CHAPTER 3. WELLS

(Lesson 2 of 4 Lessons)

3.2 WELL APPURTENANCES[24]

3.20 Typical Well Pump and Pressure Tank

The well appurtenances described and shown in this section are illustrated in Figure 3.6, which is an elevation or profile drawing of a well pump and tank installation. This is a typical well pump and tank installation showing the general features and location of the appurtenances under discussion. Many variations of this layout are possible depending upon geographic location, state and local building and plumbing codes, hydraulic factors, and individual preferences.

3.21 Valves

3.210 Check Valves[25]

Most well pump stations are equipped with some type of check valve installed on the discharge side of the pump. The purpose of the check valve is to act as the automatic shutoff valve when the pump stops. This valve prevents draining of the system or the tank being pumped to, and keeps pressurized water from flowing back down the pump column into the well. This reversal of pressurized flow into a well can cause serious problems that may include removal of the pump from service and redevelopment of the well. (This flow reversal problem does not occur in well pump installations equipped with a foot valve.)

Several different types of check valves are available such as swing check, lift check, foot check, slant disc check, flap check, double disc check, and automatic control check. Four different types of check valves are illustrated in Figure 3.7.

The important features of any check valve are that the valve must: (1) close watertight, (2) be able to safely withstand hydraulic shock loads, (3) have a low head loss, and, most importantly, (4) be equipped to close the valve disc in advance of flow reversal.

There are numerous ways to ensure rapid shutoff of the valve disc within the recommended time of $\frac{1}{20}$ to $\frac{1}{10}$ of a second. This can be accomplished with an outside lever and weight (most commonly used), spring loaded (either internal or external) disc (spring closes the disc), and compressed air assisted device (compressed air moves arm and closes disc).

3.211 Pump Control Valves

A pump control valve is a diaphragm-type valve designed to eliminate pipeline surges caused by the starting and stopping of deep well pumps. This valve is available in a "normally closed" type, or a "normally open" type.

The normally closed type valve is designed for installation in the main discharge line of the pump. The pump starts against a closed valve. When it is started, the *SOLENOID*[26] control valve is energized and the valve begins to open slowly, gradually increasing line pressure to full pumping head. When the pump is signalled to shut off, the solenoid control valve is de-energized and the valve begins to close slowly, gradually reducing flow while the pump continues to run. When the valve is closed, a limit switch assembly, which serves as an electrical interlock between the valve and the pump, releases the pump starter and the pump stops. Should a power failure occur, a built-in lift-type check valve closes the moment flow stops, preventing reverse flow regardless of solenoid or diaphragm assembly position.

The normally open type valve is designed for installation in a bypass line on the discharge side of the pump. Operation is completely automatic, fully hydraulic, and electrically controlled by a solenoid control valve. With the pump off, the valve is wide open. When the pump is started, the solenoid is energized and the valve begins to close slowly, discharging air and the initial rush of water and any sand from the pump column to the atmosphere. As the check valve closes, the pump output is gradually diverted into the main line as the main line check valve opens, thus preventing the development of starting surges.

When it is time to shut off the pump, the solenoid is de-energized. A limit switch on the valve keeps the pump motor circuit closed (power stays on). The pump continues to run while the pump control valve opens slowly and diverts pump output to the atmosphere. As pump pressure gradually decreases, the main line check valve closes slowly, effectively preventing shock or slam during the pump stopping cycle. When the pump control valve is wide open, the limit-switch assembly breaks the pump motor circuit and the pump stops.

Both the normally closed and normally open pump control valves are hydraulically operated, diaphragm-type globe or angle

[24] *Appurtenance* (uh-PURR-ten-nans). Machinery, appliances, structures, and other parts of the main structure necessary to allow it to operate as intended, but not considered part of the main structure.

[25] *Check Valve.* A special valve with a hinged disk or flap that opens in the direction of normal flow and is forced shut when flows go in the reverse or opposite direction of normal flows. Also see FLAP GATE and TIDE GATE.

[26] *Solenoid* (SO-luh-noid). A magnetically operated mechanical device (electric coil). Solenoids can operate small valves or electric switches.

