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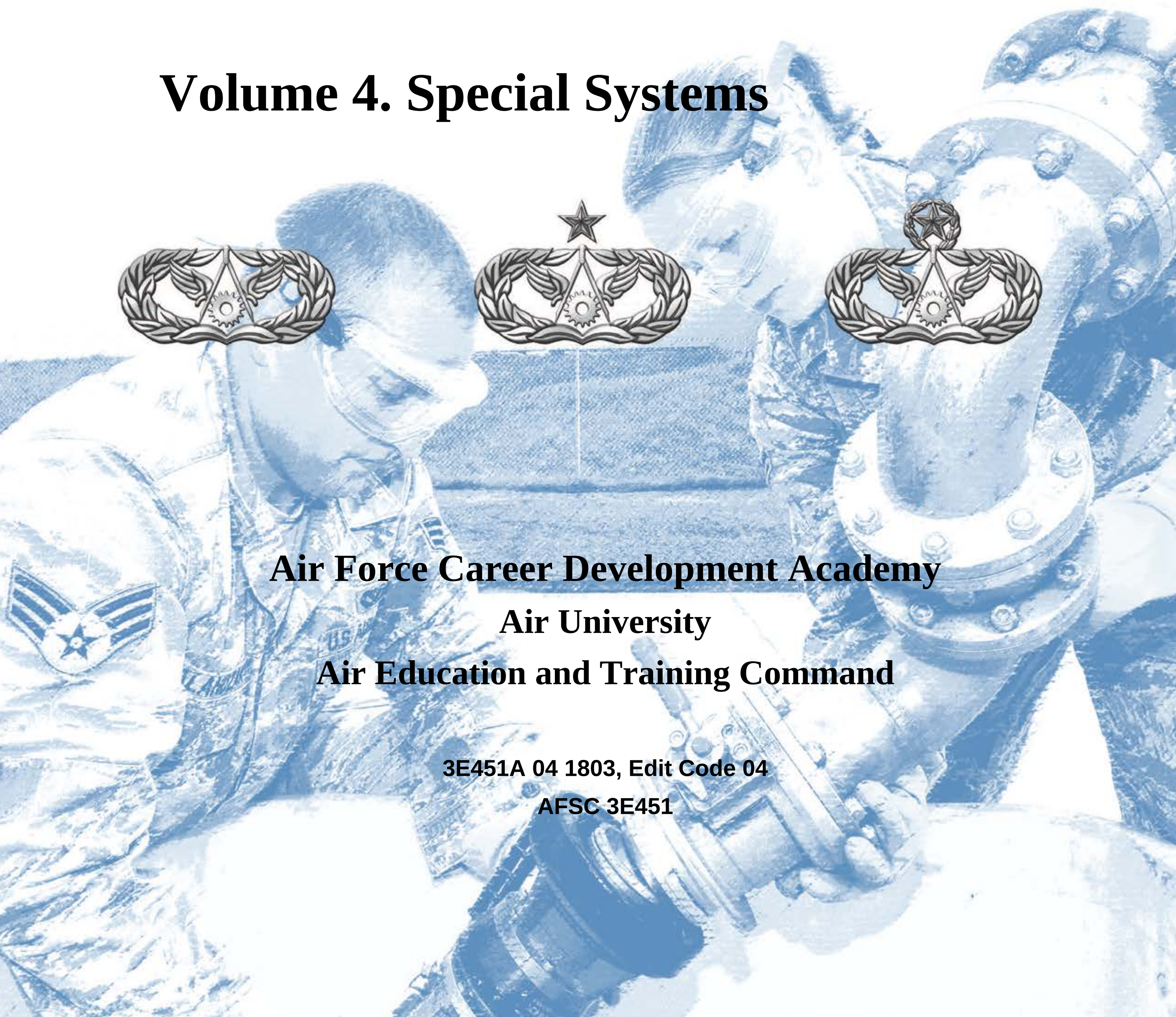
Water and Fuel Systems Maintenance Journeyman

Volume 4. Special Systems



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Volume 4, *Special Systems,* is designed to familiarize you with some of the special systems that you will encounter during your career as a Water and Fuel Systems Maintenance (WFSM) Journeyman. Unit 1 deals with the design and operation of fire protection systems and backflow prevention testing and repair. Unit 2 covers the basic fundamentals of natural gas distribution systems and the governing regulations for maintaining them. The unit also covers proper swimming pool operation and maintenance. Unit 3 discusses the basics of water treatment.

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Acknowledgment

PREPARATION of this volume was aided through the cooperation and courtesy of Viking Corporation; Kidde Fire Systems, a UTC Fire and Security Company; and Cla-Val Company.

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Corporation	CDC Figure Title	CDC Figure Number
Viking Corporation	Wet pipe alarm valve.	1–1
Viking Corporation	Dry pipe valve.	1–5
Viking Corporation	Deluge sprinkler system.	1–11
Kidde Fire Systems	Pressured wet-chemical system.	1–18
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NOTE:

In this volume, the subject matter is divided into self-contained units. A unit menu begins each unit, identifying the lesson headings and numbers. After reading the unit menu page and unit introduction, study the section, answer the self-test questions, and compare your answers with those given at the end of the unit. Then complete the unit review exercises.

Page

Unit 1. Protective Systems

THE PURPOSE OF THIS UNIT is to refresh and build on some of the basic knowledge you learned in technical school about the special systems you will work on during your career. This unit provides an overview of the basics of fire suppression, backflow prevention, natural gas, swimming pools, and water and wastewater treatment. Always refer to the manufacture's specifications, state and federal regulations, and appropriate reference material before working on any equipment or system.

1–1. Fire-Suppression Systems

Today, more and more Air Force (AF) facilities are being equipped with fire sprinkler systems. Part of your job is to keep these systems operating. For you to accomplish this mission, you will have to know how these systems work and have extensive knowledge of the different types of fire-suppression systems and the regulations that you must comply with. The two primary types of fire suppressions are facilities and aboveground fuel storage tanks. This section focuses on the facility systems. Aboveground fuel storage tank fire-suppression systems are discussed in a separate volume.

601. Wet-pipe sprinklers

This lesson discusses the wet-pipe sprinkler system. It includes its operation, restoration, testing, inspection, and components.

Operation

The wet-pipe system has closed heads so that the sprinkler system is full of water and under pressure at all times. When there is a fire, the heat causes the sprinkler head(s) to fuse or open, and the water starts flowing onto the fire. Once the water begins to flow from a fused sprinkler head, the pressure in the system piping drops, allowing the alarm check valve clapper to open (fig. 1–1).

An alarm check valve is a check valve equipped with a perforated seat. This valve stays closed as long as the pressure in the system piping is greater than the water supply pressure. The flow of water caused by one or more of the heads opening causes the clapper to open. This action not only supplies additional water to fight the fire, but it also exposes the perforations in the seat of the alarm check valve. Water now flows through the perforated seat into the alarm line and then to the retard chamber. Once the retard chamber is full, the flow of water re-enters the alarm line flowing towards the water motor alarm and/or the optional pressure switches that initiate the electrical alarms. The function of the retard chamber is to prevent large water surges from activating the alarm system causing false alarms. To prevent the accumulation of water in the retard chamber, there is a small drain outlet equipped with a restricted orifice. This drain is located at the bottom of the retard chamber.

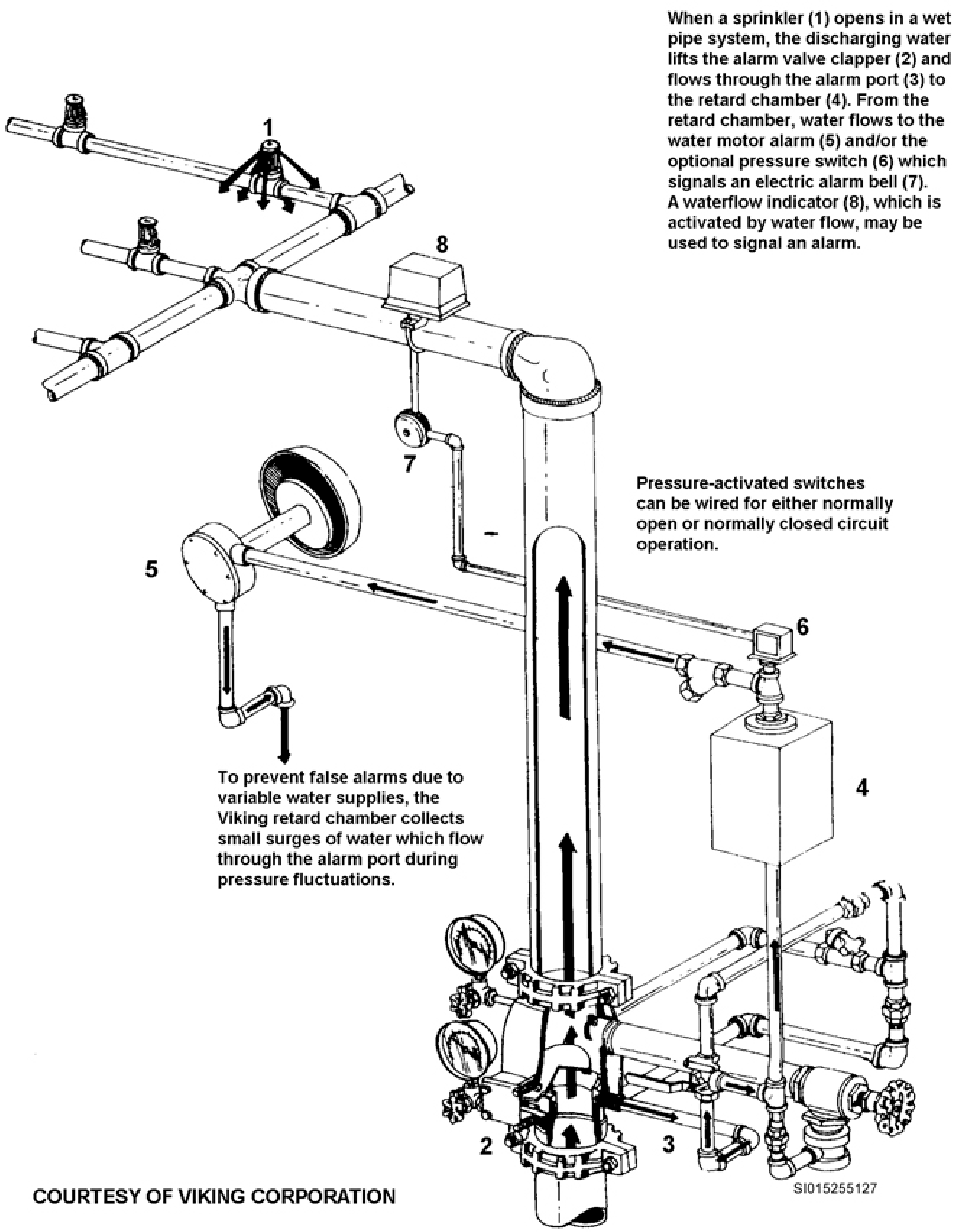


Figure 1–1. Wet-pipe alarm valve.

Pressure surges

While large pressure surges are handled by the retard chamber, small pressure surges are controlled and managed using a bypass line (fig. 1–2). This line allows the small surges to bypass the clapper. Any excess pressure is then trapped on the system side of the clapper by the check valve in the bypass line. The trapped excess pressure helps to keep the clapper seated.

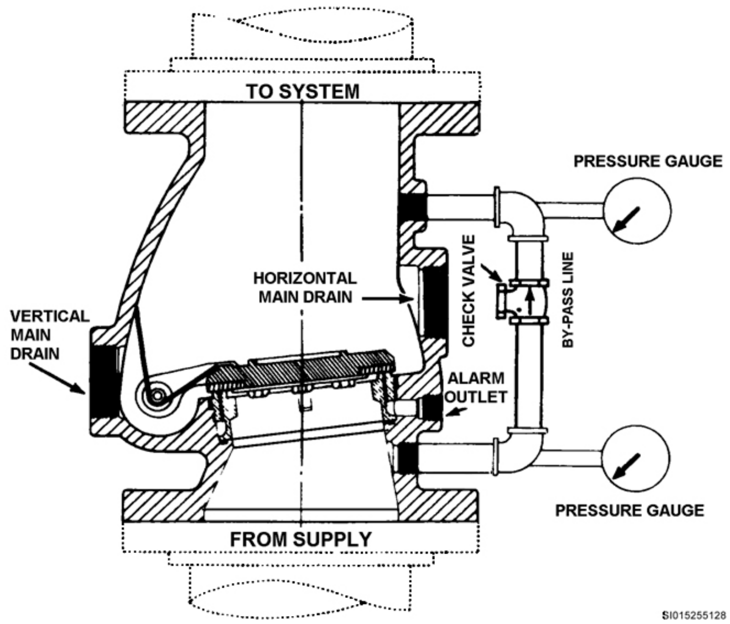


Figure 1–2. Bypass line.

Hydro-mechanical alarm

The hydro-mechanical alarm (water motor alarm) (fig. 1–3) is attached to the end of the alarm line. The alarm consists of a water-propelled paddle wheel, a drive shaft, a striker assembly, the gong, and a drain open to the atmosphere. The water flowing through the alarm line, after the retard chamber, turns the paddle wheel, which causes the striker to hit the gong. The water then is exhausted to the atmosphere.

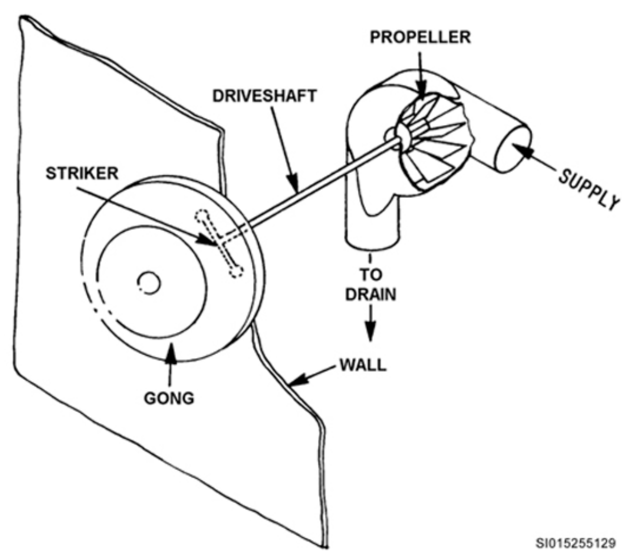


Figure 1–3. Mechanical alarm.

Electrical alarms

Electrical alarms are attached to the alarm line after the retard chamber and before the hydro-mechanical alarm by the use of pressure switches. Pressure on the sensing device closes an electrical circuit. This electrical circuit could be used to actuate electrical alarms, horns, flashing lights, or annunciators that are wired directly to the fire department.

Pressure gauges

Most sprinkler systems have two pressure gauges mounted on them. The gauge that is located above the clapper indicates pressure in the system piping. The other gauge is located below the clapper and indicates the supply water pressure available to the riser. The accumulation of excess pressure in the system piping above the clapper is an important factor in any variable pressure sprinkler system and is the basis for efficient and trouble-free service. As long as this excess pressure is maintained, the clapper valve does not open under normal conditions. The wet-pipe sprinkler system is the simplest to maintain and least expensive to install. It is suitable for locations where freezing temperatures are of no concern.

System restoration

When the fire is out, the sprinkler system is no longer required to fight the fire; close the main control valve and open the main drain valve to drain the system piping. Once all of the water has been drained from the system piping, you can restore the system following these steps.

1. Replace the fused sprinkler heads. Remember to use the right type of sprinkler head (in terms of temperature ratings) for the area to be protected and to use a sprinkler head wrench to keep from damaging the head.
2. Remove the cover plate from the alarm check valve. Inspect and clean the seat and the rubber gasket. Replace any damaged parts, and reinstall the alarm check valve cover.
3. Open the main control valve or post indicator valve (PIV) to let the system fill with water. Use the inspector's test valve at the far end of the system to bleed off any trapped air pressure in the system piping.
4. Check the pressure gauges above and below the clapper for proper readings. If the pressure on both gauges is correct, the alarms are not sounding, and the system is holding water, the clapper valve is properly seated and the system is operational.

Testing

The first step in testing is to notify the fire alarm communications center and building occupants. Do this before and after you work on any fire-suppression system. The line drawing in (fig. 1–4) helps you to follow the text.

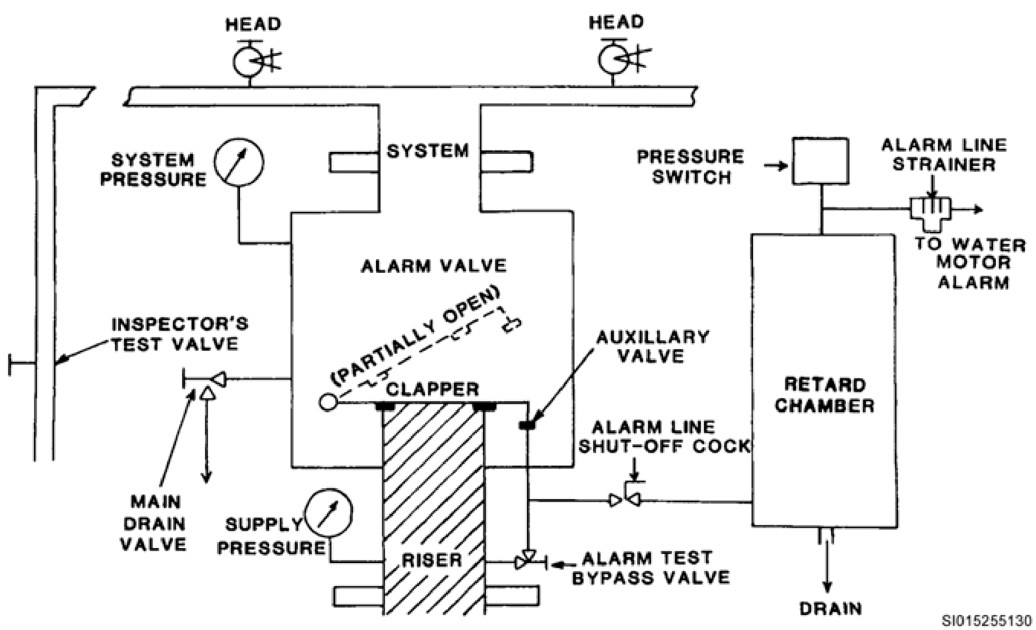


Figure 1–4. Wet-pipe valve operation.

First, read the pressure gauges below and above the alarm check valve clapper. The gauge above the clapper valve should show a higher reading than the lower gauge. This is due to either the higher static pressure at night or to water pressure surges that are trapped above the clapper of the alarm check valve. This higher reading shows that the clappers in the alarm check and bypass line check valves are seated. The lower pressure gauge shows if the proper water pressure is present in the supply riser.

To test the alarm check valve and the entire system for proper operation, open the inspector’s test valve. This valve simulates the fusing of one sprinkler head. The water pressure in the system piping above the alarm check valve drops, causing the clapper to open, which activates the entire fire-suppression system.

This test permits a buildup of water pressure in the alarm line testing the electrical and mechanical alarms. If neither alarm operates properly with a good flow of water from the inspector’s test valve, check to see if the alarm shutoff valve between the alarm check valve and retard chamber is open. This valve should be secured in the open position. If the alarm shut-off valve is open, inspect the alarm devices for proper operation. Have the electric shop check the electric alarm.

A plugged strainer screen usually causes the failure of the water motor alarm; clean it by removing the screen from the alarm line. Do not test the water motor alarm gong during periods of prolonged cold weather.

You can also use the alarm test valve to test the alarm equipment. Opening this valve permits water to flow into the alarm line, before the retard chamber, directly from the supply riser. This test is done without relieving the excess system pressure trapped in the system piping above the alarm check valve clapper.

Conducting drain flow test

Conduct the drain flow test to determine if there are partially closed valves or obstructions in the water supply system. Before you open the main drain valve, make sure that the water flowing from the main drain line does not damage the surrounding area.

Make the main drain test at the riser by opening the 2-inch drain valve fully until the supply water pressure gauge shows a steady reading. This gauge reading is the residual pressure and shows the water pressure available in the sprinkler systems with the 2-inch drain valve fully open. The normal static pressure is shown on the same gauge when the 2-inch drain valve is closed.

Record the static and residual pressures and the length of the main drain line from the outlet of the 2-inch main drain valve to the discharge opening end of the drain line. This information is used to calculate the gallons per minute (gpm) of water flowing during the main drain test. The static and residual pressures along with the gpm of water flowing are recorded to compare with the results of future main drain test results.

Future main drain test results should not indicate a substantial drop in pressure from the previously established readings. Excessive demand on the base water supply may account for small differences in the static and residual readings from those previously established; therefore, you should coordinate all inspections and main drain tests with the fire department.

When there is a pressure drop of more than 10 to 20 percent of the established readings, an obstruction (such as a partially closed valve in the water supply system) may be indicated. Make an immediate investigation and take proper remedial action.

Inspection and repair

To be dependable, a fire sprinkler system must be in good working condition. You can assure this workability by vigilant inspection and prompt repair. When you inspect wet-pipe systems, check out three main areas: the system and supply piping, the sprinkler heads, and all of the system valves.

Piping

Inspect all of the piping and hangers to ensure they are in good condition. Look for damaged and leaking pipes and for loose or missing hangers. Do not use the system piping as a support for ladders, equipment, or material used during the repair. Replace all bent or damaged pipes and missing hangers.

Repairing piping

If you need to repair a damaged pipe, shut off the main control valve to the system and notify the fire department. Refasten all loose hangers, since they will put a strain on the pipes and fittings and will cause breaks and interfere with proper drainage of the system piping. Check the system piping for proper drainage back toward the riser. After all of the repairs are made, use the previously discussed steps for restoring a wet-pipe system to service.

Protecting pipes

Protect all the piping in wet-pipe systems against freezing. Freezing prevents the flow of water through the piping, from the heads, and can cause control and alarm devices to fail. In addition, equipment may be seriously damaged or piping may rupture, causing severe water damage, expensive repairs, or interruption of protection.

Heads

It is important to make an examination of the heads in an area when changes occur in occupancy; fire hazards; or in heating, lighting, or mechanical equipment. These changes may require that different types of sprinkler heads be installed. Make sure that all heads are in good condition, that they are clean, not damaged, and free from corrosion. Install guards to protect against mechanical damage if they are needed. Partitions or stock should not obstruct the distribution of water discharge from heads. There should be a clearance of at least 18 inches under all heads. Carefully examine sprinkler heads in buildings that are subject to high temperatures (mess halls, laundries, or other special installations that use high operating temperatures). Replace any head that shows evidence of weakness with a head of the proper temperature rating. Sprinkler heads that are exposed to corrosive atmospheres should have a special protective coating of wax or factory paint. Replace the heads that are badly corroded or heavily loaded with foreign material.

Keep the required amount of replacement sprinkler heads as required by the National Fire Protection Association (NFPA). For protected facilities having under:

- 300 sprinklers heads – no fewer than six replacement heads.
- 300 to 1,000 sprinklers heads – no fewer than 12 replacement heads.
- Over 1,000 sprinklers heads – no fewer than 24 replacement heads.

Also, keep a sprinkler head wrench for each type of sprinkler installed. This supply should include heads of required designs and temperature ratings. The sprinkler head cabinet must contain heads that are similar to those currently installed in the facility. This cabinet must also have a list inside that identifies all heads installed in the system, gives a general description of the heads, quantity of each head on hand, and the issue and revision date of the list. This ensures adequate supply is on hand and enables the prompt replacement of a fused or damaged head and restores the system to full protection with minimum down time.

Valves

Inspect to ensure that all valves that control water supplies to the sprinkler system and within the system (sectional valves) are kept open at all times. Listed below are inspections that are common to all control valves. Examine each control valve for these conditions:

1. The valve is fully open and sealed properly.
2. The operating wheel is in good condition.

3. The valve is accessible at all times.
4. The valve and its parts are not subjected to mechanical damage. Provide guards if necessary.
5. The valve shows no signs of leaks.
6. A wrench, when required, is in place.

In addition, inspect the PIVs. The target should indicate that the valve is fully open. Try the wrench to feel the spring of the rod when the valve is fully open. Keep the valve about 1/4-turn back from the full open position. See that the target glass is in place and clean. Oil the target mechanism periodically. Ensure that the PIV head bolts are tight and that the barrel casing is intact.

Inspect the outside screw and yoke (OS&Y) valves to ensure the operating wheel is kept approximately ¼-turn back from the full open position and that the valve stem is clean. Tighten or repack the packing glands if the valve leaks. Coordinate all inspections and testing with the fire department.

False alarms may be caused by pressure surges. These false alarms may be reduced by relieving trapped air pressure from the system piping. False alarms involving the alarm check valve may be caused by the improper operation of the retard chamber or an obstructed bypass line check valve. In most cases, the trouble can be remedied by careful cleaning and careful resetting of the system. If false alarms continue, it is advisable to get help from the manufacturer. In rare cases, it may be necessary to maintain an abnormally high excess pressure above the alarm check valve by installing a jockey pump or adding water through the pumper connections to the sprinkler system piping. However, this may be only a temporary measure, which sometimes does not correct the problem.

602. Dry-pipe sprinklers

In a dry-pipe sprinkler system, air under pressure replaces water in the system piping above the clapper. Use dry-pipe systems only in buildings where there is not enough heat to keep the water in the pipes from freezing. When a head fuses, the air pressure escapes allowing the clapper in the dry-pipe alarm valve to open letting the water replace the air in the system piping. Most of these valves are designed so that a small amount of air pressure above the valve's clapper will hold back a much greater amount of water pressure in the supply piping below the alarm valve. A dry-pipe system can be equipped with either electric or mechanical alarms or it can have both types. Figure 1–5 shows a typical differential type of dry-pipe valve.

Types of dry-pipe valves

The two types of dry-pipe valves in use today are the differential and the low differential.

Differential

The differential type of dry-pipe valve has a double-seated alarm valve or clapper. In some systems, the airside of the clapper is considerably larger than the supply waterside. The difference in surface area between the two sides is generally expressed as a ratio of 6 to 1. The rule of thumb for determining the amount of air pressure required to hold the clapper in the dry-pipe alarm valve closed is to divide the supply water pressure by 6 and add a safety factor of 20 pounds per square inch (psi). Example, a supply water pressure of 90 would require an air pressure of 35 psi to keep the valve in the set position. 90/6 = 15+20 = 35 psi.

Set the air pressure against the highest daily water surges. High air pressure is hard to maintain and the operation of the valve is delayed if excessively high pressure is used. On the other hand, low air pressure could cause the valve to accidentally trip. When a fire fuses a sprinkler head, the system air pressure is reduced, and the entire differential air plate assembly, clapper, and clapper arm rise until the hook pawl is tripped by contacting the operating setscrew. The water clapper then opens wide and the differential air plate remains in place. Be careful not to over pressurize the system beyond the manufacturer's specifications or damage to the clapper gasket could occur. Remember, there are other types of differential dry-pipe valves that use additional chambers, such as auxiliary chambers and differential chambers. To obtain or achieve the differential requirement, review your manufacturer's specifications on these systems for how they are obtaining the differential.

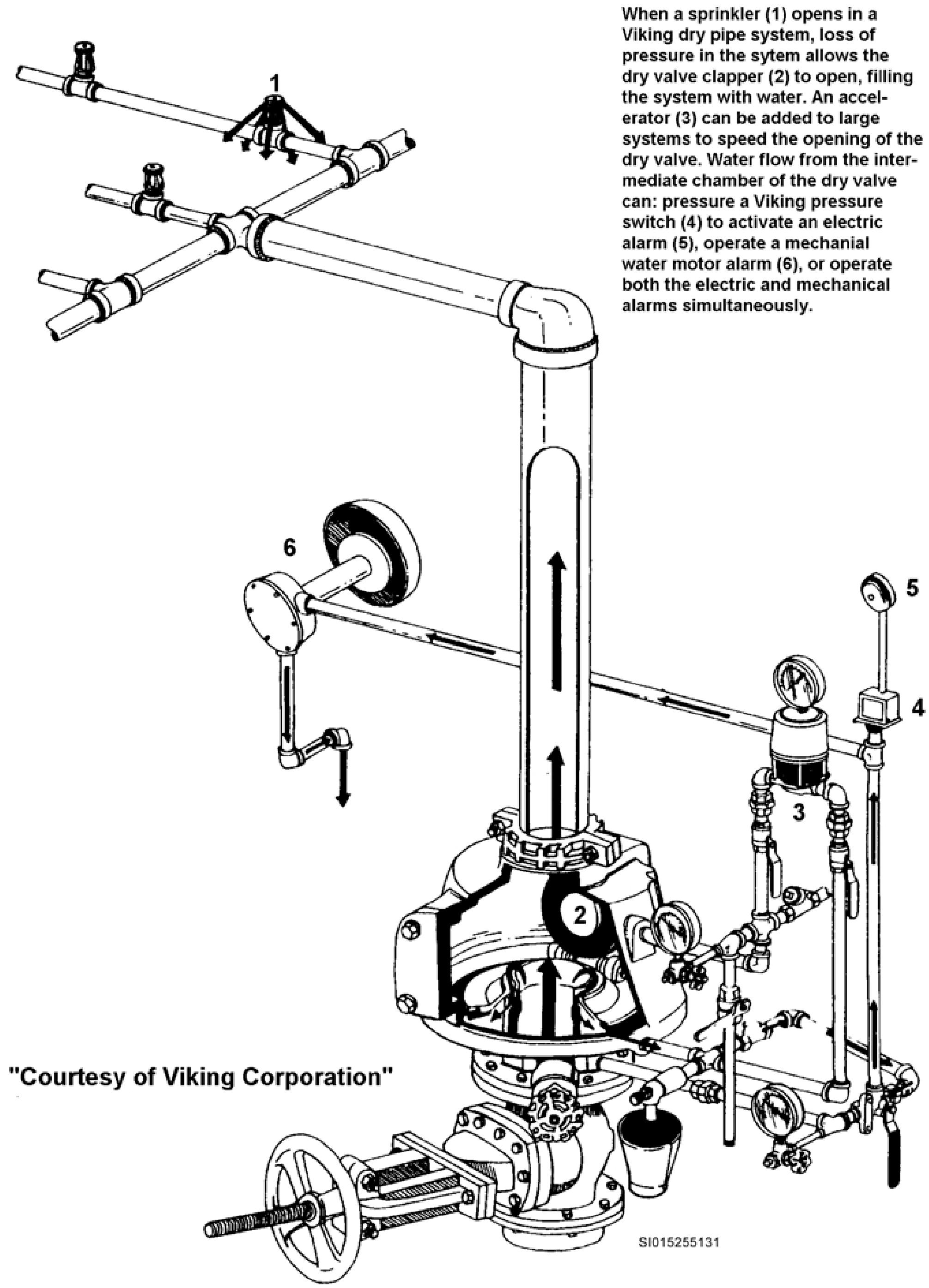


Figure 1–5. Dry-pipe valve.

Low differential

Low-differential dry-pipe valve is essentially a converted wet-pipe system with an air-water ratio of 1:1. When set up properly, they will have air pressure to equal the water pressure plus a safety factor of 15 to 20 psi on the system side of the clapper. Therefore, if the water pressure is 60 psi in this system, the air pressure needed to hold the clapper closed would be 60 psi plus a safety factor of 20 psi for a total of 80 psi of air pressure.

Air pressure required to service the dry-pipe sprinkler system may come from either a central air pressure source or a designated air supply from a compressor and tank that is used only for the sprinkler system. Regardless of the source for the compressed air, it must first pass through an air-maintenance device before it can be used in the dry-pipe system. The air-maintenance device consists of a regulator, check valve, restricted orifice, operating valves, and an air-maintenance device bypass valve. The bypass valve is used to quickly fill or refill the system to normal operational pressure.

Large systems

In a large dry-pipe system, several minutes could be lost while expelling the air from the system piping once the sprinkler head has fused. Rules have now been established that normally require a quick-opening device to be installed in systems that have a piping capacity of over 500 gallons.

There are two types of quick-opening devices in a large dry-pipe system—accelerators and exhausters.

Accelerators

The accelerator redirects the system air pressure into areas of the dry-pipe valve causing it to upset the pressure differential between the waterside and airside. When the pressure differential is reduced by the action of the accelerator, the dry-pipe valve opens quicker allowing the water to reach the fire in a shorter time (fig. 1–6).

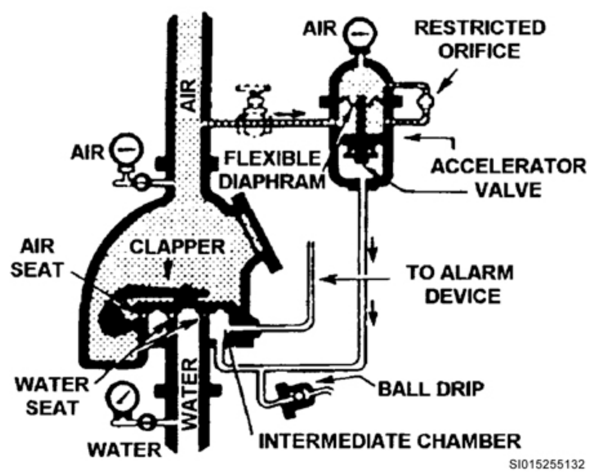


Figure 1–6. Accelerator quick-opening device.

Exhausters

The exhauster takes the air pressure in the system piping and exhausts it to the atmosphere. When a sprinkler head fuses, the air pressure below the diaphragm reduces causing the main exhauster valve to open dumping the system air pressure out into the atmosphere. The restricted orifice delays the air from escaping out of the top chamber. The opening in the exhauster is a 2-inch line that simulates the fusing of 15 sprinkler heads. This rapid loss of air pressure in the system piping speeds up the tripping of the dry-pipe valve.

Since both of these quick-opening devices are complicated mechanisms and classified as high-maintenance devices, they demand proper care and maintenance. They should be tested at least once each year by a qualified technician. Even if the quick-opening devices do not operate, the dry-pipe valve still operates. However, it takes longer to exhaust the air from the system piping and get to the trip point (fig. 1–7).

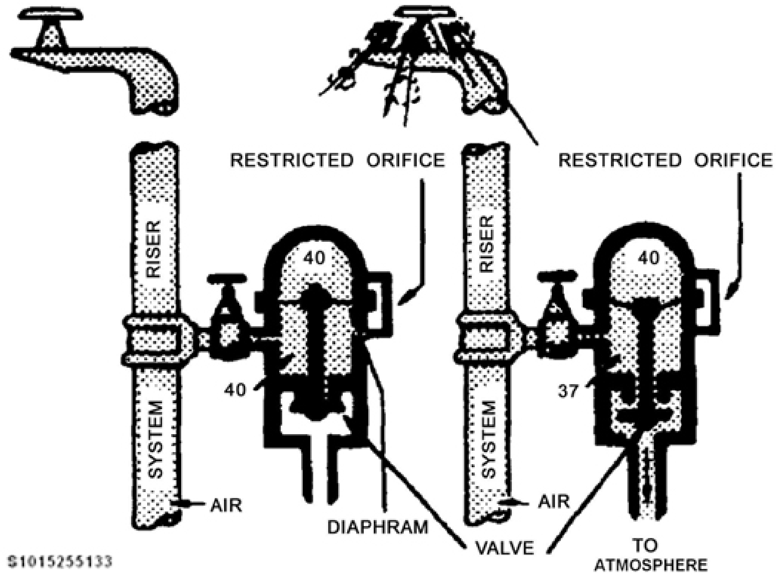


Figure 1–7. Exhauster quick-opening device.

System operation

When the sprinkler heads fuse, the air pressure is vented through the open heads causing a reduction in air pressure in the system piping. At this time, an accelerator will trip and accelerate the opening of the clapper, or the exhauster will trip and help vent the system. As the pressure differential is upset, the water pressure opens the clapper. The pressure of the flowing water causes the clapper to lock in the open position. The water then continues to flow towards the fused sprinkler heads and fill the different areas inside the dry-pipe alarm valve while at the same time water flows into the alarm line where it activates local and remote alarms. Remote alarms are the ones that ring inside the fire station. When the fire fighters arrive, and if the main riser is accessible, they may close the alarm line shutoff valve to stop the alarm signal.

Restoring the system

There are seven steps you must follow when you restore the system.

Step 1

After the dry-pipe system is no longer required to fight the fire, the main control valve is closed and the main drain is opened. As with the wet-pipe system, this stops the flow of water, reduces the water damage, and starts the draining of the system piping. It is also necessary to open any auxiliary drains at this time to drain any low points in the system piping to prevent freezing in the system. Check the ball-drip check valve to make sure it opened and drained the alarm lines. To place the system back in service, you must first replace the fused sprinkler heads and replace any of the damaged system piping. Again, be sure to install the proper sprinkler heads for the area being protected. Use the right installation wrench, often located in a box with replacement heads.

Step 2

The next step is to reset the dry-pipe valve. This must be done by hand. Figures 1–8 and 1–9 show how this is done. Remove the dry-pipe valve handhole cover exposing the interior of the valve. The clapper should be upright and held in position by a latch on the back of the valve. Trip the latch, and pull the clapper down for inspection. Thoroughly wash and clean the seats and clapper facing, if necessary, before the system is again ready for service. An accumulation of dirt is likely to damage them and cause them to leak.

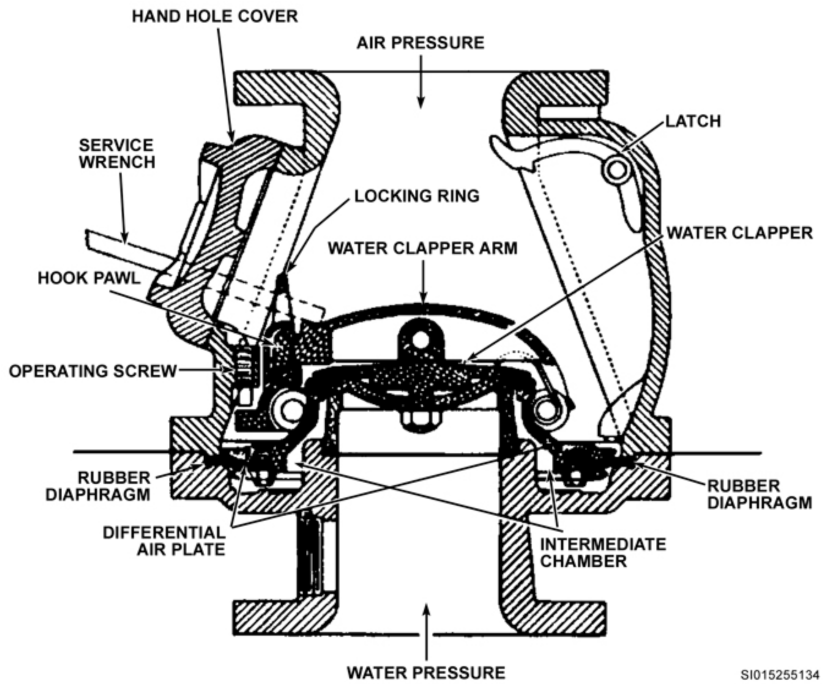


Figure 1–8. Cutaway of the dry-pipe valve.

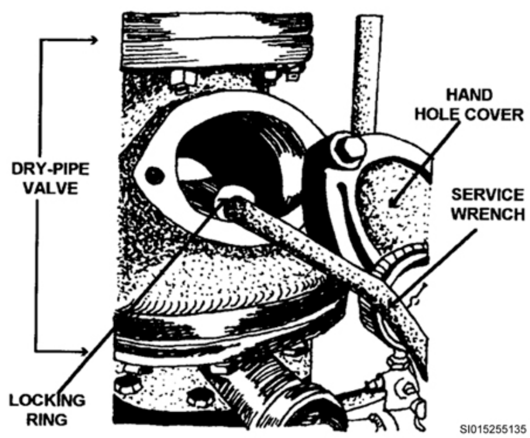


Figure 1–9. Resetting the dry-pipe valve.

Step 3

When the clapper is clean, close it using the specific tool required by the manufacturer. Lift up on the wrench handle to reset the clapper (fig. 1–9).

CAUTION: Be careful not to place your hands in a dry-pipe valve that is spring loaded once the clapper is reset. The clapper may accidentally open with a significant amount of force that could break your fingers.

Step 4

The resetting of the clappers may vary with the particular type and model of valve that you have. Follow the manufacturer's specifications to prevent accidents. Once the clapper in the dry-pipe valve is seated, close the auxiliary drain valves and reinstall the handhole cover to finish sealing the system. Add priming water to the dry-pipe valves as required by the manufacturer. The priming water is used to help make an air-tight seal and to keep the clapper rubber gasket pliable. Adjust the level of the priming water by opening the appropriate priming level indicator valves. After the proper level of priming water is established, the system is ready to be charged with the correct system air pressure.

Step 5

Check the sprinkler system making sure all of the valves where compressed air could escape are closed. Open the air-maintenance device bypass valve and charge to system piping with air. The time for charging the system should not be more than 30 minutes. If too much time is used to charge the system, there may be some air leaks that have to be corrected. On systems that do not require priming water, close the valves mentioned before and charge the system with air.

Step 6

When the air pressure is back to normal, open the main control valve slowly until water is flowing from the main drain. Slowly close the main drain valve, gently building water pressure underneath the clapper. A surge of water pressure at this time could result in the tripping of the system. This completes the restoration of the system to an in-service condition. Make sure that the automatic ball-drip check valve is dry. Leakage from this valve indicates that either the air, water seat, or other chamber seals are leaking or not seated properly. If this happens, clean the seats, check the sealing, and reset the valve again.

Step 7

If the system is equipped with an accelerator or exhauster, reset it before applying water pressure. When resetting a quick-opening device, the main control valve should be in the closed position and the system restored to service as described above.

Testing a dry-pipe system

The first step when testing a dry-pipe system is to notify the fire alarm communications center and the building occupants. Do this before and after you make the system tests. Use the line drawing in figure 1–10 as you read the following text.

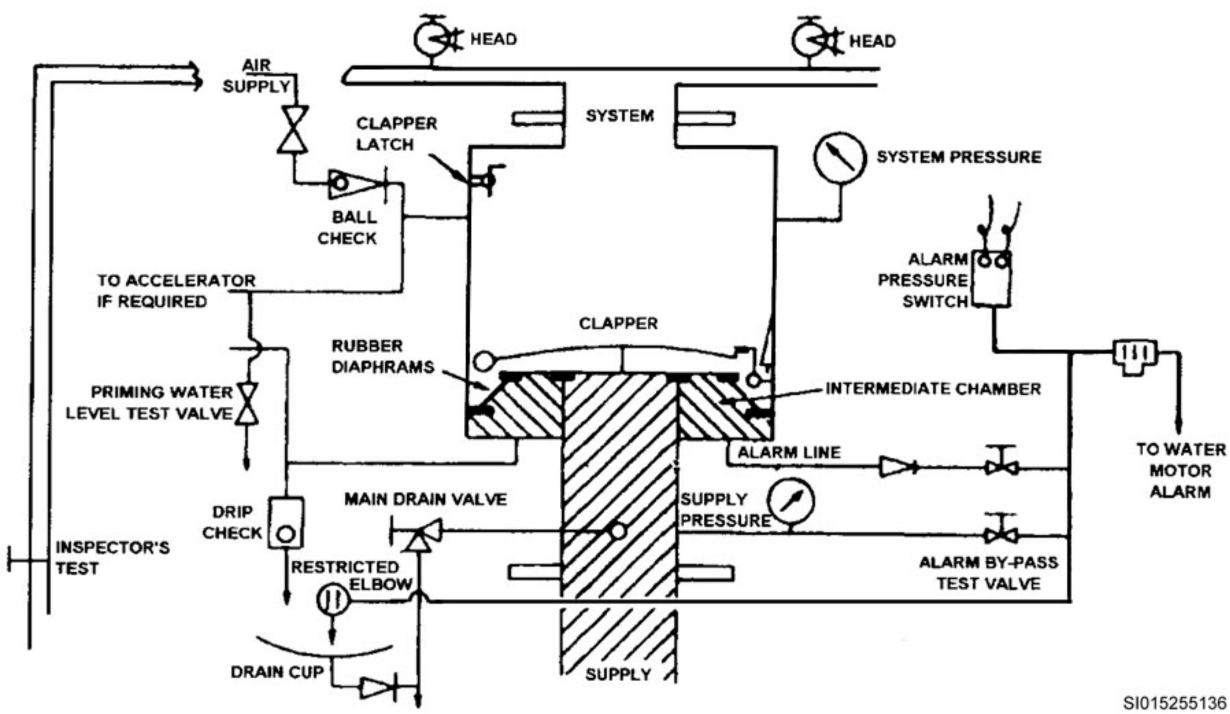


Figure 1–10. Dry-pipe system schematic.

