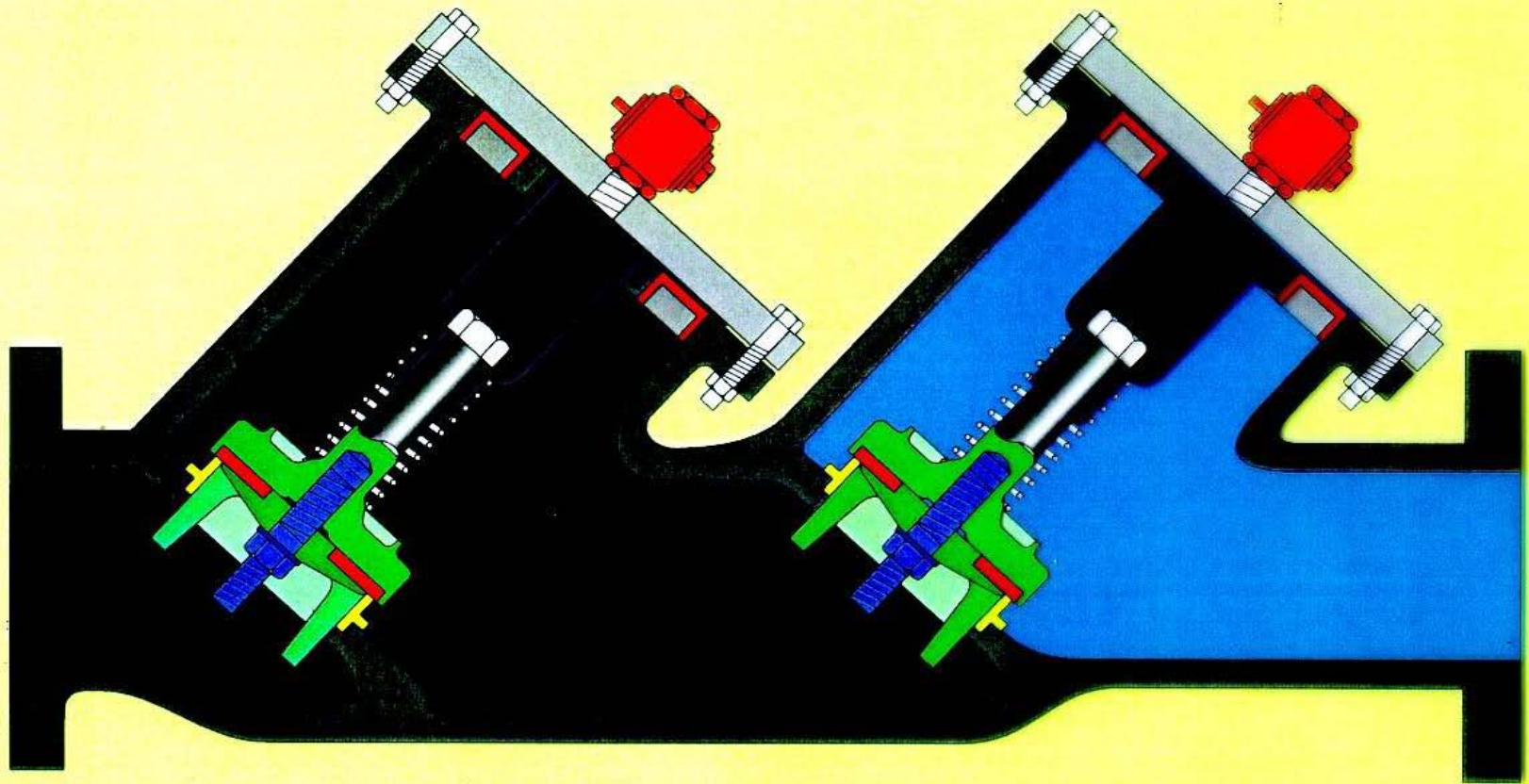
Backflow Preventer with Intermediate Atmospheric Vent

- ❖ Made for ½” and ¾” lines
- ❖ Alternative equal to pressure vacuum breakers in operation
- ❖ Protect against back siphonage and back pressure
- ❖ Can be used under continuous pressure
- ❖ Used on boiler feed water supply lines, cattle drinking fountains, trailer park water supply connections
 - other low flow applications

Double Check Valve Assembly

- ❖ 2 independently operating internally loaded check valves
- ❖ 2 tightly closing shut-off valves
- ❖ 4 appropriately located test cocks
- ❖ Back siphonage and back pressure protection
 - protection for low levels of hazard
 - non-potable source is polluted, not contaminated
- ❖ Operates with low head loss
- ❖ Must be inspected and tested annually