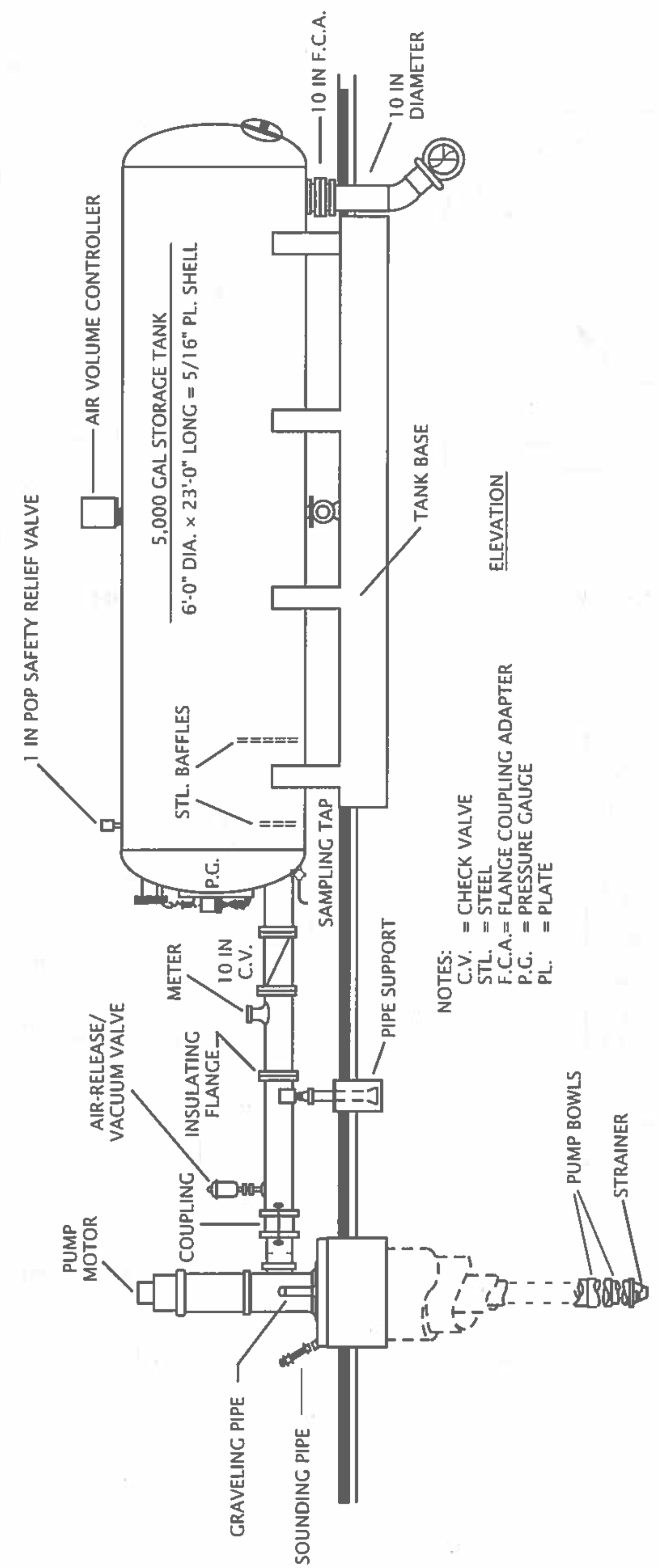
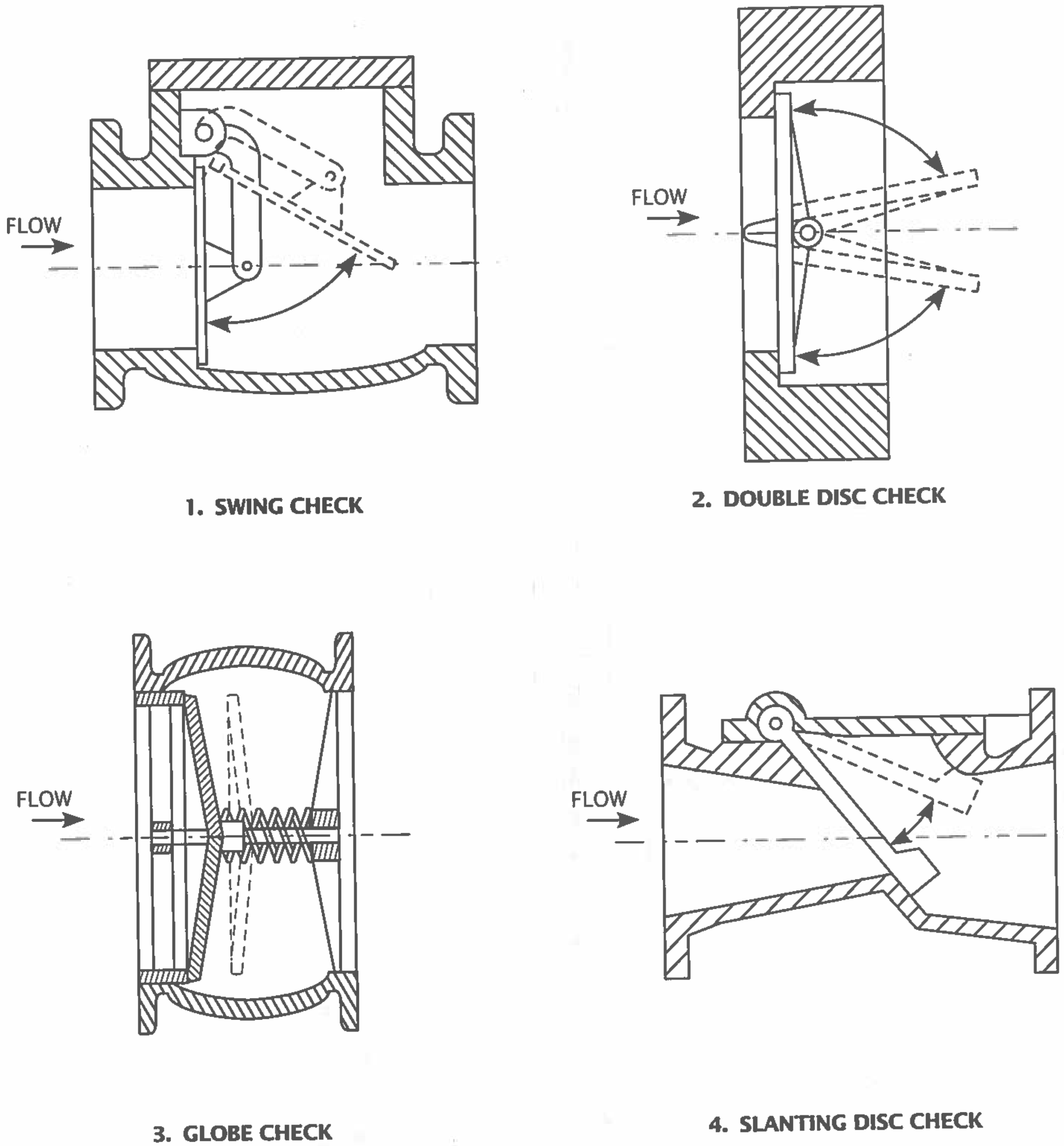


Fig. 3.6 Typical well pump and appurtenance installation



NOTE: All valves are in the closed position. The dashed lines show the open positions.

Fig. 3.7 Types of check valves

valves powered by line pressure. While somewhat different in installation and operation, the purpose of both is much the same. They eliminate pipeline surges when the pump is started and stopped. Both valves are electrically interlocked to the pump motor so that the valve is gradually opened or closed in coordination with the pump, thus protecting the pipeline from an uncontrolled surge.

3.212 Foot Valves

A foot valve is often placed at the inlet to the pump suction line in a well. The foot valve can serve several important purposes:

1. Maintains the *PRIME*[27] on the pump
2. Prevents reversal of flow into the well (which could stir up sand) when the pump shuts off
3. Eliminates problems created when there is no means of discharging air in the pump column and the air enters the system

3.22 Flowmeters

Good waterworks practice requires you to know the amount of water being delivered to the system. If chemicals are being applied at the well pumping station, then it is necessary to know the rate at which water is being pumped to the system in order to calculate the correct feed rate. A flowmeter is used to measure this flow.

Well pumps are usually designed for a certain rated capacity (flow rate) pumping against a specified head (system pressure). Because the system pressure against which a well pump must operate changes with system demand (usage), the amount of water delivered to the system usually deviates from the rated capacity given for the pump. Thus, a 1,000 gallon per minute (5,540 cu m/day) pump is supposed to deliver, under normal conditions of specified head and pipe friction, 1,000 gallons of water per minute to the discharge end of the pump. Because this ideal condition is seldom experienced in actual operation, the rated capacity of the pump is not an accurate measurement of the water delivered. Flowmeters are used to determine the amount of water actually being delivered by the pump.

Flowmeters in pipes will produce accurate flowmeter readings when the meter is located at least five pipe diameters distance downstream from any pipe bends, elbows, or valves and also at least two pipe diameters distance upstream from any pipe bends, elbows, or valves. Flowmeters also should be calibrated in place to ensure accurate flow measurements.

Many different types of flowmeters are available today such as positive displacement, propeller, turbine, orifice plate, and electronic sensor types. The most commonly used flowmeter for well pump applications is the propeller or turbine type, with magnetic drive, equipped with a register for total flow and a rate-of-flow indicator. This type of flowmeter has an accuracy of plus or minus 2 percent of actual flow within a specified range. Accessory features include remote indicator/totalizer plus an onsite strip recorder. In variable-flow well pump installations, this type of meter can be equipped to pace (regulate) auxiliary chemical feeders or chlorinators.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 138.

3.2A What is the purpose of a check valve?

3.2B List the important features of a check valve.

3.2C What is the purpose of pump control valves?

3.2D Why must flows be known when chemicals are being applied at a well pumping station?

3.23 Sand Traps and Sand Separators

Sand particles should be prevented from entering the distribution system. Nearly all wells produce some sand and tests have shown it is the sand particles larger than 200 *MESH*[28] (74 microns) that cause the most trouble in a distribution system. Almost all sand found in well water is this size or coarser. These particles can cause reduced pump efficiencies due to worn impellers, sanded water mains, excessive meter wear and plugging, wearing of household plumbing fixtures and appliances, and customer complaints.

3.230 Sand Traps

Conventional sand traps usually consist of a large tank equipped with a series of internal baffles or chambers. The tank is mounted on the discharge side of the well pump. Sand particles settle to the bottom of the tank by the force of gravity and are removed by means of blowoff valves or underdrain systems. *HYDROPNEUMATIC*[29] pressure tanks are sometimes modified with internal baffles and can function, to a limited degree, as a sand trap. Generally speaking, sand traps are costly and inefficient.