To test the alarm equipment, open the alarm test valve. This allows water to flow in the alarm line activating the alarm pressure switches and the water motor alarm. Shut the alarm test valve off when the test is completed. The main drain test is done in the same way as with the wet-pipe system.

- Test, clean, and reset all dry-pipe valves periodically. To test these valves, use a partially open or throttled main control valve. This will keep large amounts of water from entering the sprinkler system. When doing a partial trip test, open the main drain and close the main-control valve until 5 psi of water pressure is showing on the supply pressure gauge. Close the main drain valve completely.
- Trip the system by allowing the air pressure to escape through the inspector's test valve. This simulates the fusing of one sprinkler head and tests the system for proper operation with minimum air loss.
- When the dry-pipe valve trips, close the main control valve quickly before a large amount of water enters the system piping. Then open the main drain valve to drain the riser.
- Remove the handhole cover plate and thoroughly clean, examine, and reset the dry-pipe valve as mentioned before. At this time, replace any unserviceable gaskets and broken gauges.
- Clean and adjust the alarms and quick-opening devices.
- Restore the system to service as described earlier.
- Fully open the main control valve and lock or seal the valve in the open position.
- Keep a record of the length of time necessary to trip the dry-pipe valve and quick-opening devices. Carefully and completely investigate any failure of a dry-pipe valve to trip.

The quick-opening device should function properly during the partial trip test of the dry-pipe valve. If the quick-opening device does not operate properly and cannot be repaired promptly, reset the dry-pipe valve and place it in service with the quick-opening device isolated. The dry-pipe system will operate without a quick-opening device; it just takes longer for the water to reach the fire.

Inspection and repair

Dry-pipe fire sprinkler system inspections and repairs are much the same as wet-pipe systems in regard to the pipes, heads, and valves. Keep a record of the air and water pressures and temperature in dry-pipe valve areas. These readings should correspond with readings that were recorded previously. If the loss of air pressure is excessive, inspect and tighten the dry-pipe valve, fittings, and piping system. During cold weather, you may have to check pressures and the dry-pipe valve area temperatures more often. Make sure that the main water-control valve and valves to the alarm devices from the intermediate chamber are open.

Ball-drip check valve

Check to be sure that the ball-drip check valve from the intermediate, differential, and auxiliary chambers is free to move by pressing on the push rod which extends through the drip valve opening. If the valve does not have a push rod, insert a pencil through the valve opening to check it. Before and during cold weather, open the drain valves on all low points to see that the pipes are entirely free of water or ice.

Priming level indicator valve

Open the priming level indicator valve to check the level of priming water and keep it open until air begins to escape. This is done to make sure that the dry-pipe valve is not water columned and that no water is in the system piping that would freeze. If a quick-opening device is attached to the dry-pipe valve, a sudden drop in air pressure may cause it to trip the dry-pipe valve. Open the priming level indicator valve only slightly and close it immediately after air begins to escape. If the air pressure in the system is above the prescribed limit, shut off the quick-opening device to prevent tripping of the dry-pipe valve and open the priming level indicator valve until the system air pressure is reduced to the prescribed limit. Now close the priming level indicator valve.

Quick-opening device control valve

Before you open the quick-opening device control valve, reduce the air pressure in the device until it matches the pressure in the system. If there is no way to bleed air from the quick-opening device, you can reduce the air pressure by loosening the air gauge.

Leaks

After the system is operational, the valves on the water and air lines that are pressurized need to be checked for leaks. Leaks at these valves may be detected by wetting your fingers and placing them over the outlet end of the valve, or by wetting the valve stem close to the packing nut with soapy water. To stop a leak, tighten the stuffing box or replace the valve. Dry-pipe valves occasionally trip during water surges. This is usually corrected by increasing the air pressure in the system piping, but always consult the manufacturer's specifications before adjusting the system.

603. Deluge and foam systems

This lesson includes information on both the deluge and foam systems. We'll discuss how these systems protect the aircraft hangars and the advantages of the foam system when hazards involve flammable liquids.

How the deluge systems works

The deluge system has open sprinkler heads, and the system piping is under the surrounding atmospheric pressure. The water flow in the system is controlled by a deluge valve (fig. 1–11). There are two types of deluge valves: mechanical and differential. The deluge valve trips and water flows from all of the sprinkler heads at the same time. These deluge sprinkler systems require a greater water volume and pressure.

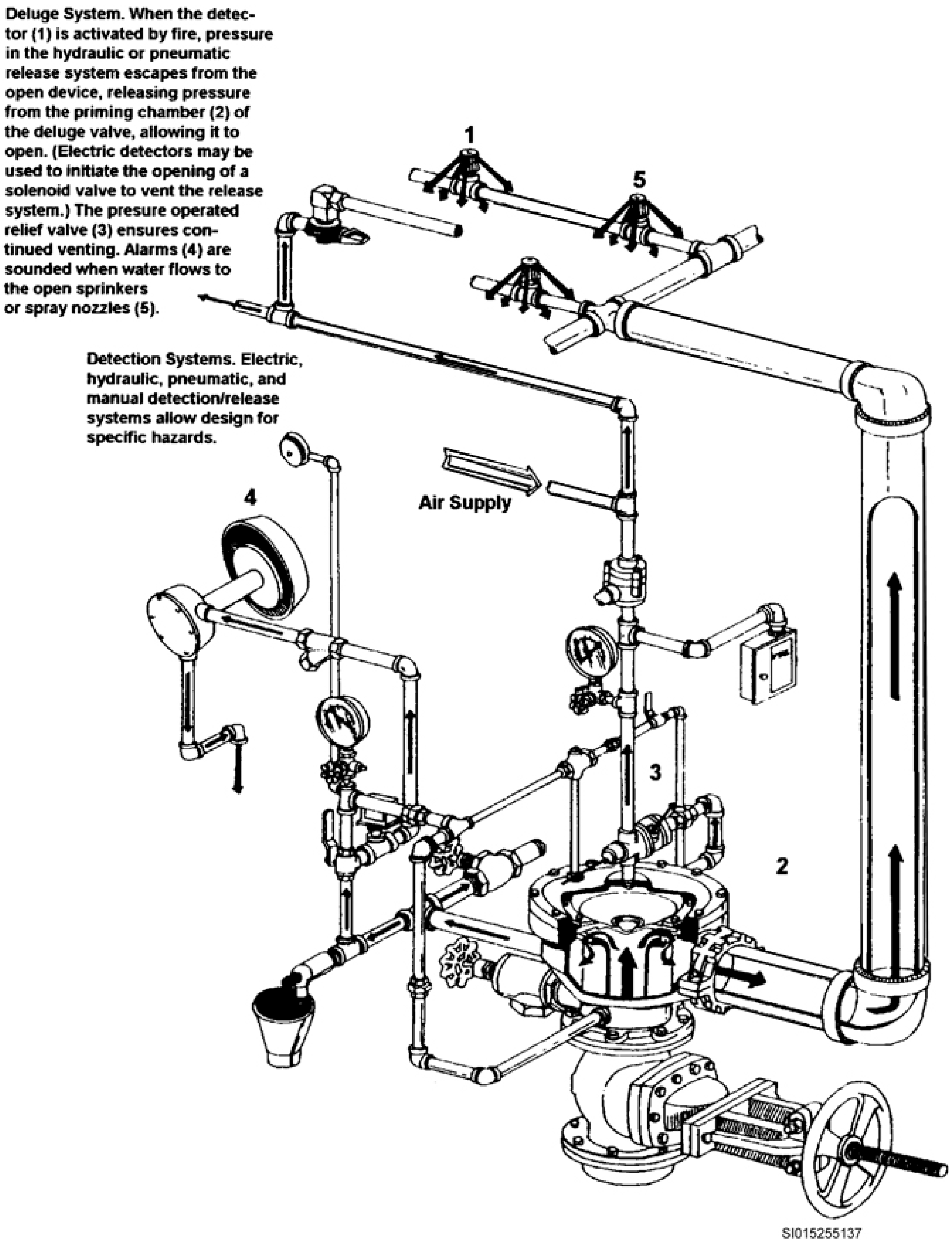
This system is normally used in extra hazardous areas (such as aircraft hangars) where there is a danger of flash fires or fires of an explosive nature that could cover a large area. Aircraft hangars are usually constructed from non-combustible material. However, this will not stop large fires that are caused by fuel and other vapors found in hangars. In such situations, an automatic deluge system is necessary for fire safety. Most modern hangars in the Air Force have a deluge system to fight fires. Some of them also have a second type of fire-suppression system.

One of the arrangements consists of a deluge system with open sprinkler heads that could discharge water over a given area in the hangar where the aircraft are parked. The second system could be a closed-head sprinkler system that discharges the extinguishing agent through fused sprinkler heads. These systems are installed in areas of the hangars that are usually designated as shops and/or offices. This type of sprinkler system differs from the systems previously discussed in the following ways:

- Sprinkler heads are of the open type.
- Number of heads per system is somewhat limited.
- The deluge valve is a special type.
- The system is operated by independent detecting devices.
- The system may be operated manually.

Activation

Automatic activation of the deluge system may be accomplished by flame, heat, or smoke detection devices. The mechanical deluge valve is usually equipped with a rate-of-rise detection system that contains heat-actuated devices (HAD). The HADs are uniformly distributed over the ceiling. When heat in a fire raises the temperature in a HAD at a rate greater than 15 degrees per minute the detection system, through a series of latches and levers, will cause the deluge valve to open. The deluge valve opens filling the riser and system piping with water.



"Courtesy of Viking Corporation"

Figure 1–11. Deluge sprinkler system.

Differential deluge valve

Figure 1–12 shows a differential deluge valve in both the STANDBY and the FIRE positions. This valve is opened by releasing the water pressure inside chamber A. The water pressure in chamber A can be released in one of four ways: electrically, pneumatically, hydraulically, or manually. The rate-of-rise detection system for this type of deluge valve is known as thermostatic-release devices. The piping connecting the thermostatic-release to the deluge valve is filled with water or air pressure. The release of this pressure causes the pressure in chamber A to be released and the deluge valve to open. To electrically operate the system, a solenoid valve is installed on the hydraulic release line. The leads from this valve can be attached to any type of electrical detection equipment: smoke alarms, heat detectors, ultraviolet (UV), and infrared detectors. Manual release of this system could be nothing more than a ball valve installed on the hydraulic line.

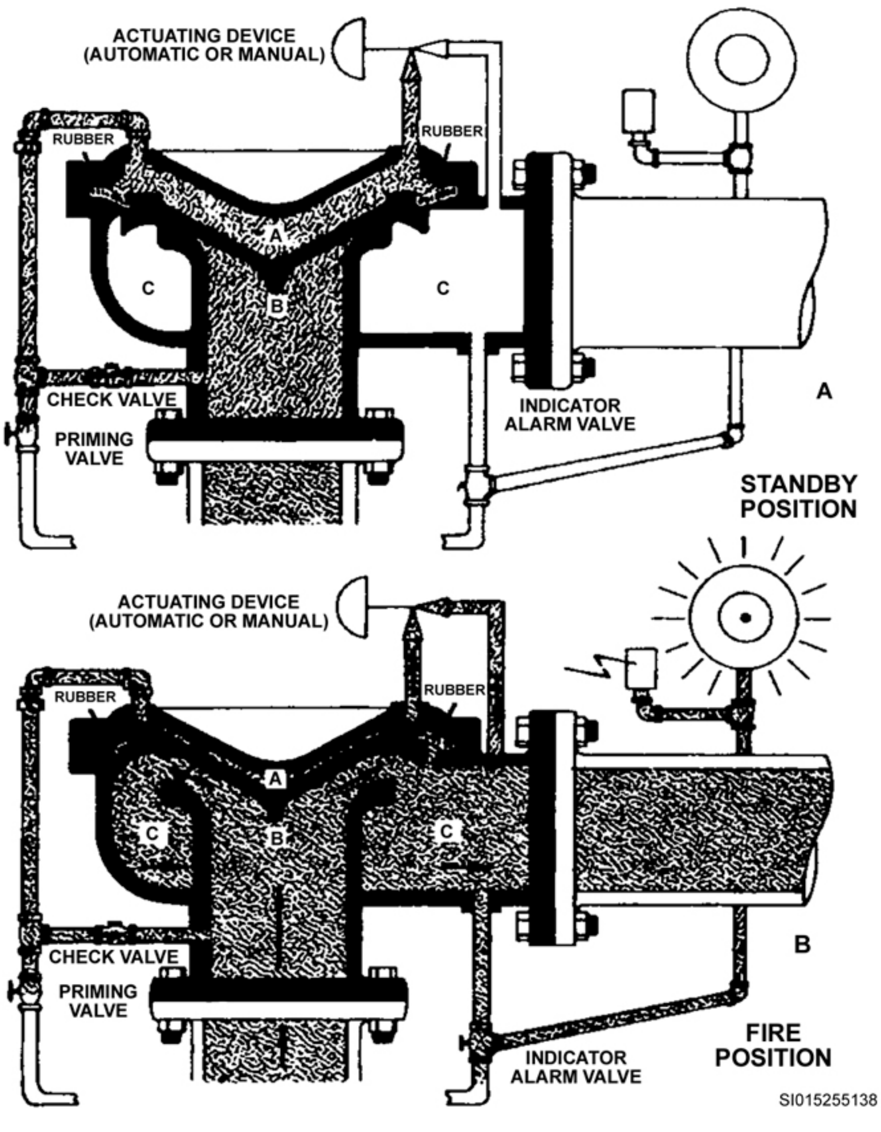


Figure 1–12. Deluge valve operation.

Activation

When the deluge valve is actuated by the detection system, or a manual release is operated, the water pressure in chamber A of figure 1–12 is immediately lowered destroying the pressure differential between chamber A and chamber B.

Figure 1–13 shows the parts involved in this operation. This pressure drop is indicated on the pressure gauge for chamber A. The pressure in chamber B then forces the clapper valve upward allowing water to enter chamber C. Chamber C is attached to the riser and the system piping. Some of the water entering chamber C flows through the alarm line activating local and remote alarm equipment. When you inspect rate-of-rise detection systems, check the HADs and the thermostatic-release devices for damage. Inspect the $^1/_8$" copper tubing that connects the HADs together and the $^1/_2$" piping that connects the thermostatic releases.

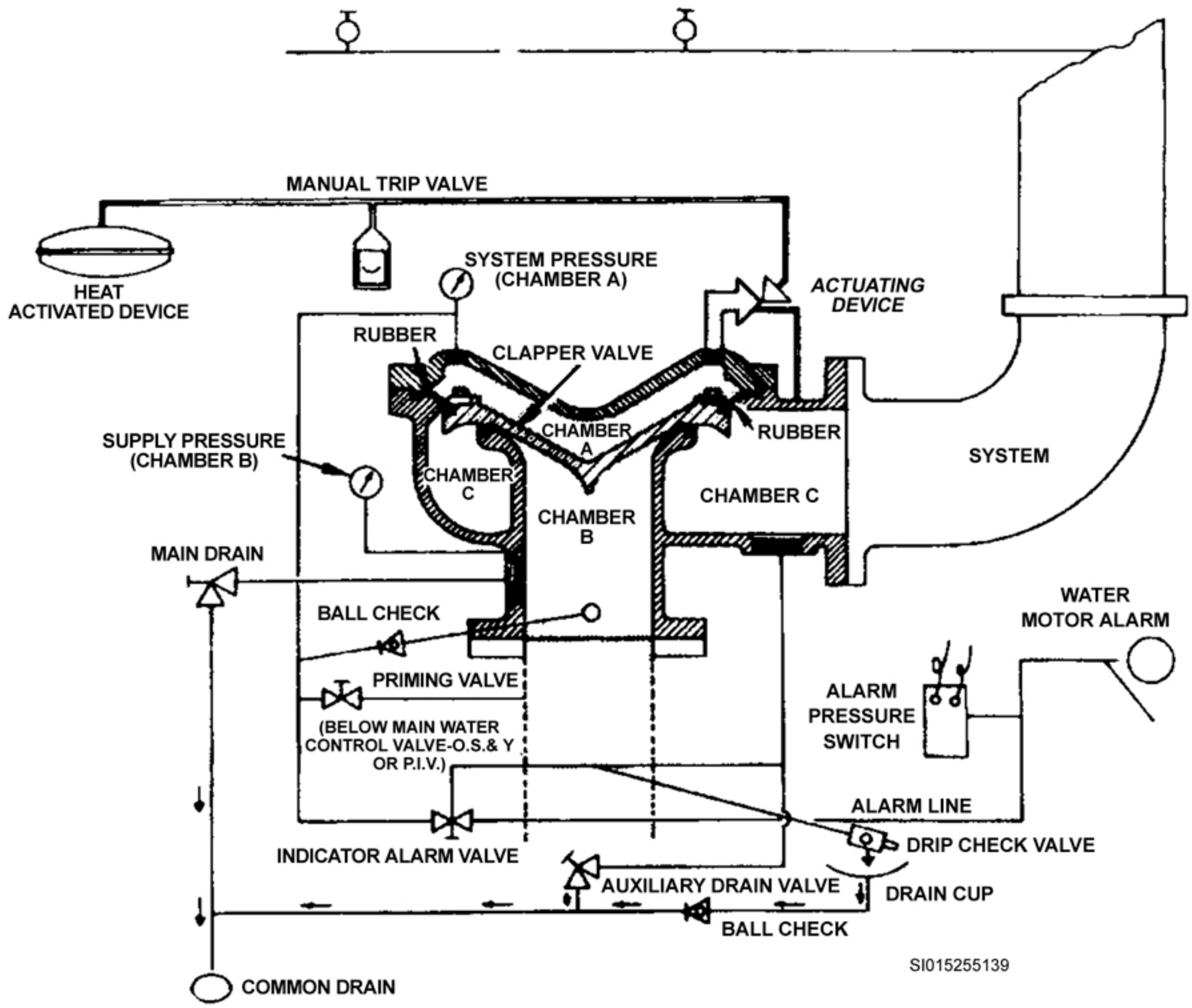


Figure 1–13. Deluge valve schematic.

Deluge system restoration

To shut down the system, close the main control valve and open the main drain and any auxiliary drain valves. As with the other sprinkler systems we have covered, this stops the flow of water, reduces the water damage, and lets the system piping drain. To place a deluge valve back in service, the first thing you do is to reset all of the release devices. Check all the systems HADs and thermostatic releases that have been subjected to the fire, making sure they were not damaged. Reset any manual releases as necessary (fig. 1–13).

Open the priming valve to prime chamber A with water. The system pressure gauge should show the normal static pressure when chamber A is primed. On some systems, the priming valve is left open; on others it is closed after restoring supply water pressure to the clapper assembly. Check the manufacturer's specifications for details.

Open the main control valve and restore water pressure to the clapper. When the water starts to flow from the main drain, slowly close this valve to gently build the pressure in chamber B. Once the main drain is closed, open the main control valve completely. The gauges for chambers B and A should now show the same pressure reading.

Close the auxiliary drain valve and check the alarm shut-off valve for proper position. Open the alarm test valve and perform an alarm test on the restored system. Check for leaks in the deluge valve and the detection systems. Check for steady readings on the system pressure gauges and if there is water leaking from the ball-drip check valve. Steady readings on the pressure gauges and no water leaks indicate the system is back in service. Since there are many manufacturers of deluge valves, obtain and study carefully their literature for systematic procedures for resetting their particular valves and components.

Inspecting and testing

The first step involved in inspecting and testing is to notify the fire alarm communications center and building occupants. Do this before and after the systems' tests are made. Use the line drawing in figure 1–13 as you read the following text.

To test the alarm equipment, open the alarm test valve. This will test the electrically operated local and remote alarms along with the water motor alarm. Shut off the valve when the test is completed. Do a main-drain test for the deluge system to determine if water supply lines are blocked or restricted. Do this in the same way as for the main-drain test on the wet or dry-pipe system.

Periodically perform operational tests on all deluge valves. Close the main control valve so that water does not enter the system piping. Test the HAD detection system by raising the temperature in the most remote HAD with the electric HAD tester (heater), if one is provided. This will test the operation of the HAD detection system and the tripping mechanism in a mechanical deluge valve. Do not use the electric heater in areas that are subject to explosive atmospheres. Instead, use a bucket of hot water or a cloth that you dip in hot water. Activating the HAD causes the system to operate as described in the section on the deluge operation. Test the thermostatic releases in much the same way by applying heat to the release device or by operating one of the electrical components hooked to the solenoid valve.

The deluge system inspections follow the same guidelines as those for the wet-pipe and dry-pipe systems in regard to piping and valves. The system and supply water pressure gauges should show the normal water pressure. Also, make sure that the main water-control valve and the valves to alarm devices are open. Check the ball-drip check valve for free movement by pressing on the push rod which extends through the valve opening. Inspect the HADs and connecting tubing for damage and corrosion.

Foam systems

The foam-water extinguishing system provides much the same general protection as the standard deluge sprinkler system. Of course, the foam-water system has a decided advantage in areas where the hazards involve flammable liquids. In aircraft hangars, the foam-water system has an advantage over a deluge system because of its smothering action for class B fires. These foam-water systems consist of a foam concentrate system attached to the permanently piped deluge system. These two systems work together mixing a foam solution in the correct proportions. The foam solution is discharged through a foam maker (sprinkler heads, foam blower, foam monitors) where it is mixed with air creating foam that controls the fire.

The foam-water system (fig. 1–14) may be divided into two parts:

- The water system, which is a deluge sprinkler system containing the main water supply line (f) and OS&Y main control valve (g).
- The foam system, which consists of a foam concentrate storage tank (r), a metering valve (j), pump (o), strainer (k), check valve (i), globe valves (q), piping (l); and actuation units (h).

Most foam systems are the deluge type that uses a special combination foam/water deluge sprinkler head. In the system shown in figure 1–14, the HADs (b) detect the fire and signal the actuation units (h) on the deluge valves (e and m). The deluge valve (c) opens and permits water to enter the system. At the same time, the companion deluge valve (m) opens and the electric motor (p) and foam pump (o) start to introduce foam concentrate into the system. The foam concentrate and water are mixed together in the correct proportions to produce foam solution. The foam solution in the piping (d) continues on to the sprinkler heads (a) where air introduced into the foam solution produces foam as the extinguishing agent.

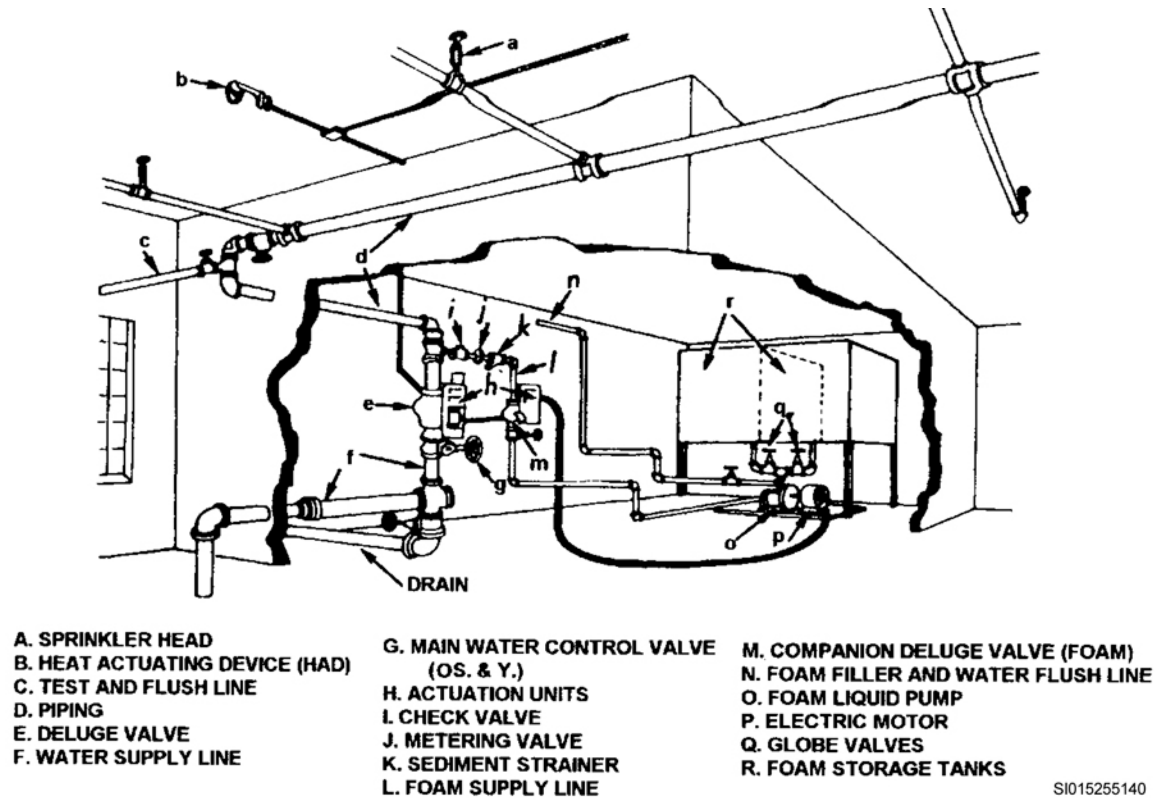


Figure 1–14. Lay out of a foam-water system.

After the fire is out, the system is shut down and drained. The foam concentrate storage tanks (r) are refilled through the filler line (n). The system needs flushing to prevent corrosion and to remove any remaining foam solution. This is accomplished by attaching a waterline to the water flush line (n) and flushing the system through the open heads or through the flush line (c). Once the foam concentrate tank is filled and the system is flushed, it can be restored to the normal operational standby position. To do this, reset the actuation units (h) and the deluge valves (e and m).

604. Special extinguishing systems

In this lesson, we will discuss carbon dioxide (CO_2), Halon, and wet- and dry-chemical systems. These systems are considered special due to the limited nature of their uses.

CO_2 systems

CO_2 systems are used to fight fires that involve flammable liquids or electronic equipment in open or closed areas where the gas may spread throughout an area. Normally, a CO_2 system is used where water or other agents may be ineffective. These systems are used in hazardous areas such as engine test cells, dip tanks for flammable liquids, solvent tanks, and electrical installations.

These fixed systems use two types of storage for the CO_2. Low-pressure storage consists of refrigerated tanks that hold the liquid CO_2 at 300 psi at 0 °F. In high-pressure storage, liquid CO_2 is stored in metal cylinders at 850 psi at an ambient temperature of 70 °F. The temperatures must not drop below 32° F or exceed 120 °F. The number of cylinders varies with the size of the protected area and the way that the CO_2 is applied. Either type may be used as shown in figure 1–15.

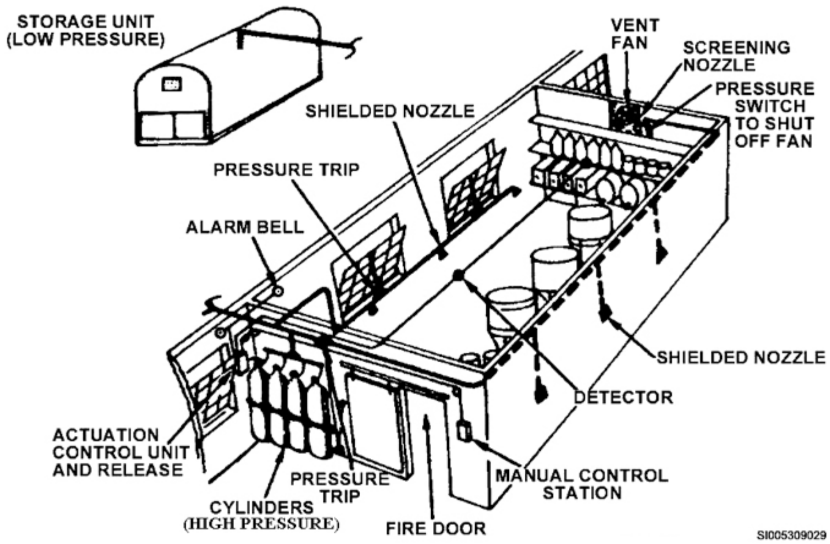


Figure 1–15. CO_2 system.

The entire layout of the fixed CO_2 system is very similar to the dry-pipe or deluge sprinkler system. In both the high- and low-pressure CO_2 system, the storage units are connected into a manifold, which branches out to fixed piping that connects to the discharge orifices or nozzles. Both systems are operated with either automatic or manual controls. Automatic operation is normally controlled by quick-operating detection devices. Automatically operated systems should also have an independent means for manual operation. Figure 1–15 shows the major parts of the system: the storage unit, piping and nozzles, detection devices, and an actuation device.

When the actuation control unit is signaled by the automatic detection devices or manual station, it functions in two ways. First, it sounds the evacuation alarm to alert the building occupants and the fire department if it is connected into the central fire department communications section. Second, after a predetermined time, the actuation device releases the CO_2 gas. Because of the smothering characteristics of the CO_2 gas, this delayed discharge allows time for personnel to evacuate the area.

The CO_2 gas passing through the piping trips the pressure switches, closes the windows and fire door, and shuts down the vent fan. This CO_2 gas passes out the fixed nozzles to extinguish the fire or inert the area, replacing the oxygen so that the air does not support a fire.

Follow your manufacturer’s recommendations and Unified Facilities Criteria (UFC) 3–601–02, *Operations and Maintenance: Inspection, Testing, and Maintenance of Fire Protection Systems*, to properly maintain your CO_2 system. The below inspection table comes directly from UFC 3–601–02.

CO_2 Systems Tasks		
Frequency	**Component**	**Tasks**
Semi-Annual	1. Liquid Level (low- pressure CO_2)	1. Verify adequate liquid level with tank level gauge.
Annual	1. Piping and Nozzles	Inspect piping for condition and proper support. Check nozzles for obstruction and alignment.

CO_2 Systems Tasks		
Frequency	**Component**	**Tasks**
	2. Flexible Hoses	1. Inspect for damage.
Annual	3. Low-Pressure Tanks	Check level and pressure gauges. Verify valve alignment.
	4. High-Pressure Cylinders	1. Inspect for condition and securing.
	5. Actuation System	Exercise control panel function, including zone valve operation. Inspect manual actuators for accessibility. Check times and time delay (pre-discharge).
	6. Auxiliary Equipment	1. Test to verify that interfaces (shutdown, door closers, and dampers) operate properly and are activated by the control panel.
2 Years	1. High-Pressure Cylinders	1. Verify CO_2 quantity by weighing cylinders.
As Required	1. Protected Enclosure/Room	1. Inspect the enclosure to verify integrity and ability to maintain agent concentration.
	2. After Modification to Compartment/Protected Enclosure	1. If uncertainty exists, follow the enclosure procedures in NFPA 2001.
As Part of Building Inspection	Entire System	Visually check: Pipe hangers. Nozzles for obstruction. Piping for leaks. Riser condition. Ensure: Detectors unblocked/uncovered. Panels secured and indicator lamps functional. Notification appliances in place. Manual stations in place and unobstructed. Nozzle covers in place.

Halon fire-suppression systems

The most common Halon systems in operation around the Air Force is the Halon 1301 systems. Although these were the preferred systems prior to the 1980s, these fire-suppression systems have been almost completely phased out in accordance with the Montreal Protocol of 1987. New installation of Halon 1301 systems is prohibited except by special approval because the gas was determined to be harmful to the atmosphere by depleting the ozone layer. Halon is considered a “clean agent,” which means it leaves no residual material behind that can damage sensitive equipment making it an excellent fire protection system for computers and electrical equipment.

Halon 1301 is the least toxic of all the types of Halon gas and does not harm personnel when concentrations are below 10 percent. A concentration of 5 percent is recommended for surface fires of ordinary combustibles. Most of the 1301 systems have been converted to ozone safe “clean air” systems. Inspect the “clean air’ system in accordance with UFC 3–601–2 and technical guidance on tasks is contained in NFPA 2001.

The type of equipment used for Halon fire-suppression systems is similar to that used for high-pressure CO_2 systems. Halon systems are stored in cylinders and pressurized like CO_2 systems. They use the same methods of detection and actuation in release devices, valves, check valves, trips, and switches.

Heat and/or smoke detectors are typically used to trip the system. Before actuation of the system an alarm will signal notifying occupants that the gas is about to be released.

Some Halon systems have an abort feature to avoid the unnecessary discharge of the gas when the situation is not dangerous. Systems that have an abort feature have an adjustable time delay before the gas is released. This delay gives personnel time to leave the area or use the manual abort switch to stop the release of gas.

If you do have a Halon system, you must inspect the system in accordance with UFC 3–601–2. Technical guidance on the tasks is contained in NFPA 12A. Below are the inspection frequencies.

Halon and Clean System Tasks		
Frequency	**Component**	**Tasks**
Annual	1. Piping	1. Inspect piping and nozzles for condition and orientation.
	2. Flexible Hoses	1. Inspect for damage.
	3. Storage Vessels	1. Inspect storage containers' exterior (tanks, spheres, cylinders).
	4. Agent and Propellant	1. Verify quantity of agent is sufficient. 2. Verify pressure of agent/propellant is sufficient.
	5. Actuators	1. Inspect manual actuators for accessibility. 2. Test actuation without agent release.
	6. Auxiliary Equipment	1. Test to verify interfaces (equipment shutdown, dampers, and door closers) operate properly and are activated by the system actuation.
	7. Valves	1. Verify valves in proper alignment.
5 Years	1. Cylinders	1. Complete external inspection of non-discharged cylinders to ensure suitability for use.
	2. Flexible Hoses	1. Pressure test hoses to ensure suitability for use.
2 Years (and after modifications to compartment)	1. Protected Enclosure (Room)	1. Inspect the enclosure to verify integrity and ability to maintain agent concentration.
As Part of Building Inspection	Entire System	1. Visually Check: Pipe hangers. Heads for obstruction. Piping for leaks. Riser condition 2. Ensure: Detectors unblocked/uncovered. Panels secured and indicator lamps functional. Notification appliances in place. Manual stations in place and unobstructed. Nozzle cover in place.

Dry-chemical fire-suppression systems

Dry-chemical systems are used to extinguish fires in dip tanks and other operations involving flammable liquids. The bicarbonate-based system used to be installed in commercial kitchen equipment, but UFC 3–600–01 specifically states, "Dry chemical extinguishing systems are no longer

UL listed or Factory Mutual (FM) Global approved for the protection of cooking equipment." All Air Force commercial kitchens now use the wet-chemical system.

Types of dry-chemical systems

There are three types of dry-chemical systems: (1) the total-flooding system, which is set up to discharge the agent into an enclosed space or room (fig. 1–16) and works like a CO_2 system; (2) a local-application system, which is set up to discharge the agent right onto the fire hazard (e.g., a paint dip tank); and (3) the hose-line system, which is set up to discharge the agent through a hose and nozzle to cover more than one area. The nozzle is connected by hose or by pipe and hose to a fixed supply tank.

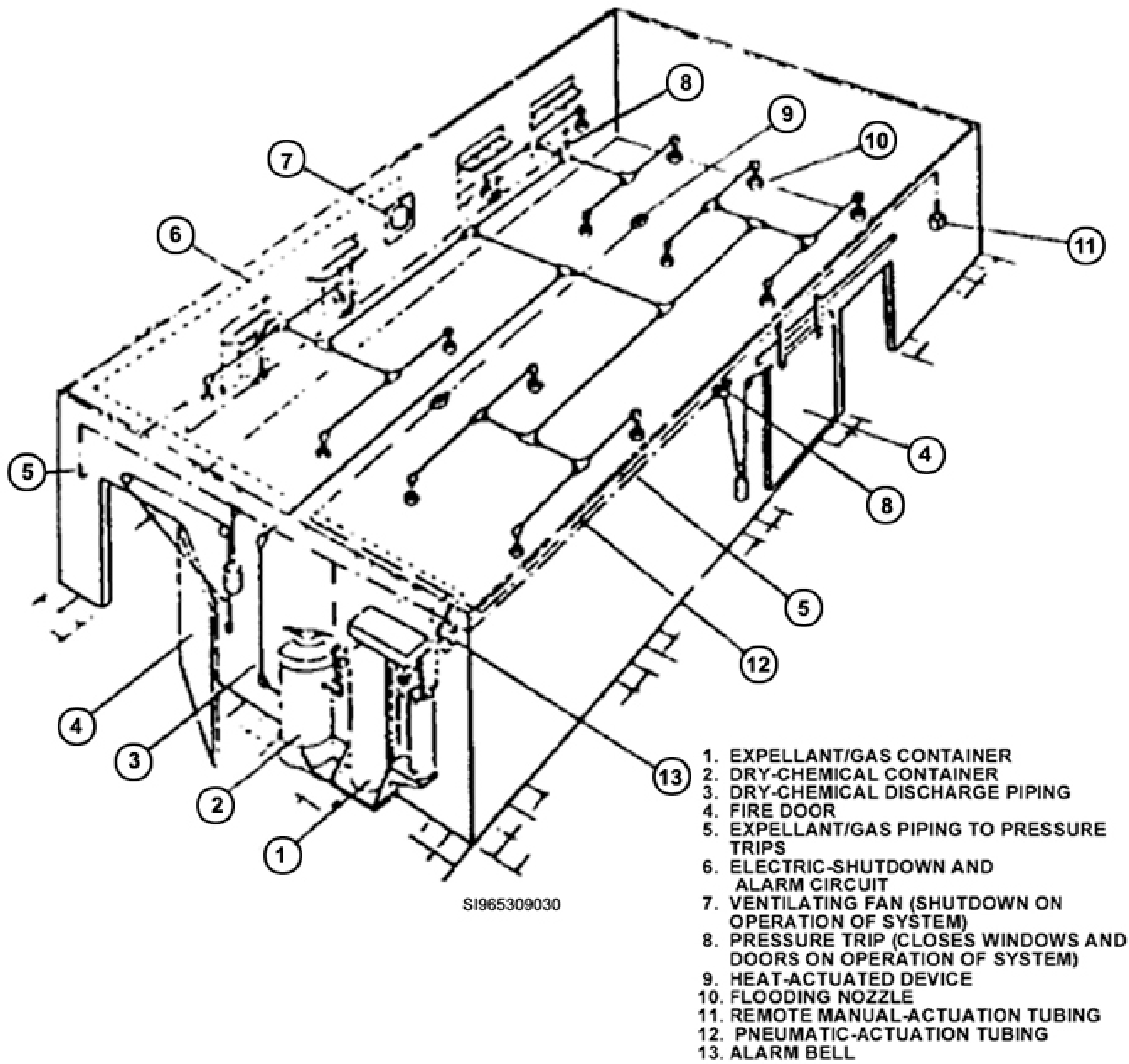


Figure 1–16. Total-flooding dry-chemical system.

System components

There are two ways to store dry chemicals. One way has the dry chemical stored in a container that is not pressurized. When the system is activated, a gas cartridge pressurizes the container and forces the agent through the pipe or hose. The second way to store a dry chemical is to place it in a container that is constantly pressurized, usually with nitrogen gas (fig. 1–17). Regardless of the method used to store the agent and gas, the operating devices, piping, and nozzles are usually the same.

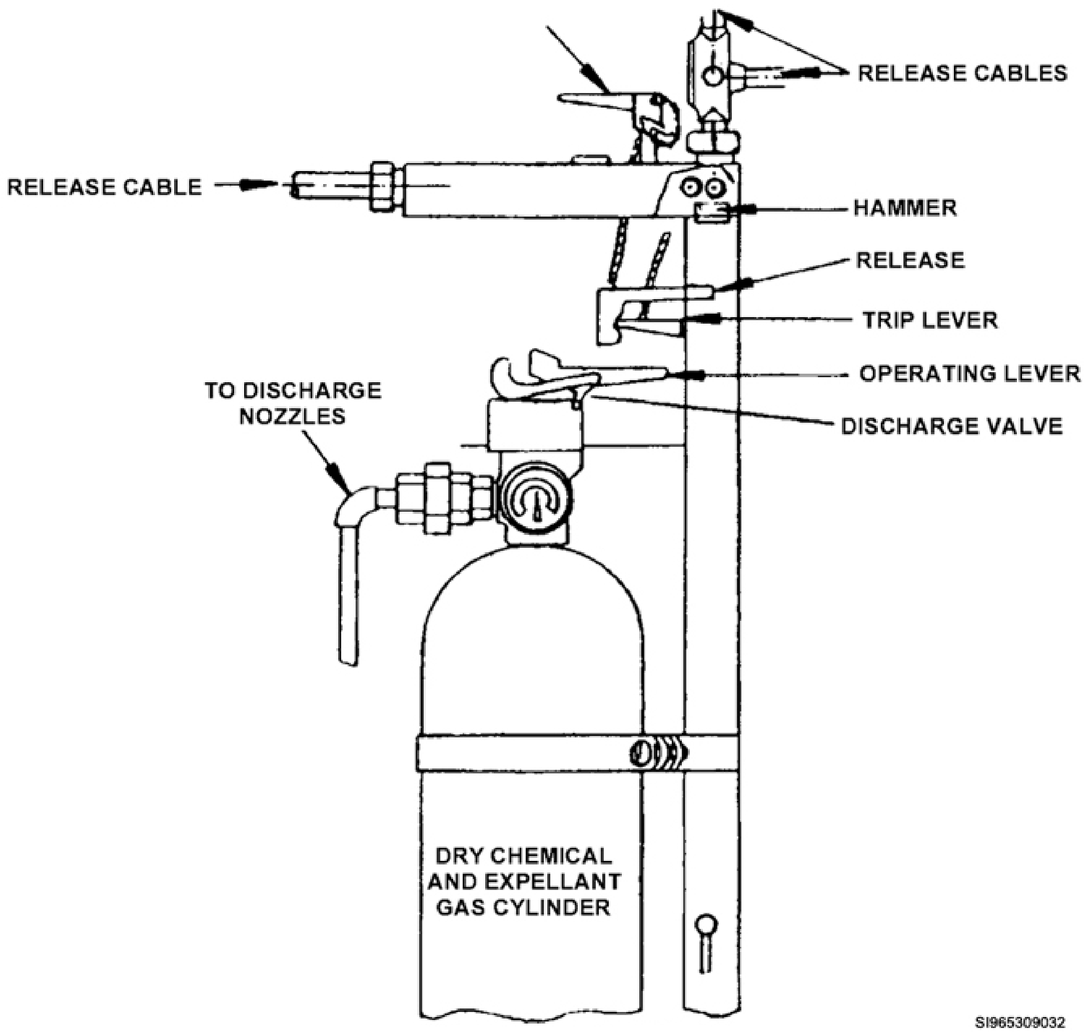


Figure 1–17. Pressured dry-chemical storage.