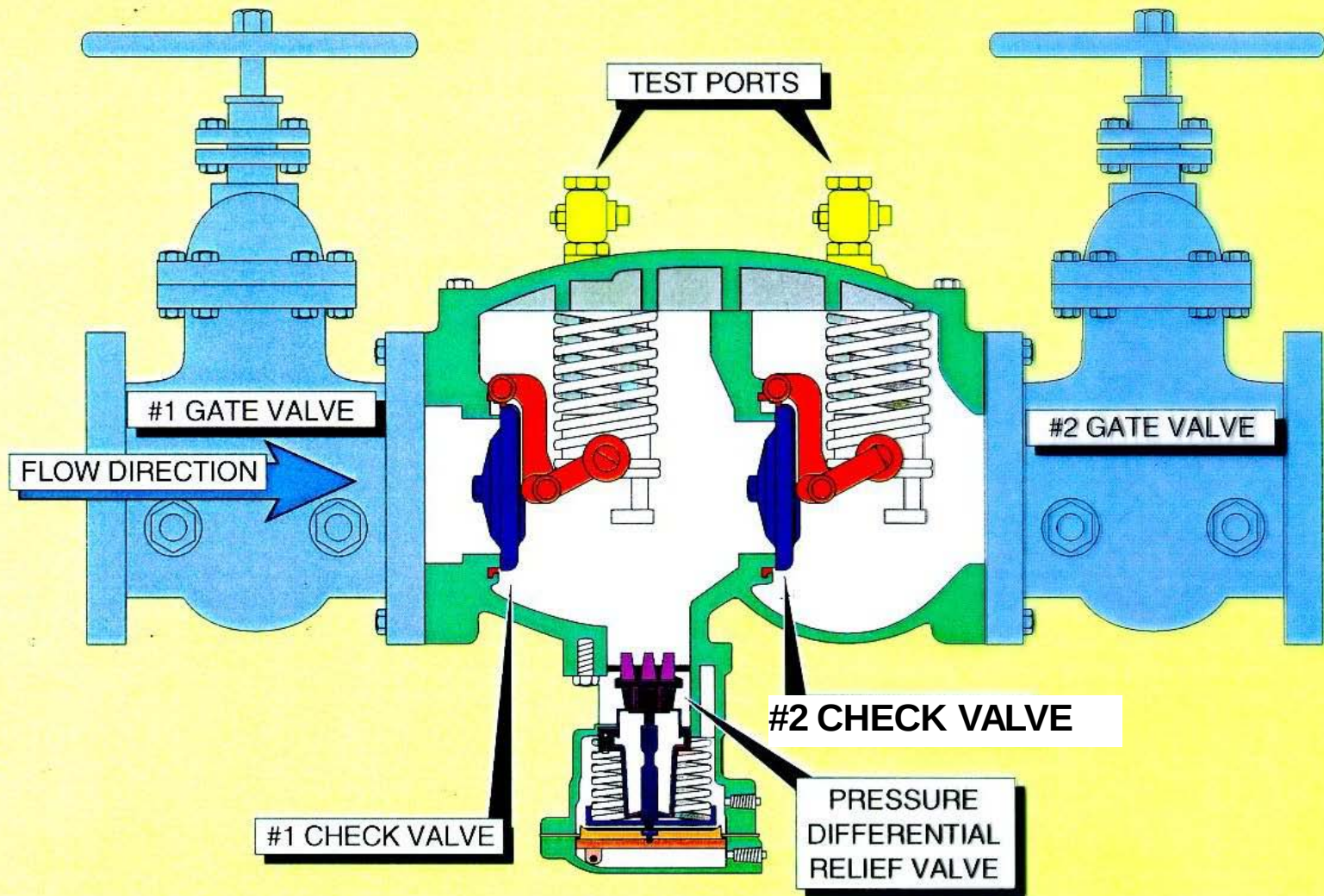
Double Check Valve



Reduced Pressure Zone Backflow Preventer

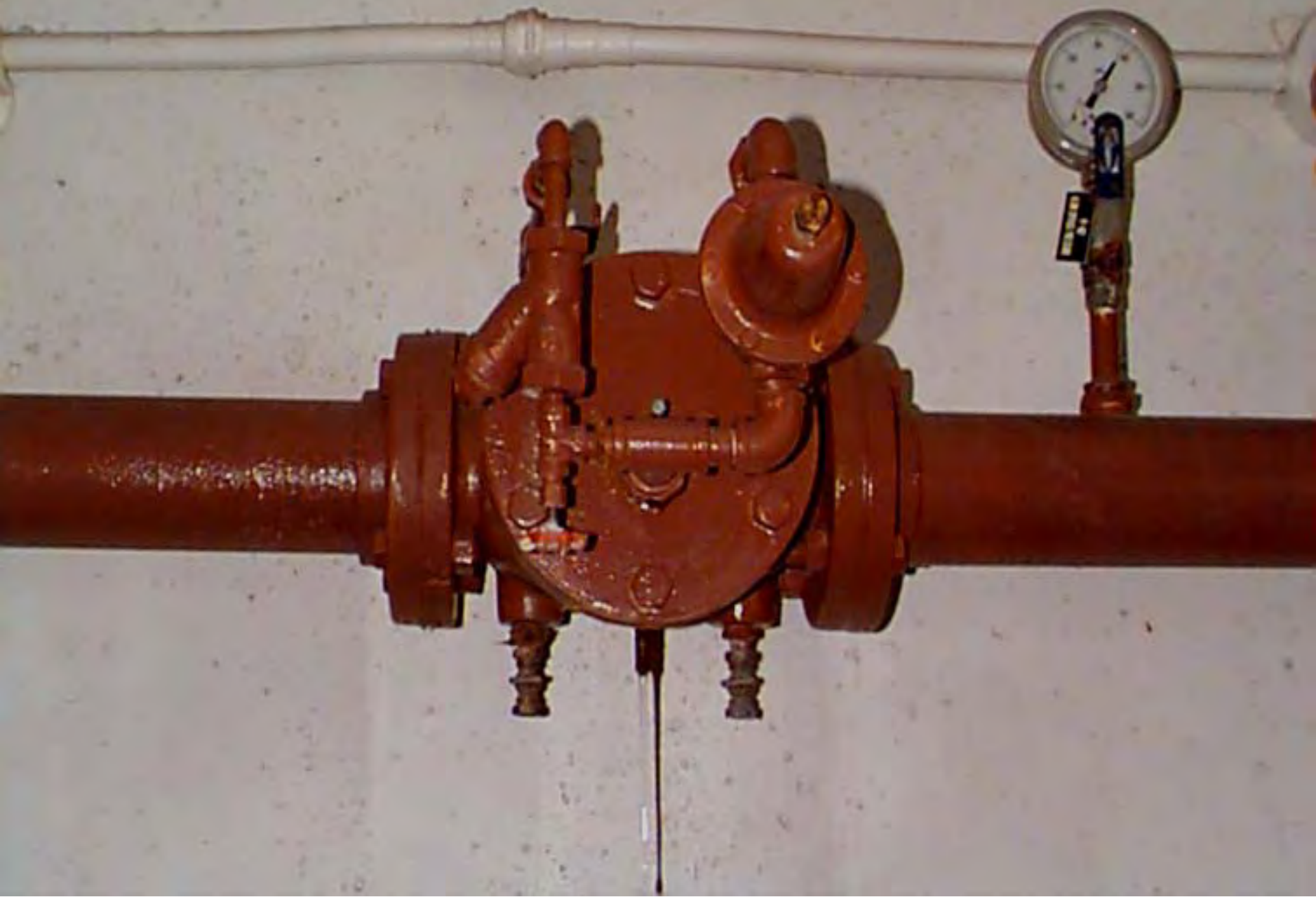
- ❖ 2 independently operating spring loaded, internally loaded check valves (#1-5 lb minimum spring; #2-2 lb minimum spring)
- ❖ 1 relief valve or dump port with a 2 lb spring
 - leakage indicator
- ❖ 2 tightly closing shut-off valves
- ❖ 4 appropriately located test cocks
- ❖ Most reliable mechanical device
- ❖ High hazard protection
- ❖ Used on all direct connections for back pressure and back siphonage
- ❖ Must be inspected and tested annually by certified personnel

Reduced Pressure Zone Backflow Prevention Assembly (RPZ)











Air gaps – good & not so good

Assessing Risks of Cross-Connections

- ❖ Every x-connection poses a different risk based on
 - probability that a physical x-connection will occur
 - ✓ even in absence of statistical info can rely on experience & training of individual making assessment
 - probability that a backflow condition will occur
 - ✓ easier to assess based on complexity & condition of system, historical data & experience
 - probability of total failure of x-c control device(s)
 - ✓ based on effectiveness of XCCP
 - probability that nonpotable substance present & will have adverse effect
 - ✓ public health risk descends from acute microbial to acute chemical to chronic chemical
- ❖ Need all 4 factors to occur simultaneously for a potable system to become contaminated

Cross Connection Control Plan

- ❖ Institutionalized control program
 - in-plant & outside
 - right-of-entry, inspection & testing
 - employee certification
 - plan review
 - penalties
- ❖ Number and type of CCC devices
- ❖ Piping systems
 - color coded, named
 - different hookups
 - flow direction
- ❖ Verify all uses in plant
- ❖ Follow the flow!



Any Questions?