3.231 Sand Separators

Most sand separators are designed around the principle of centrifugal force and are relatively effective in removing fine sand, scale, and similar materials from the water.

The centrifugal sand separator is a specifically designed hydraulic centrifuge operating on energy supplied by the well pump. Take a close look at Figure 3.8 as you read about how the separator works. Sand-laden water enters the cylindrical chamber through the feed entry. Inside the chamber, the water flows

[27] *Prime.* The action of filling a pump casing with water to remove the air. Most pumps must be primed before start-up or they will not pump any water.

[28] *Mesh.* One of the openings or spaces in a screen or woven fabric. The value of the mesh is usually given as the number of openings per inch. This value does not consider the diameter of the wire or fabric; therefore, the mesh number does not always have a definite relationship to the size of the hole.

[29] *Hydropneumatic* (hi-dro-new-MAT-ick). A water system, usually small, in which a water pump is automatically controlled (started and stopped) by the air pressure in a compressed-air tank.

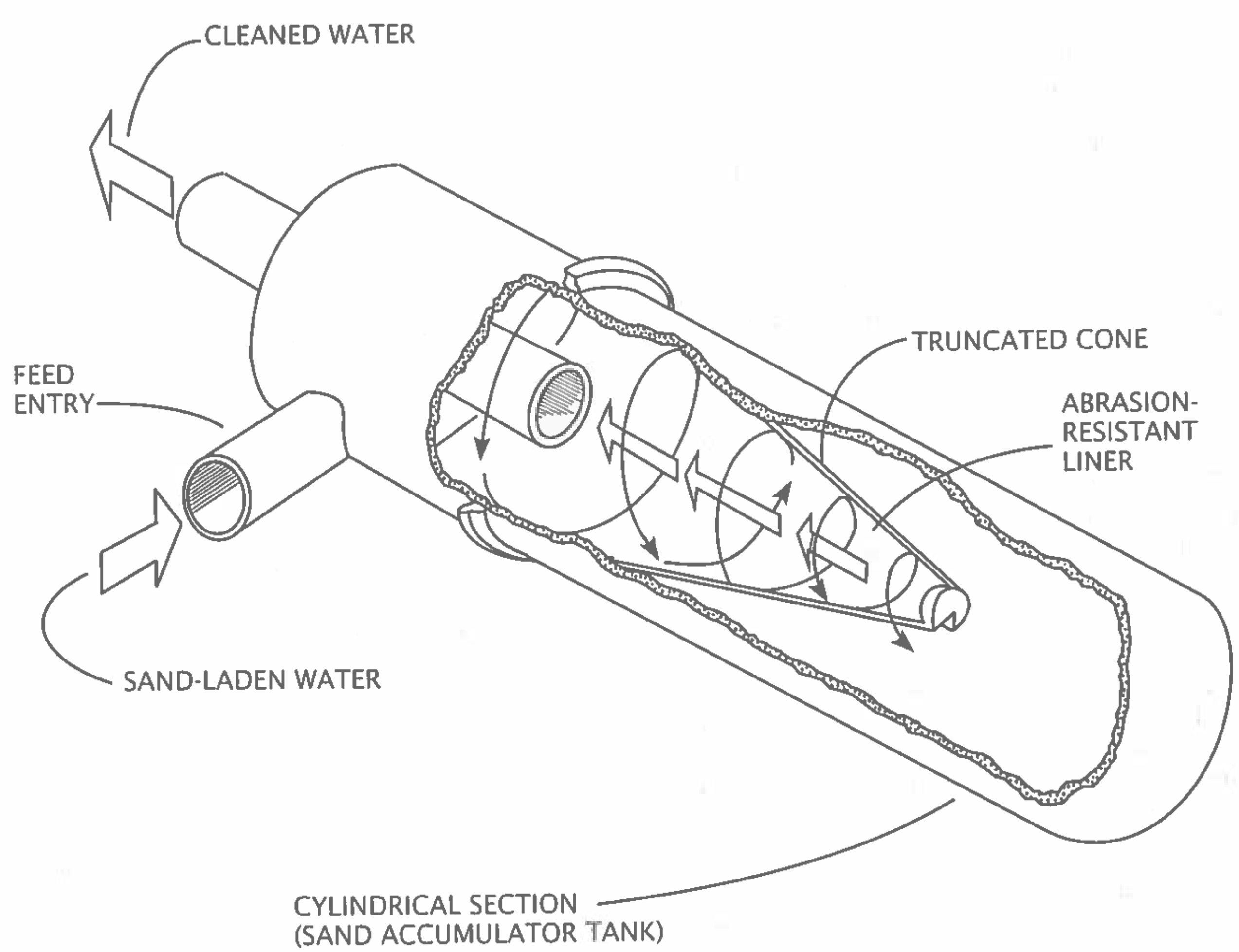


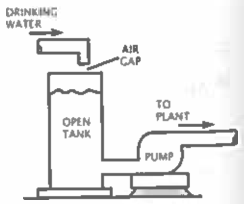
Fig. 3.8 Typical sand separator

in a circular motion around the outside of the cylinder. As the water spirals inward toward the entrance to the cleaned water exit pipe, extremely high forces act on the sand particles to rapidly force them toward the wall of the cylinder. Once the sand particles reach the cylinder wall, they progress by a downward spiraling action toward the tip of the truncated cone and are finally discharged through an *ORIFICE*[30] (slit in cone) into the accumulator tank, or underflow chamber. Sand is periodically drained from the accumulator tank or chamber by either manual or automatic means. Centrifugal sand separators are usually capable of removing 95 percent of the plus 200 mesh sand particles entering the unit.

Sanitary hazards associated with sand separators or sand traps are generally limited to the discharge system from the accumulator tank. Typically, the sand/water mixture from the accumulator tank is discharged to a sand recovery basin where the sand particles settle out and the sand-free water is disposed of to the community storm sewer or sanitary sewer main. To provide the necessary backflow protection, an *AIR GAP*[31] is required on the discharge line between the accumulator tank and the sand disposal basin or structure. Backflow protection is usually not required if the discharge line from the accumulator has a free discharge to the atmosphere and ends at least 12 inches (300 mm) above the surrounding ground elevation.

[30] *Orifice* (OR-uh-fiss). An opening (hole) in a plate, wall, or partition. An orifice flange or plate placed in a pipe consists of a slot or a calibrated circular hole smaller than the pipe diameter. The difference in pressure in the pipe above and at the orifice may be used to determine the flow in the pipe. In a trickling filter distributor, the wastewater passes through an orifice to the surface of the filter media.

[31] *Air Gap.* An open, vertical drop, or vertical empty space, between a drinking (potable) water supply and potentially contaminated water. This gap prevents the contamination of drinking water by backsiphonage because there is no way potentially contaminated water can reach the drinking water supply.



For additional information on how to solve problems caused by sand, see Section 3.7, "Sand in Well Water Systems."

3.24 Tank Coatings

Steel water storage tanks and hydropneumatic pressure tanks are generally painted on the interior surface with some type of protective coating to extend the useful life of the tank, prevent discolored water from entering the distribution system, and to facilitate cleaning of the tank.

Numerous interior tank coating materials are currently available. Many of these coatings give excellent results if the metal surfaces are properly prepared, the proper material for the job is selected, the material is applied according to the manufacturer's specifications, and it is allowed to dry thoroughly between coats and after the final coat. Adequate curing time is essential with all types of coatings and may require special techniques (such as forced ventilation and extended drying time) to ensure that *VOLATILES*[32] have been dissipated from the coating.