Operating devices

Operating devices are used to release the expellant gas (nitrogen or CO_2) from its container for the pressurization of the dry-chemical tank or to release the dry chemical if it is stored under pressure.

In fixed systems, expellant gas is released from its container for the pressurization of the dry-chemical tank or to release the dry chemical if it is stored under pressure. Expellant gas is released from its container by electrically, pneumatically, or mechanically activating the cylinder valve through the detection system or by mechanically releasing a spring that punctures the sealing disc of the gas cartridge. The dry chemical, which is stored under pressure, is released by pneumatically or mechanically actuating the discharge valve through the detection system. Hose-line systems are actuated at the cylinder by turning a hand wheel or by moving a lever.

Piping

The piping system should be made of standard weight (Schedule 40) galvanized steel pipe and standard weight galvanized steel or malleable iron fittings.

It is important that the pipe in the system is balanced to ensure pressure drop to any one nozzle is about the same as that to any other nozzle. For example, if the nozzles were installed consecutively at right angles to a straight run of pipe, the inertia of the dry chemical would carry most of it past the first nozzles. These first nozzles would discharge more gas and less dry chemical than the nozzles further down the piping system. To eliminate this, all branch piping is balanced by the use of bull heading tees. The dry chemical enters the side port and leaves through the two end ports.

Dry- and wet-chemical system maintenance is identical, and to properly maintain your system, follow the manufacturer's recommendations and UFC 3–601–02. The following inspection table comes directly from UFC 3–601–02.

Dry and Wet-Chemical Systems Tasks		
Frequency	**Component**	**Tasks**
Semi-Annual	1. Piping	1. Inspect piping for obstructions and proper support.
	2. Storage Vessels	1. Inspect agent container for condition. 2. Verify storage pressure of propellant.
	3. Agent	1. Verify quantity and quality of agent.
	4. Actuators	1. Inspect manual actuators for accessibility. 2. Inspect detection devices (fusible links or heat detectors) for contamination, and clean. 3. Test actuation system without agent release. 4. Verify interfaces (gas shutoff, power shutoff) operate properly.
Annual	1. Actuators	1. Replace detection devices (fusible links or heat detectors)
5–12 Years	1. Storage Vessels	1. Conduct hydrostatic test for pressure cylinders in accordance with Occupational Safety and Health Administration (OSHA) and Department of Transportation (DOT) standards.
As Part of Building Inspection	Entire System	1. Visually check: Pipe hangers. Heads for obstruction. Riser condition. 2. Ensure: Detectors unblocked/uncovered. Panels secured and indicator lamps functional. Notification appliances in place. Manual stations in place and unobstructed. Nozzle cover in place.

Wet-chemical fire-suppression system

The wet-chemical fire-suppression system is designed to protect commercial kitchen appliances and other flammable liquid hazards where rapid-fire knockdown is required and re-ignition is unlikely to occur. The wet-chemical agent is composed of a solution of water and potassium carbonate or potassium acetate. The agent is delivered in a fine spray and is an effective extinguishing agent for flammable liquids involving grease and oil.

As stated in the dry-chemical section, the wet-chemical system replaced the dry-chemical application (fig. 1–18) in all Air Force commercial kitchen applications according to UFC 3–600–01. The functional elements of the wet-chemical system is virtually identical to the dry-chemical system. They both use the same type of detection and release methods; the wet system's main difference is in its application. The wet-chemical system is specifically designed to protect small kitchen appliances and flammable liquids and is not used for total-flooding applications. Maintenance and inspection of both systems are identical according to the UFC 3–601–2 task for monthly, annual, and 5–12 years and as part of the building inspection.

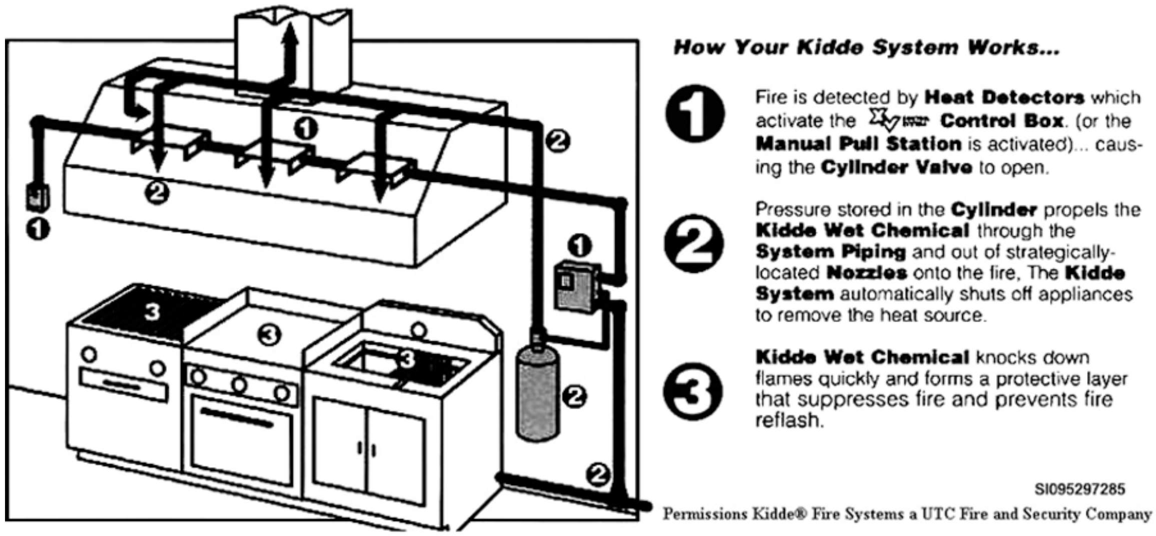


Figure 1–18. Kidde wet-chemical system.

Always remember to strictly follow the manufacturer's instructions when maintaining any dry, wet, deluge, foam, CO_2, Halon, or wet/dry chemical fire protection system. The NFPA and UFC provides specific guidance for inspection and maintenance of these systems. Always maintain detailed inspection logs to verify the required inspection and maintenance actions are completed.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

601. Wet-pipe systems

1. What types of heads are used in a wet-pipe sprinkler system?

2. How do you bleed air off the wet-pipe system when restoring it to service?

3. What is the first thing that you should do before and after working on any fire-suppression system?

4. When conducting a drain flow test, what does a pressure drop of 10–20 percent above the established readings indicate?

5. How much clearance is needed under all heads?

6. According to the NFPA, how many replacement sprinkler heads minimum must you have on hand, as a minimum, for a system with less than 300 sprinkler heads?

7. How far back from the full open position should you keep the PIV?

602. Dry-pipe sprinklers

1. What is used in a dry-pipe sprinkler system to keep the clapper seated?

2. What is the ratio in surface seat area of the differential type dry-pipe clapper valve?

3. What is required in large systems that have a capacity of over 500 gallons?

4. What are the two types of quick-opening devices?

5. How do you prevent dry-pipe clapper valves from accidently tripping due to pressure surges?

603. Deluge and foam systems

1. Where are deluge systems normally installed?

2. Explain the operation of HADs?

3. What is used in explosive atmospheres to test the operation of the HADs?

4. What is the advantage of the foam system over a deluge system?

5. What are the two parts of a foam system?

6. Why does the system need flushing after activation or testing?

604. Special extinguishing systems

1. What methods are used to store CO_2?

2. When should the liquid-level gauge on a low-pressure CO_2 system be checked?

3. Which type of Halon was commonly used in Air Force systems?

4. What type of fire is a dry-chemical system primarily used to extinguish?

5. Where would a total-flooding dry-chemical system be installed?

6. What fire protection system replaced the dry-chemical system for protection of commercial kitchens?

7. Which UFC governs the maintenance and inspection procedures for the wet- and dry-chemical systems?

1–2. Backflow Prevention

Potable water is the most precious commodity on earth and is quickly becoming less and less abundant. It is our responsibility to protect these sources of water from contamination and pollution. As mechanics whose job is to install and maintain water systems, we must identify and correct conditions of cross-connections, both actual and potential.

605. Principles

The following key terms and definitions will help you understand the principles of backflow prevention.

Backflow

Backflow is defined as the flow of water or other liquids, mixtures, or substances into the distributing pipes of a potable supply of water from any sources other than its intended source. The two types of backflow are backsiphonage and backpressure.

Backsiphonage

Backsiphonage is the flowing back of used, contaminated, or polluted water from a plumbing fixture or vessel into a water supply pipe due to a negative pressure in such pipe. An example of this negative pressure is a child drinking a malt with a straw. The child “draws” on the straw and the malt flows up the straw and into the child’s mouth. What the child is actually doing is creating a negative pressure in his mouth and the atmospheric pressure (14.7 psi at sea level) is pushing down on the surface of the malt and forcing the malt up the straw and into the child’s mouth.

Backpressure

Backpressure is caused by an increased pressure above the supply pressure. This may be due to pumps, boilers, gravity, or other sources of pressure. An example of this would be a steam-heating system with the make-up water line piped directly into the boiler. The higher pressure in the boiler could force the chemically treated boiler water back through the make-up water line and into the potable water system.

Cross-connection

Cross-connection is any connection or arrangement (physical or otherwise) between a potable water supply system and any plumbing fixture or any tank, receptacle, equipment, or device, through which it may be possible for non-potable, used, unclean, polluted, and contaminated water, or other substances, to enter into any part of such potable water system under any condition. Bypass arrangements, jumper connections, removable sections, swivel or changeover devices, and other permanent or temporary devices through which, or because of which, backflow can or may occur are considered to be cross-connections. The two types are direct (actual) and indirect (potential).

Direct (actual) cross-connection

This type of cross-connection is a direct link between the potable and non-potable water lines. The piping connected by the utilities specialist during construction of the water system makes this type of cross-connection a direct connection.

Indirect (potential) cross-connection

This type of cross-connection is also a link between the potable and non-potable water lines. What makes this type cross-connection a potential one? The conditions have to be just right for backflow condition to occur. An example being a hose attached to the end of a faucet extending the end of the water line passed the overflow rim, thus creating a cross-connection. The water pressure on the supply side of the faucet would have to create a vacuum, which would cause the wastewater to be “sucked” into the supply line, making the potable water polluted. This vacuum could occur due to a water break.

Hazardous substances

Any substance that is dangerous to the health of the consumer is considered a hazardous substance. There are two types of hazardous substances—pollution and contamination.

Pollution

Pollution means an impairment of the quality of the potable water to a degree, which does not create a hazard to the public health but does adversely and unreasonably affect the aesthetic qualities (taste, odor, color) of such potable waters for domestic use. Pollution is also defined as a ***low hazard***.

Contamination

Contamination means an impairment of the quality of the water, which creates an actual hazard to the public health through poisoning, or through the spread of disease by sewage, industrial fluids, or other waste. Contamination is also defined as a ***high hazard***.

Documentation

Record keeping is an important part of any recurring maintenance program. Records provide an accurate history of events and are helpful in future repairs. Keeping your records up to date will help you in planning and managing your backflow program. Four different forms are used to ensure an accurate account of your program. You can access the appropriate forms using the website (https://www.e-publishing.af.mil). Technicians may also use state-mandated forms, the Automated Civil Engineer System Program Management (ACES-PM) module, or another computerized maintenance management system (CMMS) approved by the base backflow prevention manager. These forms are explained in the table that follows:

Form Number	Title	Use
AF Form 848	Inventory of Cross-Connection Control and Backflow Prevention Devices	Used to inventory and list every backflow device on an installation.
AF Form 843	Backflow Prevention Inspection Data	Used for documenting all inspection data on pressure vacuum breakers (PVB), double-check valve assemblies and reduced-pressure principle devices (all spring-loaded devices). Use one form per device.
AF Information Management Tool (IMT) 845	Cross-Connection Information	Used to sketch the exact location of all devices.

606. Air gap and atmospheric vacuum breakers

Two things that protect against backsiphonage (but not backpressure) are the air gap and atmospheric vacuum breaker (AVB). Let's first look at the air gap.

Air gaps

An air gap is the physical distance between the water outlet and maximum water level or flooding rim of a fixture to which it serves.

Figure 1–19 shows an air gap. This device protects only against backsiphonage (not backpressure). It is the most positive (non-mechanical) device against backflow. Use an air gap whenever possible. The vertical space between the supply line and the flood level rim must be at least two times the diameter of the supply pipe. It can never be less than 1 inch. This means that if the supply pipe is 2 inches in diameter, then the air gap must be at least 4 inches. When a supply is moveable and can swing against a vertical surface, the distance must be three times the diameter of the supply pipe. Use an air gap on an open or non-pressure receiving vessel. Air gaps protect against low- and high-degree hazards.

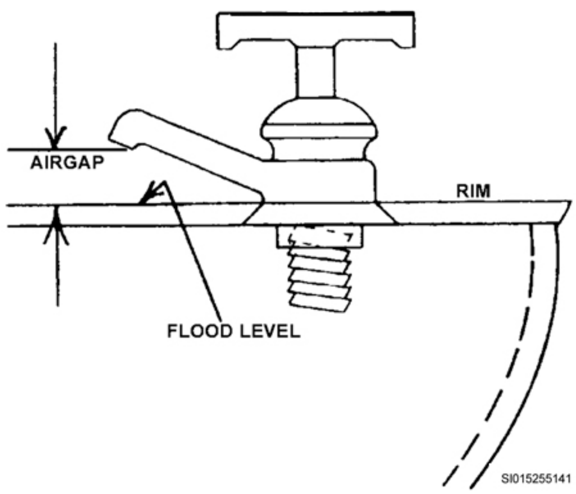


Figure 1–19. Air gap as applied to water supply.

An air gap only requires limited maintenance since there are no moving parts. The biggest problem that arises with an air gap is when the end user extends the supply pipe below the flood level rim with a hose. Simply remove the hose attachment, thus restoring the air gap.

AVB

The AVB (fig. 1–20) is another device that protects against backsiphonage (but not backpressure). It protects against low- and high-degree hazards. This device has a moving poppet that floats to the top of the body during flow conditions and stops water from spilling from the device. When the flow of water stops, the poppet/disk float drops down providing a vent opening to the atmosphere. This prevents a vacuum from occurring on the discharge line by allowing air to enter the line. This device must be installed on the discharge side of the last control valve and 6 inches above the highest usage point. Do ***not*** use this device for more than 12 hours under continuous pressure or subject it to backpressure conditions. (**NOTE:** "Continuous pressure" is a term that is applied to an installation in which the pressure is supplied continuously to a backflow-prevention device for a period over 12 hours.)

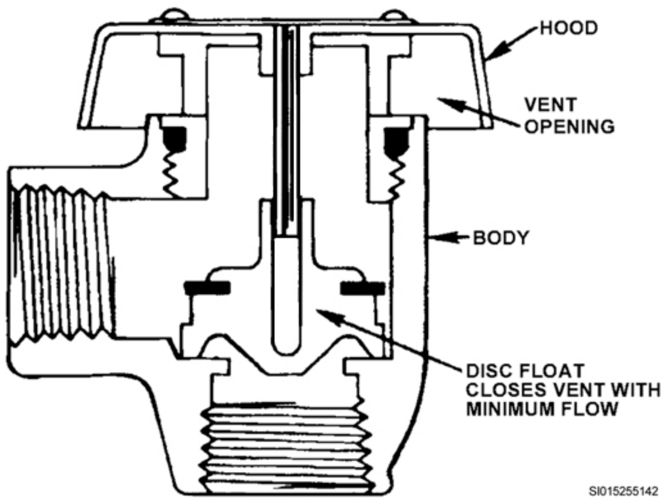


Figure 1–20. Atmospheric vacuum breaker.

Installation

In order for an AVB to work correctly, it must be properly located. Place the bottom of the vacuum breaker body at least 6 inches above the overflow rim of the fixture
(figs. 1–21 and 1–22).

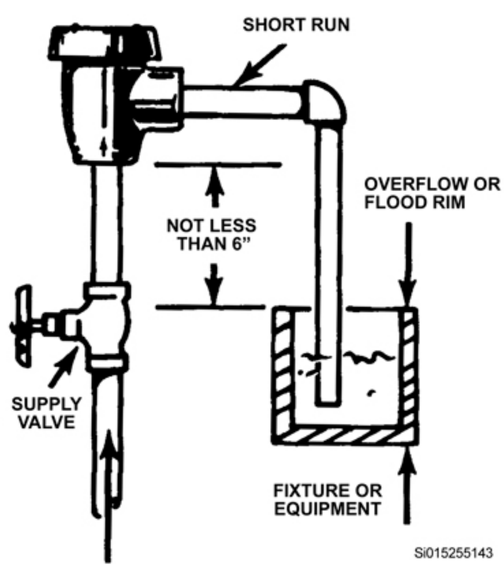


Figure 1–21. AVB location.

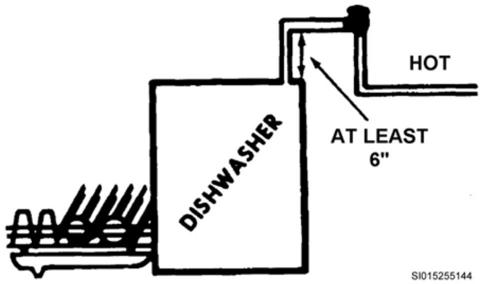


Figure 1–22. AVB for dishwashers.

Inspection

To do this inspection, first remove the hood from the top of the body. Then turn the water on. Check to see that the disc float comes up and seals the vent opening. No water should leak out the top. Next, turn the water off. The poppet should drop back down to open the atmospheric vent. If the poppet/disc float works correctly, then the AVB is okay. Replace the hood on the body, and the inspection is complete. If the poppet did not work correctly, repair or replace the device.

Maintenance and repair

There are many different makes of AVBs. Most of them are similar in design and the way they work. However, the names of the parts can differ from one manufacturer to another.

A parts breakdown is shown in figure 1–23. Use it as you go over the maintenance procedures for a vacuum breaker. First, shut off the water to the breaker. Use a wrench to remove the bonnet from the body. (**NOTE:** You may have to use a backup wrench to keep from damaging the pipes.) Take the poppet off the guide pin. Check the guide pin and the bonnet seat for damage or debris. Wipe the guide pin and bonnet seat clean with a rag. Smooth the rough spots with fine emery cloth.

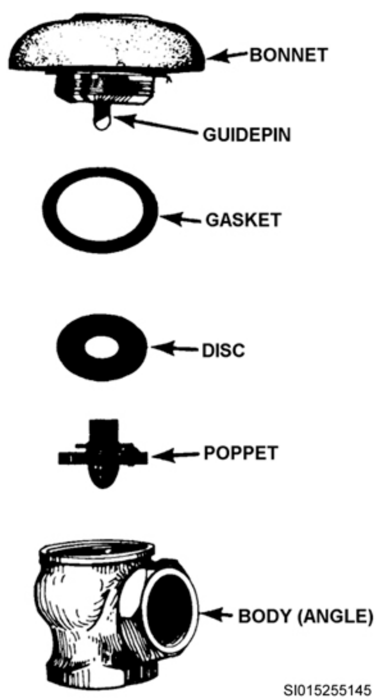


Figure 1–23. Breakdown of an atmospheric vacuum breaker.

To check the guide pin for correct alignment, hold the bonnet in your hand and place the poppet/disk float on the guide pin. Compare the overhang of the poppet disc on the bonnet seat. If the space is even all the way around, the guide pin is centered. If not, remove the poppet/disk float and tap the guide pin in the direction needed to center the guide pin with a plastic-tipped hammer. If the guide pin cannot be centered or if there are rough spots on the seat that cannot be smoothed, replace the bonnet. Replace the poppet/disk float and disc if they are damaged or if the poppet does not move freely on the guide pin. Before you reassemble the breaker, rinse all parts with clean water. Never apply pipe dope, grease, or solvent.

607. Pressure vacuum breaker

The PVB is a device that protects against backsiphonage (but not backpressure). It protects against low- and high-degree hazards and can be used under continuous pressure over 12 hours. This device has a moving, spring-loaded poppet and check valve in the body. Both springs have a tension of 1 psi. A gate valve is on both the inlet and the outlet of the body. The body also has two test cocks. When the supply line pressure drops to 1 psi or below, the spring-loaded poppet drops, thus opening the atmospheric vent. At the same time, the spring-loaded check valve closes the inlet. This prevents a vacuum from occurring on the discharge line; therefore, there is no backsiphonage.

During the normal operation of the device, the flow of water through the device pushes open the check valve. The flow also lifts the poppet, which closes the atmospheric vent preventing leakage. This device must be installed 12 inches above the overflow level of the system being supplied.

Installation

The PVB is installed and located in much the same way as the atmospheric type (fig. 1–24). However, it must be installed at least 12 inches above the overflow rim of the equipment served. In addition, it can be used in a continuous pressure system. Locate it for easy accessibility and where water spillage causes no problems.

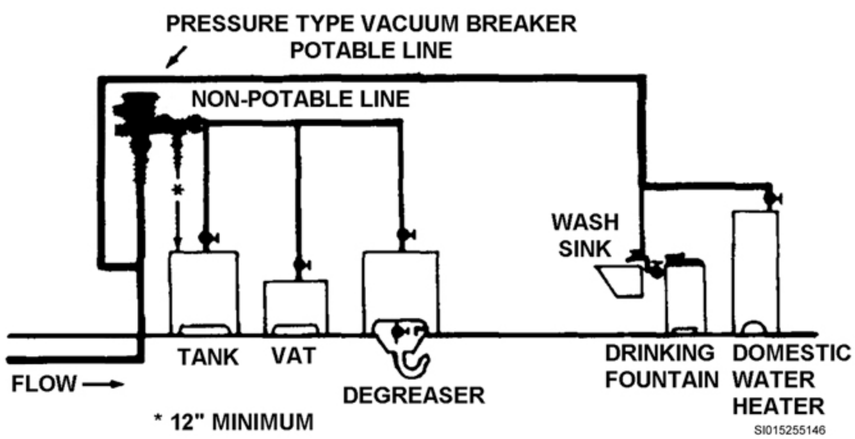


Figure 1–24. Pressure vacuum breaker location.

Inspection and testing

Select an approved tester and follow the manufacturer's testing instructions carefully. A backflow-prevention device may only be put back into service if it tests properly. After the test is completed, document your test results on the proper form (fig. 1–25).

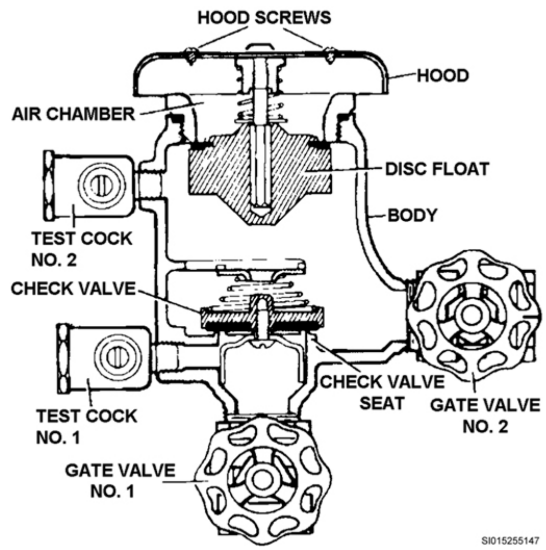


Figure 1–25. Pressure vacuum breaker.

Maintenance and repair

The following steps are only an example for maintaining one type of PVB. As devices vary from one manufacturer to another, so do the steps for maintaining them. The information here will provide you with an idea of the steps involved.

Preparation

The first step is to close the outlet-isolation valve, then close the inlet-isolation valve. Open test cock #2 to bleed the residual pressure. Next, remove the canopy nut and canopy. Unscrew the bonnet assembly from the body by hand. If it does not come loose by hand, gently use a wrench that will not mar or damage any parts. If the bonnet is damaged, replace it. Remove the poppet and disc assembly from the body. If they are damaged or worn, replace them with new parts.

Bonnet assembly

Next, check the bonnet assembly. If the spring is damaged, replace it. Do this by unscrewing the stem from the bonnet. The spring can now be removed and replaced. While the stem is removed from the bonnet, check it for rough spots or damage. You can smooth the rough spots with fine emery cloth. If the stem is damaged, replace it. Smooth any rough spots on the bonnet seats at this time with fine emery cloth. Put the bonnet assembly back together. Place the poppet on the stem and push it up against the bonnet seat with your hand. The spring should push the poppet away from the seat as you move your hand away from the seat. If this happens, the poppet and bonnet are repaired. At this time, remove the check valve from the body.

Check valve removal

To remove the check valve from the body, evenly depress the retainer about ¼ inch and rotate it 90°. The check assembly is now removed from the body. A worn check assembly disc can be replaced by removing the screw that holds the guide in place and lifting the disc out of its holder. Be careful not to damage the guide legs or the guide pin of the holder. Replace them if they are damaged. Place a new disc into the holder and position the guide in the center of the disc. Thread the screw through the guide and into the holder. Be sure to tighten the screw only enough to keep the guide from turning. Over tightening may damage or distort the guide legs. The only remaining areas to check are the check valve spring and seat. If the spring is damaged or distorted, replace it. If the seat is damaged, replace the whole device. Be sure to rinse all the parts with clean water before reassembling the device.

Reassembly

To reassemble the device, place the check assembly in the body. Position the spring into the recessed area on top of the check assembly. Reinstall the retainer, making sure the spring is centered around the raised area of the retainer. Remember to give the retainer a 90° turn after you push it into place. Put the poppet into the body. Place the O-ring on the bonnet and start the bonnet into the body. As you do so, make sure that the stem enters the hole in the poppet. Screw the bonnet down hand-tight until the bonnet flange comes in contact with the top surface of the body. Put the canopy on the bonnet and tighten the nut only until the canopy does not turn freely.

Restoration

Put the breaker back into service by rapidly opening the inlet-isolation valve. This is done to reduce spillage through the air vent. Next, slowly open the outlet-isolation valve. Finally, test the breaker to make sure it is working properly.

608. Double-check valve assembly

The double-check valve is a device that is used in direct-connection-type systems to prevent the backflow of non-toxic substances into the potable water supply. It is not to be used to protect against high-degree hazards. This is because this device shows no visual signs of malfunction. It can be used in continuous-pressure systems that are subject to backpressure or backsiphonage. This device has two independently operating, spring-loaded check valves rated at 1 psi. There is a gate valve on both the inlet and the outlet of the body. The device also has four test cocks on it. The spring-loaded check valves close tightly when the water pressure flowing through the device drops below 1 psi or when a reversal of flow occurs. If one check valve fails to close, it does not affect the operation of the other check valve, which still closes tightly. (**NOTE:** Do not use the double-check valve to protect the potable water supply from toxic substances.)

Installation

The following text gives you the basic procedures for locating double-check valves and reduced-pressure backflow preventers. Before you install them, check the manufacturer's instructions and local codes.

A double-check valve may be installed in either a vertical or a horizontal position. Locate the valves in an accessible position so that testing and servicing can be done. In an area where freezing is not a problem, locate the double-check valve outside. The best place is from 12 to 30 inches above the ground (fig. 1–26). Do *not* place the double-check valve in a pit unless it is absolutely necessary and only when it is approved by local codes. The test cock side of the double-check valve assembly (DCVA) *should* be located at least 24 inches away from the wall and allow at least 12 inches on the non-test cock side. This will provide sufficient room to test and maintain the preventer. If the valve is located in a building, allow at least the same amount of space as you would for an outside location.

Inspection

Double-check valves have to be inspected to make sure that they work correctly. These procedures cover two tests that you may perform on double-check valves.

Test one

Check valves #1 and #2 must be tested to ensure that they hold tight against 1 psi in the direction of flow. Select an approved backflow tester and read the manufacturer's testing instructions carefully. Record your test results on the proper AF form.

Test two

In the second test, both check valves must hold tightly against reverse flow. Again, select an approved tester, and read the manufacturer's testing instructions carefully. After test two is complete, annotate your results on the proper AF form.

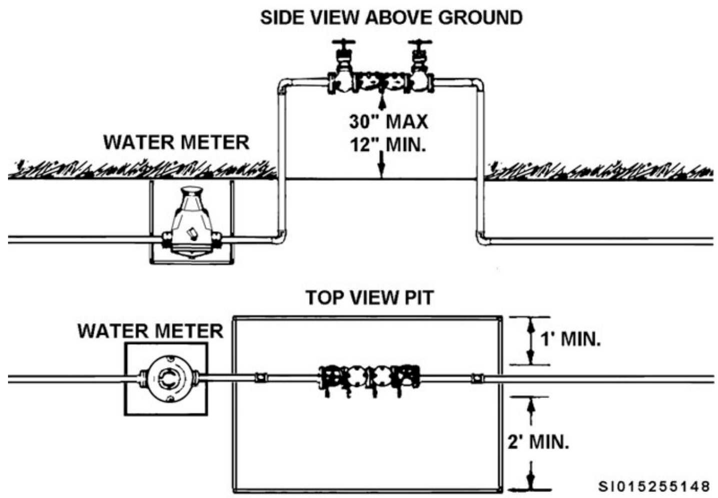


Figure 1–26. Double-check valve location.

Maintenance and repair

Like other backflow preventers, double-check valves have to be properly maintained so that they work properly. Since the two check valves in the device are identical, we cover the maintenance procedures of only one of them.

Preparation

Figure 1–27 shows the parts breakdown of one type of device. Use this figure as you go over the maintenance procedures. Start by shutting off both the inlet and outlet-isolation valves. Bleed the residual pressure by opening test cocks #2, #3, and #4. Remove bolts that hold down the check valve cover. Next, remove the cover and O-ring. You can now lift out the first check module and O-ring.

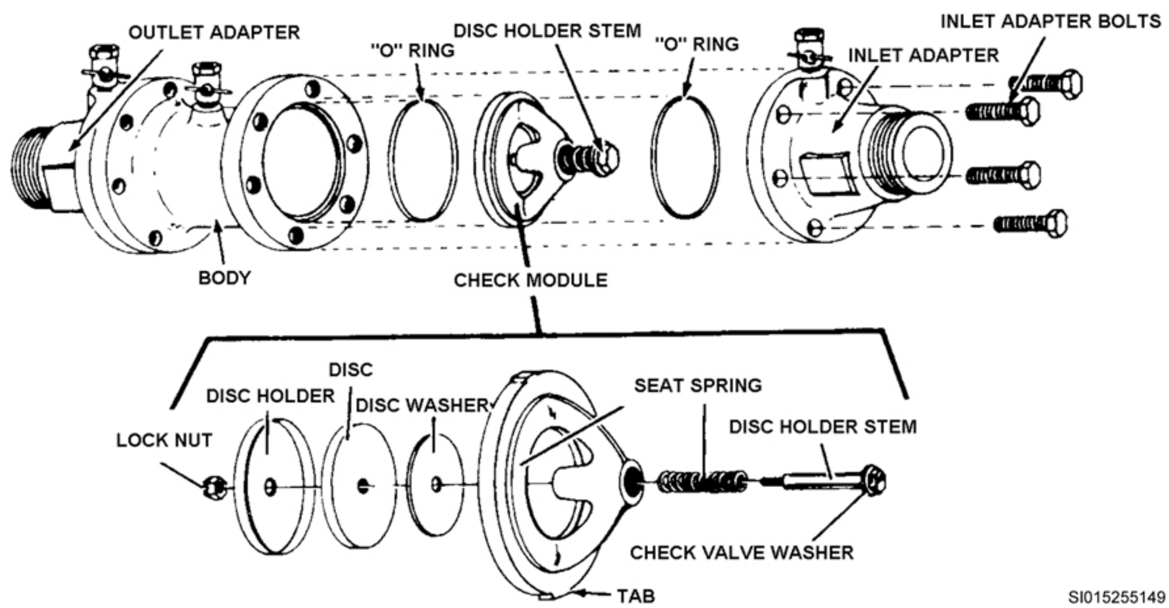


Figure 1–27. Double-check valve.

Disc

Expose the disc for inspection by putting pressure on the disc holder stem to overcome the spring tension. Wipe off the disc and seat and check for wear or damage. If either exists, take the check module apart. Do this by removing the locknut while you maintain pressure on the disc holder stem. Use the correct size open-end or box-end wrenches so that no damage is done to the nut or stem. Remove the disc from the stem at this time. Slide the disc holder stem and spring out of the seat casing, and check them for damage. Replace them with new parts if necessary. Smooth any rough spots on the seat with fine emery cloth that you spread over a flat tool.

To replace the disc and reassemble the check module, first place the check-valve washer and spring on the stem. Next place the seat casing over the stem. Push it down to compress the spring until the stem projects beyond the seat ring. Now place the disc washer on the stem. Follow this by placing the disc holder on the stem with a new rubber disc. Then thread the locknut onto the stem. Hold the head of the stem while you securely tighten the locknut. Make sure that you use the correct size wrenches. The check module is now ready to be put back in the body.

O-ring

Place an O-ring on the check module and position it in the body. (**NOTE:** Tabs on the check module prevent misassembly of the check module in relation to the direction of flow. The spring end of the module is out of the body on the inlet end.) Place an O-ring over the check module and against the body. Now place the inlet adapter on the check module. Insert the adapter bolts and tighten them using the correct size wrench.

To remove the second check-valve assembly, remove the outlet adapter bolts. The maintenance procedures are the same. When you reassemble the second check valve, put the spring end of the check module in the body.

Restoration

Place the double-check valve back in service by reinstalling it in the line and tightening the unions. Open the inlet-isolation valve and then the outlet-isolation valve. Bleed any air out of the device through the test cocks. Now test the double-check valve to make sure it is working okay.

Use these maintenance procedures only if they apply to the type of double-check valve you are working on. If not, get the correct service manual from your supervisor or have it ordered from the manufacturer.

609. Reduced-pressure principle devices

The reduced-pressure principle device may be used on all direct-connection-type systems to prevent the backflow of low- and high-hazard substances into the potable water supply. This device is used in continuous-pressure systems that are subject to backpressure or backsiphonage. It is the most positive (mechanical) device against backflow. It has two independently operating spring-loaded check valves. The spring tension of check valve #1 is rated at a range of 5–8 psi. The spring tension for check valve #2 is rated at a range of 1–2 psi. A pressure-differential relief valve is located in a reduced-pressure zone between the two check valves and has a spring tension of at least 2 psi. Isolation valves are located on both the inlet and the outlet of the body along with four test cocks. The isolation valves are considered part of the device. During the normal operation of this device, both check valves are open and the relief valve is closed.

Installation

Install and locate the reduced-pressure principle device in the same way as the double-check valve. Figure 1–28 shows the proper location of the device in a building or a pit.

NOTE: A floor drain must be installed in these locations.

Notice that the relief valve opening is located at least 12 inches above the floor drain. A positive drain must be provided. Never solidly pipe the relief valve to a drainage ditch or a floor drain. Maintain an air gap.

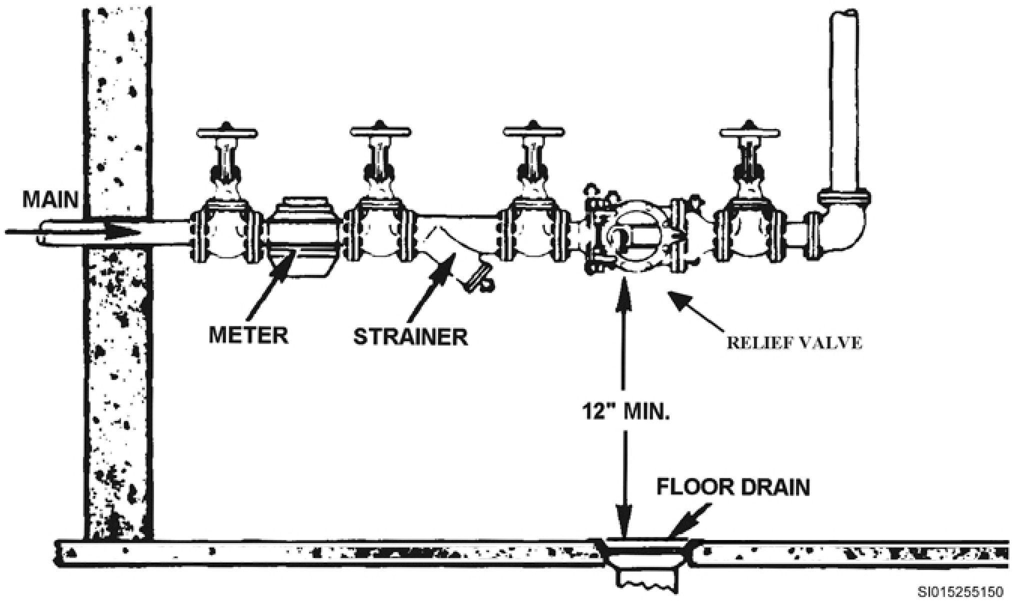


Figure 1–28. Reduced-pressure principle device located in a building or pit.

The opening on the relief valve must be easily seen so that problems can be detected. Figures 1–29 and 1–30 show some typical locations for reduced-pressure principle devices in relation to equipment.

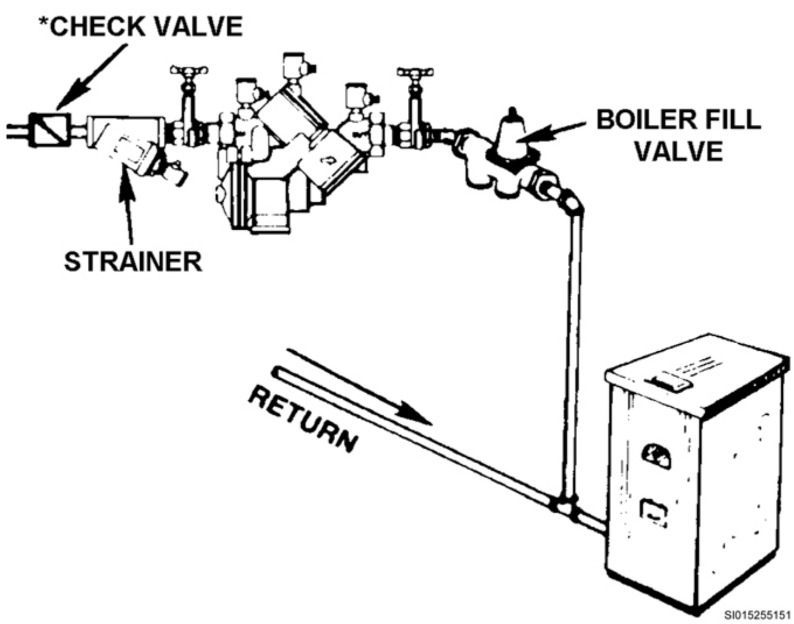


Figure 1–29. Reduced-pressure principle device.

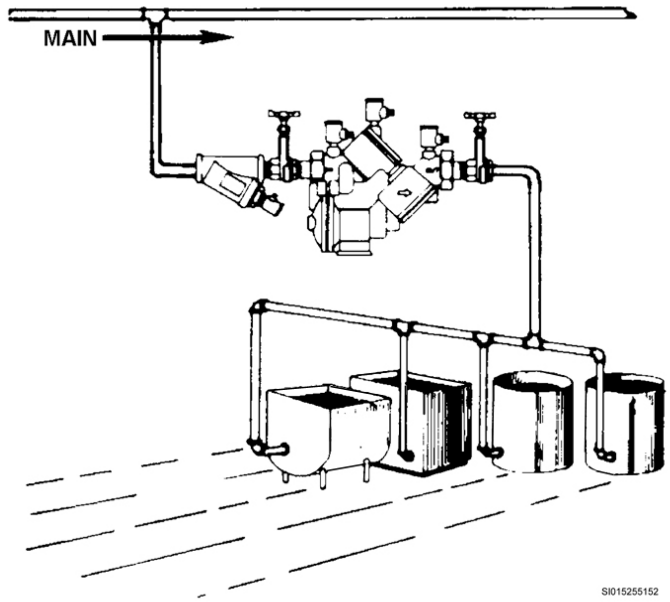


Figure 1–30. Reduced-pressure principle device to chemical tanks.

Inspection

Inspect reduced-pressure principle devices to make sure they work correctly. There are three tests conducted on the reduced-pressure device. Remember, a reduced-pressure principle device consists of two shut-off valves, two spring-loaded check valves, and a spring-loaded relief valve.

Test one

The purpose of this first test is to check the operation of the pressure-differential relief valve. Select an approved tester and read the testing instructions carefully. When the test is complete, record your results on the proper AF form.

Test two

The purpose of test two is to test check valve #2 for tightness against reverse flow. Select an approved tester and read the manufacturer’s testing instructions carefully. Record results on the proper AF form.

Test three

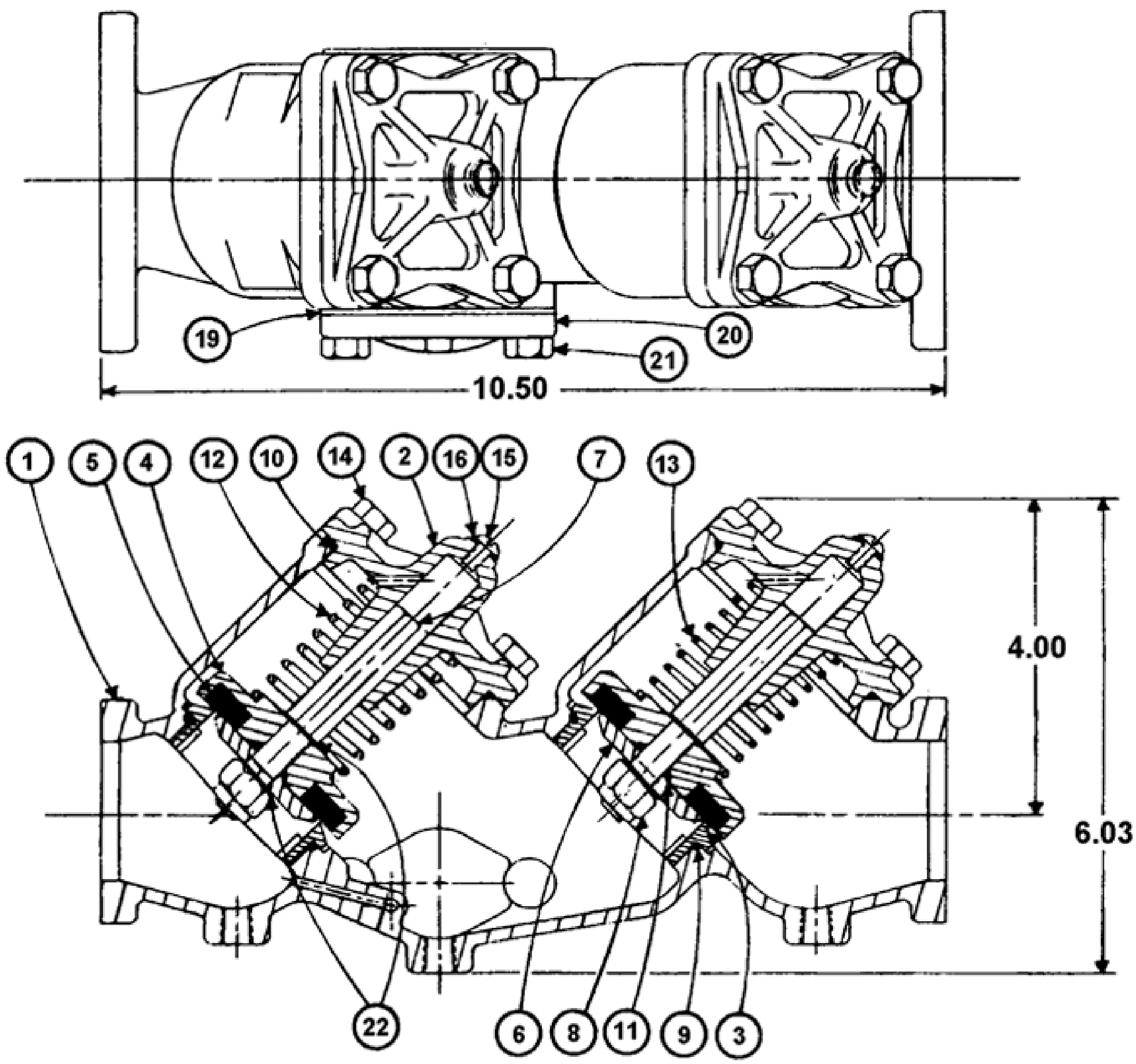
The purpose of test three is to determine the static pressure drop across check valve #1. Again, select an approved tester and carefully read the manufacturer’s testing instructions. When test three is completed, record the results on the proper AF form.