Before applying any coating, the water system operator must verify that the selected paint, lining, coating, thinners, and conditioners contain no toxic ingredients that might contaminate the water in the tank. Many states require that paints and coatings used in potable water systems be approved by the state. The National Sanitation Foundation publishes two standards to provide guidance to states regarding the acceptability of paints and coatings for use in potable water service (NSF Standard 60, Drinking Water Treatment Chemicals—Health Effects; NSF Standard 61, Drinking Water System Components—Health Effects; available from National Sanitation Foundation International, PO Box 130140, 789 N. Dixboro Road, Ann Arbor, MI 48113-0140, phone: (800) NSF-MARK ((800) 673-6275) or (734) 769-8010, e-mail: info@nsf.org, or website: www.nsf.org. Additionally, paints and coatings approved for use by the Food and Drug Administration (FDA) for continuous contact with aqueous (watery) foods as defined in the Code of Federal Regulations (21 CFR) are generally acceptable for use in potable water systems.

The paint or coating should also meet AWWA Specifications.[33] Products that contain lead or PCBs[34] are not recommended for potable water use. Coatings using trichloroethylene and tetrachloroethylene should also be avoided.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 138.

3.2E Why should sand particles be prevented from entering the distribution system?

3.2F Why are sand traps not recommended for the removal of sand from well water?

3.2G What types of materials may be removed from water by a sand separator?

3.2H What sanitary hazards are associated with sand traps or sand separators?

3.2I Why are steel water storage tanks and hydropneumatic pressure tanks painted on the interior surface with some type of protective coating?

3.25 Surge Suppressors

In certain situations, a booster pump is used in conjunction with the main well pump. This type of operation usually involves pumping a small amount of water to a specific pressure zone in the distribution system that operates at a much higher pressure or higher elevation than the main well pump system.

Frequent start/stop operation of the booster pump, combined with the higher system pressure, could create problems such as pulsation, vibration, and possible damage to the piping network. To correct this problem, surge suppressors are sometimes installed on the discharge side of the booster pump. Their function is to absorb shock waves in the fluid (water) system and prevent their transmittal through the line.

One relatively simple surge suppressor design consists of a flexible, fully enclosed rubber bladder or diaphragm mounted within a steel shell and connected to the piping system with flanged fittings. The upper chamber is filled with air or nitrogen gas. When a surge occurs, flow from the main system line enters the surge suppressor through a specially designed metering port where a portion of the *KINETIC ENERGY*[35] is dispelled. The dampened pressure surge then continues into the lower fluid chamber where the remaining kinetic energy is dissipated by compressing the air or gas in the upper pressurized chamber. When the compressed air or gas expands, forcing the fluid back into the main system, more residual kinetic energy is lost in the controlled flow back through the metering port.

Hydropneumatic tanks also serve as surge suppressors and can be used in a direct line of flow mode or connected to the booster pump discharge line by means of a tee fitting.

3.26 Air and Vacuum Valves

An air and vacuum valve, commonly referred to as an air release and vacuum breaker valve, has a large venting orifice and is used to exhaust large quantities of air very rapidly from a deep well pump column when the pump is started. After the air has been exhausted from the pump column, the valve closes and

[32] *Volatile* (VOL-uh-tull). (1) A volatile substance is one that is capable of being evaporated or changed to a vapor at relatively low temperatures. Volatile substances can be partially removed from water or wastewater by the air stripping process. (2) In terms of solids analysis, volatile refers to materials lost (including most organic matter) upon ignition in a muffle furnace for 60 minutes at 550°C (1,022°F). Natural volatile materials are chemical substances usually of animal or plant origin. Manufactured or synthetic volatile materials, such as plastics, ether, acetone, and carbon tetrachloride, are highly volatile and not of plant or animal origin. Also see NONVOLATILE MATTER.

[33] *D102-06 AWWA STANDARD FOR COATING STEEL WATER-STORAGE TANKS.* See Section 3.38, "Additional Reading," for ordering information.

[34] *PCBs.* Polychlorinated biphenyls. A class of organic compounds that cause adverse health effects in domestic water supplies.

[35] *Kinetic Energy.* Energy possessed by a moving body of matter, such as water, as a result of its motion.

remains closed. When the pump stops, the valve will immediately open to allow air to re-enter the pump column and prevent a vacuum from developing.

The orifice of the valve must be equipped with an approved vent assembly consisting of a downturned, screened opening mounted at least 12 inches (300 mm) above the finished surface of the well lot or above any anticipated high-water (flood) level. The open end of the vent must be equipped with holes or fine mesh screen to keep insects out of the well.

The valve should be properly sized (usually a minimum of two inches (50 mm)) to allow the unrestricted flow of air into and out of the pump column. Improperly sized or poorly constructed vents could cause the well pump base gasket or sealing material to be blown out on pump start-up. This in turn could allow insects and foreign debris to be drawn into the well when the pump stops.

3.27 Pressure Relief Valves

Pressure relief valves should be installed on all hydropneumatic tanks. Excessive internal pressures (surge pressures), often referred to as *WATER HAMMER*,[36] could cause the tank to explode or rupture. A typical pressure relief valve is illustrated in Figure 3.9.

Water hammer is frequently encountered in water supply and treatment facilities. Water hammer may be caused by the quick opening or closing of valves such as fire hydrant valves, the start-up or shutdown of pumps, other conditions that could cause a pulsation of pressures above and below the operating pressure, and a rapid acceleration or deceleration of the velocity of flow. The increased pressure may be several times the normal operating pressure, which can seriously damage hydropneumatic tanks, valves, and the piping network.

Water hammer can be controlled or eliminated by using pressure relief valves. These automatic valves have a spring tension preset to a certain operating pressure. In the case of well pump installations, the valve is usually set at 125 pounds per square inch (862 kPa or 8.8 kg/sq cm). Pressure in excess of this setting will open the valve, allowing air or water to escape and preventing an excess pressure buildup.

3.28 Air Chargers

3.280 Methods of Air Charging

Several methods are available for adding air to a hydropneumatic tank. One method is to use the air in the well pump column. Instead of discharging the air in the column to atmosphere when the pump starts, the column of air is forced into the tank. With this method, the tank must be equipped with an air release valve and a riser pipe extending down to the midpoint of the tank. The riser pipe is designed to maintain an approximate air-to-water ratio in the tank of 50:50. This method should be used with caution due to the possibility that during periods when the well pump is cycling on and off at a frequent rate, excess air may not be discharged fast enough through the air release valve and the tank may become oversaturated with air. If this occurs, air could be pumped out into the distribution system with resultant problems and consumer complaints.

A second method of air charging a tank is to manually add air to the tank as needed using a portable air compressor. This technique can be very time consuming and costly.

The most satisfactory method is to automatically add air by means of an on-site, permanent, air-charging device. Two general types are currently available: the hydraulic principle type and the motor-driven air compressor type.

3.281 Hydraulic Principle Air Charger (Figure 3.10)

The hydraulic principle air charger uses the water pressure of the tank to force air into the tank. The unit normally mounts vertically on one end of a horizontal pressure tank. This unit consists of a closed cylindrical tube section, an upper and lower float, a pilot valve, a one-way air valve, plus a water supply line with sand strainer connected near the bottom of the tank, and an air discharge line connected to the top of the tank.