Maintenance and repair

There are two areas on a reduced-pressure principle device you must maintain. One is the check valves and the other is the relief valve.

Check valves

Most devices have two independently acting internally loaded check valves that are located in one body. The parts of both check valves are the same and interchangeable with one exception. In some larger models of backflow preventers, check valve #1 has a HEAVY, green-colored spring while check valve #2 has a LIGHTER, orange-colored spring. The heavy spring in the #1 check valve establishes a sufficient pressure differential across the #1 check valve. This is necessary to ensure that the pressure-differential relief valve can maintain the pressure in the zone between the two check valves at least 2 psi less than the inlet pressure.



ITEM NO.	PARTS LIST DESCRIPTION	D QTY REQD	RP QTY REQD
1	BODY	1	1
2	COVER	2	2
3	SEAT	2	2
4	RETAINER, DISC	2	2
5	DISC	2	2
6	GUIDE, DISC	2	2
7	STEM	2	2
8	NUT, SELF-LOCKING	2	2
9	O-RING, SEAT	2	2
10	O-RING, COVER	2	2
11	O-RING, STEM	2	2

ITEM NO.	PARTS LIST DESCRIPTION	D QTY REQD	RP QTY REQD
12	SPRING, #1 CHECK	1	1
13	SPRING, #2 CHECK	1	1
14	BOLT, HEX HEAD	8	8
15	SCREW, ROUND HEAD	2	2
16	WASHER	2	2
17			
18			
19	GASKET (D-2 ONLY)	1	
20	COVER, FLANGE (D-2 ONLY)	1	
21	BOLT, HEX HEAD (D-2 ONLY)	2	
22	WASHER	4	4

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Figure 1–31. Check valve parts breakdown.

Preparation

Use the parts breakdown shown in figure 1–31 as you go over the maintenance procedures. Start by shutting off both the inlet- and outlet-isolated valves. Bleed the residual pressure by opening test cocks #2, #3, and #4. You are now ready to take check valve #1 apart. Do this by removing the four bolts from the cover. The spring tension should force the cover out of the recess in the upper part of the check-valve body. If the cover does not come out, tap it lightly with a brass or plastic-tipped hammer until it is accessible. Check the cover O-ring for evidence of pinching or damage. Replace it if necessary. Lift the spring out of check valve #1.

Poppet disassembly

Now lift out the poppet assembly. It consists of the disc retainer, disc, disc guide, stem, stem nut, stem O-ring, and fiber washer. Check all the parts for wear or scale buildup and clean or replace as needed. To replace the parts of the poppet assembly, use a vise with jaws of brass or some other soft material to hold the stem. Place the stem in the vise with the disc retainer as close to the jaws as possible. Make sure that you do not damage the stem because it has to go up into the stem guide of the cover. Now use the proper size wrench to remove the stem nut. Remove and replace any parts that need replacement at this time.

With the poppet out of the body, check the seat for damage. Polish out small nicks on the inside of the seat with very fine emery cloth. Do not polish the seating area; the beveled area of the seat is CRITICAL and should not be disturbed. Replace the seat and seat O-ring if the seating area is damaged. Use only the correct size seat-removing tool.

Poppet reassembly

Reassemble the poppet check valve in reverse order from the way you took it apart. Make sure that the HEAVY spring is placed in check valve #1 during reassembly. Place an O-ring on the cover and start the cover into the body. The poppet stem must enter the cover stem guide as the cover is pushed down on the body. Hold the cover down as you start the four bolts by hand. Finish tightening the bolts with the proper size wrench. Alternate from side to side until the bolts are tight. Test the check valve after you complete all work on the device. The procedures for maintaining check valve #2 are the same as for #1. However, remember the LIGHTER spring goes in check valve #2.

Relief valve

These maintenance procedures are for the relief valve that is part of the backflow preventer. Figure 1–32 shows a parts breakdown of a relief valve. As when you worked on the check valves, turn the water off and bleed the residual pressure before you work on the relief valve. The following procedures cover the disassembly of the unit.

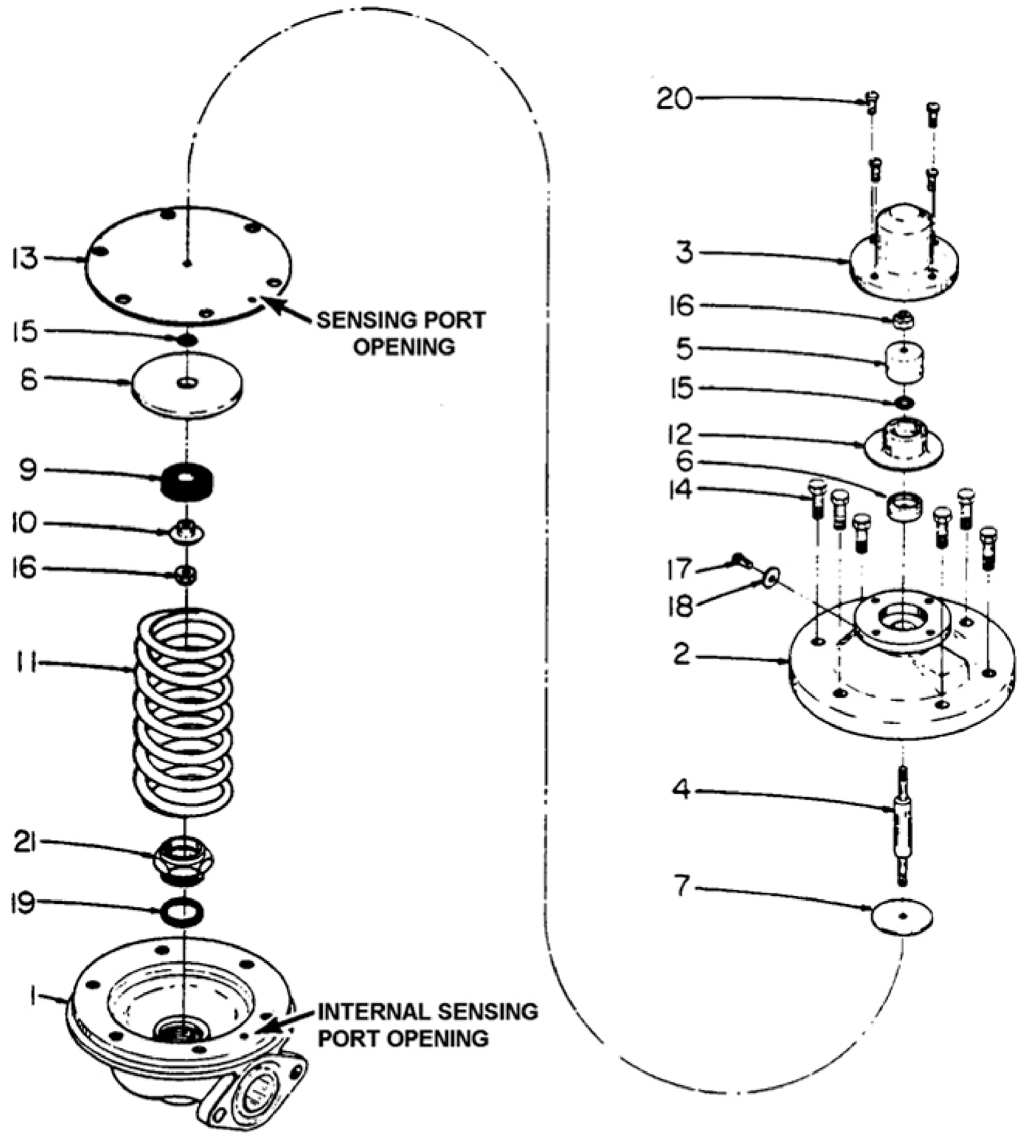
Preparation

Remove the cover by taking out the four cover screws. Next, remove the intermediate body. Use the correct size wrench to remove all of the body hex-head screws except for two. Leave these two on opposite sides of the bolt circle. While you exert pressure downward on the intermediate body to prevent the forcible ejection of the intermediate body by the spring, remove the two remaining hex-head screws and remove the intermediate body.

Intermediate body

Examine the intermediate body assembly closely, paying particular attention to the condition of the Bellofram (rolling diaphragm) or diaphragm. Inspect for small pinholes, tears, cleanliness, and so forth. Next, check the areas near the stem nuts for cleanliness. Remove the stem assembly from the intermediate body by removing the upper stem nut. Use the proper size wrench or socket on both the upper and lower stem nuts. Lift off the piston, the upper stem O-ring, the Bellofram, and the retainer plate. Notice the machined recess in the bottom of the piston that accommodates the upper stem O-ring. The stem may now be removed from the body. Clean and replace all parts as necessary.

To remove the diaphragm assembly from the stem, use a vise with jaws of brass or some other soft material. Place the stem in the vise with the diaphragm washer as close to the jaws as possible. Use a wrench of the proper size to remove the lower stem nut.



PARTS LIFT

ITEM NO.	PARTS DESCRIPTION	QUAN. PER UNIT
*1	Body	1
2	Body Assembly, Intermediate	1
3	Cover	1
4	Stem	1
5	Piston	1
6	Plate, Retainer	1
7	Washer, Diaphragm	1
8	Retainer, Disc	1
*9	Disc	1
10	Guide, Disc	1
11	Spring	1

*Recommended Spare Parts

PARTS LIFT

ITEM NO.	PARTS DESCRIPTION	QUAN. PER UNIT
*12	Bellofram	1
*13	Diaphragm	1
14	Screw, Hex Head	6
*15	O-Ring, Stem	2
*16	Nut, Self-locking	2
*17	Screw, Round Head	1
*18	Washer	1
19	O-Ring, Seal	1
20	Screw, Fill Head	4
21	Seal	1

*Recommended Spare Parts

"Courtesy of CLA-VAL CO"

SI015255154

Figure 1–32. Relief valve parts breakdown.

Disc assembly removal

Remove the disc guide, disc, and disc retainer as an assembly. Remove the diaphragm lower stem O-ring, and diaphragm washer from the stem. Notice that the diaphragm washer is flat and does not have a machined recess to accommodate the lower stem O-ring.

To remove the disc from the disc retainer, remove the disc guide. It should fall out. Insert a flat, blunt tool through the hole in the disc between the disc and the disc retainer and pry the disc out. The disc retainer has a machined lip that holds the edge of the disc (fig. 1–33). Lift the spring out; clean and examine it. Replace it only as necessary.

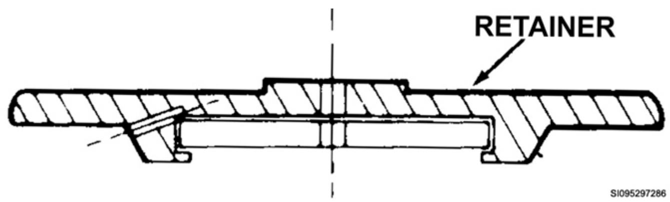


Figure 1–33. Disc retainer.

Inspect the seat for nicks or dents and cleanliness. In the event the seat is nicked or dented, use very fine wet or dry sandpaper to polish out the blemish. If you cannot polish out the damage, replace the seat and seat O-ring. Clean and replace all parts as necessary.

Reassembling the device

Reassembly of the unit is the reverse of the disassembly procedures. Ensure that the disc is completely and firmly under the machined lip of the disc retainer on all sides. Install the diaphragm washer, diaphragm, lower stem O-ring, disc retainer assembly, disc guide, and lower stem nut on the stem. Note that the serrated area of the disc retainer is placed against the diaphragm.

Make certain the stem is free of nicks and burrs and then insert the stem assembly through the intermediate body. Then assemble the plate retainer, Bellofram, upper stem O-ring, piston, and upper stem nut. Do not overtighten the upper and lower stem nuts. Ensure that they are both snug.

Make sure that the holes in the diaphragm line up with the holes in the intermediate body. Insert all hex-head screws except for two through the top of the intermediate body and diaphragm. Leave out the two hex-head screws on opposite sides of the bolt circle. Make sure that the internal sensing port opening in the diaphragm and the intermediate bodies are properly lined up. Check that the diaphragm does not fold over and block the sensing port.

Position the spring over the seat in the main body. Position the intermediate body over the main body so the sensing port openings line up. Now press the intermediate body down on the main body. Hold it until you start two screws on opposite sides of the bolt circle. Start and hand-tighten all of the remaining hex-head screws. Use the proper size wrench to finish tightening the hex-head screws. Figure 1–34 shows the proper tightening sequence to follow.

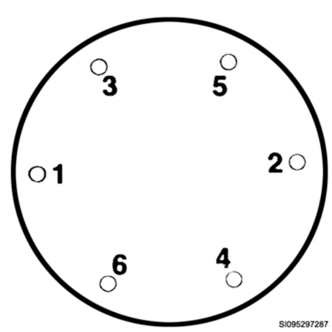


Figure 1–34. Screw tightening sequence.

Position the Bellofram flat against the upper portion of the intermediate body. Position the cover so the vent hole is on the opposite side of the sensing port. Insert and tighten the cover retaining screws.

Restoration

Work on the backflow preventer is now complete. Place the device back in service by opening both shutoff valves. Bleed any air by loosening the vent screws in the check-valve covers. The device must now be tested for proper operation. These maintenance procedures are only examples and may not apply to the type of reduced-pressure principle device you are working on. If not, get the correct service manual from your supervisor or have it ordered from the manufacturer.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

605. Principles

1. What are the two types of backflow?

2. What are the two types of cross-connections?

3. What are the two types of hazardous substances?

4. What AF Form is used as a master inventory all cross-connections on an installation?

5. What AF Form is used to document inspection data of a double-check valve assembly?

606. Protection against backsiphonage

1. What is an air gap?

2. What is the minimum size of an air gap?

3. If the water supply is 3 inches, what is the minimum size air gap that can be used?

4. The atmospheric vacuum breaker is designed to protect against what type of backflow?

5. What does the term “continuous pressure” mean?

6. How are atmospheric vacuum breakers installed?

607. Pressure vacuum breaker

1. Explain the operation of a PVB?

2. How are PVBs installed?

3. How should you place the PVB device back in service?

608. Double-check valve assembly

1. How are the double-check valve assembly used?

2. How are double-check valve assemblies installed?

3. Explain the first test that is performed on double-check valves?

4. Explain the second test that is performed on the double-check valves.

609. Reduced-pressure principle device

1. Explain the operation of a reduced-pressure principle device?

2. How is the reduced-pressure principle device installed?

3. What is the difference in spring tension between the two check valves of a reduced-pressure principle device?

4. What does the heavy spring in the #1 check valve ensure?

Answers to Self-Test Questions

601

1. Closed.
2. Use the inspector's test valve at the far end of the system.
3. Notify the fire alarm communications center and building occupants.
4. It indicates an obstruction, like a partially closed valve in the water supply system.
5. 18 inches.
6. No fewer than six.
7. ¼ turn.

602

1. Air under pressure replaces the water in the system above the clapper.
2. 6 to 1.
3. Quick-opening device.
4. Accelerators and exhausters.
5. Shut off the quick-opening device to prevent tripping of the dry-pipe valve and open the priming level indicator valve until the system air pressure is reduced to the prescribed limit.

603

1. In extra hazardous areas such as aircraft hangers where there is a danger of flash fires or fires of an explosive nature that could cover a large area.
2. HADs are a rate-of-rise detection system which causes the deluge valve to open through a series of latches and levers.
3. Use a bucket of water or a cloth dipped in the water.
4. Its smothering action for class B fires.
5. The water system and the foam system.
6. To prevent corrosion and remove any remaining foam solution.

604

1. Low-pressure storage consists of refrigerated tanks which hold the liquid CO2 at 300 psi at 0 °F. In high-pressure storage, liquid CO2 is stored in metal cylinders.
2. Semiannually.
3. 1301.
4. Flammable liquids.
5. In an enclosed space or room.
6. The wet-chemical system.
7. UFC 3–601–2.

605

1. Backsiphonage and backpressure.
2. The two types are direct (actual) and indirect (potential).
3. Pollution and contamination.
4. AF Form 848.
5. AF Form 843.

606

1. The physical distance between the water outlet and the maximum water level or flooding rim of a fixture to which it serves.
2. One inch.
3. 6 inches.

4. Backsiphonage and not backpressure.
5. It means that pressure is supplied continuously to a backflow prevention device for over 12 hours.
6. With the bottom of the breaker body at least 6” above the overflow rim of the fixture.

607

1. When the line pressure drops to 1 psi or below, the spring-loaded disc float drops, thus opening the atmospheric vent.
2. Must be installed at least 12 inches above the overflow rim of the equipment served.
3. Rapidly open the inlet valve and slowly open the outlet gate valve, finally, test the breaker to make sure it is working properly.

608

1. Use in direct connection-type systems to prevent the backflow of non-toxic substances into the potable water supply. It can be used in continuous pressure systems that are subject to both backpressure and backsiphonage.
2. Install either vertical or horizontal, locate valves in a warm and accessible position, 12 to 30 inches above the ground, and 24 inches away from the wall on the test side and 12 inches away from walls on the back side.
3. Test one - Check valves #1 and #2 must be tested to ensure that they hold tight against 1 psi in the direction of flow. Select an approved backflow tester and read the manufacturer’s testing instructions carefully. Record your test results on the proper AF form.
4. Test two - In the second test, both check valves must hold tightly against reverse flow. Again, select an approved tester and read the manufacturer’s testing instructions carefully. After test two is complete, annotate your results on the proper form.

609

1. It has two independently operating, spring-loaded check valves. The spring tension of check valve #1 is rated at a range of 5–8 psi. The spring tension for check valve #2 is rated at a range of 1–2 psi. A pressure-differential relief valve is located in a reduced-pressure zone between the two check valves and has a spring tension of at least 2-psi. Isolation valves are located on both the inlet and the outlet of the body along with four test cocks. The isolation valves are considered part of the device.
2. In the same way as a double-check valve assembly.
3. Check valve #1 has a HEAVY spring, while check valve #2 has a LIGHTER spring.
4. The heavy spring in the #1 check valve ensures that a sufficient pressure differential is established across the #1 check valve. This is necessary to ensure that the pressure-differential relief valve can maintain the pressure in the zone between the two check valves at least 2 psi less than the inlet pressure.

Complete the Unit Review Exercises before continuing to the next unit.

Unit Review Exercises

Note to Student: Consider all choices carefully, select the *best* answer to each question, and *circle* the corresponding letter. When you have completed all unit review exercises, transfer your answers to the Field-Scoring Answer Sheet.

Do not return your answer sheet to the Air Force Career Development Academy (AFCDA).

1. (601) What type of fire suppression system has closed heads, is full of water, and is under pressure at *all* times?
   a. Dry pipe.
   b. Wet pipe.
   c. Deluge.
   d. Foam.

2. (601) In a wet-pipe sprinkler system, what causes the clapper valve to open?
   a. One or more heads opening.
   b. Manual operation of a pull station.
   c. High steady inlet water pressure.
   d. Malfunctioning of the water motor alarm.

3. (601) What is the *first* step in restoring a wet-pipe sprinkler system?
   a. Notify building occupants.
   b. Clean up water damage.
   c. Replace damaged heads.
   d. Open main control valve to fill system.

4. (601) When restoring a wet-pipe sprinkler system, any trapped air can be bled off by
   a. using the inspector’s test valve.
   b. slowly opening the main water-control valve.
   c. using the bleed valve on the alarm valve clapper.
   d. opening the alarm line strainer.

5. (601) What should you do if false alarms are being caused by pressure surges?
   a. Relieve trapped air pressure.
   b. Eliminate water pressure.
   c. Add water pressure.
   d. Add air pressure.

6. (602) What are the two types of quick-opening devices in a large dry-pipe system?
   a. Mechanical and pneumatic.
   b. Releasers and accelerators.
   c. Exhausters and releasers.
   d. Accelerators and exhausters.

7. (602) How long should it take to recharge a dry-pipe system during restoration?
   a. 15 minutes.
   b. 30 minutes.
   c. 45 minutes.
   d. 1 hour.

8. (602) When inspecting a dry-pipe sprinkler system, record and compare to previous readings the air and water pressures and
   a. humidity.
   b. temperature.
   c. time of day.
   d. time of inspection.

9. (602) How do you correct occasional trips in dry-pipe systems caused by water surges?
   a. Decrease water pressure.
   b. Increase water pressure.
   c. Decrease air pressure.
   d. Increase air pressure.

10. (603) What type of fire suppression system has open sprinkler heads, and the system piping is under surrounding atmospheric pressure?
    a. Dry pipe.
    b. Wet pipe.
    c. Deluge.
    d. Dry chemical.

11. (603) What are the two possible positions of the differential deluge valve?
    a. On and off.
    b. Open and closed.
    c. Standby and fire.
    d. Standby and activated.

12. (603) What is used to test heat-actuated devices (HAD) in an explosive atmosphere?
    a. Electric heater.
    b. Open flame.
    c. Hot water or hot cloth.
    d. Heat gun with special shield.

13. (603) When a deluge fire sprinkler system is operational, the main water control valve is
    a. open and the alarm valve to control devices is open.
    b. closed and the alarm valve to control devices is open.
    c. open and the alarm valve to control devices is closed.
    d. closed and the alarm valve to control devices is closed.

14. (603) The extinguisher system that provides the same general protection similar to that of the foam-water system is the
    a. deluge system.
    b. wet pipe system.
    c. pre-action system.
    d. dry pipe system.

15. (603) The foam system has an *advantage* because of its smothering action for class
    a. A fires.
    b. B fires.
    c. C fires.
    d. D fires.

16. (603) In a foam system, what is mixed with the foam to control fires?
    a. Air.
    b. Soap.
    c. Pure oxygen.
    d. Carbon dioxide.

17. (603) The purpose of flushing the foam system is to prevent
    a. malfunctions.
    b. freezing.
    c. activation.
    d. corrosion.

18. (603) The foam system is operational when it is in the
    a. on position.
    b. off position.
    c. fire position.
    d. standby position.

19. (604) Inspect carbon dioxide (CO_2) systems high-pressure cylinders for condition and securing
    a. weekly.
    b. monthly.
    c. semi-annually.
    d. annually.

20. (604) 1301 Halon systems will *not* harm personnel in concentrations below
    a. 10 percent.
    b. 15 percent.
    c. 20 percent.
    d. 25 percent.

21. (605) What are the two types of cross-connection?
    a. Direct and indirect.
    b. Deadly and harmful.
    c. Pressure and gravity.
    d. Potable and non-potable.

22. (605) Which term is defined as an impairment of the potable water that does *not* adversely affect public health?
    a. Contamination.
    b. Cross-connection.
    c. Pollution.
    d. High hazard.

23. (605) What form is used for documenting all inspection data on spring-loaded devices?
    a. Air Force (AF) Form 848.
    b. AF Form 843.
    c. AF Form 844.
    d. AF Information Management Tool (IMT) 845.

24. (605) What form is used to sketch the exact location of all devices?
    a. Air Force (AF) Form 848.
    b. AF Form 843.
    c. AF Form 844.
    d. AF Information Management Tool (IMT) 845.

25. (606) What is the *smallest* air gap allowed?
    a. 6 inches.
    b. 4 inches.
    c. 2 inches.
    d. 1 inch.

26. (606) What is the correct size air gap if the supply pipe is 2 inches in diameter?
    a. 1 inch.
    b. 2 inches.
    c. 3 inches.
    d. 4 inches.

27. (606) The *biggest* problem that arises with air gaps is when the
    a. air gaps clog.
    b. air gaps are too large for the fixtures.
    c. supply line is extended below the overflow rim with a hose.
    d. supply arms are too short and create a large air gap.

28. (606) The type of backflow preventer that prevents backsiphonage of toxic substances but *cannot* be used under continuous pressure is the
    a. atmospheric vacuum breaker (AVB).
    b. pressure vacuum breaker (PVB).
    c. reduced-pressure device.
    d. double-check valve.

29. (606) How is the atmospheric vacuum breaker (AVB) installed in terms of the overflow rim of a fixture?
    a. 6 inches below.
    b. 6 inches above.
    c. 12 inches above.
    d. 12 inches below.

30. (606) The *first* step in an inspection of an atmospheric vacuum breaker (AVB) is to
    a. remove the hood.
    b. close the breaker.
    c. ensure the vent is open.
    d. ensure the disc is floating.

31. (606) On an atmospheric vacuum breaker (AVB), if the guide pin *cannot* be centered, replace the
    a. bonnet.
    b. guide pin.
    c. poppet.
    d. disc.

32. (607) If the seat area on a pressure vacuum breaker (PVB) is damaged, replace the
    a. seat.
    b. check valve.
    c. whole device.
    d. inlet valve.

33. (607) When restoring a pressure vacuum breaker (PVB) to service, open the inlet gate valve quickly in order to
    a. reduce spillage through the air vent.
    b. reseat the spring on the poppet.
    c. reseat the disc assembly.
    d. align the guide pin.

34. (607) What is the *last* thing you do after you repair a pressure vacuum breaker (PVB)?
    a. Test the device.
    b. Open test cock #2.
    c. Open test cock #1.
    d. Open gate valves.

35. (608) The double-check valve assembly (DCVA) is *not* used to protect against high-degree hazards because it
    a. cannot be used under backsiphonage conditions.
    b. cannot be used under continuous pressure.
    c. shows no visual signs of malfunctions.
    d. shows visual signs of malfunctions.

36. (608) What backflow prevention device has two spring-loaded check valves rated at 1 pound per square inch (psi)?
    a. Vacuum breaker.
    b. Double-check valve.
    c. Reduce pressure.
    d. Pressure breakers.

37. (608) The *first* test on a double-check valve assembly (DCVA) is to ensure the check valves hold tight against
    a. 1 pound per square inch (psi) in the direction of flow.
    b. 3 psi in the direction of flow.
    c. 1 psi against reversed flow.
    d. 3 psi against reversed flow.

38. (609) If backflow protection of high-hazard substances under continuous pressure and back-pressure is needed, then the *best* device is the
    a. reduced-pressure backflow preventer.
    b. atmospheric vacuum breaker (AVB).
    c. pressure vacuum breaker (PVB).
    d. double-check valve.

39. (609) In a reduced-pressure backflow preventer check valve, the spring tension range for check valve #1 is
    a. 1–2 pounds per square inch (psi) and check valve # 2 is 5–8 psi.
    b. 5–8 psi and check valve # 2 is 1–2 psi.
    c. 3–4 psi and check valve # 2 is 5–6 psi.
    d. 5–6 psi and check valve # 2 is 3–4 psi

40. (609) The purpose of test # 1 on the reduced-pressure backflow preventer is to
    a. determine static pressure drop across check valve # 1.
    b. test check valve # 2 for tightness against reverse flow.
    c. test the operation of the pressure-differential relief valve.
    d. determine the tightness of check valve # 2 against normal flow.

41. (609) The purpose of test # 3 on the reduced-pressure backflow preventer is to
    a. determine static pressure drop across check valve # 1.
    b. test check valve # 2 for tightness against reverse flow.
    c. test the operation of the pressure-differential relief valve.
    d. determine the tightness of check valve # 2 against normal flow.

Please read the unit menu for unit 2 and continue ➔

Student Notes

Unit 2. Natural Gas Systems and Swimming Pools

NATURAL GAS DISTRIBUTION SYSTEMS are similar to water distribution systems. Similarities include the ways of assembling the piping and valves and some of the terms used to identify components of the system. Due to the hazardous nature of natural gas, there are strict regulations that establish specific guidance for safe operation and maintenance of these systems. This unit discusses natural gas characteristics, different piping used, and the tools and assembly methods for installing piping systems.

2–1. Natural Gas Distribution Systems

Having a good grasp of plumbing systems will help you when you are working with natural gas systems. A main difference is the hazard associated when working with these systems; education on these systems will help you to approach the hazard safely. In the next lesson we discuss the basic characteristics found in gas distribution systems.

610. Characteristics of gas distribution systems

Typical natural gas distribution systems include piping, valves, and regulators. All of these systems are sized and installed to enable the gas system to operate efficiently and provide adequate service to the user.

Piping layout

Natural gas is usually transported by pipeline from the main storage facility. The base distribution pipes are called distribution mains. These mains branch out and carry the gas to all areas on the base. There are two different distribution main designs: loop and radial.

The first design, the loop, has all the mains joined into an integrated network (fig. 2–1). In the second design, the mains are not connected and long dead-ends result (fig. 2–2). Gas service lines begin at the distribution mains and go to the buildings that use the gas.

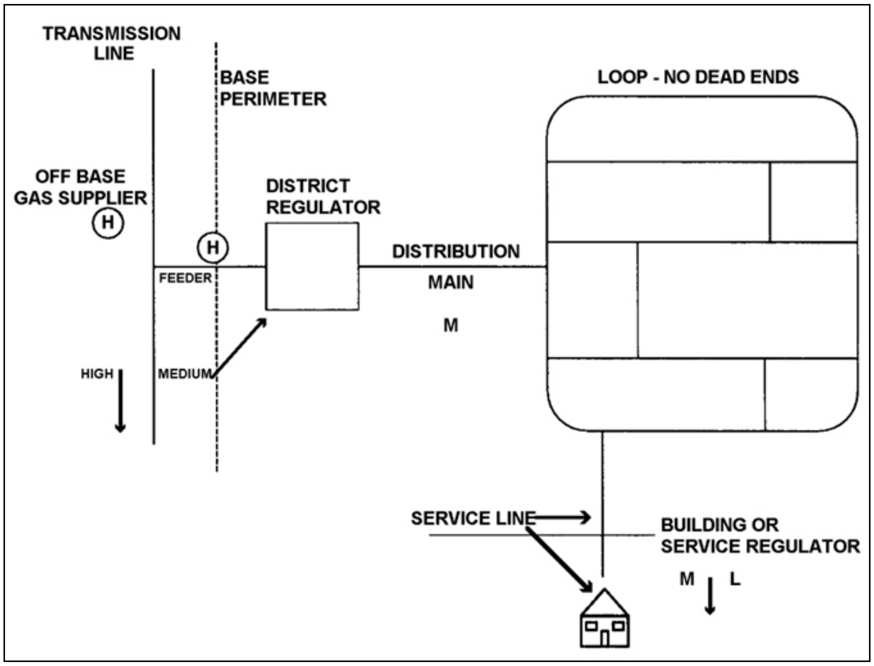


Figure 2–1. Loop gas distribution system.

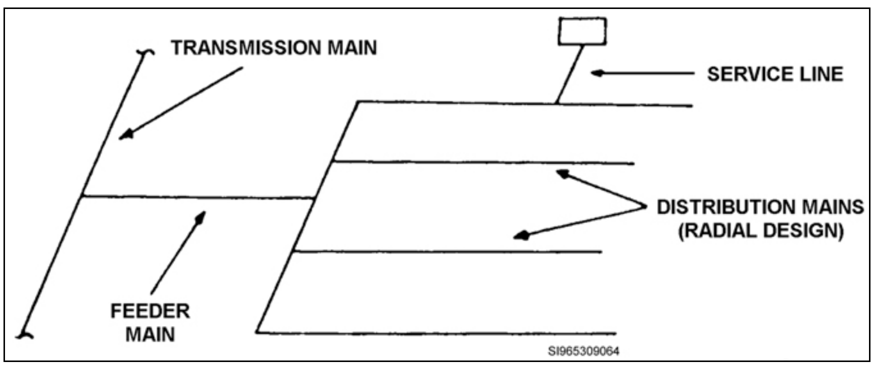


Figure 2–2. Radial gas distribution system.

Materials

In gas systems, various types of materials are used. These materials for pipe and fittings are made of steel, plastic, or copper.

Steel pipe

Steel gas pipe (commonly referred to as “black iron”) is widely used in gas systems in both gas mains and service lines. This pipe may be joined in three ways: threading, welding, and compression. You may run into some 4” (and smaller) cast-iron distribution mains, which are still in place in older systems. Cast iron is not used anymore because of problems with excess leakage.

Plastic pipe

Polyethylene (PE) pipe is the most commonly used plastic pipe. PE pipe is joined by thermal fusion joints and compression joints.

Copper pipe or tubing

Copper pipe or tubing is joined by flared joints and soldered joints when the melting temperature of the solder is above 1,000°F. The use of copper pipe or tubing may be restricted in some areas. If used, the pipe or tubing must be at least wall-thickness type "L."

Valves

The successful operation of a gas system depends largely on the number of valves that are installed and the location of the valves. There should be enough valves in key locations so that any section of the system can be completely isolated without disturbing gas service to the rest of the system. This is essential in the event of a line break, fire, or major maintenance and repair.

There are two types or classes of valves that are used in gas systems: lubricated plug valves and gate valves. The lubricated plug valves are the most dependable for gas service since they allow a complete shutoff. Figure 2–3 shows an example of the lubricated plug valve. Other valves include PE butterfly or ball valves, which are just dropped into place and fused during pipe construction.

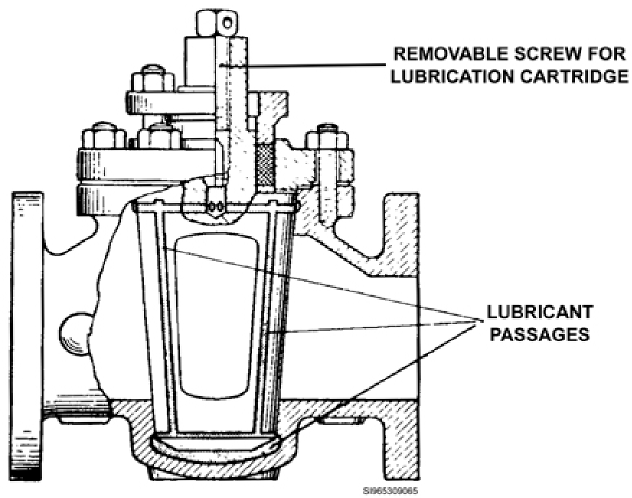


Figure 2–3. Lubricated plug valve.

Regulators

A regulator is defined as "a mechanism for controlling or governing the movement of machines, the flow of liquids and gases, etc." A regulator is often referred to as a "pressure reducer" or a "throttling valve." The function of the regulator is to maintain a given pressure on the outlet or downstream side that is lower than the pressure on the inlet or upstream side. Two different types of regulators are used in base gas systems: the district regulators and the service regulators. The district regulators reduce the pressure before the gas enters the distribution system. This type of regulator must be able to reduce from pounds of pressure to pounds of pressure; for example, reducing the pressure from 50 psi to 20 psi. An example of the district regulator is shown in figure 2–4.

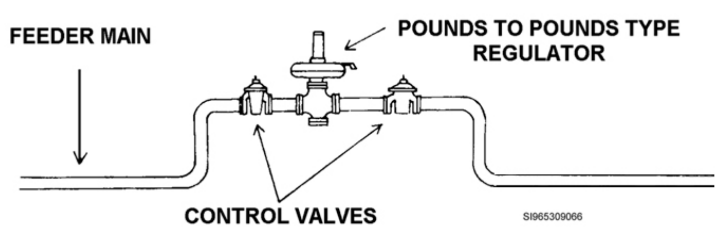


Figure 2–4. District regulator.

Service regulators are installed on the building service line because the distribution system pressure is too high for the appliances that use the gas. Service regulators must be able to reduce the gas from pounds of pressure to ounces of pressure; for example, reducing the pressure from 20 pounds to 4 ounces. An example of a service regulator is shown in figure 2–5.

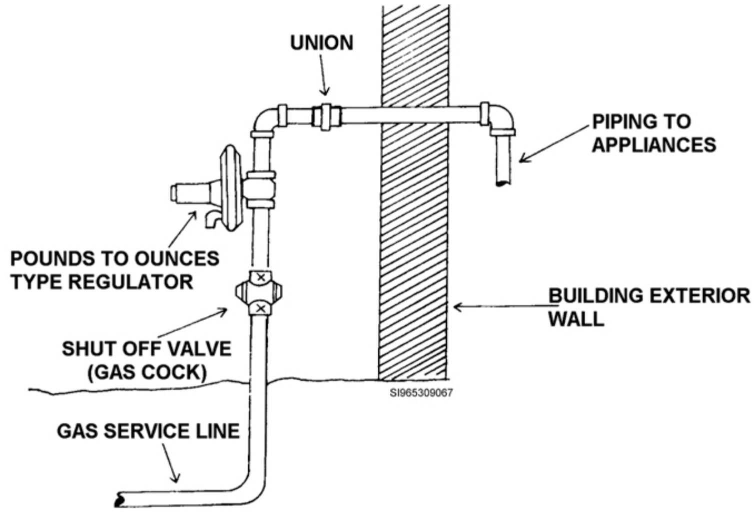


Figure 2–5. Service regulator.

Types of systems

The ideal natural gas system would bring gas from the wells, through all the mains, and to the user without the need for any pressure regulation. This system would need the ideal operating conditions of a constant demand matched by a constant supply. Unfortunately, these ideal operating conditions do not exist. Because demand for gas varies, flow of gas varies, and pressure losses vary; an ideal system cannot be obtained. Because of the different pressures required to transport, distribute, and finally use the gas, piping networks need to be classified according to their operating pressures. The table below describes the pressure ratings of natural gas systems.

Natural Gas Systems Operating Pressures	
Pressure Rating	**Description**
High pressure (HP)	This pressure rating applies to pressures above 50 psi. There is no definite top limit. Some pipeline companies maintain pressures as high as 1,200 psi since these lines are designed for the long-distance transmission of gas.
Medium pressure (MP)	This term applies to gas systems that are at a pressure of 1½ to 50 psi. Air Force base distribution systems operate at MPs. MP may also be called intermediate pressure.
Low pressure (LP)	A system is considered low pressure if the pressure is less than 1½ psi. LP is sometimes referred to as “utilization pressure.” Most LP systems, however, deliver gas at a pressure ranging from 3 to 8 ounces psi.

The amount of pressure needed for proper operation depends on the system design. A well-looped system in which the distribution mains are tied together to make an integrated unit can run on lower pressures than a radial-type system. The maximum distribution design pressure is 50 psi for a military installation. The service regulators are installed at each building to reduce the pressure to about 4 ounces per square inch before it enters a building.

611. Using polyethylene gas pipe

Most types of gas piping are installed in the same manner as the pipes that are used for waterlines. Since there are many similarities, the way each type of pipe is installed is not discussed. However, there is one type of pipe that has special installation methods. This type of pipe is PE.

Locator wire

To aid in the detection of buried PE pipe, install a metal wire along the pipe. The locator wire is placed in the trench during backfill operations approximately 6 inches above the pipe. The locator wire should not touch the pipe in any way.

Directional changes

Slight changes in PE gas pipe may be made by bending as long as the bending causes *no* buckling, wrinkling, or crimping of the pipe. If the change of direction causes any of these effects on the pipe, elbow fittings that are joined to the pipe by heat fusion must be used. Do not use a compression-type fitting any closer than 10 feet from any point of directional change in the pipe (elbow and tee).

Static electricity

Static electricity is one of the major safety concerns when you work with PE pipe. The charges are developed on the surface of the pipe in two ways: (1) by physical handling of the pipe in storage, shipping, and installation and (2) by the flow of gas that contains dust, rust, scale, or dirt particles through the pipe.

Static charges develop in all situations when you work with PE pipe. The charges may be neutralized by wiping the entire outer surface of all PE pipe and fittings with a cotton cloth that is soaked with water and liquid dishwashing detergent. You must constantly wipe the pipe and fittings while work is being done.

Do not wear work clothes that are made from synthetic materials or use work rags that are made from synthetics because synthetic materials tend to generate static charges. Cotton or cotton-blend fabrics are recommended.

612. Tools used in assembling polyethylene gas pipe

Heat fusion of PE gas pipe must be accomplished by using tools that are specifically designed for that purpose. There are many different manufacturers of pipe and tools. The basic tools needed do not vary much even though they come from various companies. They all have the same purposes in the pipe assembly process.

Alignment jig

Use the alignment jig to hold the pipe in position any time you make butt fusion joints. In fact, do not make butt fusion joints *unless* you use the alignment jig. One piece of pipe is held stationary on one side of the jig while another piece of pipe is held by the movable side of the jig. The movable side allows the pipe ends to be moved together and moved apart for perfect alignment with each other.

Facing tool

The facing tool is used to square the ends of the pipe for butt fusion. Small cutting blades on both sides of the tool provide for shaving off the ends of the pipes that are to be butt-fused. Facing tools may be motorized or manually operated.

NOTE: The cutting blades are very sharp and can really cut up your hands.

Cold ring

A cold ring serves as a pipe rounding and straightening tool. A cold ring is necessary for every type of fusion performed. In butt fusion, cold rings are installed on both sides of the jig. In saddle fusion, cold rings are needed on both sides of the fusion area. In socket fusion, a cold ring is used on the pipe end to ensure roundness and proper depth of penetration into the socket fitting.

Squeeze tool

This device is used to squeeze the pipe together and stop the gas flow when repairs or new installations are needed to be made.

Heating irons

Heating irons are used to melt pipe and fittings for assembly. They may be gas fired or electrically operated. Electrically heated tools that are operated on 110-volts alternating current (AC) are recommended. A portable AC generator or welding machine that has a 110-volt AC outlet may be used as a power source in the field.

It is sometimes necessary to adjust the operating temperature of a heating iron. This can be done by turning the adjustment screw that is located in the hole adjacent to the thermometer either clockwise or counterclockwise in ¼-turn increments. Depending on the manufacturer, a ¼ turn will cause a 25–100° temperature change. This is a "hit and miss" process.

Teflon-coated heater faces, which bolt onto the heating irons, are available for the various types and sizes of fusion joints that are made. Clean heater faces with a wooden stick, such as a tongue depressor and a cotton cloth. Never use steel wool or wire brushes because they damage the Teflon coating.

Chamfering tool

The chamfering tool is necessary for socket-type fusion. Chamfering is the process of beveling the end of the pipe (45°) to get rid of excess plastic which would hinder the fusion process. The pipe end to be inserted into the socket of a fitting must be chamfered if the pipe is larger than 1 inch in diameter.

Depth gauge

A depth gauge is used to set the cold ring at the proper penetration of the pipe end into the socket fitting.

613. Assembly procedures for polyethylene gas pipe

The two methods of assembling PE gas pipe that we will discuss are the socket fusion and butt fusion process.

Socket fusion

These joints are made by heating the end of a pipe and the inside of a socket fitting, bringing the two together, and allowing the joint to cool. When it is properly made, the joint is stronger than the pipe itself. Care must be taken not to overheat or underheat the material. Using a torch or some other open flame device as a source of heat is not permitted.

Heating temperatures, heating cycle times, and cooling times vary for each manufacturer's brand of pipe. Closely follow these specifications in order to make good fusion joints. (**NOTE:** Do *not* attempt to join materials from different manufacturers. Do *not* attempt this fusion if an explosive condition exists.) The steps below are the procedures for making socket fusion joints:

1. Preheat the heating tool to the temperature specified by the manufacturer.
2. Chamfer the end of the pipe if the pipe size is larger than 1 inch. When you chamfer, be careful not to remove more than half the wall thickness of the pipe. A correctly chamfered pipe end is shown in figure 2–6.
3. Use a depth gauge to measure how far the pipe is to be inserted into the socket.
4. Attach a cold ring where the depth gauge stops.

5. Bring the pipe and fitting in contact with the heater faces with enough force to hold them steadily in place for the prescribed heating cycle.
6. At the end of the cycle, snap the fitting from the heating tool briskly to keep the melted PE from sticking to the tool.
7. Snap the heating tool from the pipe end.
8. Stab the fitting onto the pipe end smoothly and squarely. Be careful not to twist or turn the fitting or pipe during or immediately after the stab. The fitting should be against the cold ring if the fitting has been placed on the pipe to the proper depth.
9. Hold the hot joint steady for the cooling time specified by the manufacturer. This ensures proper bonding.
10. Do not work or test the pipe until an additional 3 to 5 minutes have passed.

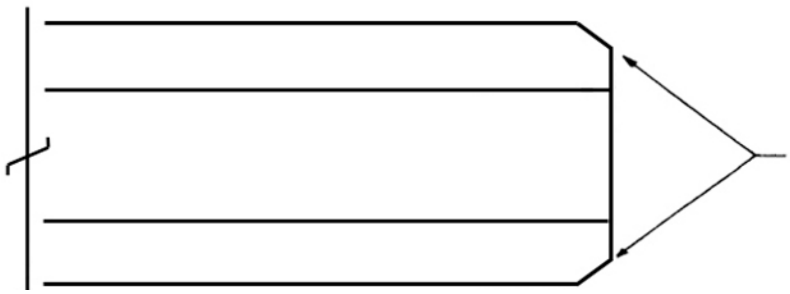


Figure 2–6. Correctly chamfered pipe end.

Butt fusion

This joint consists of holding two ends of pipes in contact with a flat heating tool at the same time. Once the pipe ends have melted, the tool is removed and the pipe ends are then forced together and allowed to cool. Since the surface area of the pipe ends being joined is small, it is essential that the pipe ends be properly mated by using a butt fusion machine. This machine is commonly called an alignment jig. The jig is capable of holding the pipes in perfect alignment and perfectly joining the pipe ends.

Heating temperatures, heating cycle times, and cooling times vary for each manufacturer's brand of pipe. These specifications must be closely followed in order to make good fusion joints. (**NOTE:** Make *no* attempt to join materials from different manufacturers.)

To make butt fusion joints, follow these steps:

1. Preheat the heating tool to the required temperature.
2. Place the pipe ends into the jig, allowing only a slight protrusion into the joining area in the center of the machine (approximately $^{3}/_{4}$"). This can be seen in figure 2–7.
3. Place the facing tool in the center of the machine so that it is between the two pipe ends.
4. Using the movable carriage on the jig, force the pipe ends against the facing tool.
5. Rotate the facing tool so that the cutters on the facing tool shave the pipe ends. When the facing process is completed, the pipe ends should be smooth, flat, and square.
6. Using the movable carriage, move the pipe ends away from the facing tool and remove the tool.
7. Using the movable carriage, move the pipe ends together to check the fit and alignment. If the alignment and fit are incorrect, repeat steps 3 through 7.
8. After correct fit and alignment have been achieved, place the heating tool in the center of the machine.

9. Bring the pipe ends against the heating tool and apply a steady force until a bead of molten material is totally visible around the ends of both pipes. This is when the heating cycle begins.
10. Relax the force, but maintain full contact of both pipe ends against the heating tool.
11. At the end of the heating cycle, snap the movable carriage back. This separates the pipe from the heating tool.
12. Remove the heating tool and bring the pipe ends together quickly. Be careful not to slam the pipe ends together as this causes too much of the molten material to be squeezed out. Apply enough force to cause the fusion bead to approximately double its size but not overlap itself. Hold the joint in place for the time specified by the manufacturer.
13. Do not test or work on the pipe for 30 minutes after the fusion is made.
14. Clean the heater faces as soon as possible.

NOTE: Do *not* attempt this fusion if an explosive condition exists.

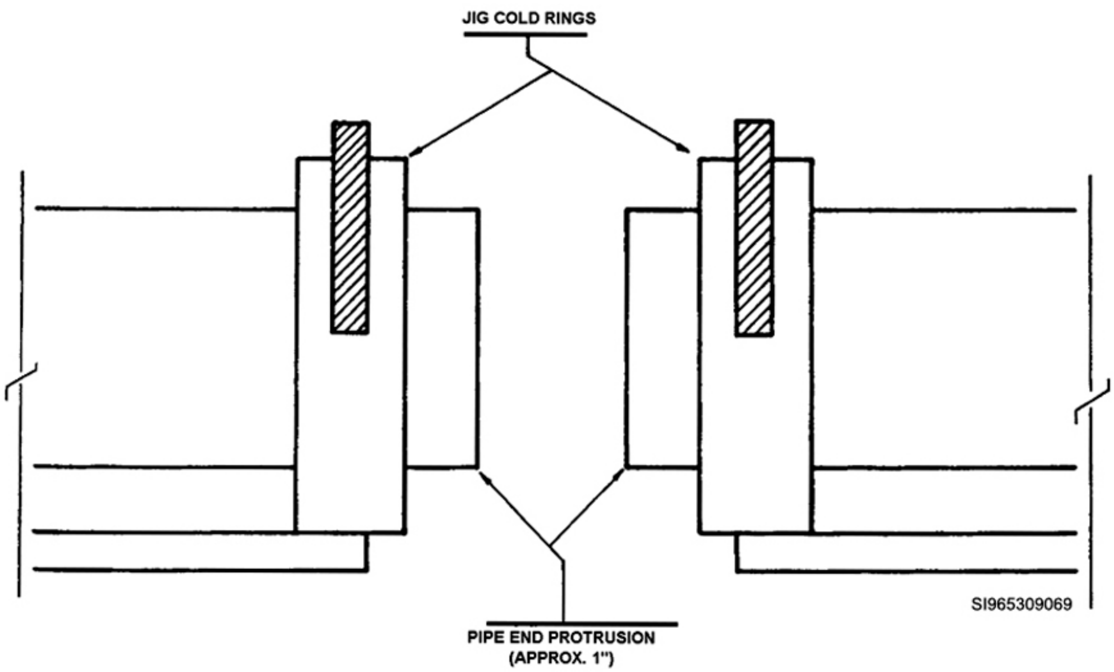


Figure 2–7. Pipe ends placed in joining area.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

610. Characteristics of gas distribution systems

1. How is natural gas normally transported?

2. What are the two installation designs for distribution mains?

3. What types of materials are used in gas systems?

4. Where is steel pipe used in gas systems?

5. What is the minimum wall-thickness of copper pipe used in gas distribution systems?

6. Why are plug valves best for gas systems?

7. What function does the district regulators perform in the piping system?

8. Where are service regulators installed?

9. What pressure rating applies to gas above 50 psi?

10. What is considered to be medium pressure in gas systems?

611. Using polyethylene gas pipe

1. Why should a wire be buried with PE gas pipe?

2. When is slight bending of PE gas pipe permitted?

3. How does static electricity develop on gas pipe?

4. Which type of fabrics tend to generate static charges?

612. Tools used in assembling polyethylene gas pipe

1. When can you butt-fuse without an alignment jig?

2. What is the purpose of a cold ring?

3. What is a squeeze tool used for?

4. What should be used to clean Teflon heater faces?

5. Which type of fusion requires the use of a chamfering tool?

613. Assembly procedures for polyethylene gas pipe

1. When may you use a torch or other open flame for fusing?

2. Where should you attach the cold ring when you are socket-fusing two pieces of pipe?

3. How long should you hold the pipe to the heater faces when you socket-fuse?

4. How do you know if the fitting is deep enough in the socket?

5. How should the pipe protrude into the center of the alignment jig?

6. Where do you place the facing machine when you prepare pipe for fusing?

2–2. Maintaining Gas Distribution Systems

To properly inspect and maintain gas piping, you must be familiar with the piping system. Gas maps must be kept current and in a location where everyone can have quick access to them. You should know the right steps involved in inspecting for leaks and the correct operation of all the leak detection equipment that is used. You must follow safe maintenance procedures to minimize risks to yourself and others.

614. Locating leaks in gas pipe

Locating gas leaks can be as simple as wiping a soap solution over exposed piping. In fact, this is the recommended way of locating leaks on exposed pipes. In this lesson, we discuss line walking, barhole survey, and vegetation surveys as methods of locating gas pipe leaks.

Line walking

Most of the leaks in gas pipes are underground. If these leaks are not found and repaired in a timely manner, they could result in injury to personnel and damage to property. Perform the process known as line walking (using a flame ionization leak detector) annually on all underground gas systems.

Complete the survey by walking along all the gas lines with a flame ionization (FI) gas leak detector. The FI unit is capable of detecting one-half ppm of any hydrocarbon gas. It is best to do the line walking in the early morning when the weather is calm and damp. If there are strong winds, the FI unit is not as effective.

Barhole survey

The barhole survey is the most expensive and time-consuming method of locating underground gas leaks. This is why this method is used only to pinpoint leaks that have already been detected by line walking. Gas has a tendency to migrate, taking the path of least resistance. This makes it possible for the gas leak to actually be in a location that is far away from the point where the gas was detected. This makes it necessary to pinpoint the leak before you excavate.

To complete a barhole survey, drive a bar into the ground beside the gas pipe. The hole should be to the same depth as the bottom of the pipe, if possible. Make the hole approximately 1 foot to the side of the pipe to prevent damaging the pipe or the coating on the pipe. Then test the barhole by using a combustible gas indicator.

The combustible gas indicator is a gas leak detector that gives a reading of the percentage of gas in the air. To get an accurate reading, the detector must be calibrated for methane gas. The piece of equipment is designed to be used in confined areas such as buildings, manholes, and barholes.

Make sure the barholes are evenly spaced and that the first sets of holes are between 10 to 50 feet apart. When the amount of gas in each hole has been checked, make other barholes between the barholes that have the highest gas concentrations. This reduces the area of excavation needed to find the exact leak location.

Vegetation survey

This type of survey is feasible only during the growing season. Even though natural gas is not toxic to vegetation, it damages plant life because it displaces oxygen and dehydrates the soil. Since dry and withered foliage is evidence of gas leakage, test any such area by the use of barholes and a combustible gas indicator. Be sure to investigate any change in the appearance of plant life that could be caused by a gas leak. Air Force Instruction (AFI) 32–1067, *Water and Fuel Systems,* Chapter 7, gives complete information that deals with gas leak surveys. Refer to this manual if more in-depth information is needed.

615. Repairing gas leaks

Once the gas leaks have been discovered, you must make repairs in a safe and timely manner. The type of repair made depends on the type of pipe.

Steel pipe

Leaks in steel pipe usually result from corrosion or faulty joints. Corroded or damaged pipe must be removed and replaced. If threading is permissible, make sure that all threaded joints are properly coated with an acceptable coating or wrapped to protect the joint from future corrosion. Most coatings are of an asphalt base and may or may not require heating before installation. Always check with the manufacturer’s installation specifications and use the proper safety precautions.

Sometimes it may be necessary to transition from steel pipe to plastic. Gas piping manufacturers have developed a full line of transition fittings that are excellent for such changeovers. These fittings are manufactured with a short piece of steel pipe that is already threaded or beveled for welding on one end. The other end is designed with a short piece of PE that is ready for fusion or with a compression fitting that is ready for assembly to the existing piping.

Make sure the plastic section of the fitting is protected if the fitting is welded to steel piping. This can be done by wrapping the fitting with wet rags. Provide full continuous support for the fitting in the trench to prevent as much movement as possible. Be very careful during backfilling procedures. Protective sleeves can also be installed around the transition fitting to prevent damage from backfilling. Figure 2–8 shows examples of transition fittings.

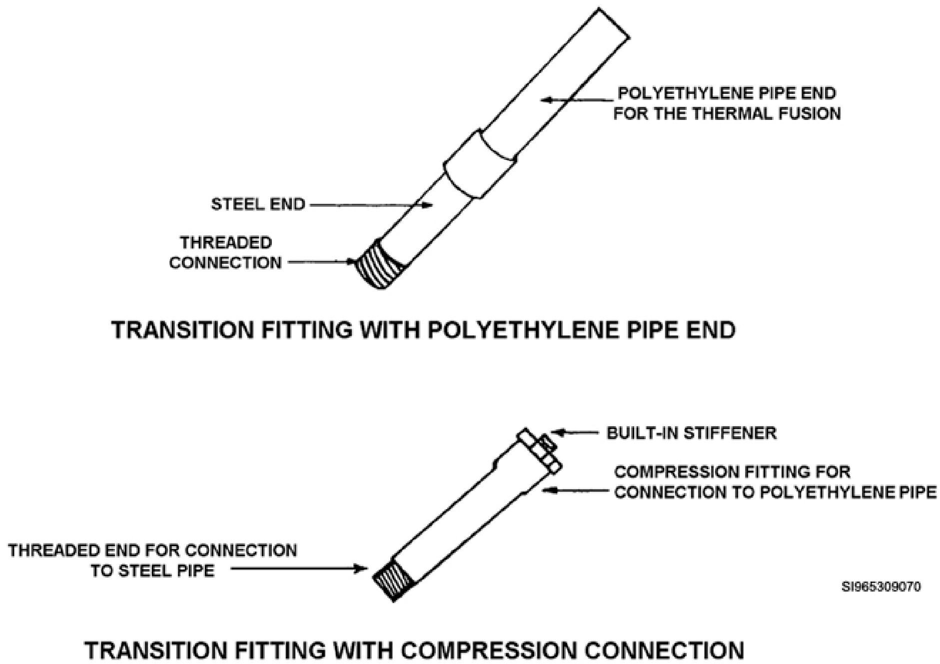


Figure 2–8. Transition fittings.

Plastic pipe

Leaks in plastic pipe usually develop because of equipment damage to the pipe or because of errors that were made during the installation of the pipe. Remove and replace leaking areas. Do pipe replacement using the procedures for installation. Make sure the new and old types of pipe are compatible when you fuse. On PE pipe, a compression coupling may be used to connect sections of pipe. Follow these procedures when you install the couplings:

1. Thoroughly clean the ends of the pipe.
2. Place a reference mark on the pipe one-half the compression coupling length from the ends of the pipes that are being joined.
3. Inspect the coupling gaskets for cleanliness. Also, make sure the gaskets are suitable for natural gas systems.
4. Apply soapy water liberally to the gasket and the pipe to act as a lubricant.
5. Insert an approved insert stiffener of the correct size into the end of the pipe. The stiffener is used to prevent the pipe from becoming distorted when the coupling is tightened. The stiffener should fit so that it installs easily but does not slip out of place. It should not stick out from the end of the pipe.
6. Insert the pipe into the coupling and check the reference marks for correct positioning of the coupling. The marks should be at the coupling ends. This ensures that the coupling is positioned over the stiffener.
7. Tighten the coupling.

8. Before backfilling, check for leaks by using a soapy water solution.
9. Wrap the coupling or coat it to control corrosion.

Procedures for valves

Since the majority of valves in gas distribution are lubricated plug valves, leaks are usually repaired by simply adding lubricant to valves that have dried out. If this does not stop the leak, resurfacing or replacing the valve may be necessary.

When you perform maintenance on valves, there are some additional items that you should correct if they are needed. One of these includes correctly marking underground valves. Many bases are marking street curbs to help identify the location of valves. Also, you can paint the covers of valve boxes to make locating and identification quicker and easier. Annotate your maps with notes that concern the location and depth of valves.

Often, you may need to replace or adjust valve boxes so that they are at the required height. Most valve boxes are made of cast iron or plastic and are approximately 6 inches in diameter. On larger valves, the base of the valve box may be mounted at the bottom of the valve bonnet. Smaller sizes may have the valve box sitting completely over the valve. The top sections of valve boxes are usually telescoping so that the cover can be adjusted to ground or street level.

Remove any debris you find from the valve box. Also, check for corrosion or damage, proper elevation of the cover, and alignment of the box over the valve. Correct alignment is necessary to ensure that the key used to operate the valve can be lowered onto the valve properly. If a valve box is severely damaged or corroded, or if the proper height and alignment cannot be made, dig up the valve box and replace it.

616. Natural gas systems state and federal regulations

Whether you are treating water or wastewater, installing plumbing, or driving home from work, there are laws, regulations, and codes that we must follow. These laws, regulations, and codes are in place to provide a safe environment for all of us to work and live in. In this lesson, we will briefly cover the DOT regulations and federal laws that govern the operation and maintenance of your natural gas system. It is your responsibility to know these laws when maintaining gas systems.

Department of Transportation Regulation

Public Law 104–304 requires the United States (US) DOT to develop and enforce minimum safety regulations for the transportation of gases by pipeline. The safety regulations became effective in 1970 and are published in Title 49 of the Code of Federal Regulations (CFR), Parts 190, 191, 192, and 199. The Office of Pipeline Safety of DOT’s Pipeline and Hazardous Materials Safety Administration (PHMSA) is charged with their enforcement.

The gas pipeline safety regulations apply to natural gas systems and operators of natural gas master meter systems. The pipeline safety regulations require operators of natural gas systems to deliver gas safely and reliably to customers, provide training and written instruction for employees, establish written procedures to minimize the hazards resulting from natural gas pipeline emergencies, and keep records of inspection and testing.

Natural gas operators who do not comply with the safety regulations may be subject to civil penalties, compliance orders, or both. If safety problems are severe, a “Corrective Action Order” may be issued by the Office of Pipeline Safety (OPS). This could result in the shutdown of the system.

State agencies may enforce pipeline safety regulations under certification by OPS. The state agency is allowed to adopt additional or more stringent safety regulations for intrastate pipeline transportation as long as such regulations are compatible with the federal minimum regulations. However, if a state agency is not certified, the DOT retains jurisdiction over intrastate pipeline systems.

Operators should check with the pipeline safety agency in their state to determine:

- Whether a state agency has safety jurisdiction.
- Whether the state agency has pipeline safety requirements that exceed the federal regulations.
- The inspection and enforcement procedures of the state agency.

The Office of Pipeline Safety provides a Guidance Manual for Operators of Small Natural Gas Systems located on the web at http://ops.dot.gov/regs/small_ng/SmallNaturalGas.htm. This manual was developed to provide an overview of pipeline compliance responsibilities under the federal pipeline safety regulations. It is designed for the nontechnically trained person who operates a master meter system, a small municipal system, or small independent system. This manual provides a set of examples that operators of small natural gas systems can use to meet the minimum requirements of the pipeline safety regulations.

Pipeline Safety Improvement Act of 2002

Public Law 107–355, The Pipeline Safety Improvement Act of 2002, was signed into law on December 17, 2002. The Act mandates significant changes and new requirements in the way that the natural gas industry ensures the safety and integrity of its pipelines. The law applies to natural gas transmission pipeline companies and providers.

Requirements

Central to the new law are the requirements it places on each pipeline operator to prepare and implement an “integrity management program.” This program among other things, requires operators to identify so-called “high-consequence areas (HCA)” on their systems, conduct risk analyses of these areas, perform baseline integrity assessments of each pipeline segment, and inspect the entire pipeline system according to a prescribed schedule and using prescribed methods.

Other provisions of the law include:

- Participation in planned-excavation, one-call notification programs.
- Increased penalties for violations of safety standards.
- “Whistle-blower” protection for pipeline system employees.
- Qualification programs for employees who perform sensitive tasks.
- Authorization of some state participation in interstate pipeline oversight.
- A required multi-agency program of research, development, demonstration, and standardization to enhance the integrity of pipelines.
- An interagency task force to expedite environmental reviews when necessary to expedite pipeline repairs.
- Government mapping of the pipeline system and assembling pipeline operator contact information for public dissemination.

If you work with natural gas systems at your installation, you need to be familiar with Public Law 107–355 Pipeline Safety Improvement Act of 2002 located on the web at http://ops.dot.gov/library/docs/107_cong_public_laws.pdf.

Natural gas is a very safe source of energy if you practice proper operation and maintenance. Know how to maintain your system and abide by these regulations and laws discussed here. Also, be aware of your local regulations and laws concerning your natural gas system. Remember, these laws exist because of the lives lost due to negligent safety practices of others.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

614. Locating leaks in gas pipe

1. Where are most of the leaks in gas piping?

2. What amount of gas is the FI unit capable of detecting?

3. When is a barhole survey used?

4. How deep do you place the bar when you do a barhole survey?

5. What effect does gas have on vegetation and soil?

615. Repairing gas leaks

1. Why do most leaks in steel pipe occur?

2. What can you use to prevent damage to the plastic when you weld a transition fitting?

3. Why do leaks usually occur in plastic pipe?

4. Why do you apply soapy water to plastic you are assembling with a compression coupling?

5. What can be done to make valves easier to locate?

6. Why are the tops of valve boxes telescoping?

616. Regulations governing gas distribution systems

1. Who is required by Public Law 104–304 to develop and enforce minimum safety regulations for the transportation of gases by pipeline?

2. Operators should check with the pipeline safety agency in their state to determine what three items?

3. What act mandates significant and new requirements in the way that the natural gas industry ensures the safety and integrity of its pipelines?

4. What does the Pipeline Safety Improvement Act of 2002 require each pipeline operator to prepare and implement?

2–3. Swimming Pools

In this section, we will cover information needed for proper operation of a swimming pool. You cannot effectively operate swimming pools unless you become familiar with the very basics of swimming pool design, types of treatment, operational procedures, and fundamentals of swimming pool chemistry.

617. Types of pools and operations fundamentals

There are four important considerations of the importance in maintaining good swimming pool operations. First and foremost is disease prevention and safety. Aesthetics and economical practices, although important, play a lesser role.

Disease prevention

Diseases can be spread through contaminated swimming pool water, by contact with contaminated objects, or by persons in the pool or pool area. Some of the illnesses caused by contaminated swimming pool water are colds and other respiratory infections; typhoid fever; amebic dysentery; bacillary dysentery; cholera; diarrhea; hookworm; tapeworm; infectious hepatitis; intestinal disorders; and miscellaneous eye, ear, nose, throat, and skin infections.

Tiny organisms, such as bacteria and viruses, cause these diseases. Some are so small they can only be seen through a powerful microscope; therefore, it is highly important that you kill or remove the organisms from swimming pool water.

Bacteriological tests of pool water are performed at regular intervals by the installation surgeon to determine if the water is safe for swimming. The tests require 1 to 2 days for completion; hence, they reveal the bacteriological quality of the water as it was at the time of testing, not as it is at any other given time or times. Thus, bacteriological testing serves primarily as a check on good safe water rather than a check of the water at the time it is in use.

Two bacteriological tests are made on pool water samples. The first detects the presence of live coliform organisms (fecal coliform); the second test shows the total number of bacteria present (heterotrophic plate count). The presence of coliform organisms shows sewage contamination of the water, which means that disease germs can be present. When coliform organisms are found in a sample, the test should be taken again. If the second test is also positive, take steps to find the source of contamination and stop it. These tests take a maximum of 24 hours to complete. This usually means that you will not have any results for 2 days, since the first 24 hours after sampling is part of the test.

The test for fecal coliform bacteria should not show more than 4 colonies per 100 milliliters (ml). If more are present, some form of sewage contamination is present. The source of contamination should be located and corrective measures taken. A possible problem could be that the pool water purification equipment is defective or inefficient.

Safety requirements

Cloudy water caused by improper swimming pool water treatment could possibly obscure a drowning swimmer from lifeguards. Lifeguards need to be able to see into the pool from their observation posts.

Economy of practice

Chemical over-usage and wasting water can add up quickly in terms of dollars overspent. Each pound of chemical we use costs money. It is not free for us to waste because we don't want to spend the time making sure the pool is operating efficiently. Prematurely backwashing a diatomaceous earth (DE) filter for example, will waste the chemical because a full filter run wasn't realized. Leaving the chlorine feed rate too high in the evening is another form of chemical waste. Long, inordinate backwash runs on a pressure sand filter is a good example of wasting water. Good routine maintenance is also a secondary factor in economy of practice. Improper maintenance procedures can cause damage to filter pumps. Improper sequence of valve operation can also cause damage to the whole filter system.

Types of pools

Pools are built according to the requirements of the location, terrain, climate, and type of use for which it's intended. There are two basic types of pools: fill and draw and recirculating.

Fill and draw pools

These pools are exactly what their name implies—they are filled and then drained later when the water becomes objectionable. Fill and draw pools do not have a filtration system or an overflow system. These types of pools are not approved for military installations.

Recirculating pools

The recirculating pools (fig. 2–9) are characterized by two major components: a filtration system and an overflow system. Other than various differences in shape and size, the largest difference between them is the type of overflow system each one is constructed with. The primary purpose of a pool overflow system is to provide a continuous skimming of the water surface. Skimming the pool surface does two major things: removes floating hair strands and other debris, and more importantly, it removes suntan oils which have come off the swimmers with each bathing. The three types of pool overflow systems we will discuss are the trough (gutter), rimflow, and surface skimmer. The major construction difference between these three types of overflow systems is whether overflowed water is filtered or wasted. Let's discuss these overflow systems more closely.

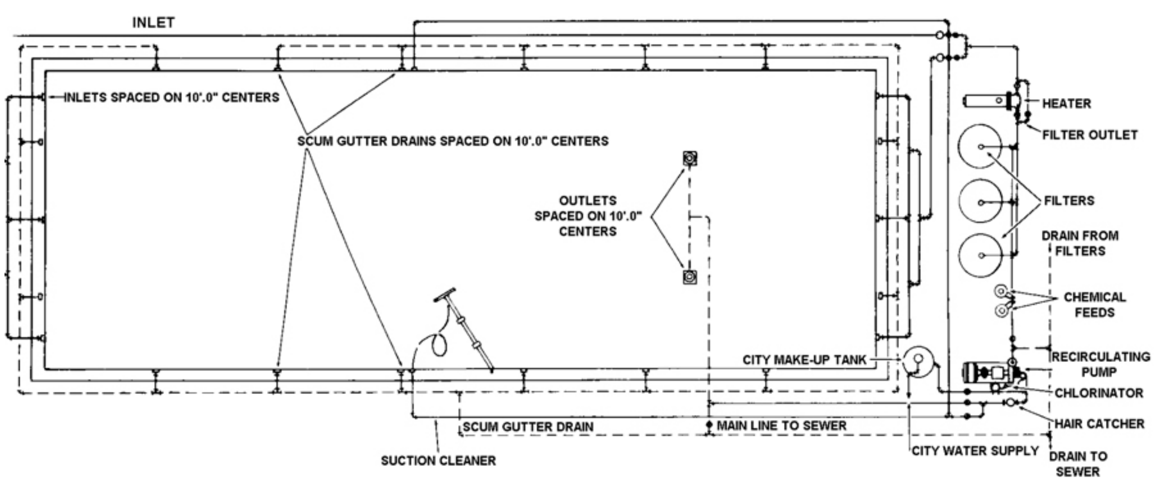


Figure 2–9. Top view of a typical pool recirculation system.

Trough (gutter) type

The trough type of overflow pool (fig. 2–10) is characterized by a continuous 4–6” deep gutter that runs along the perimeter of the pool. The gutter is actually built into the inner sidewall of the pool. The gutter acts as both a skimmer to remove suntan oils and hairs, as well as a hand-hold for the swimmers. Overflow water entering the gutter runs along the perimeter length of the graded gutter until collected into the closest trough opening. This overflow water is then piped by gravity flow towards the filter room where it is filtered.

There are various designs of overflow collection systems once *in* the filter room. The first type is the free-flow of overflow water *into* an open filter basin such as in most DE filters. In the second type of filter room pool overflow collection system, overflow water goes into an open wet pit that *feeds* a closed, pressurized sand-filter by way of a filter pump (also on some pressurized DE filters). There are also instances where gutter overflow water is wasted into the sanitary drainage system and is therefore not treated. By and large, though, most AF bases have pools in which a gutter system does feed the filter and water is not wasted. The gutter overflow system is found at most AF bases.

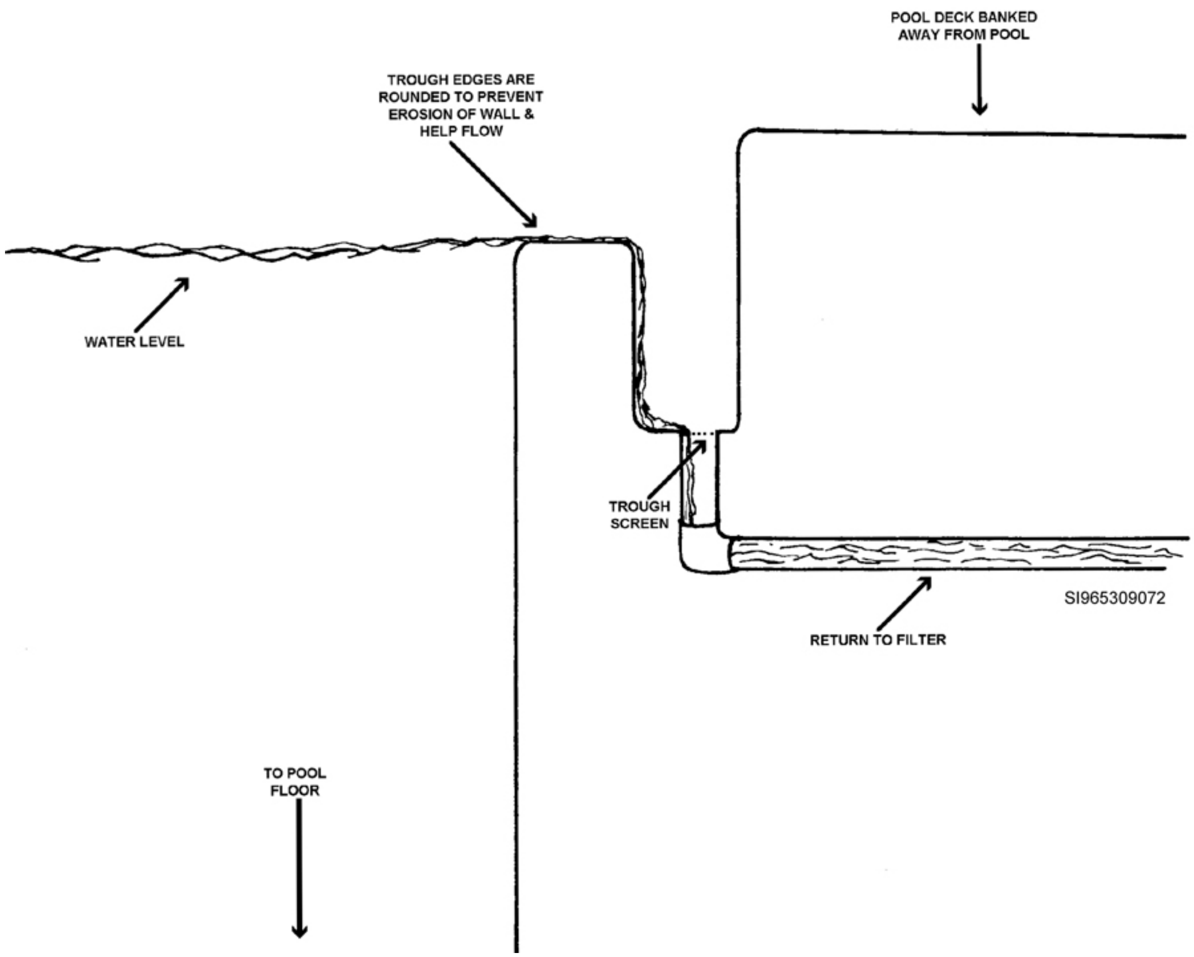


Figure 2–10. Cross-sectional view of a trough type overflow collection gutter.

Rimflow type

The rimflow type of overflow pool (fig. 2–11) is an older design that is not common to industry any more. In this type, the water level is maintained to the level of the surrounding deck. The deck of the pool is actually sloped down away from the sidewall of the pool. Trenches are placed in the deck of the pool in strategic locations so that overflow water drains into them. Metal grates cover the trenches to prevent trash from entering the overflow collection system. The trenches carry the overflow water by gravity flow to the filter room or to waste as described in the gutter-type overflow system. The deck is easily cleaned, but care should be taken that cleaning detergents do not cause problems such as foaming in the recirculation system.

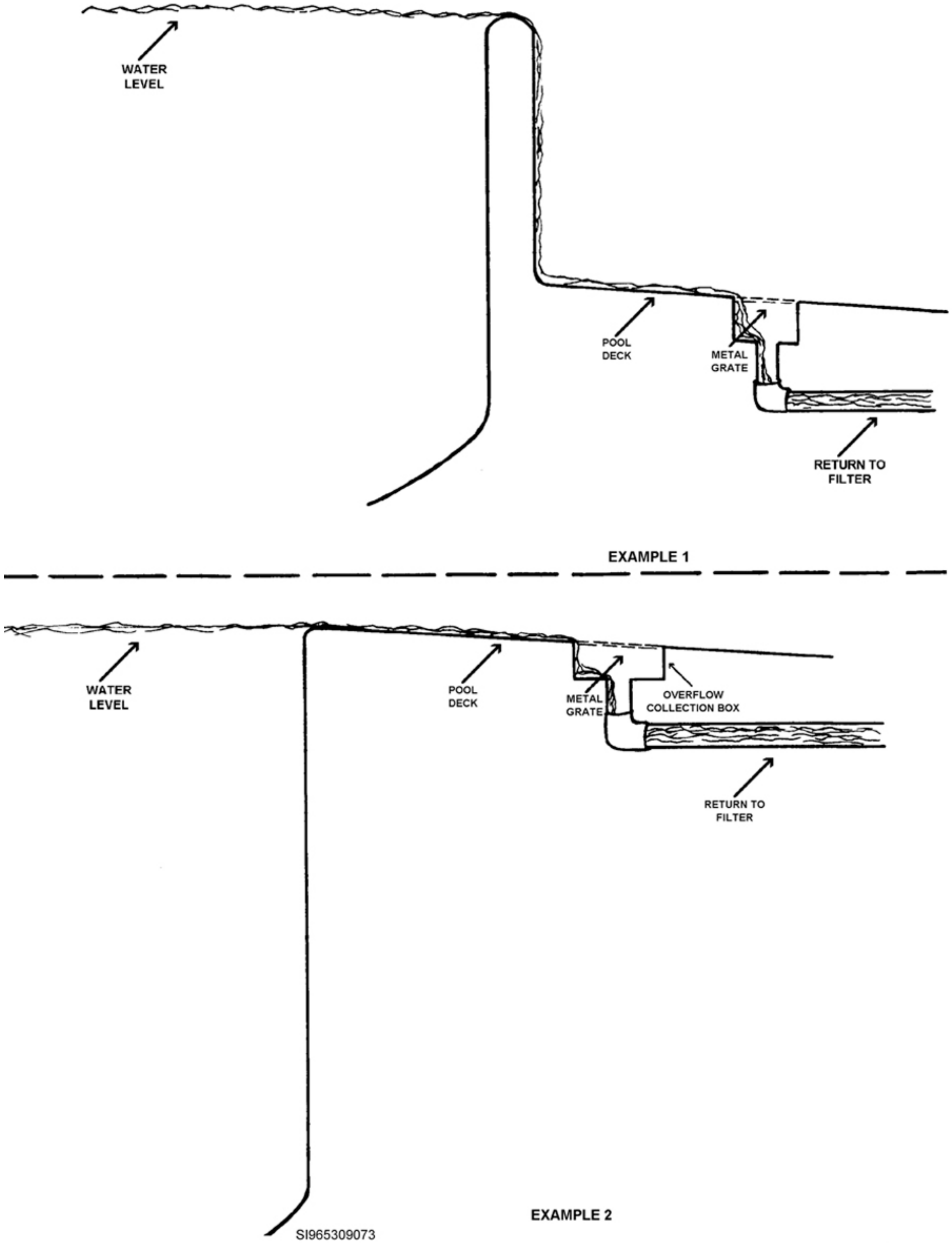


Figure 2–11. Cross-sectional view of a rimflow-type overflow collection system.

Surface skimmer type

This type of overflow system (fig. 2–12) is found in smaller pools such as motel pools. This overflow system consists of box-like openings constructed into the sidewall of the pool at intervals of 15 to 25 feet. The water level of the pool is kept high enough so that water can flow into the box. Each box has a clapper valve that swings down, away from the pool, towards a sump constructed 1–2 feet away from the sidewall of the pool. A removable leaf strainer is placed in the bottom of the sump. The sump is covered with a round plastic lid. Overflow water is carried towards the filter room just as in the gutter type and the rimflow type. Pools with surface skimmers are labor intensive in that the basket must be removed and cleaned often or else skimming does not occur. Also, depending on wind direction, one sump may have more debris than the others.

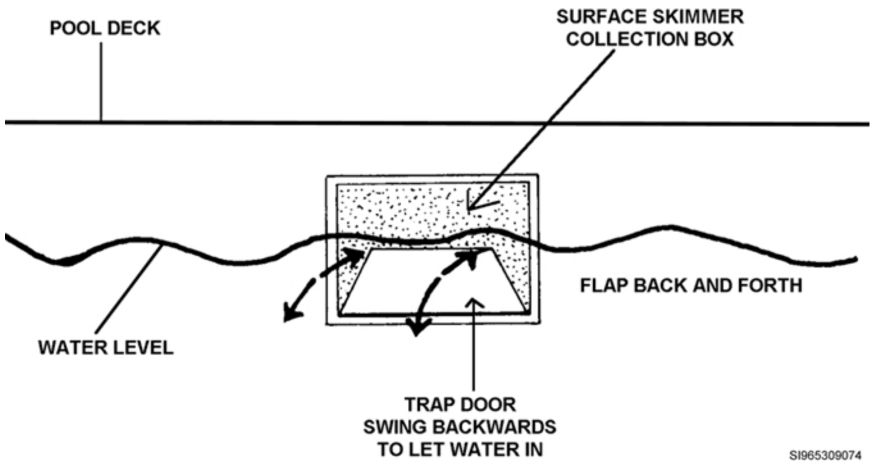


Figure 2–12. Front view of a partially open surface skimmer.

Wading pools

Wading pools, usually called baby pools, are small pools that are the same size as the fill and draw types except that they do have a recirculation system. They are sometimes tied into the recirculation systems of the larger parent pool that is adjacent to them or they continuously drain into the sewer system. When this happens they are much easier to operate. When they have their own filter system, baby pools should be completely recirculated through the filter every three hours. This is because babies will urinate and defecate into the pool. The pools usually do not have an overflow collection system. These pools are highly labor intensive in that they must be scrubbed down with bleach each time they are drained. The lifeguards will usually do the cleaning operation. Your job is to ensure that the filter system is operating properly.

618. Swimming pool chemistry

Testing pool water with the proper instruments is vital in determining how the pool is operating. There are four basic tests that you perform to maintain proper swimming pool operations. The result of the tests will indicate what is going on with the treatment. You can’t alter the treatment without interpreting the tests. In this lesson we will discuss the following tests or parameters:

- Potential hydrogen (pH).
- Turbidity.
- Chlorine residual.
- Water temperature.

pH

pH is the measure of alkalinity or acidity of water. The pH scale goes from 0–14. A pH of 7 is considered neutral—neither acid nor alkaline. pH 7 is the perfect chemical balance of any liquid.

Numbers below 7 are acidic while numbers above 7 are alkaline. The pH of pool water should be between 7.2 and 7.8. pH values below 7 and higher than 8 can cause eye irritation. Pool water that is continuously below pH 7 can promote the corrosion of the pool piping over a long period of time. A high pH will not only reduce the effectiveness of chlorine, but also will precipitate higher chlorine feed rates, which, in turn, will increase the purchase of chlorine because more chlorine must be added to overcome the high pH.

Turbidity

The simplest definition of turbidity is “water cloudiness” due to suspended dirt, undissolved chemicals, algae, or other foreign materials. Turbidity of water is measured by a spectrophotometer. Spectophotometry is the measure of any liquid or substance by light diffraction. Be aware though, that water may be “turbid” long before it even appears cloudy to the human eye. In the turbidity, you are measuring the amount of very fine suspended particles in the sample. The increase of suspended materials in any turbidity could indicate a problem with the filter system or overuse of pH stabilization chemicals, just to name two. Turbidity is measured and reported in Nephelometric turbidity units (NTU).

Black disk

Unfortunately it’s not always convenient to carry a spectrophotometer to the pools every day. For this reason, you can also interpret pool turbidity rather quickly by painting a 6” black disc at the deepest end of the pool when the pool is empty. Every time you check the pool during the season, look at the disc. It should be clear around the edges. If the disk looks unclear you may just need to backwash the filter.

Hand-held turbidity meters

Although not required by AF instructions, you may go ahead and perform a daily turbidity check of pool water using any variety of the small handheld units that are available today. Each unit is different, so we will only discuss the general outline of how these handheld units work. Basically, a sample is taken and the vessel wiped clean. Another vessel, containing a known, unopened standard is inserted into the meter. The meter is turned on and calibrated to the known standard. Next, the vessel containing the standard is removed from the meter and the other vessel containing the sample is inserted into the meter. The meter is turned on and a reading is taken. Established parameters for pool clarity (in NTU) are as follows:

Turbidity results interpretation table	
Exceptionally clear:	0.1—0.2
Good:	0.2—0.3
Acceptable:	0.3—0.5
Poor (unacceptable):	> 0.5

Be aware that pool water is usually clearer (lower in turbidity) than potable water because pool water is continuously being recirculated through a filter and it is not subject to picking up suspended particles from long networks of pipes like potable water is.

Chlorine residual

Chlorine is the disinfectant of choice for all swimming pools. As we discussed earlier, swimming pools are open to the general public and, consequently, we have to make sure that people don’t get sick from swimming in a pool. Remember that swimming pool water is continuously contaminated by bathers and children who sometimes urinate or defecate while swimming. These conditions present a potential health hazard when pool water is not chlorinated sufficiently. The chlorine residual of a swimming pool should never be below 0.4 milligrams per liter (mg/L) of free-available chlorine. Swimmers’ eyes will not become irritated from chlorine as long as the residual is between 0.4 mg/L and 2.0 mg/L free available. This range satisfies our goal of disinfection and economy of practice. Feeding excess amounts of chlorine to keep residuals higher than 2.0 mg/L should only be done when getting the pool ready for bacteriological testing (during pre-opening procedures) or when doing any form of superchlorination (discussed later). Having said that, there are a few factors that will affect your ability to maintain a proper chlorine residual. Let's discuss these now.