The unit adds air to the tank on the upward compression stroke and releases water on the downward exhaust stroke. The unit continues to cycle until the preset air-to-water ratio is reached. Approximately 2⅔ gallons (10 liters) of water is discharged from the unit during each complete cycle. The drain line from this unit should not be directly connected to a sewer line. An air-gap separation is recommended to protect the tank from backsiphonage.

3.282 Air Compressor Air Charger (Figure 3.11)

This type of air charger is composed of three primary elements: the air compressor, the liquid level switch, and the pressure switch. The liquid level switch senses the water level in the tank by an electrode suspended into the tank. When the water

[36] *Water Hammer.* The sound like someone hammering on a pipe that occurs when a valve is opened or closed very rapidly. When a valve position is changed quickly, the water pressure in a pipe will increase and decrease back and forth very quickly. This rise and fall in pressures can cause serious damage to the system.

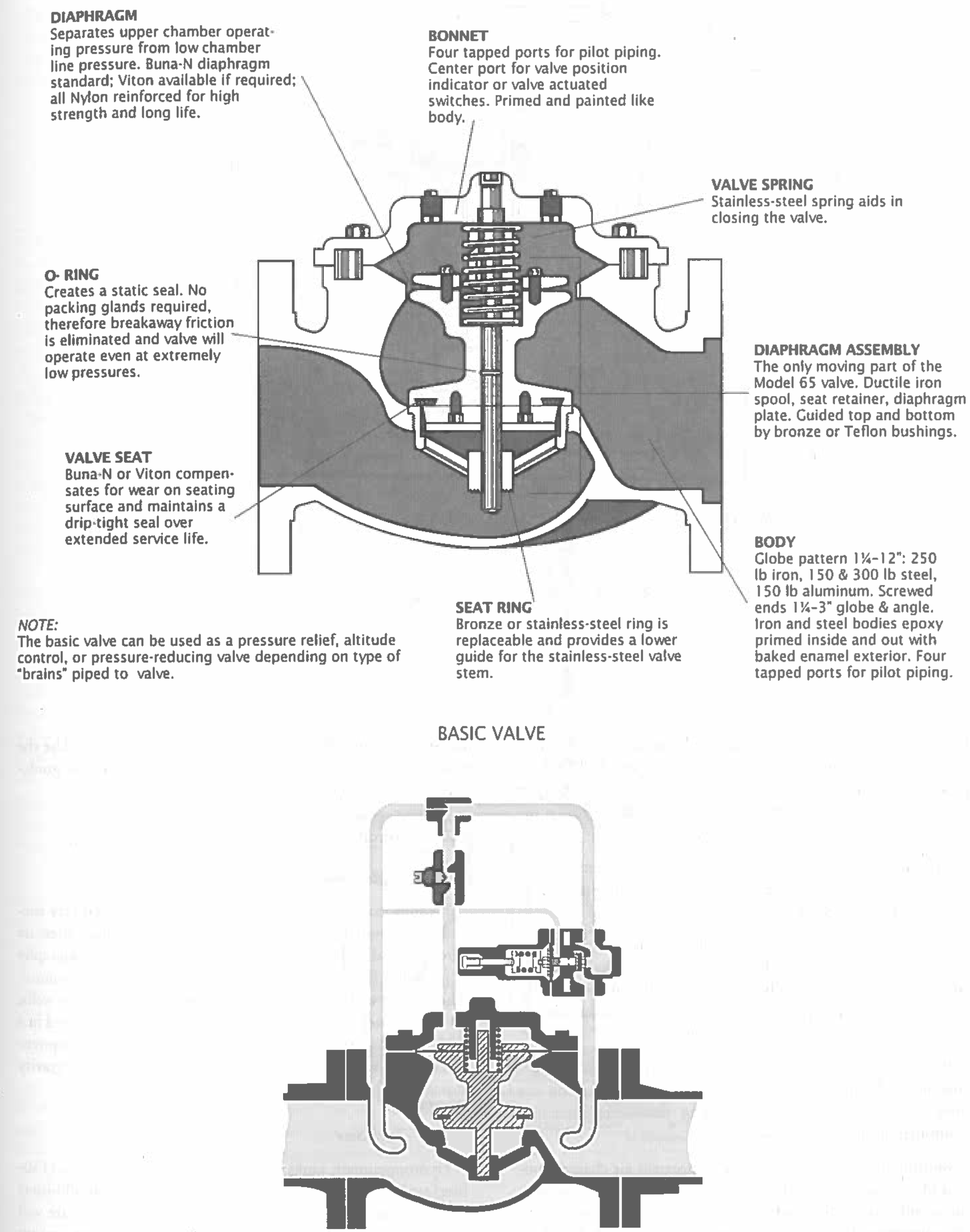


Fig. 3.9 Pressure relief valve
(Permission of OCV Control Valves)

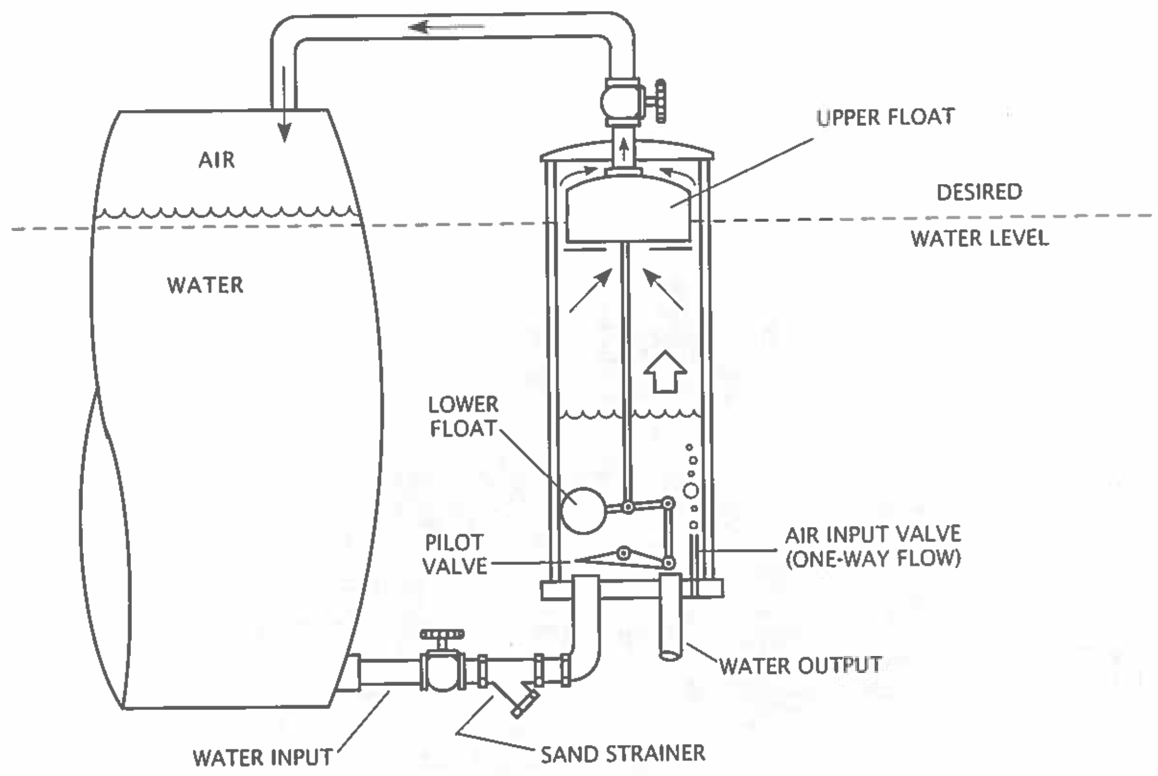


Fig. 3.10 Typical hydraulic principle air charger

level in the tank exceeds the preset level, the liquid level switch starts the compressor and air is pumped into the tank. The compressor runs until either the pressure rises sufficiently to open the unit's pressure switch or the water level descends below the preset level.

The unit mounts directly on top of the hydropneumatic tank and is protected by a weatherproof cover. No drain lines are required and the air entering the compressor is filtered.

The two types of air chargers require routine maintenance and have not been trouble-free. However, the desirability and advantages of automatically maintaining the proper air-to-water ratio in a hydropneumatic tank far offset the operational problems of these two types of air charging devices.

Routine maintenance on the hydraulic principle air charger consists of draining the Y (wye) pattern sand strainer on the inlet line as needed and maintaining the freeze-protection equipment if mounted outdoors.

Routine maintenance on the air compressor air charger consists of lubrication, cleaning the filter element on the compressor air inlet as needed, and maintaining the correct tension on the compressor belts. Set up a maintenance program based on the specific type of facilities that you are working with. Use the manufacturers' bulletins and maintenance procedures as guidelines.

3.29 Hydropneumatic Pressure Tank Systems

3.290 Applications

Hydropneumatic pressure tank systems can be used very successfully in well pump operations to maintain adequate pressure throughout distribution systems. In areas where the topography is generally flat, hydropneumatic systems are quite common. They can be used for small water systems with one or two wells, for larger water systems with many wells strategically located in a grid system, or to supply service to isolated areas. Hydropneumatic pressure tank systems can also be integrated with gravity storage systems, although this is not a widespread practice.

3.291 Tank Size

Hydropneumatic tanks range in capacity from 40-gallon (150-liter) tanks serving single families to 21,000-gallon (80,000-liter) or larger size tanks for public water systems. The tank size will depend on many factors such as geographic location, pump

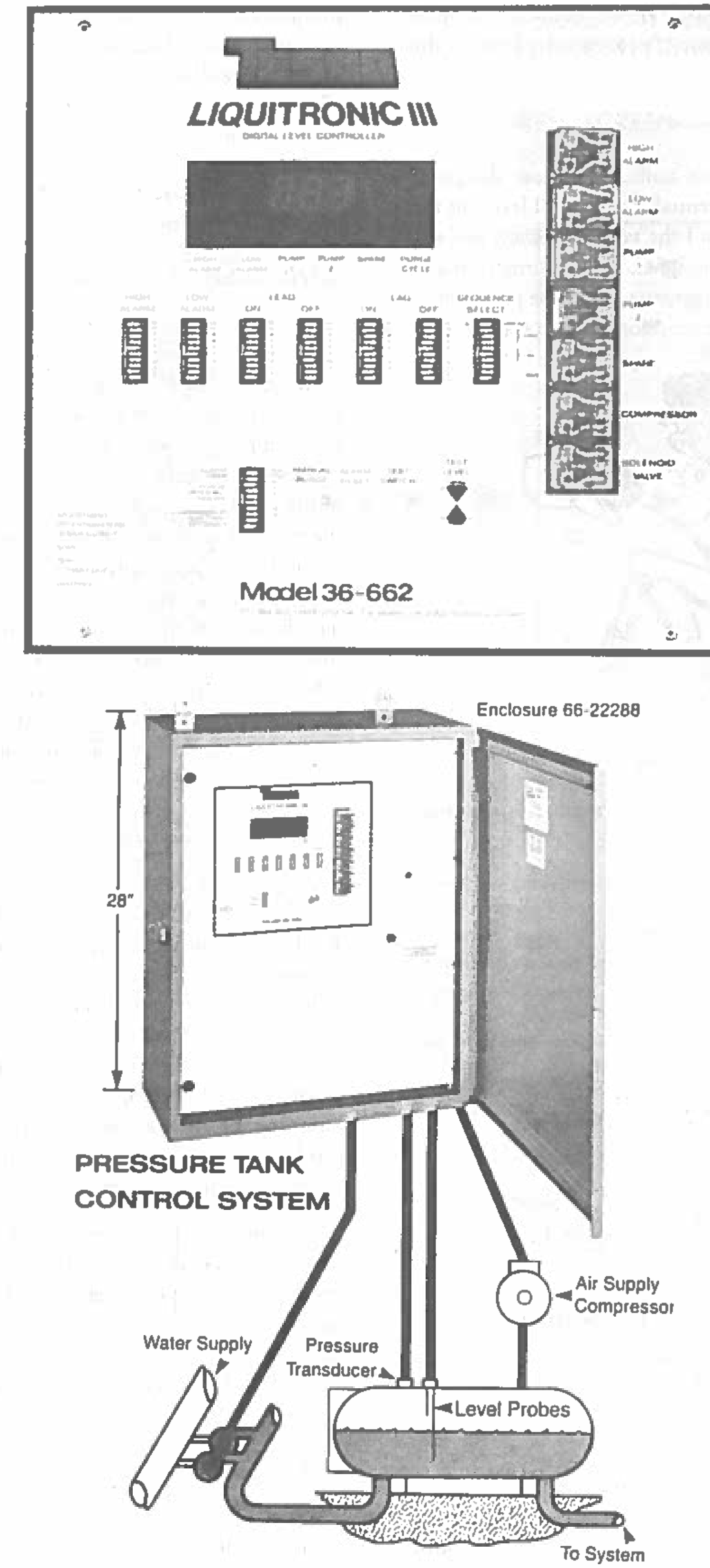


Fig. 3.11 Air compressor air charger
(Permission of TESCO, Sacramento, CA)

capacity, peak demand, pump cycling rate, economics, past operational experience, and the amount of property available to the water supplier for plant facilities.

3.292 Operation

When hydropneumatic pressure tank systems are designed, the best operating pressure differential, the control levels in the tank, the pumping differential and the tank efficiency, and the tank size are determined by the designer. This information and procedures for any necessary adjustments should be provided in the operation and maintenance instructions for the system.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on pages 138 and 139.

3.2J Under what circumstances might a booster pump be installed?

3.2K What is the purpose of surge suppressors that are sometimes installed on the discharge side of a booster pump?

3.2L What is the purpose of an air release and vacuum breaker valve?

3.2M Why are pressure relief valves installed on hydropneumatic tanks?

3.2N What is the purpose of an air charger?

3.2O The size of a hydropneumatic tank is influenced by what factors?

3.3 WELL MAINTENANCE AND REHABILITATION

3.30 Importance of Well Maintenance

If the well casing, well screen, filtering material, and other appurtenances of a well are properly designed and correctly installed by a qualified well driller, maintenance of a well will be minimized. However, wells, like all other waterworks facilities, need periodic routine maintenance in the interest of a continuous high level of performance and a maximum useful life. The usual attitude toward maintenance of wells is "out of sight, out of mind." Consequently, very little or no attention is paid to wells until problems reach crisis levels, often resulting in the complete loss of the well. The importance of a routine maintenance program for the prevention, early detection, and correction of problems that reduce well performance and useful life cannot be overemphasized. A maintenance program can pay handsome dividends to a well owner and will certainly result in long-term benefits that exceed the cost of implementation and continuation of the program.