Sunlight

Sunlight is the number one individual consumer of chlorine in a pool. The hotter and brighter it is outside, the higher the feed rate of chlorine will need to be. If it's going to be a hot day, you need to increase the feed rate early in the morning so that by noon you are maintaining a residual without having to over feed later in the afternoon.

Bathing load

As the bathing load (# of swimmers) increases, the feed rate of chlorine will also need to increase. This is because the swimmers will splash more of the water into the air (volume for volume) than would be done otherwise. Splashing causes sunlight and air to remove chlorine from the water. Additionally, the higher the amount of bathers, the higher the proportionate amount of urine in the pool.

pH

By itself, chlorine gas has the tendency to acidify water. Therefore, at some bases, chemicals are added to counter this acidifying effect of chlorine. Soda ash (sodium carbonate) is added to counter the acidity in the water. At some bases though, the natural pH of the water is high enough (7.8–7.9) so that the addition of chlorine to swimming pool water will bring the pH down to an acceptable level (7.3–7.5). Consequently, if the base water supply is already precariously low in pH (6.9–7.2), you will need to add soda ash to keep chlorine from acidifying the water too much. Therefore, increased usage of chemicals such as soda ash will have a countering effect on the effectiveness of chlorine.

Temperature

Water temperature affects how fast chlorine is used up. The warmer the water, the faster chlorine gets used up. This is why pools equipped with heaters should not be set so high that chlorine is wasted. Generally, heated pool water should not be any warmer than 78°F. At enclosed pools, the air temperature should not be more than 5° warmer or 2° colder than the pool water temperature. Although you personally do not have authority to change heater settings at a pool, you should be monitoring it and reporting irregularities to heating, ventilation, air conditioning/refrigeration (HVAC/R) personnel.

Other factors affect the effectiveness of chlorine. *All* of the factors, when presented together, make your job of keeping a good residual a difficult one.

619. Treatment systems

There are two forms of swimming pool water treatment: physical treatment using filters and chemical treatment using chlorine and soda ash. Usually, these two forms of treatment are used together. In this lesson we discuss the various types of treatment systems associated with swimming pools.

Physical treatment

Suspended particles, which can be blown into the pool by the wind or carried into it by the swimmers, must be removed by filtration. The filters used to remove suspended particles are usually pressure-type sand filters or DE filters. In some cases, cartridge filters are used for smaller baby pool filtration systems. Filter sizes for swimming pools are designed to filter all the water every 6 to 8 hours. This is considered an acceptable "turnover" rate. Swimming pool filters are generally installed in a bank of three to five filters.

Pressure sand filters

Design engineers will usually be responsible for the specification of the filter size installed for a swimming pool. In either case, the correct size filter should be able to treat the total volume of water in the pool every 6–8 hours. Pressure sand filters are basically steel cylinders which contain graded layers of sand on top of a layer of medium gravel supported by yet another layer of coarse gravel. An underdrain collection system supports all of the filter media and also collects the filtered water, channeling it back to piping leading to the pool. The secondary purpose of the underdrain collection system is to evenly distribute water during the backwashing process. The grade of the filter media may be adjusted to modify the filter flow rate—either faster or slower. Generally though, the slower the filter flow rate, the better the quality of water in turbidity units. There are two kinds of pressure sand filters: vertical and horizontal (figs. 2–13 and 2–14).

Filtration principle

Water enters the top of the filter and is distributed evenly over the filter surface area using a header distributor. The force of the discharge from the filter pump into the filter forces the water to flow evenly through the first layer of media—the sand. The sand media is the only “filtering” media in the filter. The two layers of medium gravel and coarse gravel serve only to support the sand, prevent sand from breaking through into the pool, and to channel water towards the underdrain collection system—nothing else.

During the filter run, suspended matter builds up on the sand filter media, decreasing the flow rate and improving the filtering action. This will continue until the now encrusted sand filter surface can no longer allow flow to pass through the filter evenly. Without immediate backwashing, the force of the pump will push water towards the weakest area of the sand surface, forming a “crack” in the bed. From this point on, the filter will not work properly as unfiltered water will simply pass through the crack right down to the underdrain collection system.

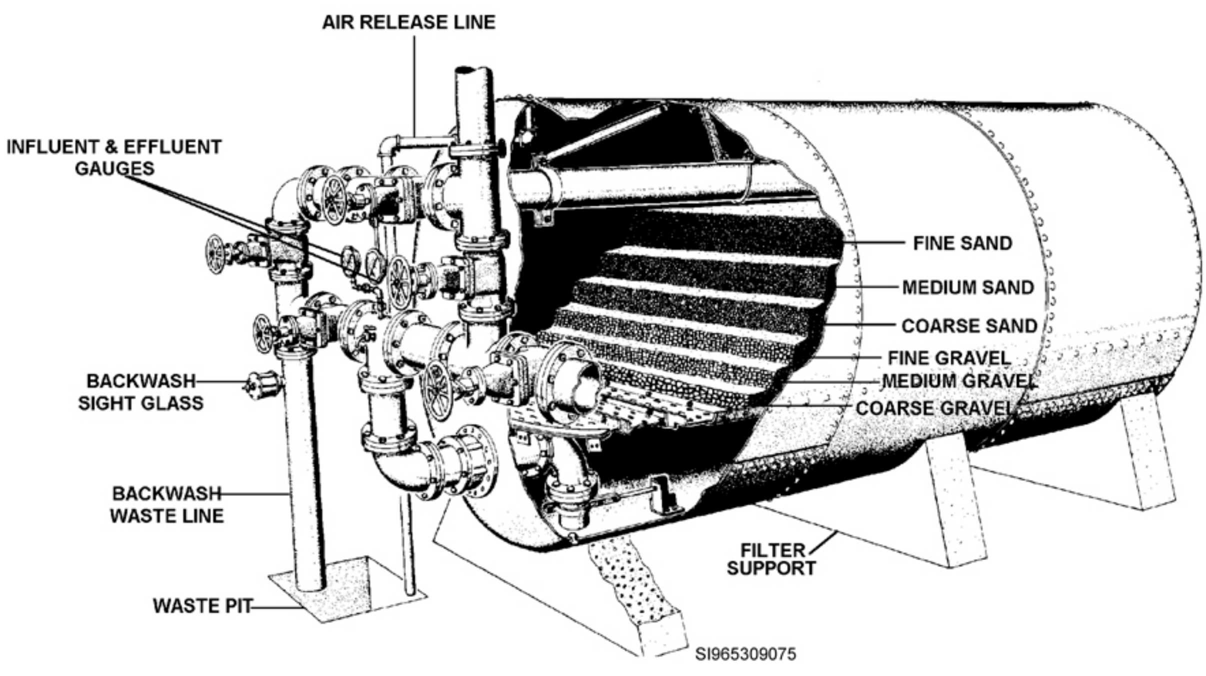


Figure 2–13. Horizontal pressure sand filter.

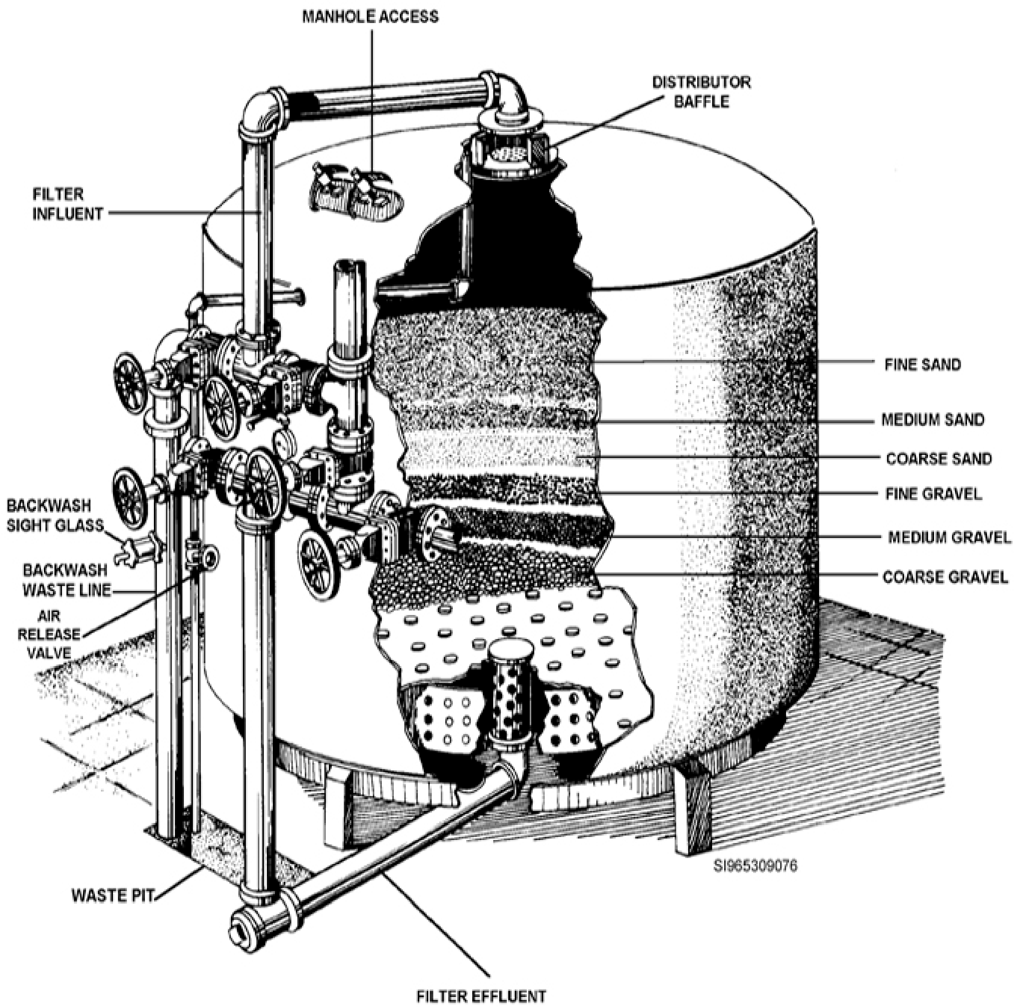


Figure 2–14. Vertical pressure sand filter.

Backwashing principle

Backwashing refers to reversing the flow of water through the filter to “wash” the filtering media (sand) free of encrusted particles. During backwashing, the valves of the filter are arranged so that when the pump is turned back on, it will force the water to go to the bottom of the filter and out the top of the filter to waste. The roles of the distributor header (at the top of the filter) and the underdrain collection system (at the bottom of the filter) are now reversed. The underdrain collection system will now distribute water upwards from the bottom of the filter towards the distributor header which now serves as a wash water collector. During this process, the three layers of sand, medium gravel, and coarse gravel are lifted upwards to (1) regrade the filter medias and (2) wash encrusted particles from the sand media. This is called “media expansion.” Generally, an expansion of 20–25 percent is good enough for cleaning action while 40 percent is optimum. Continued expansion of the media more than 40 percent will wash waste sand out of the filter—requiring someone to add sand to the filter later on. Expansion cannot be measured in a pressurized sand filter but you will know that the backwash flow rate is too high if you see sand in a sample of backwash water.

DE filters

DE is a white powder that is made from the skeletons of microscopic aquatic organisms called diatoms. It is mainly used by industry as a filter aid. DE is mined from quarries much like limestone. DE filters will typically remove 99.9 percent of suspended solids when operated properly. DE is used as the filter media in a DE filter. The filter's only major drawback is that they must be closely watched for filter break through.

Filtration principle

DE is added to the filter in a "slurry" form (mixed with water) and is allowed to coat specially designed filter membranes using a recirculation process. The filter membrane is made of fine plastic, metal, or ceramic mesh and is called the "septum" (sock). The sock is pulled over a water collection manifold to give it a base against which DE may form a porous layer. During the recirculation process, enough DE is added in a slurry to "precoat" the socks as shown in figure 2–15. There are two major types of DE filters: open pit and pressurized steel cylinder. Both major types will have socks over collection manifolds installed in them.

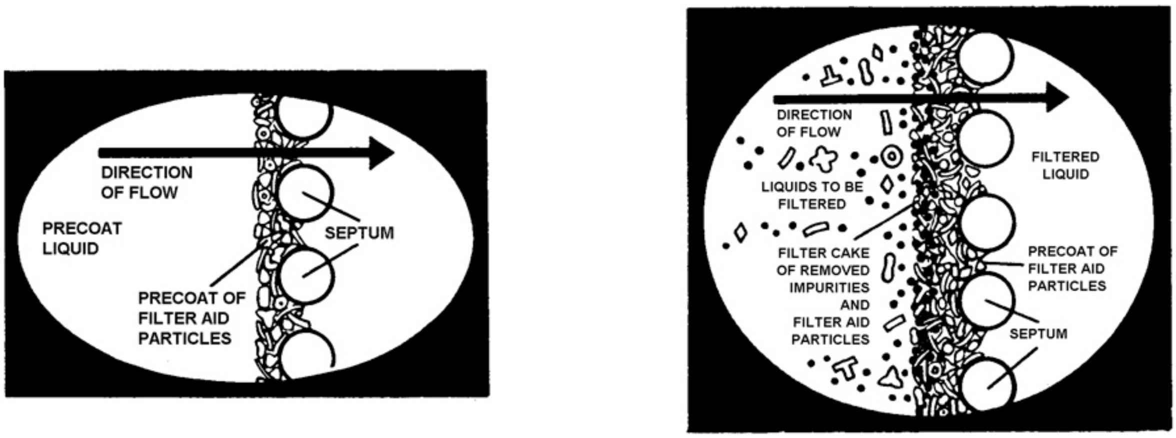


Figure 2–15. Precoating process of a DE filter sock.

The pressurized DE filter is very much like a pressurized sand filter except that the filter media is not sand supported by gravel; it's DE supported by socks, which are, in turn, supported by the collection manifolds. An example of a pressurized DE filter is shown in figure 2–16. In a pressurized DE filter, pump water pressure forces water through the porous DE membrane much like the pressurized sand filter.

The open-pit DE filter differs from the pressurized DE filter in that the open-pit type has an open top and is not under pump pressure. Instead, it is under vacuum. Water is sucked through the DE filter media using a filter pump as shown in figure 2–17. So the major difference between these two major types of DE filters is that the filter pump is ahead of the filter in the pressurized type and after the filter in the open-pit type. The open-pit type DE filter system is more labor intensive than the pressurized DE filter because during the backwashing process, much more care must be used in washing the socks. (**NOTE:** We will discuss backwashing procedures later in this unit.)

Both the open-pit and the pressurized-types of DE filters work based on the same principle. As suspended solids build up on the filter media, turbidity is lessened until such a point that the filter media (also called cake) can no longer allow water to flow through. At this point, filter "cracks" will start developing on the media if the unit is not backwashed immediately. In some cases, filter breakthrough can be delayed by the addition of more DE slurry in small "maintenance doses" during the filter cycle. The limiting factor in maintenance doses is the suction head capacity of the filter pump.

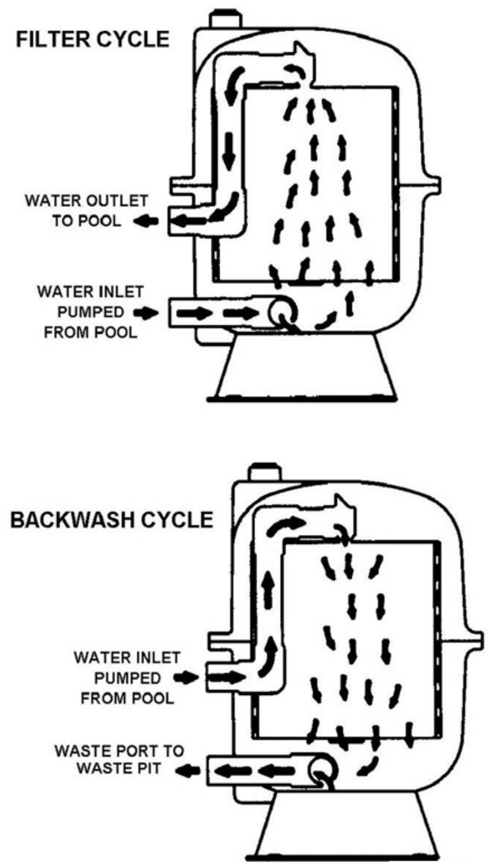


Figure 2–16. Pressurized DE filter.

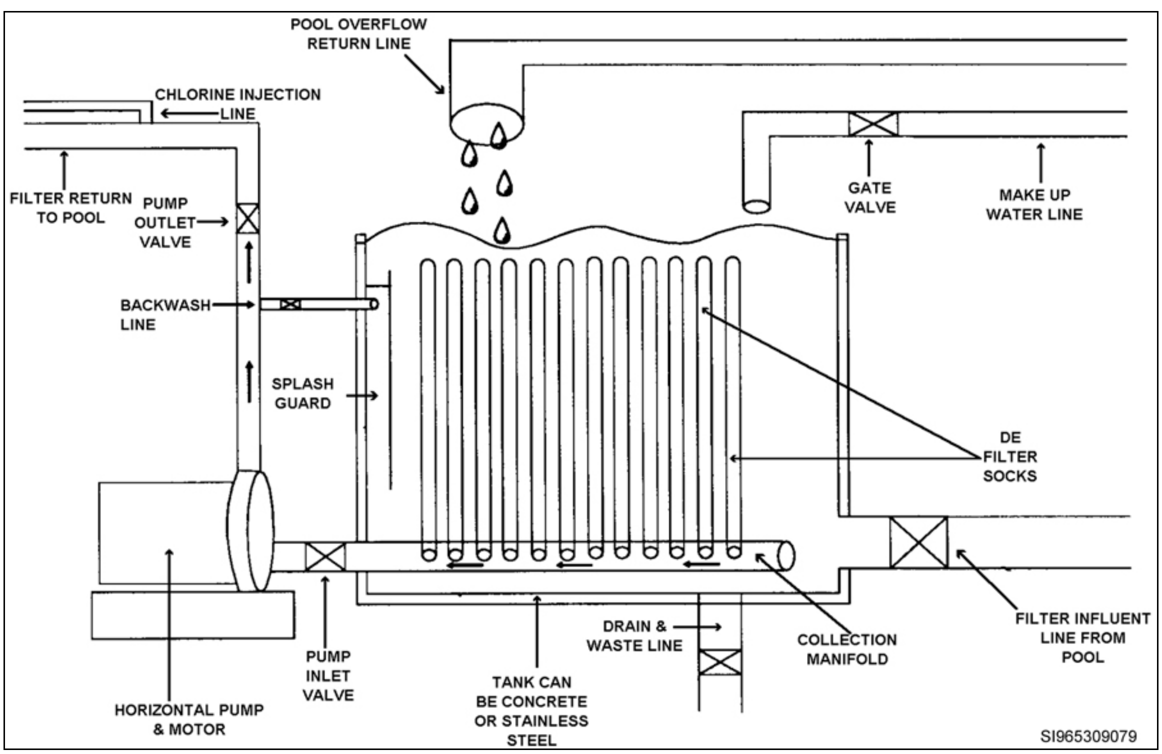


Figure 2–17. Open pit type DE filter.

Cartridge filters

Cartridge filter systems are commonly associated with small baby pools. Cartridge filter systems usually come as a pre-assembled pump and filter unit. The cartridge filter housing can be removed by unscrewing a wingnut-type clamping band. The cartridge looks very much like an air filter for a car except that it is much taller and smaller in diameter. Good cartridges are easily cleaned during the swimming season by hosing them down clean using a pressure water sprayer.

Chemical treatment systems

Physical treatment alone is not enough to properly treat swimming pool water. Chemical treatment is also needed to ensure that pathogens do not live in the water. Physical treatment *clarifies* the water while chemical treatment is used primarily to *disinfect* the water. When we talk about chemical treatment of swimming pool water we are really discussing two forms of chemical treatment—disinfection and pH adjustment. Water is disinfected using chlorine while pH is balanced using sodium carbonate (soda ash). In some cases, even sodium hydroxide is used to balance pH when chemical costs of soda ash become prohibitive. Sodium hydroxide is more concentrated than soda ash, so care must be taken when using it. There are only two practical methods of delivering enough chlorine to disinfect a swimming pool. These methods are chlorine gas injection and solution injection using calcium hypochlorite tablets.

Gas injection

Chlorine gas is 100 percent chlorine while the tablets are 65 percent chlorine. Both methods are very effective, especially when they are operated properly. Chlorine gas is available in 150-pound (lb.) cylinders and 1-ton cylinders (for conventional water treatment). In the gas injection method, (fig. 2–18) chlorine gas is fed into an "injector" that is installed in the effluent line of a booster pump (pump hidden in this figure).

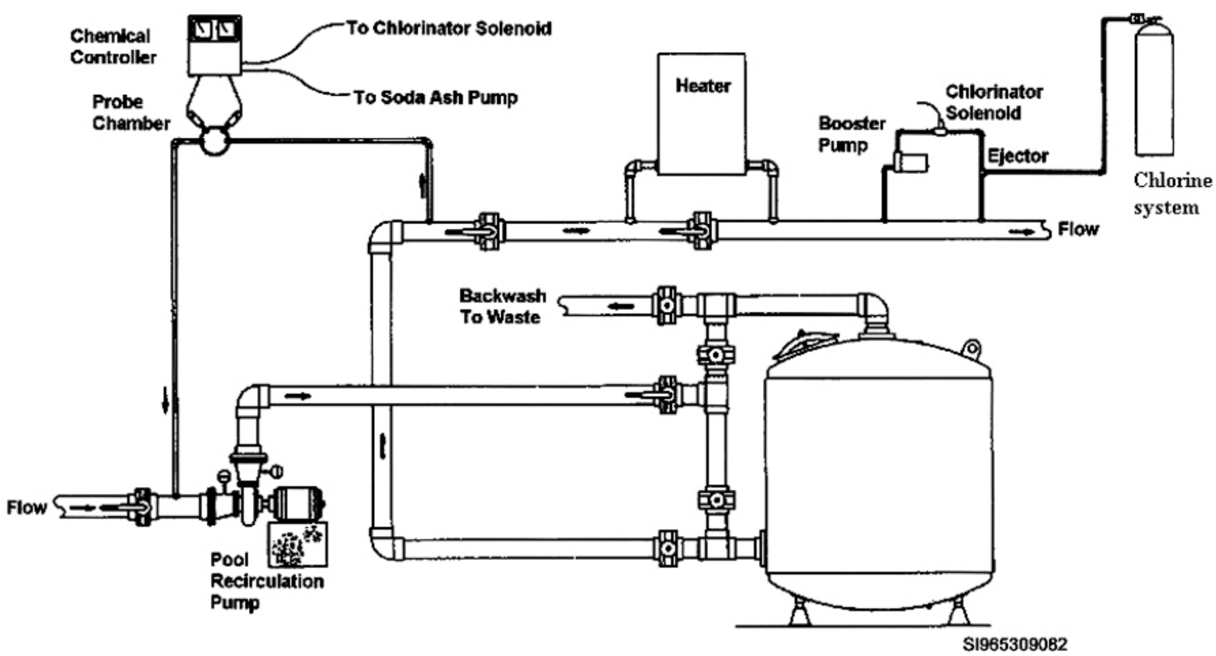


Figure 2–18. Chlorine gas feed system.

A line from the feeder is installed into the injector port, creating suction. The feeder also has a gas supply line coming from the chlorine cylinders. The feeder withdraws gas from the cylinder using the vacuum created by the injector and feeds it into the injector port. The injector port not only serves to provide vacuum but also to mix the chlorine gas into solution before it reaches the pool. The feeder is regulated using an adjustment knob which controls a bleeder valve in the feeder. On the feeder, a tube-like sight glass that contains a floating ball indicates the feed rate. As the withdrawal rate is increased, the ball rises in the sight glass. The sight glass is graduated in pounds per day. You should read the feed rate from the middle of the ball. Do not try to feed more than 80 lbs. per day using these chlorinators. Doing so will cause the bottle to freeze up, preventing the efficient withdrawal of gas. Gas injection of chlorine is by far the most used method of disinfecting large, Olympic-size swimming pools. Chlorine should always be added to the return line from the filter to the pool.

Calcium hypochlorite feeders

Another way of disinfecting a swimming pool is to dissolve high-test hypochlorite (HTH) tablets into a water solution. This is done using a cartridge feeder like the one shown in figure 2–19. In this type of chlorine feed system, calcium hypochlorite tablets (called *pucks* after the shape of a hockey puck) are loaded into a cylinder made of fiberglass. A water line from the filter pump discharge line is fed into the cylinder while another line is routed from the cylinder to the swimming pool filtered water return line. A small bleeder valve is installed on the cylinder to dispense a metered amount of the solution from the cylinder. When the bleeder valve is opened, unchlorinated water from the filter pump discharge is continuously going into the cylinder and chlorinated water (that has come into contact with the pucks) is allowed to go into the return line to the pool. This type of system is highly effective in maintaining good chlorine residuals without the problems associated with gas chlorination. These systems do not freeze up like gas delivery systems, and are actually cheaper to use than gas chlorination. Most field professionals do not know of this type of chlorine feed system and may not believe in it at first. These systems will prove themselves in less maintenance problems, cheaper delivery of chlorine, and most paramount, safer delivery of chlorine.

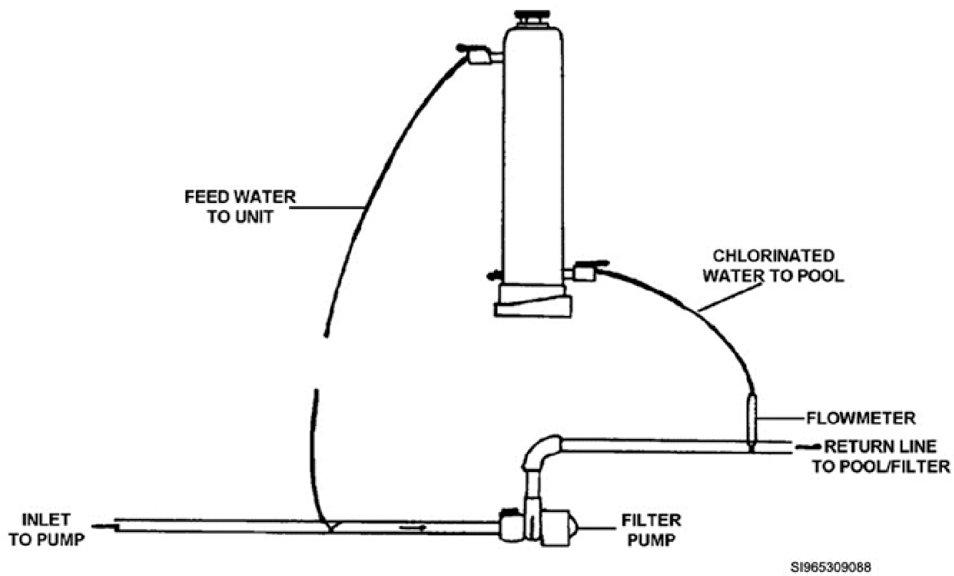


Figure 2–19. Calcium hypochlorite feeder set up.

Superchlorination

Superchlorination is the process of adding excess amounts of chlorine on a weekly basis to thoroughly kill any coliforms that would otherwise be present. AFI 48–114, *Swimming Pools, Spas and Hot Tubs, and Natural Bathing Areas,* directs that bacteriological analysis be done to the pool 72 hours prior to pool opening. Two separate tests are done to ensure that the pool water is safe: the heterotrophic plate count (HPC) and the fecal coliform (FC) test. To ensure a good bacteriological survey, you must superchlorinate the pool for 24 hours at a dose of 10 parts per million (ppm) prior to any sampling performed by the bioenvironmental engineers (BE) (medical group). This is why a good superchlorination period is so important. The limits for bacteriological testing are as follows:

For the HPC

A test result greater than 200 colony forming units (CFU) per ml is a potential indicator of poor water quality. In such cases the test is repeated. Disturbances such as rain or high winds (depositing sand) can cause the HPC test to exceed 200 CFUs.

A test result of more than 500 CFU indicate poor water quality and require that immediate actions be accomplished to improve the quality of the water prior to the pool being opened.

For FC testing

A test result indicating the mere *presence* of fecal coliforms is also a potential indicator of poor water quality. In such cases, the test is repeated for the same reason as in the HPC test (wind and rain prior to sampling).

A test result greater than 4 colonies per 100 milliliters indicates poor water quality. Remedial actions to lower the count to acceptable levels must be completed before the pool is opened.

There should not be any doubt as to the purity of the pool water. Superchlorination is also done subsequent to the pool opening after each confirmed presence of excessive amounts of coliforms. The pool is closed during superchlorination. Routine HPC and FC testing on a regular basis need not be accomplished as long as regular maintenance is done on the pool filtration system (fig. 2–20) and superchlorination/backwashing is done at least once a week. The point of this discussion on bacterial testing was two-fold: to inform you of the HPC and FC limits so that you may be more able to effectively deal with BE and also to make you understand that it is much easier to do the routine swimming pool maintenance (backwashing and superchlorination) correctly than to have to deal with the medical authorities on a regular basis.

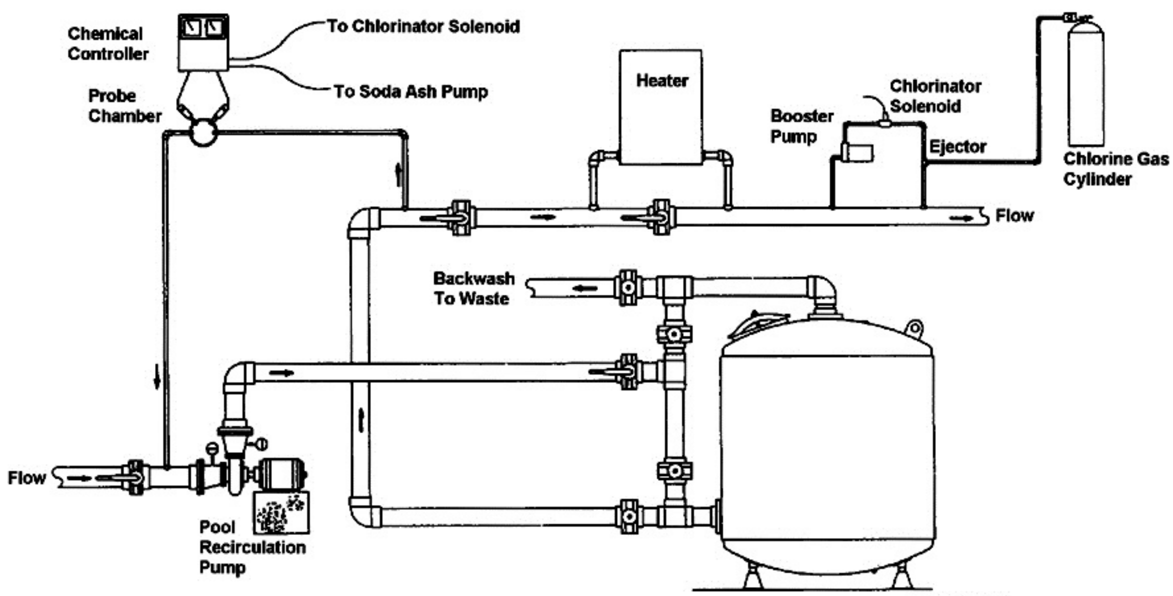


Figure 2–20. Swimming pool filtration system.

pH balancing

Chlorine tends to lower the pH in water. For this reason, we must raise the pH of the water when needed to prevent redness of the eyes in the swimmers. Several different methods may be used to do this. Sodium carbonate is usually used to raise the pH of swimming pool water by first mixing it into solution and feeding it into the return line to the filter. Sodium carbonate (soda ash) can be added to make up water by batch feeding (fig. 2–20) in a makeup tank or by using a chemical feeder that is tied into the return line to the pool. Soda ash may also be added directly to a DE filter pit. Be aware though, that by doing so you may be shortening the filter run. There are some instances where the initial pH of the base water is high enough that you don't need to add soda ash as long as you are adding makeup water. The pH of swimming pool water needs to be kept between 7.2 and 7.8 to prevent redness of the eyes. In some cases, you can use sodium hydroxide (which is stronger) to raise pH when (1) cost of sodium carbonate is high, or (2) you are adding so much soda ash that it would be easier to use sodium hydroxide. Be careful when using sodium hydroxide because it is a very powerful chemical. A sodium hydroxide solution will feel slippery to your fingers if you touch it.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

617. Importance of good swimming pool operations

1. What is the most important reasons you should practice good swimming pool operations?

2. What is the maximum amount of bacteria that can be in a coliform test without indicating sewage contamination?

3. What are the two basic types of pools?

4. What is the primary purpose of a pool overflow system?

5. What is one disadvantage of swimming pools with surface skimmers?

618. Swimming pool chemistry

1. What are the four tests that you must do to properly operate a swimming pool?

2. What is the proper pH range for swimming pool water?

3. What is the minimum amount of chlorine that should be in a swimming pool during normal operations?

4. How does sunlight affect the chlorine in a pool?

619. Treatment systems

1. What are the two forms of swimming pool water treatment?

2. What is the purpose of an underdrain system in a pressure sand filter?

3. What is the optimum bed expansion of a sand filter?

4. Which chemical is used to raise the pH of water in swimming pools?

5. What could happen if you try to feed more than 80 pounds of chlorine per day using the chlorinators?

6. To ensure a good bacteriological sample for BE engineering before opening the pool, what must you do prior to opening?

2–4. Maintenance of Swimming Pools

So far, we have discussed the operation of swimming pools. Now we will discuss how we maintain swimming pools so that we can obtain their maximum efficiency. First, let's define what we mean by "maintaining" when it comes to swimming pools. Maintenance of swimming pools pertains to any task or action that must be performed to maintain the continuous operation of the pool. Maintaining means:

- Backwashing the filter.
- Refurbishing chlorine dispensing systems.
- Cleaning the hair catcher.
- Preventing corrosion of pipes and systems.
- General housekeeping of the filter room.

All of these actions, when combined together, will accomplish your duty to maintain a swimming pool. When one or more of these actions is neglected, you can count on having problems during the operation of the swimming pool. Let's discuss these actions more closely.

620. Backwashing filter systems

A swimming pool filter must be backwashed to maintain its ability to remove suspended solids from the pool. But how do you know when to backwash? The earliest way to know when to backwash is when the turbidity of the water starts to rise. When the turbidity starts to climb, you can count on having to backwash soon. The best way to know when to backwash is when the filter indicates that it needs a good backwashing. Depending on the filter system in question, you will always have one or two gauges to tell you that the filter needs backwashing. Generally, pressure sand filters will always have an inlet and outlet pressure gauge. On the other hand, a DE filter will always have a vacuum gauge installed somewhere in the filter pump suction line.

Backwashing pressure sand filters

The two pressure gauges on a pressure sand filter are usually located in front of the filter. Both gauges will have sensor lines going from the gauge to the point on the filter that they are intended to measure. In some cases, the filter gauges may be "tapped" into the lines themselves as illustrated in figure 2–21.

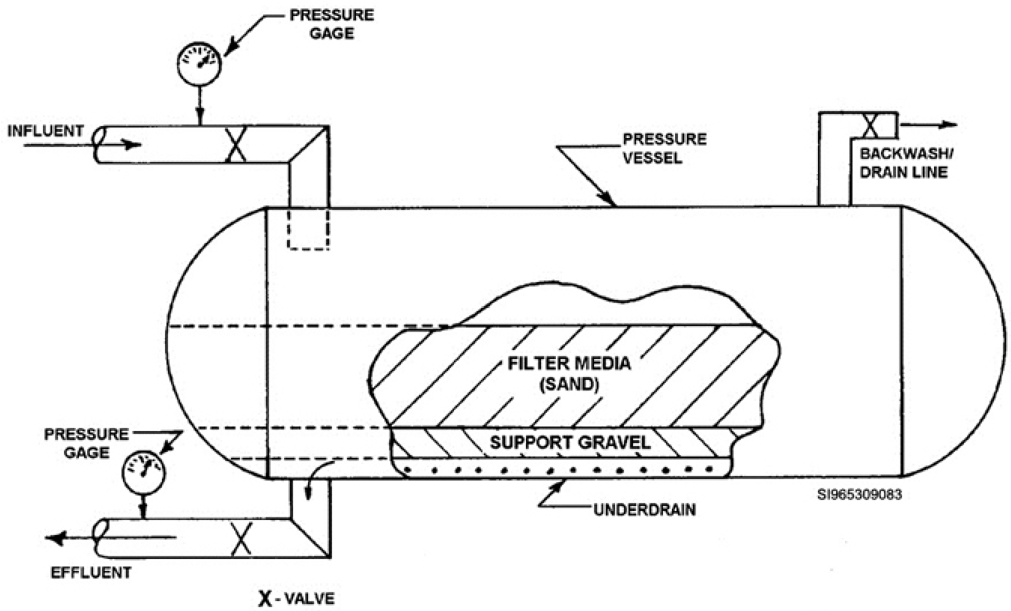


Figure 2–21. Location of filter gauges on a pressure sand filter.

Wherever their actual location, one gauge will measure "influent" (inlet) pressure while the other will measure "effluent" (outlet) pressure. You must backwash the filter when there is an 8 psi difference between the influent and effluent pressure. When we say an 8 lb. difference we mean that the influent pressure is 8 psi higher than the effluent pressure. This is referred to as "head-loss." This principle is true with all pressure sand filters. The best way to backwash a filter is to follow the flow of the water as it will go through the filter. Even though valve placement in all filter rooms will be constructed differently, the following valve sequence will always prevail when you backwash a pressure sand filter:

1. Shut down the chlorine feeder—this is always the first step.
2. Shut the filter pump off.
3. Close the valve that returns water to the swimming pool slowly.
4. Close the valve that feeds the top of the filter.
5. Open the valve that feeds the bottom of the filter.
6. Open the valve that allows water from the top of the filter to go to waste—usually in a small pit.
7. Turn the filter pump on.

After you turn the filter pump on, dirty (brown water) will start to flow through the waste pipe into the pit. You are now backwashing the filter. Continue to backwash the filter until the water going to waste looks clear. For an optimum filter run, you need to backwash the filter until the backwash water looks absolutely clear. To check for this, take a sample vial (that you use to sample water for chlorine) and fill it with backwash water. If the water looks as if it has some suspended solids in it continue the backwash. You may stop the filter pump (backwashing) when you get an *absolutely* clear sample of backwash water in the vial. This whole process will not usually take more than 10 minutes to complete. After you stop the filter pump, return the filter to the "service" position by reversing all the valve positions described above. Your last step will be to turn the chlorine feeder back on.

Backwashing DE filters

Backwashing a pressurized DE filter is very much like backwashing a pressure sand filter. The only difference is that you don't have to precoat a pressure sand filter as you do a DE pressurized filter. When you observe an 8 lb. difference between influent and effluent pressure, you backwash the filter. You reverse the valve positions from the "filter" position to the 'backwash" position as we discussed earlier.

After backwashing, take the filter out of the backwash position and put the filter in the recirculation mode to add the DE to the precoat funnel. The DE is mixed into the water that is in the precoat funnel and sucked into the filter by vacuum. Usually the DE is added in three equal "slugs" to maintain uniform distribution of the DE onto the elements. As you introduce each slug of slurry into the filter, close the valve underneath the precoat funnel (fig. 2–22) right before it starts to suck air. Fill the funnel back up and open the valve just enough to prevent a vortex from occurring in the funnel. You do not want to introduce air into the filter. If air is introduced, you may expel it out of the filter air bleed off valve. The filter is recirculated until a sight glass indicates clear water. You then return the filter to the service position while the pump is running. Each filter is arranged differently so we won't go into actual valve sequences. Nevertheless, always remember not to shut the pump off because this will "bump" the DE off of the elements and you will have to recirculate again. By and large, it is much easier to backwash a pressurized DE filter than an open-top one. This is mainly because it is easier to precoat a DE filter that is under pressure as opposed to one that is under vacuum (open-top).

If you have an open-top DE filter, the procedures are a little different. You will need to backwash open-top DE filters when the filter pump suction gauge registers between 5–10 inches of vacuum. Open-top DE filters are more time-consuming to backwash. Nevertheless, the following procedures will always apply when backwashing an open-top DE filter.

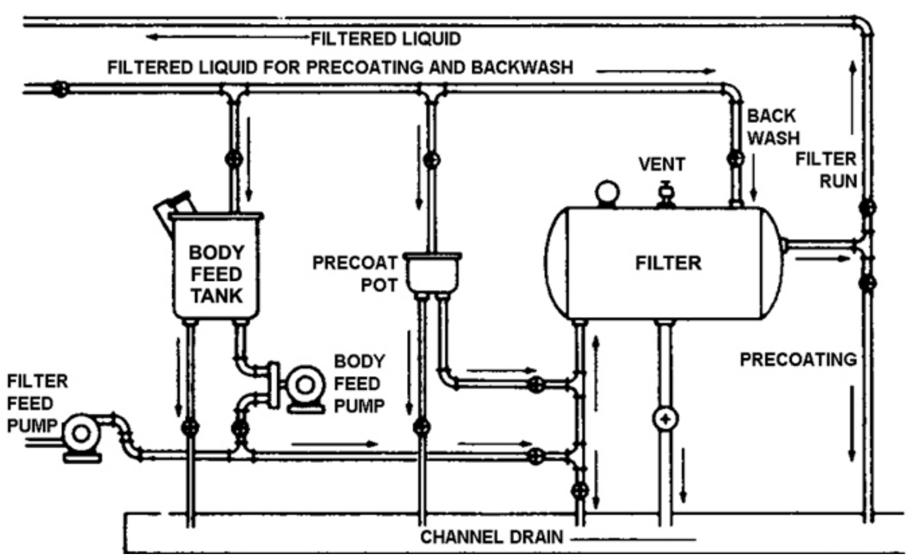


Figure 2–22. Precoat funnel location in a pressurized DE filter system.

Preparatory steps

Shut down the chlorine feeder—again, this is always the first step. Shut the filter pump off. Close the valve of the swimming pool *influent* line to the filter pit—do this quickly if the filter room is lower than the pool. If you don't close this valve quickly, the filter pit will overflow. Then, close the valve to the swimming pool return line (filter pump discharge to the pool). Open the drain line from the filter pit to waste. Let the filter pit drain completely. Open the filter pit recirculation line half-way.

Wash the filter elements

Take a fire hose with a good nozzle attachment and wash down all of the filter elements (socks) thoroughly. Dirty DE should be going to waste at this time through the filter pit drain line. Wash each element from top to bottom on both sides of the element. You may stop hosing down the elements when you do not see any more dirty water going to waste and all of the old DE is off of the socks.

Fill the pit back up

Close the filter pit drain and fill the filter pit with water to a point at least 6 inches above the elements. In some cases you fill the pit back up with fresh water—using a makeup water valve, or pool water—using the swimming pool influent line to the pit. The pool water method of filling is much faster than filling with freshwater.

Precoat the filter elements

When the filter pit is full, close the makeup water valve or pool water influent line. Turn the filter pump on. You now have the filter in the "recirculation" mode to coat the filter elements (socks). Add the appropriate amount of DE into the filter pit water. The appropriate amount of DE will usually give long filter runs. To be precise or when there isn't an already known amount added, you should add 0.1–0.2 lbs. of DE per filter element square foot (sq/ft) area. As you add the DE, the water in the pit will become cloudy. When the water turns clear in the pit you know that the DE has completely coated the filter elements. Ideally, the filter elements should be precoated with at least $^{1}/_{16}$ of an inch to $^{1}/_{8}$ of an inch of DE. The coating process may take up to 40 minutes depending on the size of the filter pit and the size of the filter pump.

Return to service

You may now return the filter to service by first opening the line that feeds the pit with pool water (pool effluent). If the filter pit is lower than the pool, only open this valve halfway. Quickly close the recirculation line halfway. Then, slowly open the line that returns filtered water back to the pool (pool influent) to the half way position. Next open the filter influent (pool effluent) line the rest of the way. Close the filter pit recirculation valve and open the pool influent (filter pump discharge) valve the rest of the way-very slowly. Opening it too fast will cause the DE to be "bumped" off of the filter elements. If the filter pit gets a little cloudy it's ok. It will clear back up. The last step is to turn the chlorine feeder back on.

Cartridge filters

Cartridge filters are by far the easiest to clean. Since the filtering element is a removable cartridge, most people will have two cartridges available for the filter housing at any one time. One will be in the filter housing while the other will be on standby. To clean this type of filter, shut off the chlorine feed and the filter pump. Isolate the filter housing by closing both inlet and outlet valves to and from the filter. Loosen the clamp band and remove the top of the housing to expose the cartridge. Remove the dirty cartridge and install a clean one (which was on standby). Replace the top of the filter housing and clamp the band tight. Return the filter to service by opening all valves and turning on the filter pump and the chlorine feed.

Cleaning the hair catcher

Every time you backwash a filter, you should clean the filter pump hair catcher (fig. 2–23) since the filter system is already down. The hair and leaf catcher prevents these and other foreign objects from clogging or damaging the pump. Clean the hair catcher right after you are done backwashing, prior to turning the filter pump back on to return the filter to service. The hair catcher is a small pit made of steel that is installed in a pipe line by way of flanges very much like a valve is installed. Inside the hair catcher is a wire meshed or slotted metal bucket. The water must first pass through this bucket in order to go into the filter pump. The hair catcher is always located in the filter pump influent line which is the pool effluent line. Most hair catchers are equipped with two buckets for easy replacement.

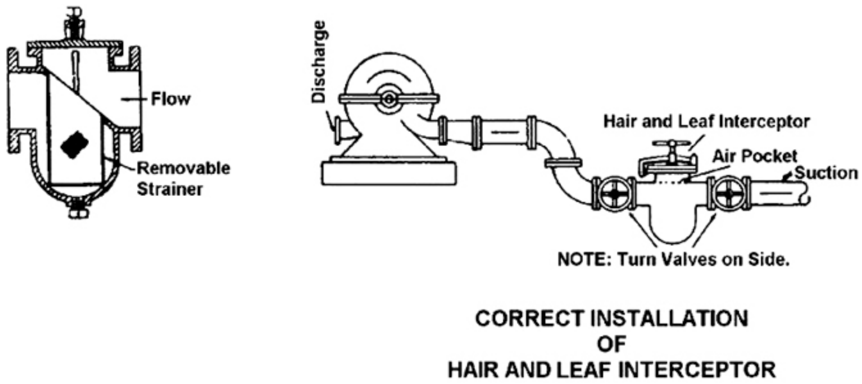


Figure 2–23. Hair catcher.

To clean the hair catcher you must loosen the wingnut that keeps the top of the hair catcher tightly sealed. Once the wingnut is loosened you may remove the top (flange) and pull out the bucket. Install a clean bucket and replace the flange. Tighten the wingnut securely and proceed to return the filter to service. On the inside lip of the top of the hair catcher top flange is a rubber gasket. This gasket has a tendency to wear down (flatten) over the years, allowing air to be sucked into the pump when it is on. This will cause the pump to airlock if a new gasket is not installed. You should make a new gasket for the flange and replace the old one every year.

Filter pump

Keep an eye on the filter pump packing gland. If it is leaking more that 2–5 drops per minute you will need to tighten the packing gland. When further adjustment on the gland cannot be made, you must replace the packing. Check the motor for abnormal temperatures. Since this type of motor is running all the time, it *will* be hot. Yet, the motor temperature should not be so hot that you can’t momentarily touch it for 5 seconds without burning yourself. Always keep a spare filter pump and motor on hand at the pool or shop.

621. Replenishing chlorine feed systems

The most dangerous job during swimming pool operations and maintenance is replenishing chlorine feed systems. Replacing chlorine cylinders and replenishing calcium hypochlorite chlorine feeders are both very dangerous tasks that must be accomplished with the utmost care. These systems can not only kill you but also kill others. Do not attempt to change a chlorine cylinder by yourself unless the following conditions apply to you:

1. You have been thoroughly trained on how to change a cylinder.
2. You feel comfortable doing it by yourself after you have done it under the watchful eye of your trainer.
3. You have been signed off on this task by your trainer.

Chlorine cylinders

Chlorine gas cylinders are the most widely used form of delivering chlorine—to a water supply or a large Olympic swimming pool. Chlorine gas comes in two types of cylinders: the 1-ton cylinder and the 150 lb. cylinder. The 150 lb. cylinder is what we use at most AF bases. These cylinders actually weigh 100 lb. empty and 250 lb. full. Hence, each has 150 lb. of chlorine gas in it. Since these cylinders are very heavy you should be very careful when handling them. To replace a chlorine cylinder follow the procedures described below.

Safety procedures

The first step in replacing a chlorine cylinder is to turn on the exhaust fan in the chlorine feed room. Know the location of the gas mask and open the gas mask container. Leave the gas mask outside the chlorine room where it will be readily accessible if you need to use it. Do *not* allow others inside the chlorine room while you are changing a cylinder. Also do not allow anyone to talk to you from outside the room—they might distract you.

Shutting off the valve

You should not replace a chlorine cylinder unless it is empty. Even though the cylinder is empty you will need to shut off the cylinder valve. First, use the wrench to loosen the packing gland of the valve (fig. 2–24). Next, put the wrench on the valve stem and close the valve hand tight. Take the cylinder cap and *lightly* tap the wrench once in the clockwise direction. Be careful not to spin the cylinder off of the scale while you are shutting the valve. Finally, re-tighten the packing gland. You are now ready to remove the feeder off of the cylinder.

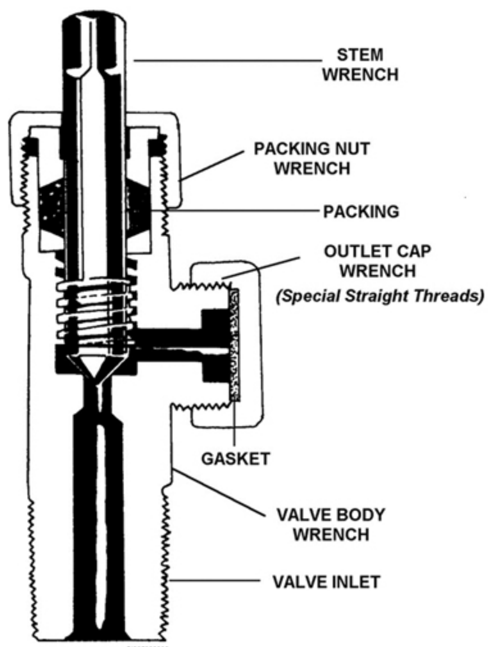


Figure 2–24. Chlorine cylinder valve.

Removing the vacuum feeder

Know the location of the valve cap (if not attached to the cylinder). First, close the feeder bleed valve clockwise to prevent gas from coming out of the feed hole of the feeder. Using the wrench, loosen the nut in the back of the feeder that tightens the feeder onto the cylinder. Quickly remove the feeder (with hoses) off of the cylinder and place out of the way. Quickly thread the valve cap back on to the valve and tighten with the wrench. Wait a few minutes and check for leaks by squeezing an ammonia (ammonium hydroxide) bottle around the valve cap and packing gland. If a leak is present a white fume will appear.

Moving cylinders

Next, tighten the cylinder cap back onto the empty cylinder. Remove the chain from around the cylinder (fig. 2–25) and carefully remove the cylinder off of the scale by slightly tilting it enough to spin the cylinder off the scale. You spin the cylinder in this way until it is out of the way and place it with all the other empty cylinders. Next, take a full cylinder and spin it onto the scale in the same way you do an empty one. Make sure the cylinder is in the middle of the scale and secure it with the chain. Remove the cylinder cap.

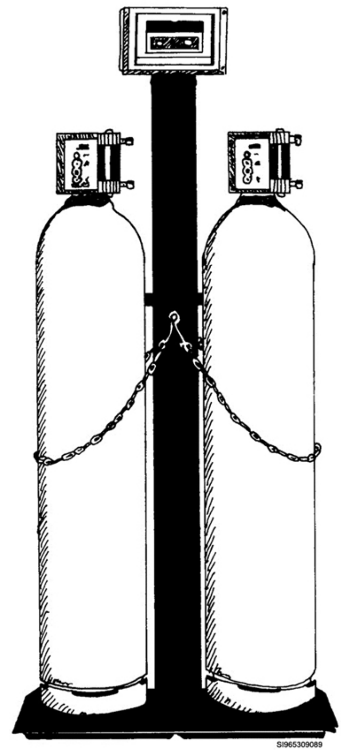


Figure 2–25. Chlorine cylinder scale.

Installing the vacuum feeder

Before you install the feeder onto the full cylinder, you must remove the old lead gasket from the feeder. You can use a pocket knife to remove the gasket. Put one new gasket onto the feeder and set the feeder aside. Next, remove the valve cap of the cylinder and closely examine the surface of the valve mouth. If there is even a slight amount of gasket material (from the valve cap) left on the mouth of the valve you will need to scrape it off with your pocket knife. Most chlorine leaks at the mouth of the valve occur because there is still gasket material left on the mouth. This causes an imperfect seal between the lead gasket and the valve mouth. Next, install the feeder onto the cylinder. Tighten the nut of the feeder vise hand tight only, as this is all that is needed to flatten the lead gasket and cause a perfect seal.

Restoring chlorine feed

Next, go ahead and open the feeder valve so that the feeder will start feeding once you open the cylinder valve. Opening the feeder valve ahead of the cylinder valve does two things:

- Prevents a gas leak through the lead gasket because the gas under pressure has nowhere to go.
- Prevents surge damage to the feeder diaphragm.

To open the cylinder valve you must first loosen the packing gland just enough so that the valve will open easily. To open the valve you put the wrench on the valve stem and *lightly* tap the wrench counterclockwise. Open the valve one full turn and no more. This is for two reasons:

- Maximum delivery can be obtained at a full turn open.
- You don’t want the valve to be fully opened—in case you need to close it in a hurry.

Once the cylinder valve is open you may go ahead and check for leaks using your ammonia bottle. Remember, if you see a leak, a white fume will appear indicating the presence of chlorine. If no leaks are present, set the feeder rate to the appropriate rate. Finally, tighten the packing gland. Your job is now complete.

Calcium hypochlorite feeders

Calcium hypochlorite feeders (fig. 2–26) are designed to dissolve chlorine tablet pucks into a water solution within the confinement of a cylinder. The cylinder is usually made of fiberglass and has an inlet and outlet valve. Water pressurized from the filter pump enters the cylinder at the top and travels through the pucks and is discharged at the bottom of the cylinder.

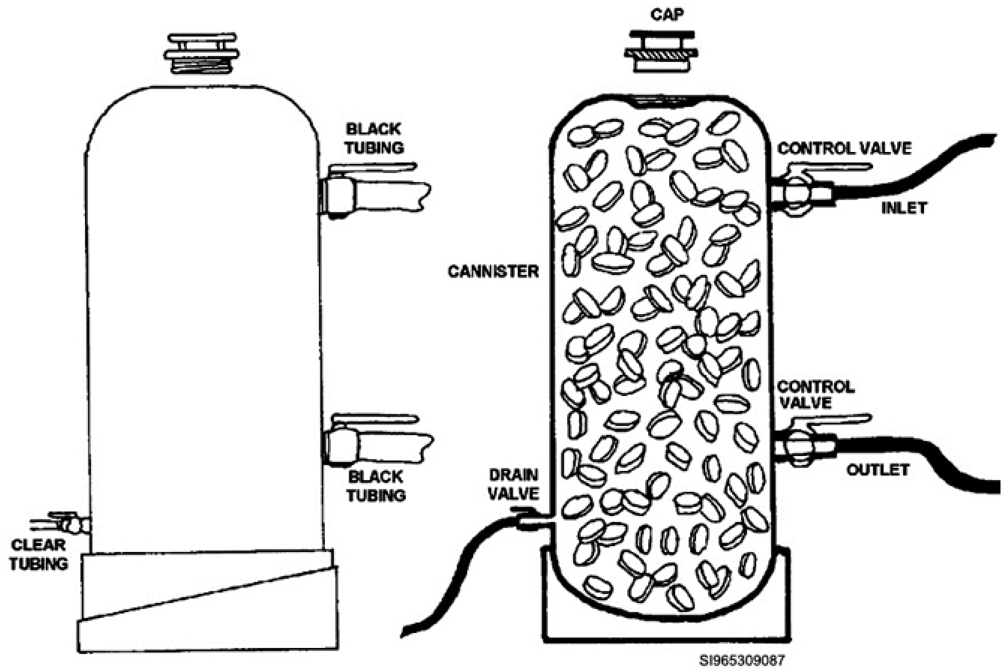


Figure 2–26. Calcium hypochlorite feeder.

Another variation of the standard calcium hypochlorite feeder is the Pulsar commercial feeder (fig. 2–27). This type of system uses “briquettes” instead of pucks. The major difference between the standard fiberglass cylinder-type puck feeder and this briquette feeder is that the briquettes in the pulsar feeder are not under continuous pressure. In this type of feeder, unchlorinated feed water enters the dissolving tank and percolates through the briquettes. Chlorinated water then drips into the discharge tank where it is fed by gravity flow or vacuum into the filter system.

In the standard puck feeder, the pucks themselves are always submerged in pressurized water (fig. 2–27). The chlorinated solution is then injected by vacuum into the return line to the swimming pool. A flow meter at the injection point indicates solution feed of chlorinated water in gpm. Using calcium hypochlorite pucks to feed chlorine into a pool is the safest method to deliver chlorine efficiently. Puck feeders do not have the safety considerations that a full-blown gas leak can impose on the base population. These feeders are as effective as gas chlorination.

Recharging a calcium hypochlorite feeder

For the puck feeder, your first step will again be to turn on the exhaust fan. Close both the inlet and outlet valves to the cylinder. Loosen the top of the cylinder just enough to assure that there is no back pressure. Once this is done, remove the top and add enough new pucks into the cylinder until the level of pucks is within 3 inches of the top. Tighten the cylinder top back onto the cylinder and open both of the inlet and outlet valves wide open. This is to remove all of the trapped air in the cylinder. Once all the air is removed, go ahead and set the bottom valve to the discharge rate desired on the flowmeter. Usually, 0.5 to 1 gpm is sufficient to maintain a good residual during the night. During the day you can increase the rate to 4–5 gpm. A recharge will usually last one month. To recharge the pulsar feeder, you simply remove the cover (which is not under pressure) and add more briquettes to the dissolving tank (fig. 2–27).

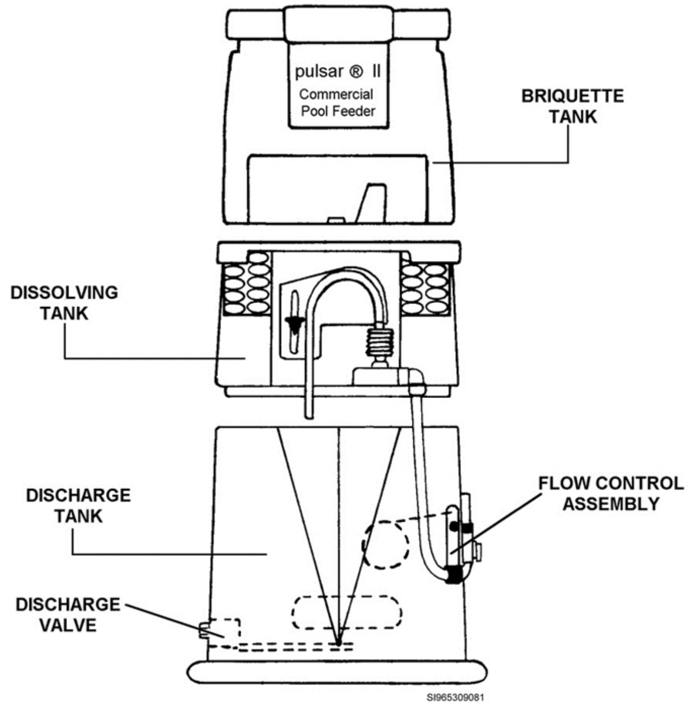


Figure 2–27. Pulsar calcium hypochlorite feeder.

Safety considerations

Because a lot of fumes are generated once you open the top of the cylinder, you will need to make sure the exhaust fan is on and that there is enough ventilation to carry the fumes away from you. Have all of the lids of buckets of chlorine tablets loosened so that you can quickly load the cylinder/feeder. Speed is of prime importance here. You want to get the pucks in the cylinder as fast as possible and close the top. This minimizes the amount of fumes to which you will be exposed to.

In this lesson, we discussed a few of the different disinfection systems for pools. There are numerous other disinfection systems that are effective, but we covered the most hazardous systems to make you familiar with them. Chlorine gas is deadly, and you need to take your job seriously when working with this type of system.

622. Corrosion control and housekeeping

One of the most important maintenance items in any swimming pool filter room is corrosion control and general housekeeping. Unfortunately, these two areas somehow do not always get the attention they deserve. Filter systems are expensive. The pump, exposed piping, and the filter itself are expensive to replace. For this reason, protective coatings of paint are necessary to prevent corrosion. Housekeeping is also a vital component of good swimming pool maintenance.

Corrosion prevention

We paint our equipment to accomplish two important things: prevent corrosion and beautify our equipment. Nothing is more pleasing to the eye as a well-maintained, well-kept filter system. You don’t have to be elaborate in the painting scheme. Usually two to three colors can effectively be used to make the filter system stand out. We generally use blue for “filtered” water, yellow for “unfiltered” water, and red for backwash water lines. Hand rails, if used, should be painted yellow and black for safety.

Housekeeping

There is never a valid reason for a dirty filter room. It is always good practice to sweep the floors once a week and empty the trash as needed. In filter systems that use DE, wash down the floor and squeegee the standing water so that no one slips or falls. If a spare parts bench is kept in the filter room, make sure all accountable materiel is tagged and organized so that others may find the needed parts quickly. If a part needs to be repaired, such as a gas chlorinator, tag it as such and bring it back to the shop. Do not leave unserviceable items around—someone else may try to use them.

Filter room security

Do not leave the filter room or the chlorine room unsecured while you are getting samples or working around the pool. Little kids may venture into the filter room and hurt themselves. Additionally, people might try to “sneak” into the pool area without paying.

Record keeping

A log book is provided at each pool to record what is happening at the pool from day to day. The log book is there for an important reason—to log chlorine and pH readings and maintenance actions done. Keep the log book neat and clean. The log book is an official AF record of the events of each visit to the pool by water and fuel systems maintenance (WFSM) personnel. DO NOT fudge the log book.

Inventory records

Inventory records are used to keep track of chemicals. They become especially important when it is time to reorder chemicals. A chemical inventory should be accomplished each week during the pool season. This is the best way to prevent “shortages” of a chemical.

Repairs

A well-maintained pool will seldom need repairs. There will be the occasional leaks in piping and chemical feed systems, but preventative maintenance can keep most repairs down to a minimum. If repairs are needed and are not urgent, schedule them when the pool is closed for the season. Most large maintenance actions will be accomplished in the spring before the initial start-up; use this time to plan any necessary repairs. All major repairs like resurfacing the pool and replacing filtration systems will typically be accomplished through contracting. Keep up on the maintenance items discussed above, and you will reduce any unexpected emergency repairs required during the pool’s open season.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

620. Backwashing filter systems

1. What is the earliest way you can know that a filter systems will need backwashing?

2. What do the two pressure gauges on a filter system measure?

3. How long does it usually take to backwash a sand filter?

4. When do you stop recirculating the DE filter?

5. What type of filter is the easiest to clean?

621. Replenishing chlorine feed systems

1. What are the two types of chlorine cylinders?

2. What should you do before you open or close a chlorine gas cylinder valve?

3. How should you remove the lead gasket from the vacuum feeder?

4. What should you used to detect a chlorine leak?

5. What will the chlorine leak look like when you test for it?

6. What form of chlorine does calcium hypochlorite feeders use?

622. Corrosion control and housekeeping

1. Why should you paint filter room piping systems?

2. What color should you paint pipes that contain filtered water?

3. Why should you never leave filter rooms unsecured?

Answers to Self-Test Questions

610

1. Pipelines.
2. Loop and radial.
3. Steel, plastic, and copper.

4. Mains and service lines.
5. Type "L."
6. They allow for a tight gas shutoff.
7. They reduce the pressure before the gas enters the distribution system.
8. On the building service line.
9. High pressure.
10. 1½ to 50 psi.

611

1. To help locate the buried pipe.
2. As long as it does not buckle, wrinkle, or crimp the pipe.
3. By physical handling of the pipe in storage, shipping, and installation; and by the flow of gas that contains dust, rust, scale, or dirt particles.
4. Synthetics.

612

1. Never.
2. A pipe rounding and straightening tool.
3. To stop the gas flow.
4. Wooden stick and cotton cloth.
5. Socket fusion.

613

1. Never.
2. At the end of the depth gauge on the pipe.
3. For the prescribed heating cycle.
4. The fitting should be against the cold ring on the pipe.
5. There should be only a slight protrusion.
6. In the center of the machine.

614

1. Underground.
2. One-half ppm.
3. To pinpoint leaks that have already been detected by line walking.
4. Same depth as the bottom of the pipe and 1 foot to the side.
5. It damages plant life and dehydrates the soil.

615

1. Because of corrosion or faulty joints.
2. Wet rags.
3. From damage by equipment or from faulty installation.
4. To act as a lubricant.
5. Mark street curbs and paint valve boxes.
6. So they can be adjusted to ground level.

616

1. The US DOT.
2. Whether a state agency has safety jurisdiction, whether the state agency has pipeline safety requirements that exceed the federal regulations, and the inspection and enforcement procedure of the state agency.
3. The Pipeline Safety Improvement Act of 2002.

4. Integrity management program.

617

1. Disease prevention and safety.
2. 4 colonies per 100 ml.
3. Fill and draw, and recirculating.
4. To provide for a continuous skimming of the pool surface.
5. The basket must be cleaned often or the filter pump will not receive enough water. They are labor intensive.

618

1. pH, chlorine, temperature, and turbidity.
2. Between 7.2 to 7.8.
3. 0.4 mg/L.
4. Sunlight tends to dissipate chlorine.

619

1. Physical and chemical.
2. To support all the filter media and collect filtered water.
3. 40 percent.
4. Sodium Carbonate (soda ash).
5. The chlorine bottles could freeze.
6. Superchlorinate the pool for 24 hours at 10 ppm.

620

1. By doing regular turbidity tests.
2. Influent and effluent pressure.
3. 10 minutes.
4. Until sight glass indicates clear water.
5. Cartridge filter.

621

1. The 1 ton and the 150 lb. cylinder.
2. Loosen the packing gland.
3. A pocket knife.
4. An ammonia bottle.
5. White fumes will appear.
6. Dry tablets called pucks.

622

1. To prevent corrosion.
2. Blue.
3. Unauthorized personnel might venture in and injure themselves.

Complete the Unit Review Exercises before continuing to the next unit.

Unit Review Exercises

Note to Student: Consider all choices carefully, select the *best* answer to each question, and *circle* the corresponding letter.

42. (610) What are the methods of joining polyethylene (PE) gas pipe?
    a. Compression and mechanical.
    b. Solvent weld and mechanical.
    c. Compression and thermal fusion.
    d. Solvent weld and thermal fusion.

43. (610) What type of valve is the *most* dependable for gas service because it allows a complete shutoff?
    a. Check.
    b. Globe.
    c. Gate.
    d. Plug.

44. (610) The function of a regulator in a natural gas systems is to
    a. maintain pressure on the outlet side that is lower than the pressure on the inlet side.
    b. maintain pressure on the outlet side that is greater than the pressure on the inlet side.
    c. prevent gas escaping from the distribution piping.
    d. prevent gas escaping from the service piping.

45. (610) What is the natural gas operating pressure rating for an Air Force (AF) installation?
    a. Low.
    b. Medium.
    c. Standard.
    d. Non-standard.

46. (611) What type of wet, detergent-soaked cloth do you wipe polyethylene (PE) pipe with to remove static discharge?
    a. Rayon.
    b. Tweed.
    c. Cotton.
    d. Polyester

47. (611) What type of clothing should you wear if you are working with polyethylene (PE) gas pipe?
    a. Nylon.
    b. Rayon.
    c. Polyester.
    d. Cotton or cotton blend.

48. (612) When assembling polyethylene (PE) gas pipe, the purpose of using an alignment jig is to
    a. heat the the pipe to the correct temperature for fusing.
    b. square the ends of the pipe for butt fusion.
    c. hold the pipe in position for butt fusion.
    d. straighten and round the pipe.

49. (612) What tool do you use to stop the flow of gas in polyethylene (PE) pipe?
    a. Alignment jog.
    b. Squeeze tool.
    c. Depth guage.
    d. Cold ring.

50. (613) The purpose of using a depth gauge when you thermal-fuse polyethylene (PE) gas pipe is to
    a. determine the length of pipe protruding from the alignment jig.
    b. establish amount of pipe to be inserted into socket fitting.
    c. determine the length of fitting needed for pipe assembly.
    d. establish the amount of pipe needed for butt fusion.

51. (613) How long should you wait before you work with a socket-fused joint on polyethylene (PE) gas pipe?
    a. 1 to 3 minutes.
    b. 3 to 5 minutes.
    c. 5 to 10 minutes.
    d. 10 to 15 minutes.

52. (614) You should conduct a line-walking gas leak survey every
    a. 6 months.
    b. 12 months.
    c. 18 months.
    d. 24 months.

53. (614) When you are locating gas leaks, for what substance should your combustible gas indicator be calibrated?
    a. Butane.
    b. Propane.
    c. Methane.
    d. Any hydrocarbon.

54. (614) What gas survey is the *most* expensive and time-consuming?
    a. Flame ionization.
    b. Gas detection.
    c. Vegetation.
    d. Barhole.

55. (615) What fitting is used for connecting steel gas pipe to polyethylene (PE) gas pipe?
    a. Unions.
    b. Couplings.
    c. Insulating flanges.
    d. Transition fittings.

56. (616) Which government department is required, by law, to develop and enforce *minimum* safety regulations for the transportation of gases by pipeline?
    a. Department of Justice (DOJ).
    b. Department of Defense (DOD).
    c. Department of Transportation (DOT).
    d. Department of Homeland Security (DHS).

57. (616) What Title of the Code of Federal Regulations (CFR) applies to natural gas systems?
    a. 49.
    b. 39.
    c. 29.
    d. 19.

58. (616) What safety act mandates significant changes and new requirements in the way that the natural gas industry ensures the safety and integrity of its pipelines?
    a. Pipeline Safety Improvement Act of 2000.
    b. Pipeline Safety Improvement Act of 2001.
    c. Pipeline Safety Improvement Act of 2002.
    d. Pipeline Safety Improvement Act of 2003.

59. (617) How long does it take for completion of a bacteriological test of swimming pool water?
    a. 1–2 hours.
    b. 1–2 days.
    c. 3 hours.
    d. 3 days.

60. (617) Other than size and shape differences, the largest differences between recirculation pools has to do with the type of
    a. filter system each is constructed with.
    b. pump system each is constructed with.
    c. overflow system each is constructed with.
    d. chlorine feed system each is constructed with.

61. (617) What is the *most common* type of pool overflow system found at Air Force (AF) bases?
    a. Gutter.
    b. Wading.
    c. Rimflow.
    d. Surface skimmer.

62. (618) Which water test do you use to determine the acidity or alkalinity of pool water?
    a. Potential hydrogen (pH).
    b. Chlorine.
    c. Turbidity.
    d. Hardness.

63. (618) The potential hydrogen (pH) scale is from
    a. 0–10
    b. 0–14.
    c. 1–10.
    d. 1–14.

64. (618) What is the *highest* amount of turbidity allowed in swimming pool water?
    a. 5.
    b. 0.5.
    c. 0.05.
    d. 0.005.

65. (618) What is the number one individual consumer of chlorine in the pool?
    a. Potential hydrogen (pH).
    b. Sunlight.
    c. Bathing load.
    d. Temperature.

66. (619) What are the two forms of treatment for swimming pools?
    a. Physical and chemical.
    b. Precipitation and adsorption.
    c. Filtration and chemical absorption.
    d. Disinfection and potential hydrogen (pH) balancing.

67. (619) What is the *secondary* purpose of the underdrain collection system in a pressure sand filter?
    a. Filter large debris.
    b. Filter fine particles.
    c. Evenly distribute water for filtering.
    d. Evenly distribute water during the backwashing process.

68. (619) As the filter run of a pressurized sand filter progresses along, the quality of filtered water will
    a. increase until filter cracks occur.
    b. decrease until filter cracks occur.
    c. not change regardless of filter cracks.
    d. remain the same as long as filter cracks do not occur.

69. (619) What is the purpose of the septum or “sock” in a diatomaceous earth (DE) filter?
    a. To channel water to the collection manifold.
    b. The sock forms a base against which DE will form.
    c. To filter the water as it travels to the collection manifold.
    d. The sock is used to remove the DE during the backwash process.

70. (619) How are cartridge filters cleaned?
    a. They can be sprayed clean.
    b. By backwashing the filter.
    c. They are just replaced.
    d. They are bleached.

71. (619) How often should swimming pools on Air Force (AF) bases be superchlorinated?
    a. Yearly.
    b. Weekly.
    c. Monthly.
    d. Quarterly.

72. (620) What is the *main* difference between backwashing a pressurized diatomaceous earth (DE) filter and pressurized sand filter?
    a. There is no difference.
    b. You must precoat a DE filter.
    c. Different types of filter pumps are used.
    d. The backwash run is longer on a sand filter.

73. (620) What will happen if you do *not* quickly close the influent valve to an open top diatomaceous earth (DE) filter that is lower than the pool right after you shut off the filter pump?
    a. The filter pump will reverse its rotation.
    b. Nothing, this is a normal procedure.
    c. The DE filter pit will overflow.
    d. The filter pit will drain.

74. (620) Which type of filter is the easiest to clean?
    a. Cartridge filter.
    b. Sand filters.
    c. Pressurized sand filters.
    d. Open top diatomaceous earth (DE) filters.

75. (621) What should you use to detect the presence of a chlorine gas leak around the cylinder and feed hoses?
    a. Sodium sulfite.
    b. Sodium hydroxide.
    c. Ammonium sulfite.
    d. Ammonium hydroxide.

76. (621) How can chlorine cylinders be moved around in the chlorine room?
    a. By using a truck.
    b. By spinning the cylinder.
    c. By carrying it up to the desired location.
    d. They are never moved until supply comes by with the fork lift.

77. (621) Depending on the feed rate, how long will a recharge on a calcium hypochlorite solution feeder usually last?
    a. 1 day.
    b. 1 week.
    c. 1 month.
    d. 1 season.

78. (622) What is the *best* way to prevent chemical shortages concerning a swimming pool?
    a. Order plenty at the beginning of the year.
    b. Accomplish a chemical inventory weekly.
    c. Weigh all chemicals weekly.
    d. Order chemicals when low.

Please read the unit menu for unit 3 and continue ➔

Unit 3. Water Treatment

WATER TREATMENT is the process of removing or destroying enough of the impurities present in the raw water to make it safe to drink. The type of treatment depends upon the quality of the water. The order in which the treatment generally takes place is coagulation, flocculation, sedimentation, filtration, and disinfection. However, it is not essential that these processes be carried out in this order. In certain cases, some of them are eliminated. Filtration and disinfection are, in some cases, enough to furnish a good drinking water.

Once a source of water, such as a deep well, has been established, we must have water system components to clarify, purify, and deliver potable water. Some of your duties and responsibilities are operating, maintaining, repairing, and keeping reports on one of the AF's water plants.

AF regulations, instructions, and manuals recommend that installations acquire their water from established sources when possible. This reduces development costs and eliminates interference with local demands on water supplies. It is the responsibility of the supplier to deliver water to an agreed-upon point where the AF control starts. Water supplied by a city has been treated; therefore, only additional chlorination and fluoridation are required at some bases.

By now, you may have already surmised correctly, that water is treated according to its individual characteristics. The term "water treatment" is all-inclusive in that there is no one specific way to treat water—it all depends. Water from a relatively clear water source may only need filtration and disinfection, whereas highly turbid waters will need full conventional water treatment. Moreover, water high in hardness will need softening as opposed to full conventional water treatment. You will most likely see applications where water may only need post chlorination. COST is the governing factor in the water treatment process. Why go all out and treat water completely for impurities that are simply not there. There are many forms of water treatment. In this unit, we will focus primarily on conventional water treatment, softening, filtration, and disinfection.

623. Conventional water treatment

Conventional water treatment is in order for large municipalities whose water supply consists of waters that are highly turbid and contain undesirable biological characteristics. When we use the term "conventional water treatment," we are really talking about using the normal accepted methods of treating surface waters. This includes, but is not restricted to, coagulation, flocculation, sedimentation, filtration, and finally, disinfection using chlorination—in that order. Let's discuss each of these individual processes using a typical water plant as an example.

Delivery

Water is delivered to the water plant using one or more very large transfer pumps. Water is pumped from the source via an intake structure known as an intake point. An intake point is a slotted collection structure that is extended into the reservoir, lake, river, or stream and transfers water from the source to the pump. The purpose of the intake point is not only to draw the water from the source but also to prevent foreign objects from entering the plant. A slotted screen at the end of the intake point prevents sticks, weeds, and dead animals from being drawn into the intake structure and plugging up the transfer pump. The intake point may be located quite a distance from the water plant.

Coagulation

As soon as water is delivered to the water plant, it is coagulated (mixed) with chemicals. Coagulation is the mixing of chemicals with the raw water to form a "floc" or precipitate. This floc traps and enmeshes the suspended matter—including some of the bacteria—forming larger, heavier particles. Mixing is accomplished in seconds using a "rapid flash mixer" (fig. 3–1). In some older systems, baffled mixing chambers (racetracks) are used instead of flash mixing to mix the water with the coagulant. These slow mix baffled chambers are typically called "end around" or "over and under" chambers.

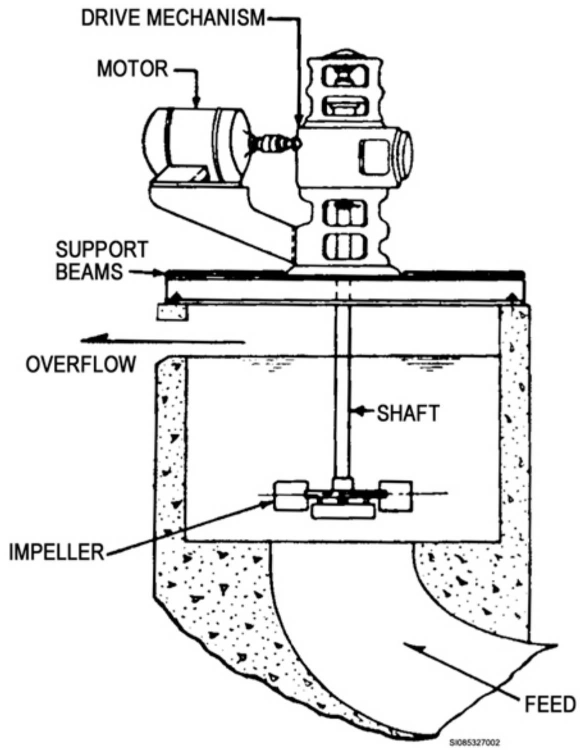


Figure 3–1. Rapid flash mixer.

Coagulant chemistry

Coagulation is the physical reaction of alkalinity (water's capacity to neutralize acids) and the addition of the coagulant (chemical) to form an insoluble floc that will readily settle later on during the sedimentation process. It's simple enough; yet, the water treatment professional must understand the chemical reaction that takes place during coagulation.

The pH of the water will actually determine which chemical compounds will predominate during the reaction. Lower pH values in the raw water enhance the coagulation process because the coagulant compound itself (aluminum sulfate [alum]) is positively charged. This is the perfect environment for the positively charged compounds of aluminum sulfate to react with the opposing negatively charged colloids and particulates (alkalinity) in the water to be treated (fig. 3–2). In fact, colloidal particles in natural waters usually have a negative surface charge. Thus, the natural alkalinity of the water serves as a buffer during the chemical reaction, preventing drastic downturns in pH values. Coagulants react with the alkaline substances in the water to form an insoluble gelatin substance that attracts the suspended silt and disease organisms. Chemically, the substances that have been formed are aluminum or ferric hydroxide. When the alkalinity of the raw water is dangerously low, a coagulant aid such as calcium carbonate (lime) or sodium carbonate (soda ash) is added to increase the alkalinity. This will, in turn, maintain an optimum pH range for the coagulation reaction to take place. This optimum pH range generally lies between 5 and 7.

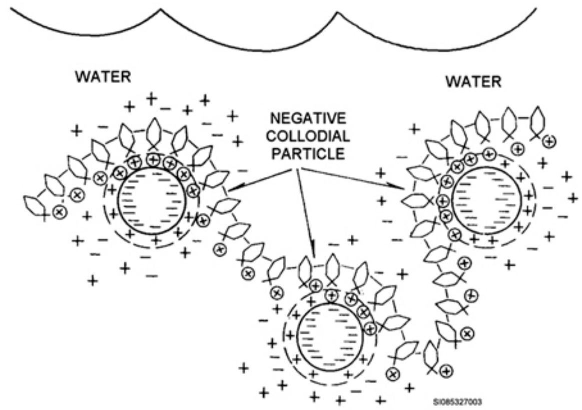


Figure 3–2. Coagulation.

Coagulant chemical dosing

Inherent in achieving the most optimum coagulation is maintaining the correct dose of the coagulant and coagulant aid. Underdosing and overdosing of coagulants will lead to reduced solids-removal efficiency later on during the sedimentation process and will shorten filter runs during the filtration process. The correct dose is initially determined by performing a jar test. Thereafter, the correct dose is maintained by regularly performing jar tests. The jar test is a laboratory test that simulates a water treatment plant's coagulation process using different doses of chemical and varying speeds of mixing (fig. 3–3). The plant lab technician should perform the jar test weekly and whenever pH, alkalinity, and turbidity changes occur.

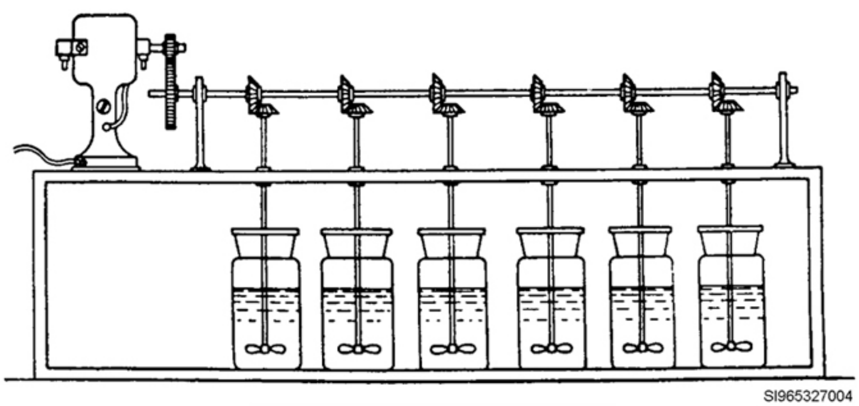


Figure 3–3. Jar test apparatus.

Coagulating chemicals

Metallic salts such as aluminum sulfate (Al_2SO_4), ferric sulfate (Fe_2SO_4), ferrous sulfate ($FeSO_4$) and synthetic polymers are used as primary coagulants. However, the most commonly used coagulant is alum because it is effective; cheap; and easy to handle, store, and apply. The degree to which these positively charged coagulants will react with the negatively charged colloids and particulates in water depends on the valence of the added metal. A double-charged ion is more effective than a single-charged ion, and a triple-charged ion is more effective than a double-charged ion. Consequently, tri-valent positive ions such as aluminum (Al) added as aluminum sulfate and iron (Fe) added as ferric sulfate or ferric chloride are the most effective metallic coagulants known to man. Aluminum sulfate is the most widely used chemical because ferric sulfate has a tendency to pick up moisture during storage and ferric chloride is extremely corrosive. Therefore, ferric sulfate and ferric chloride must be stored in special containers made of glass, plastic, or rubber.

Flocculation

Flocculation is the water treatment term for the slow stirring process that occurs at incrementally lower speeds after coagulation has occurred. In many instances, coagulation and flocculation may occur simultaneously. This is because floc will start to form right after chemicals are added during coagulation. However, these are two separate processes. During flocculation, the coagulated water is allowed to slow down by flocculation chambers (fig. 3–4). This allows even larger flocs to materialize. This separate contact time allows smaller flocs to collide with each other gently enough that larger flocs are formed. Larger floc formations are governed by the rate at which collisions occur between the smaller floc particles—generally speaking, the slower the rate the better.

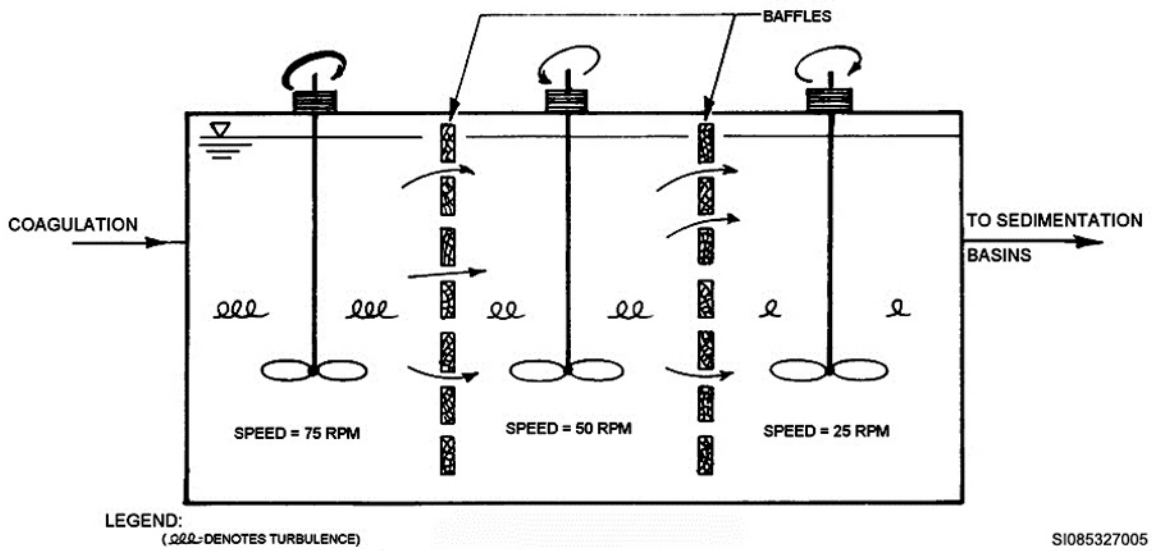


Figure 3–4. Flocculation.