3.31 Factors Affecting the Maintenance of Well Performance

3.310 Adverse Conditions

The factors affecting the maintenance of well performance or yield are numerous. Care should be taken to distinguish between factors associated with the normal wearing of pump parts and those directly associated with changing conditions in and around the well. A perfectly functioning well, for example, can show a reduced yield because of a reduction in the capacity of the pump due to excessively worn parts. On the other hand, the excessive wearing of pump parts may be due to the pumping of sand that entered the well through a corroded well screen. Corrosion may reduce the pump capacity but, at the same time have little or no effect on a properly designed well. There will be some overlap in what is called well maintenance and what is called pump maintenance. Conditions or well maintenance problems that should be guarded against are overpumping and lowering of the water table, clogging or incrustation of a screen, or corrosion or collapse of a screen.

3.311 Overpumping

Overpumping was discussed in Section 3.021, "Overdraft," so we will only summarize the problems here. Overpumping an aquifer can damage the aquifer by reducing the storage and production capacity of groundwater systems. The net result is consolidation of the water-bearing formations, which provides less storage space, a lowering of the water table, and a reduced yield from the well. Other problems that may develop from overpumping or installing the pump suction too high include pumping air and also water cascading into the well. The well production rate is normally determined by the well driller and hydrogeologist at the time the well is drilled and developed.

Overpumping may cause sand pumping. This will subject the pump to excessive wear, which over time can reduce its operating efficiency. Under severe conditions, the pump may become sand locked, either during pumping or after shut-off. Should sand locking occur, the pump must be pulled, disassembled, cleaned, and repaired, if necessary, before being placed back into service.

3.312 Clogging or Incrustation of Screen

A well screen is a filtering device attached to the bottom of the casing. It allows groundwater from the aquifer to enter the well. It also keeps sand out of the well. Well screens are designed to fit individual well casings and are composed of many slits or louvers as shown in Figure 3.12. As can be seen from this figure, if the slits in the screen become incrusted and blocked, the available openings for water to move through are severely limited. The most common cause of a decrease in the capacity of a well is

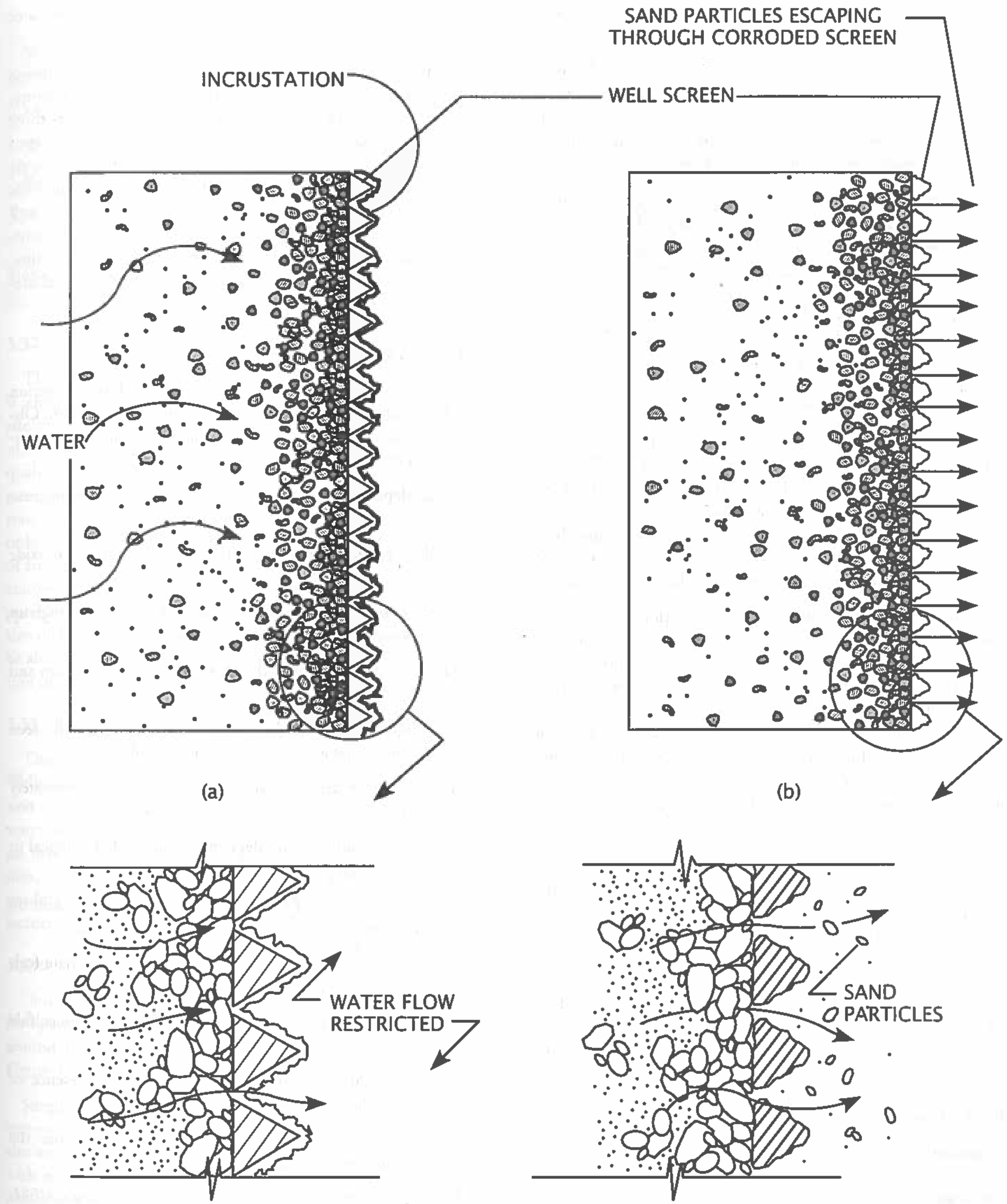


Fig. 3.12 Well screen incrustation and corrosion
(also see Figure 3.52, page 159)

the clogging of the well screen openings and the aquifer's pore spaces around the well screen by incrusting deposits.

Incrusting waters are usually alkaline. Physical and chemical changes in the water cause dissolved minerals to change to their insoluble states and settle out as deposits. These deposits block the screen openings and the aquifer pore spaces immediately around the screen, with a resulting reduction in the well's yield.

Excessive carbonate hardness is a common source of incrustation in wells. Incrusting deposits may be of the hard, cement-like form typical of the carbonate and sulfate compounds of calcium and magnesium, the soft, sludge-like forms of the iron and manganese hydroxides, or the jelly-like slimes of iron bacteria. Iron may also be deposited in the form of ferric oxide with a reddish-brown, scale-like appearance. Less common is the deposit of soil materials such as silt and clay.

3.313 Corrosion or Collapse of Screen

Corrosion is a process that results in the gradual decomposition or destruction of metals. Corrosive waters are usually acidic and may contain relatively high concentrations of dissolved oxygen, which is often necessary for and increases the rate of corrosion. High concentrations of carbon dioxide, total dissolved solids, and hydrogen sulfide (with its characteristic odor of rotten eggs) are other indications of a possibly corrosive water.

Besides water quality, other factors such as velocity of flow and dissimilarity of metals also contribute to the corrosion process. The greater the velocity of flow, the greater is the removal of the protective corrosion end products from the surface of the metal and hence the exposure of that surface to further corrosion. This is another important reason for keeping the velocity through screen openings within acceptable limits. The use of two or more different types of metals such as stainless steel and ordinary steel, or steel and brass or bronze should be avoided whenever possible. Corrosion is usually greatest at the points of contact of the different metals or where they come closest to contact.