Flocculation detention times generally must be between 5 to 30 minutes for the best settleable flocs to form and settle. In most small package plants, flocculation is used in connection with sedimentation. Larger conventional water treatment plants will use separate rectangular basins (fig. 3–5) for the sole purpose of achieving the best floc possible prior to sedimentation. Forming a good floc can be a tricky job. Putting in the proper chemicals in the proper amount to do a good job calls for skill and experience. Make no mistake, the first indication of whether or not the right amount of chemicals have been added during flash mixing is the presence of heavy settleable flocs in the flocculation basins.

Sedimentation

Sedimentation is the water treatment word used to denote the process in which flocculated matter settles to the bottom of a sedimentation tank or clarifier. Sedimentation is further helped by slowing the velocity of the water to such an extent that flocs cannot do anything else but settle to the bottom of a tank. Generally, a 2 to 3 hour detention time is needed in a sedimentation tank to allow flocculated solids the chance to settle. It can be said that sedimentation alone provides about 60 percent of the actual treatment of water. In other words, sedimentation tanks (clarifiers) carry the majority of the load in any full treatment water plant. More often than not, sedimentation basins also accommodate flocculation basins within them (fig. 3–6). In rectangular sedimentation basins, a baffle separates the flocculation basin from the sedimentation basin. The baffle further serves to slow the velocity of incoming raw water down to levels that will allow precipitation of the flocs.

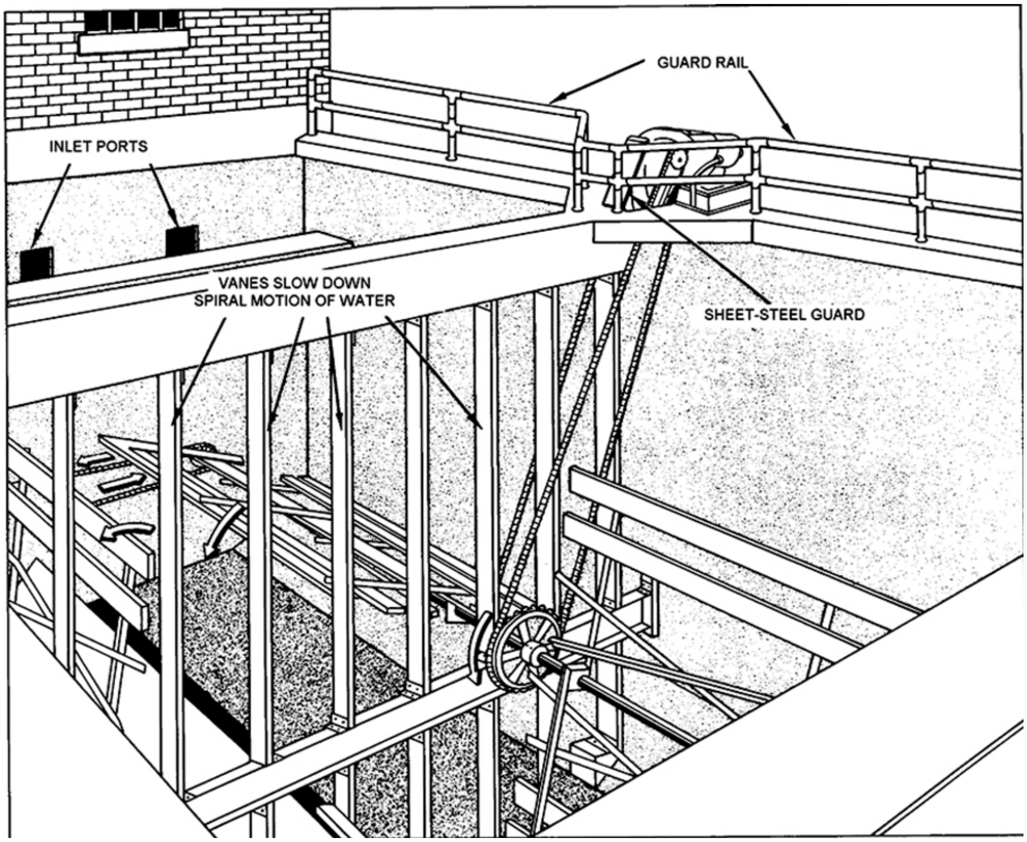


Figure 3–5. Flocculation basins in a conventional plant.

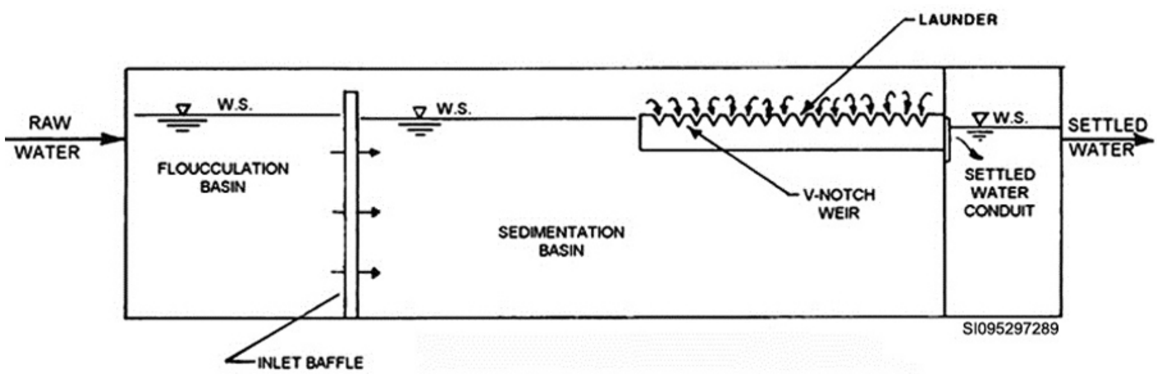


Figure 3–6. Rectangular sedimentation basin.

Circular sedimentation basins (also called clarifiers [fig. 3–7]) are used in smaller package plants. Although both rectangular and circular clarifiers have the same theory of application, there are enormous differences between them. Smaller, less baffled circular clarifiers are more susceptible to short-circuiting than smaller rectangular clarifiers. Rectangular clarifiers have the notable problem of their inability to remove sludge from the corners of the basin. Largely, it is more preferable to have a rectangular clarifier than a circular one. The distance from the inlet to the outlet alone is the major contributing factor in preventing short-circuiting in a rectangular clarifier. Whether or not a circular or rectangular clarifier is used, you need to be aware of the purposes of each component of a clarifier. The four components of a clarifier usually consist of an influent zone, settling zone, sludge zone, and effluent zone. The individual names may change from design to design, but the purpose will always remain the same.

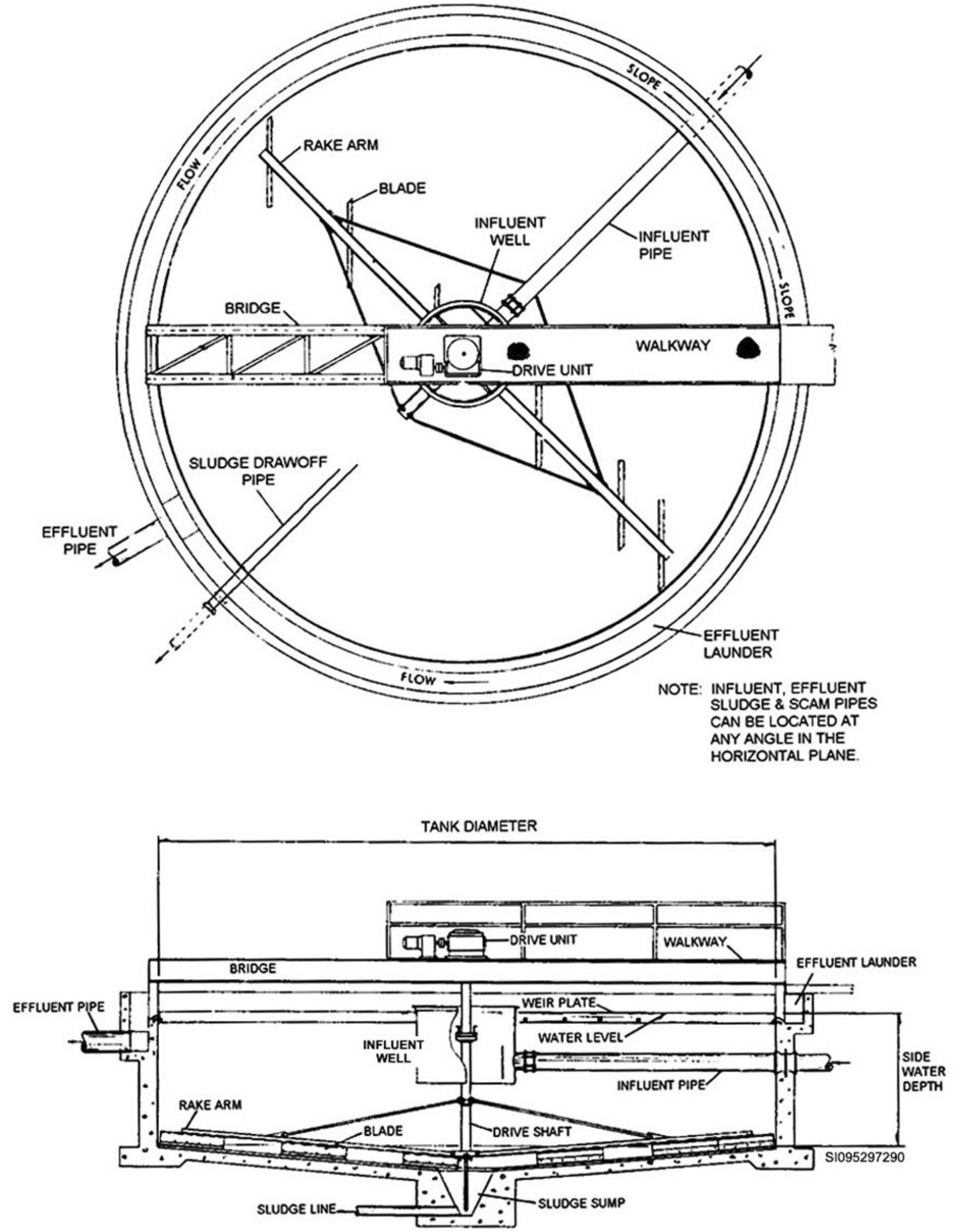


Figure 3–7. Circular clarifier.

Influent zone

The inlet or "influent zone" of a clarifier is where flocculated water first enters the clarifier. Water entering this zone is still moving relatively fast as compared to the speed this same water will have as it exits the clarifier. A baffle that further slows down the water characterizes the end of the influent zone. In a rectangular clarifier, the baffle will run the width of the basin, stretching from one wall to the opposing wall of the tank. In a circular basin, the baffle is circular in nature and is located within 5 feet of the epicenter of the clarifier where flocculated water first enters the tank (fig. 3–8). The sole purpose of the influent zone is to slow incoming water enough so that sedimentation may begin in an even stiller environment.

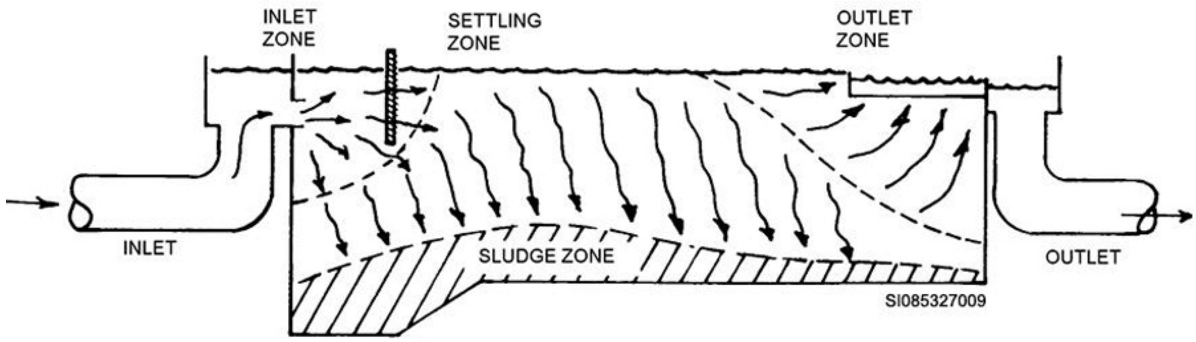


Figure 3–8. Rectangular clarifier.

Settling zone

As water enters the settling zone (fig. 3–8), suspended matter trapped by the floc begins to settle. The settling zone of a clarifier extends from the inlet side all the way to the outlet side. Settling rate and forward velocity will determine the actual location of where floc will finally settle down. Heavy flocs will settle soon after entering the settling zone, while lighter, fluffier flocs settle farther down the settling zone, closer to the outlet zone. Water in the settling zone should look appreciably clearer as you walk down the clarifier from the inlet zone to the outlet zone.

Sludge zone

The sludge zone is the term to describe the area in which settled matter will come to rest, on the floor of the clarifier. The majority of settling action will occur in the floor space of the beginning two-thirds of the tank (fig. 3–8). This is why the sludge hopper of the tank is always located below the inlet to the tank. The remaining one-third of the tank (towards the outlet) will have much less settled matter. Settled material in the sludge zone is called the sludge blanket. The sludge blanket may rise up to 2 feet off the floor. The thicker the sludge blanket, the better clarification will be attained. The sludge blanket not only condenses sludge to an efficiently disposable consistency but also acts a “magnet” for fluffier colloids, which still may not be heavy enough to settle.

Effluent zone

The effluent (outlet) zone serves to collect and discharge clear water. Clarified water is allowed to leave the sedimentation tank through V-notched weirs at the top of the outlet zone. The weir allows water to splash onto the collection trough (effluent launder). The effluent launder is graded to allow water flow towards the collection pit. From the collection pit, water is sent to the filter. The velocity of water in a settling tank is lowest in the outlet zone approximately six inches below the weir. This flow is so slow that any observable pin-floc would be barely creeping up to the weir.

Sedimentation rate

Sedimentation rate refers to the speed and efficiency in which flocculated colloids will settle. Unfortunately, not all sedimentation tanks are built or used exactly the way they are supposed to be. Aside from this, many external factors not related to the actual construction of the tank also affect sedimentation rate. The table below briefly explains each of these eight very important factors.

Factors affecting sedimentation rate	
Factor	**Description**
Detention time	The amount of time provided for settling should never be lower than 2 hours. The faster water has to flow through the tank, the worse the settling rate will be.
Characteristic of suspended matter	Dense particles of sand and soils will settle faster than fluffier flocs. This is affected by whether or not the proper amount of coagulation and flocculation was achieved prior to sedimentation.
Short-circuiting	Depends on the shape of the tank. This is why a long, narrow tank is better than a short, wide tank.
Influent and effluent arrangement	Influent water must be distributed evenly to the tank at the inlet zone. Weirs at the outlet zones must be even to collect effluent water at an equal rate throughout the length of the weir. Minor changes here improve or worsen settling rates drastically.
Surface loading rate	This refers to surface loading measured in gallons per day per sq/ft. Lower surface loading rates are achieved by opening more tanks to service.
Currents	Fast moving sludge scrapers can unintentionally create strong sub-currents, disturbing the settling process.
Temperature	Colloids will settle faster in warm water than they will in cold water.
Wind	High winds can cause surface currents (wave action) and reduce settling efficiency.

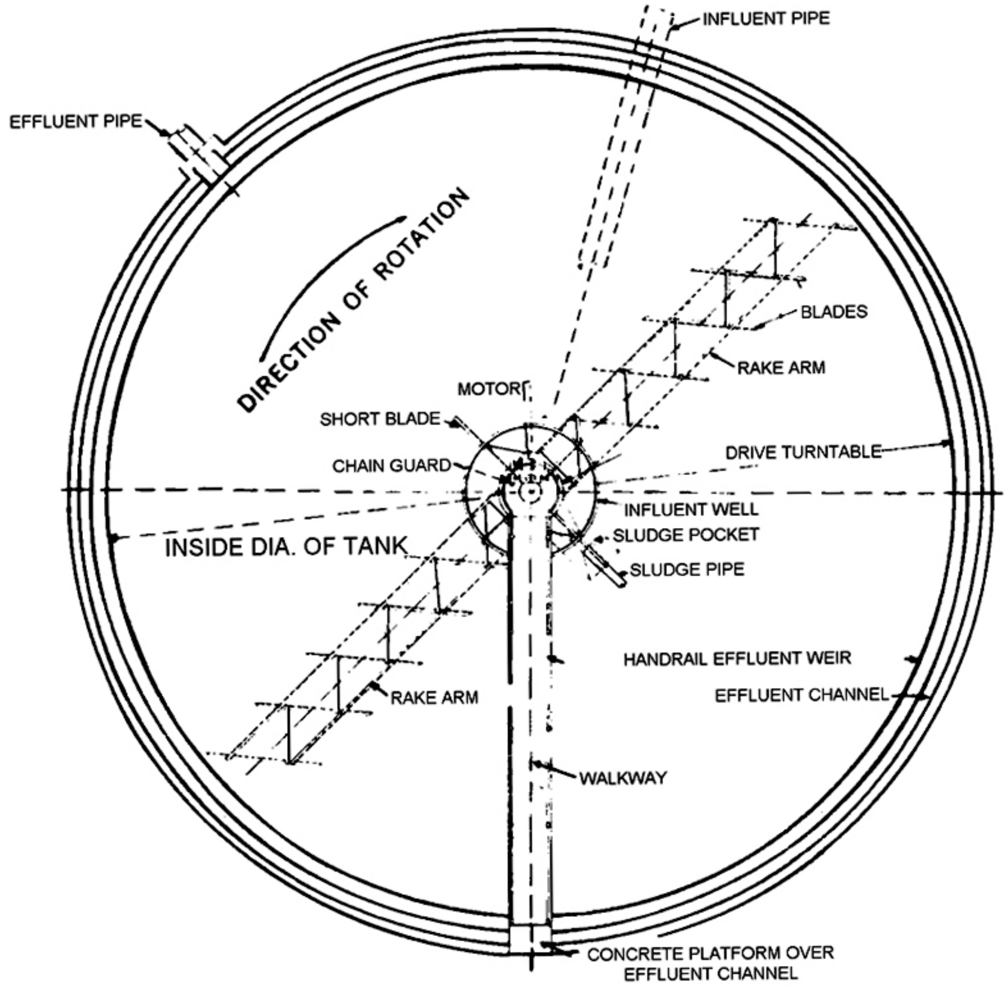
As you can see from the table above, these factors are also variables. A proportionate combination of two or more of these factors can drastically affect settling rate. There are a few other factors involved here which we will discuss later in this lesson.

Sludge collection and removal

You already know that approximately 60 percent of the treatment load in a conventional water plant is carried by the sedimentation basin (clarifier). Settled sludge must be removed from the tank properly and efficiently for the clarifier to continue its job of retaining sludge long enough for clarified water to flow out. Without a sludge collection and removal system, a sedimentation basin would have to be drained and the sludge pumped out manually.

Circular clarifiers and rectangular clarifiers are built with sludge scraping systems, while at the same time, provide a method to remove the sludge. Circular clarifiers are equipped with rotating mechanical rakes (fig. 3–9). Rubber or neoprene blades attached to the rakes progressively move accumulated sludge closer to the center outlet of the tank with each 360-degree pass of the arm. At the center of the tank, a 3-foot deep pit, called the sludge hopper, concentrates all the accumulated sludge to prevent water from flowing along with the sludge during sludge withdrawal. Sludge is usually removed by gravity to the sanitary sewer at prescribed times. Sludge withdrawal method and rates will vary from plant. Operator experience and individual basin design best dictate when and how long to remove sludge.

Rectangular clarifiers remove sludge based on the same principles as a circular clarifier. The difference is they each use a different collecting mechanism. In a rectangular clarifier, wooden flights (scrapers) connected to mechanical drag chains push the sludge along towards the inlet of the tank. As the flight reaches the sludge hopper (at the inlet of the tank), just enough momentum is provided to gently push the sludge into the sludge hopper before the flight starts its upward turn towards the motor-driven gear reducer at the top of the clarifier (fig. 3–10). The disadvantage of this type of sludge collecting mechanism is the high maintenance costs involved when replacing wearing parts such as the wooden scrapers. Additionally, chain links wear or must be removed to shorten the chain in summer time and links must be added to lengthen the chain during winter. Operator experience and individual basin design best dictate when and how long to remove sludge.



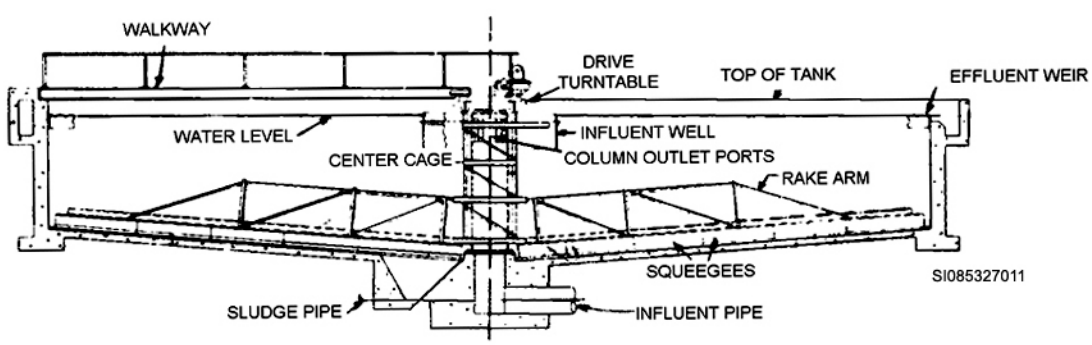


Figure 3–9. Circular clarifier.

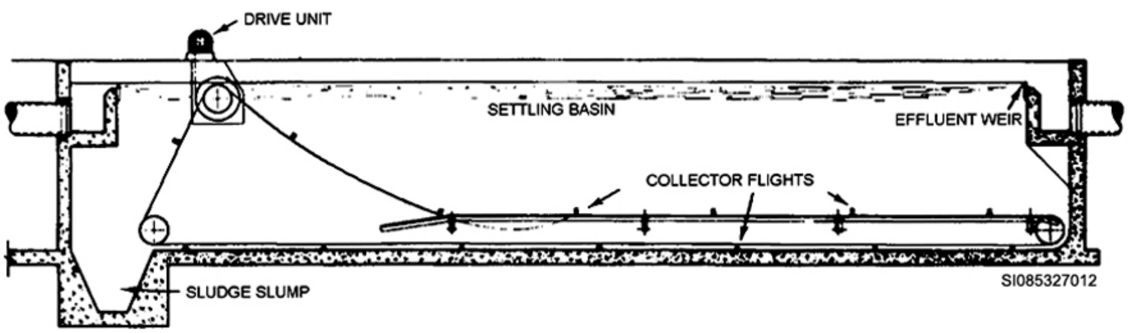


Figure 3–10. Rectangular clarifier.

Clear wells

Clarified water is channeled to a clear well by the effluent pipe of the clarifier (also connected to the effluent launder). The clear well is a very deep pit that is used to concentrate a large enough volume of water to allow uninterrupted filtration when the plant is on. Without the clear well, the filters would have to be stopped often. The clear well also allows the addition of pH stabilizing chemicals such as sodium carbonate (soda ash) prior to the water being filtered. Since the clear well is an open pit containing pre-filtered water, the maximum amount of security should be exercised to prevent unauthorized personnel from having access to it.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

623. Conventional water treatment

1. What are the five accepted methods of water treatment?

2. What is coagulation?

3. How is the correct chemical dose determined for proper coagulation?

4. What chemicals are used as primary coagulants?

5. What is flocculation?

6. What is sedimentation?

7. What are the four major zones of a sedimentation tank?

8. How does temperature affect settling rate in a sedimentation tank?

624. Water softening

Hardness is a measure of the soap-consuming power of water. Hardness is caused by solute metallic ions such as calcium and magnesium, which react with water to form precipitates and certain anion salts such as bicarbonates, sulfates, and chlorides to form scale. Consequently, when using hard water, large amounts of soap are needed to form suds. The table below will help you understand the degrees of hardness in water.

Levels of hardness	
Description	***mg/L***
Extremely soft to soft	0–45
Soft to moderately hard	46–90
Moderately hard to hard	91–130
Hard to very hard	131–170
Very hard to excessively hard	171–250
Too hard for household use	250+

Hard water may be softened by two different types of treatment—chemical precipitation and ion exchange. The chemistry of modern softening processes is much more complicated than conventional forms of water treatment; therefore, you must have a thorough understanding of the relationship between hardness and alkalinity.

Alkalinity and hardness

Alkalinity is the capacity of water to neutralize acids. This capacity is mainly caused by the amount of carbonates, bicarbonates, and hydroxides present in water. Yet, these same compounds are also the salts of calcium and magnesium. Now, when the pH of water is less than 8.3, all alkalinity in the water is in the bicarbonate form and is expressed as “natural alkalinity.” When the pH of the water is above 8.3, the alkalinity may consist of bicarbonate, carbonate, or hydroxide salts. As the pH increases even higher, the alkalinity is made up of mostly carbonate and hydroxide salts. Total alkalinity is the sum of the bicarbonate, carbonate, and hydroxide salt. The relationship of alkalinity to hardness also determines whether carbonate or non-carbonate hardness is present.

- When the alkalinity is greater than total hardness, all of the hardness is in the carbonate form.
- When the total hardness is greater than the alkalinity, the alkalinity is carbonate hardness and the non-carbonate hardness is the difference between total hardness and alkalinity.

You must know the form of the alkalinity and hardness present in water to decide which lime precipitation process you need to use. Let us first discuss the chemical precipitation process.

Precipitation

The chemical precipitation process is used primarily to treat large amounts of water which when treated, do not have zero (or near zero) hardness. During the chemical precipitation process, calcium and magnesium compounds are changed from soluble to insoluble forms and then removed by sedimentation and filtration.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

624. Water softening

1. What is “hardness” in water?

2. At which level of hardness does water become too hard for ordinary household consumption?

3. What is total alkalinity?

4. State the two basic relationships of alkalinity and hardness.

625. Filtration

There are two main classes of filtration in the water treatment industry. The first, called conventional filtration, refers to the filtering of water after some sort of formal coagulation, flocculation, and sedimentation. The second, direct filtration, refers to filtering water that has only been coagulated and flocculated, omitting sedimentation. No matter whether the treatment process was conventional water treatment using alum and lime or softening using chemical precipitation, some sort of filtering process must be used to remove particulates that did not settle during clarification. Hence, filtration is used to remove suspended solids.

You may have surmised by now that water treatment is a combination of various interrelated steps that are followed in order. Consequently, one of the more important steps in purifying water is filtration. You may look at the process of filtration as the water plant operators “insurance policy” for clear water. Filtration is accomplished using several different types of filters, a few of which we will discuss in this lesson. The three methods of filtration are gravity sand filtration, pressure sand filtration, and DE filtration.

Figure 3–11 shows three methods of sand filtration. Filtration is the process of straining the water through beds of porous material. These filter beds are usually layers of fine sand on top of coarse sand and gravel (fig. 3–12). In water treatment, the filtering process has to be very efficient because of the extremely small size of materials to be removed from the water.

Gravity sand filtration

Essentially, gravity filters are open-top, rectangular, concrete boxes about 10-feet deep. In all gravity filters, the water level or pressure (head) above the filter media forces the water through the filter (fig. 3–13). An underdrain system at the bottom is covered by gravel, which, in turn, supports a wide array of filtering media, depending on individual plant design. Filter classification is based on the amount and type of filtering media. These three classes are mono media, dual media, and multimedia. Gravity filters (fig. 3–13) are more prevalent in large water treatment plants. Since water flow through a filter is accomplished by gravity, they are also much cheaper to operate (do not require pumps).

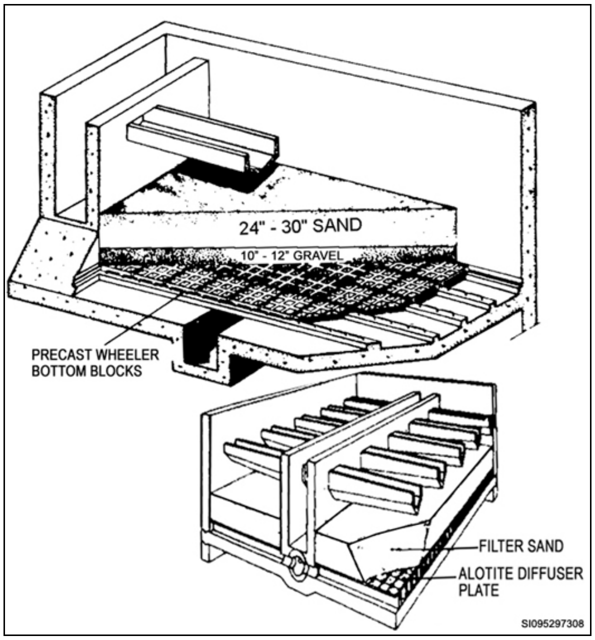


Figure 3–11. Filter bed media.

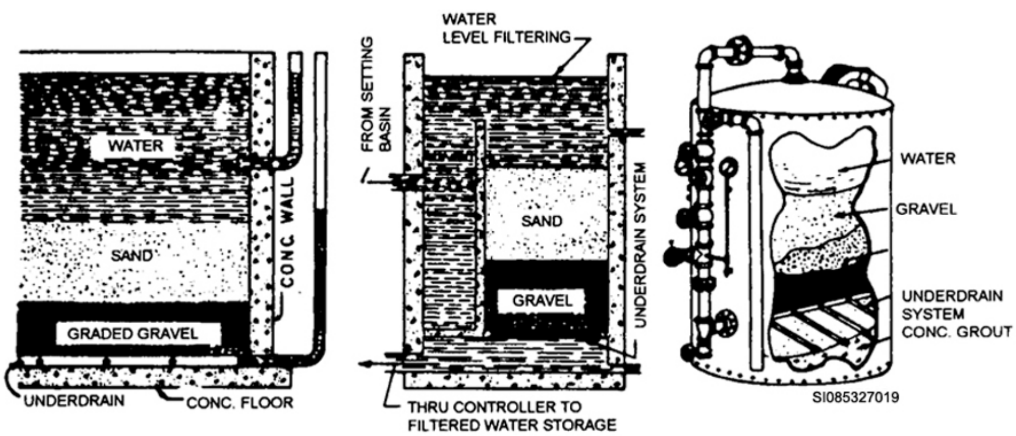


Figure 3–12. Three forms of filtration using sand.

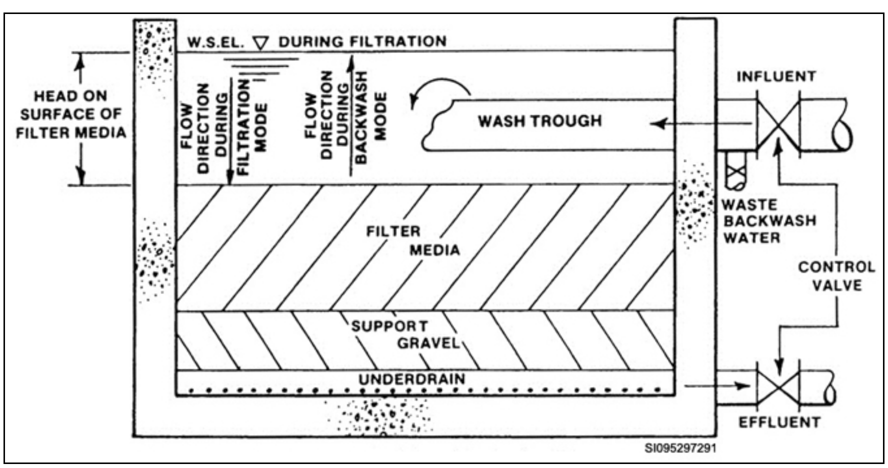


Figure 3–13. Basic gravity filter.

Rapid sand filters

Most gravity sand filters used in the US are multimedia "rapid sand filters." This means that the media used in these filters allows for higher filtration flows of 2 to 10 gpm per square foot of filter bed surface area. However, regulatory agencies limit this filter rate to 2–3 gpm. When the filter gets too dirty and head-loss increases, the filter is cleaned by reversing the flow of water though the filter (backwashing). During backwashing, the surface of the top layer (media) in the filter is also surface washed using diffusers to break up deposits on the top layer as water flow is reversed through the filter. Each filter design may have a specific variation of surface washing using water or surface scouring using air. The source for backwash water is usually a ground storage tank located on the plant grounds. Rapid sand filters are backwashed in various ways depending on individual design piping arrangements and modern technology.

Slow sand filters

These are ordinary mono-media gravity filters which are only designed to filter water at rates of 0.015–0.15 gpm per square foot. The majority of particulates removed by this filter are trapped in the top 5 inches of sand. When the filter is clogged, the first 5 inches of sand must be physically removed and new sand applied on top of the existing media. Slow sand filters are very unpopular because of the need for physical backwashing and their requirement for a very expansive filtering area in order to achieve the demand flow made on the plant.

Pressure sand filtration

Pressure sand filters have exactly the same classes of media as the gravity filters, and their principles of operation are identical with the exception of two features: the filtering media in a pressure filter is enclosed (under pressure) and water is forced through the filter by pump pressure. Since filtering is accomplished by pump pressure, backwashing must also be accomplished by pump pressure. A separate pump called the "backwash pump" is used for this purpose. The backwash pump of a pressure sand filter is always much larger (higher head and gpm) than the pump used to filter water through the filter. This is because of the need for bed expansion of the media during backwashing in order to clean and restratify the filter. Pressure sand filters are most common in smaller water plants. The maximum recommended filtration rates for pressure sand filters is 2–3 gpm per square foot of filter bed surface area. Pressure filters are less reliable than gravity filters because of variations in pump pressure (filter pumps kicking on and off depending on clear well levels), whereas gravity filters will usually be under a constant pressure.

Filter efficiency

Most water plants are designed so that between 30–40 percent of the treatment load of the plant is placed on filtration. Consequently, filter removal rates will depend on the quality of filter influent water—the lower the quality, the lower the removal will be. Most sand filters can remove up to 99.5 percent of the original turbidity in the raw water as long as the treatment steps accomplished prior to filtration were adequate. When previous treatment steps are not fully successful, turbidity removal rates can be less than 50 percent of the original raw water turbidity. This is because more of the treatment load was placed on the filter as opposed to the sedimentation process. As you can see, the steps involved in the water treatment process are very interrelated—one seriously affecting the performance and efficiency of the other. Good filter efficiency allows less of a burden to be placed on disinfection—the next area of our discussion.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

625. Filtration

1. What are the two main classes of water filtration?

2. What are the three methods of filtering water?

3. What are the two types of gravity sand filters?

4. What is the standard regulatory limit on the filter rate of a rapid sand filter (in gpm)?

5. What percent of the treatment load is placed on a water plant's filtration system?

626. Disinfection

Disinfection is the last major process in water treatment. Disinfection is the process of destroying pathogenic organisms. Water treatment plant disinfection is usually accomplished using some form of chlorine gas or solution. The disinfection process is relatively simple, yet this should never be downplayed by the importance it plays in a water supply. Simply said, disinfection is the last chance to make sure that all remaining pathogens (if any) are killed. Even though the disinfection process is only responsible for 0–2 percent of the treatment load, the ultimate safety of a potable water supply depends on this process being accomplished effectively every day, 365 days a year—without fail.

Process

Chlorine gas is fed into filtered effluent by solution injection. The injection of chlorine gas at a water plant is very much like the one used at a swimming pool. Chlorine gas is drawn out of a pressurized cylinder by a vacuum system and injected into a solution that is then fed into water leaving the filter on its way to a storage tank. Chlorinated water is allowed a 30-minute minimum contact time in a tank before it is fed into the distribution system via a pump or elevated storage tank. The major difference between a gas injection system at a swimming pool and that of a water plant is the size of the equipment and amount of gas fed per day. Largely, water plants use larger chlorination equipment yet feed less chlorine gas per day (gallon for gallon). This is because there is a smaller chlorine demand put forth by treated water than there is in swimming pool water.

Chlorine gas disinfection is moving away from the conventional gas chlorinators for safety and cost reasons. One of the most common ways to accomplish disinfection is chlorine generators. These systems pass a saltwater solution through an electrically charged cell that separates the chloride from the sodium to make chlorine. This system eliminates the safety hazards associated with gas chlorine.

Disinfection chemistry

It's not completely known how chlorine kills disease-producing bacteria, viruses, and pathogens. Some say that chlorine attacks the cells of microorganisms thus destroying it and others say that the toxic character of chlorine inactivates the enzymes that organisms use to break down their food supply—thus starving them to death. The bottom line is that chlorine kills these microorganisms.

Chlorine demand

As chlorine is injected into water, several chemical reactions take place. The first of these involve the molecules of the water, and the other involves the organic and inorganic compounds in the water. As more and more chlorine is added to the water, a "stopping point" for chlorine's reaction to the organic and inorganic compounds materializes. This is called chlorine demand. We can say that chlorine demand has been met when chlorine no longer reacts to kill the organisms attached to organic and inorganic matter in the water—they are all dead. Furthermore, the addition of more chlorine into the water after demand has been met merely builds up a residual of the disinfectant in the water—it does not disinfect the water any more.

Chlorine residual

As more and more chlorine is added to the water after the chlorine demand has been met, chlorine residual is chemically observed by doing chlorine tests. Chlorine residual is also called "free-available" chlorine. Water leaving the water plant *must* have sufficient "free-available" chlorine to counteract microorganisms that may be growing in the distribution system. If water leaving the plant encounters a large number of organisms and inorganic materials that create a *demand* on the free-available chlorine in the water—then that portion of the free-available chlorine that went to satisfy the new demand is called "combined-residual" chlorine.

Combined-residual chlorine is the amount of chlorine that is "tied" up by the formation of other compounds (chlororganics and chloramines) in the water. As a result, combined chlorine is not available to kill microorganisms. "Total" chlorine is the amount of free-available chlorine residual plus the amount of combined-chlorine residual added together. The water supply becomes vulnerable as more chlorine becomes "combined," and there is not enough free-available chlorine to fight microorganisms. This is why water leaving the plant must *always* have enough free-available chlorine to meet unexpected demand in the various dead ends and loops of the distribution system.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

626. Disinfection

1. What is disinfection?

2. What chemical is used to disinfect water at water plants?

3. What percent of the treatment load of a water plant is placed on disinfection?

4. How long is the standard contact time that chlorinated water is allowed to sit prior to feeding it to the distribution system?

5. What is chlorine demand?

6. What is chlorine residual?

Answers to Self-Test Questions

623

1. Coagulation, flocculation, sedimentation, filtration, and disinfection.
2. The process of mixing chemicals into water to form a floc.
3. By performing a jar test.
4. Metallic salts such as aluminum sulfate, ferric sulfate, ferrous sulfate, and synthetic polymers.
5. The slow stirring process that occurs right after coagulation to form larger and larger settling flocs.
6. The process in which flocculated matter settles to the bottom of a settling tank (clarifier).
7. Inlet zone, settling zone, sludge zone, and outlet zone.
8. The warmer the weather the better settling will be.

624

1. The measure of the soap-consuming power of water.
2. At a level above 250 mg/L of hardness.
3. The sum of the bicarbonate, carbonate, and hydroxides in water.
4. (1) When the alkalinity is greater than the total hardness, all of the hardness is in the carbonate form.

   (2) When the total hardness is greater than the alkalinity, the alkalinity is carbonate hardness and the non-carbonate hardness is the difference between total hardness and alkalinity.

625

1. Conventional filtration and direct filtration.
2. Gravity sand, pressure sand and DE.
3. Rapid sand and slow sand filters.
4. 2–3 gpm per square foot of filter area.
5. 30–40.

626

1. The process in water treatment of killing pathogenic organisms.
2. Chlorine.
3. 0–2 percent.
4. 30 minutes.
5. The stopping point for chlorine's reaction with organic and inorganic compounds. The demand is met when chlorine no longer reacts to kill any more organisms.
6. The amount of chlorine remaining over and above chlorine demand. Sometimes called "free-available chlorine."

Complete the Unit Review Exercises.

Unit Review Exercises

Note to Student: Consider all choices carefully, select the *best* answer to each question, and *circle* the corresponding letter. When you have completed all unit review exercises, transfer your answers to the Field-Scoring Answer Sheet.

Do not return your answer sheet to the Air Force Career Development Academy (AFCDA).

79. (623) What is the *first* thing that happens when water is delivered to the water plant?
    a. Coagulation.
    b. Flocculation.
    c. Filtered.
    d. Sedimentation.

80. (623) What is the *most* commonly used coagulant chemical?
    a. Synthetic polymers.
    b. Aluminum sulfate.
    c. Ferric sulfate.
    d. Sand.

81. (624) What is hardness in water?
    a. The measure of the soap-consuming power of water.
    b. The measure of the bicarbonate-consuming power of water.
    c. Anion salts such as calcium and magnesium which precipitate in water.
    d. Solute metallic ions such as bicarbonates, carbonates, and chlorides which cause scale.

82. (625) A filter bed *usually* consists of layers of
    a. fine sand on top of gravel.
    b. coarse sand on top of gravel.
    c. coarse sand on top of fine sand.
    d. fine sand on top of course sand and gravel.

83. (625) Filter flow rates through a rapid sand filter can range between
    a. 2–10 gallons per minute (gpm) per cubic foot (cu/ft) of area.
    b. 2–10 gpm per square foot (sq/ft) of area.
    c. 2–3 gpm per cu/ft of area.
    d. 2–3 gpm per sq/ft of area.

84. (626) What percentage of the treatment load is placed on chlorination in a typical plant?
    a. 0–2.
    b. 0–5.
    c. 0–10.
    d. 0–25.

85. (626) Chlorine residual is also called
    a. complex chlorine.
    b. combined chlorine.
    c. free-available chlorine.
    d. total available chlorine.

Glossary of Abbreviations and Acronyms

AC	alternating current
ACES-PM	Automated Civil Engineer System Program Management
AF	Air Force
AFI	Air Force instruction
Al	aluminum
Al_2SO_4	formula for aluminum sulfate
alum	aluminum sulfate
AVB	atmospheric vacuum breaker
BE	bioenvironmental engineer
CFR	Code of Federal Regulations
CFU	colony forming unit
CMMS	computerized maintenance management system
CO_2	formula for carbon dioxide
DCVA	double-check valve assembly
DE	diatomaceous earth
DOT	Department of Transportation
FC	fecal coliform
Fe	iron
Fe_2SO_4	formula for ferric sulfate
$FeSO_4$	formula for ferrous sulfate
FI	flame ionization
FM	Factory Mutual
gpm	gallons per minute
HAD	heat-actuated device
HCA	high-consequence area
HP	high pressure
HPC	heterotrophic plate count
HTH	high-test hypochlorite
HVAC/R	heating, ventilation, air conditioning/refrigeration
lb.	pound
IMT	information management tool
LP	low pressure

mg/L	milligrams per liter
ml	milliliter
MP	medium pressure
NFPA	National Fire Protection Association
NTU	Nephelometric turbidity unit
OPS	Office of Pipeline Safety
OS&Y	outside screw and yoke
OSHA	Occupational Safety and Health Administration
PE	polyethylene
pH	potential hydrogen
PHMSA	Pipeline and Hazardous Materials Safety Administration
PIV	post indicator valve
ppm	parts per million
psi	pounds per square inch
PVB	pressure-vacuum breaker
sq/ft	square foot
UFC	Unified Facilities Criteria
US	United States
UV	ultraviolet
WFSM	water and fuel systems maintenance

Student Notes

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