If corrosion occurs on a well screen, the slits may enlarge enough for grit and sand to be carried into the well along with water. This, in turn, will damage the pump and appurtenances. If the corrosion is severe enough, total collapse of the screen could occur. Casing failure by corrosion ruins a well as fast as failure of the screen. Failure can allow clay and polluted or otherwise unsatisfactory water to get into the well. Corrosive well waters can destroy steel casings in less than six months, thus ruining many wells.

3.314 Biofouling

Bacterial growth is responsible for more than 80 percent of the blockages in wells. Not only are bacteria responsible for biofilm slimes that can block flow pathways in wells, but the sticky adhesive polymeric material the bacteria produce provides an excellent base for mineral accumulation. The slimes that are produced are often a hard, cemented mass capable of extensive blockage of screen and slot openings as well as gravel pack and formation flow paths. Also, bacterial growth accounts for a major portion of the corrosion process in the well, resulting in the accumulation of iron oxides that block flow and cause water quality decline.

The biofilm is actually the habitat of the bacteria and consists of the bacteria and the exopolymer, or polysaccharide polymer, the bacteria produce. This polysaccharide polymer serves three beneficial functions for the bacteria: (1) it enables the bacteria to attach to surfaces, (2) it provides protection for the bacteria from chemical or physical activity, and (3) it captures nutrients or food the bacteria need. The major groups of bacteria in well systems that cause biofouling and result in the blockage, corrosion, or water quality problems include the groups of slime formers, the iron oxidizers, and anaerobes (of which the sulfate-reducing bacteria are the most offensive).

3.315 Field Testing of Deposits

If incrustations are causing problems in a well, the collection of samples of the deposits can provide helpful information. Observation should first be made as to color and density of the incrustation sample.

- **Black deposit:** may indicate an iron sulfide or a manganese deposit.
- **Dark to reddish brown:** usually indicates a ferric iron oxide deposit.
- **Bright yellow:** most probably sulfur and usually seen high up on the drop piping and casing, often above water level.
- **Light tan deposit:** can be dolomite, a mixture of calcium and magnesium carbonate.
- **Very light color to white:** calcium carbonate, usually seen with other minerals providing additional colors.
- **Very heavy or dense deposit:** the deposit is predominately mineral.
- **Very light or low density deposit:** considerable biological or organic material present.

Placing a few drops of hydrochloric acid or muriatic acid on the incrustation may elicit some additional information.

1. Considerable foaming or frothing indicates a carbonate (calcium, magnesium, or iron).
2. Hydrogen sulfide gas or rotten egg odor indicates iron sulfide present.
3. A strong chlorine odor indicates the possible presence of manganese dioxide.
4. No effervescent or frothing or odor usually indicates the presence of iron oxide, calcium sulfate, or silica.

The information in Sections 3.314 and 3.315 is from *CHEMICAL CLEANING, DISINFECTION, AND DECONTAMINATION OF WATER WELLS*, John H. Schnieders, 1st Edition, 2003. Published by Johnson Screens, Inc., PO Box 64118, St. Paul, MN 55164-0118. ISBN 978-09726750-0-0. Reprinted by permission of Johnson Screens / a Weatherford Company and by permission of the author, Dr. John H. Schnieders, Ph.D., CPC.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 139.

3.3A List three major well maintenance problems.

3.3B How can overpumping an aquifer damage the aquifer?

3.3C What kinds of incrusting deposits can develop in wells?

3.3D True or False? Incrusting waters are usually alkaline while corrosive waters are usually acidic.

3.3E Why should the use of two or more different types of metals be avoided in a well?

3.32 Preventive Maintenance and Repairs

The best possible procedure for a good maintenance program is adequate recordkeeping. This aspect of the operator's responsibility cannot be overemphasized. Regular water level measurements in the well before and after pumping, flow rates, water quality samples, length of time pumping, and accurate data on pump repairs and causes are a few of the records that should be routinely kept. The records should be kept neatly and in logical order. This collected data will be an invaluable tool in the hands of an engineer, hydrogeologist, chemist, or skilled operator. Operators should monitor this data to look for early warnings of potential problems such as overpumping. In areas where extensive oil or gas exploration is being conducted, operators should be alert for changes in water quality, which could indicate pollution of an aquifer.

3.33 Casing and Screen Maintenance

The types of materials that go into the well are very important. Wells composed of materials with little or no resistance to corrosion can be destroyed beyond usefulness by a highly corrosive water within a few months of completion. This will be the case no matter how excellent the other aspects of design, construction, and maintenance. A poor selection of materials can also result in collapse of the well due to inadequate strength. All these factors have a considerable influence on the useful life of a well.

3.330 Surging

"Surging," which is a form of plunging, is a procedure used for opening pores in the screen and for cleaning the gravel pack around the screen. A typical surge arrangement is shown in Figure 3.13.

Surging is commonly used for new well development to remove sand from the area around the well screen. However, it is also an effective procedure in combating incrustation when used with acid treatment. Care must be exercised when using surge plungers within the screen area itself and in wells in which aquifers contain large amounts of clay. In cleaning screens, the plunger can become sand-locked by the settling of sand above it. In cleaning the gravel pack around the screen, the action of the plunger can cause the clay to plaster over the screen surface. Plungers should be used only under the supervision of someone experienced in their use.

3.331 High-Velocity Jetting

"High-velocity jetting" is the spraying of water at a high velocity. This is an effective form of backwashing, which, when used with acid treatment, is another procedure for removing incrustation from well screens and casings. Jetting can also be used for reopening the pores of the aquifer and removing sand from the immediate vicinity of the well screen.

A simple form of a jetting tool for use in wells is shown in Figure 3.14. An appropriately sized coupling with a steel plate welded over one end is screwed or welded to a pipe. The jetting tool's outside diameter will vary depending on the inside diameter of the well. The maximum and minimum differences in diameter between the jet tool and well screen are two inches (50 mm) and one inch (25 mm) respectively. That is, if the well screen has a 10-inch (250-mm) inside diameter, then the jet tool should have an outside diameter between eight and nine inches (200 and 225 mm). Two to four 3/16- or 1/4-inch (5- or 6-mm) diameter holes, equally spaced around the circumference, are drilled through the full thicknesses of the coupling and the jetting pipe at a fixed distance along the coupling from the near surface of the steel plate. Better results can be obtained if properly shaped nozzles are used instead of the straight, drilled holes shown in Figure 3.14, but these are also acceptably effective.

The procedure is to lower the tool on the jetting pipe to a point near the bottom of the screen. The upper end of the pipe is connected through a swivel and hose to the discharge end of a high-pressure pump such as the mud pump used for hydraulic rotary drilling. The pump should be capable of operating at a pressure of at least 100 pounds per square inch (psi) (690 kPa or 7 kg/sq cm) and preferably at about 150 psi (1,040 kPa or 10.5 kg/sq cm) while delivering 10 to 12 gallons per minute (GPM) (0.6 to 0.8 *L*/sec) for each 3/16-inch (5-mm) nozzle or 16 to 20 GPM (1.0 to 1.25 *L*/sec) for each 1/4-inch (6-mm) nozzle on the tool. For example, a tool with two 3/16-inch (5-mm) diameter nozzles would require a pumping rate of about 20 to 24 GPM (1.25 to 1.5 *L*/sec), while a tool with three 1/4-inch (6-mm) diameter nozzles would require a pumping rate of 48 to 60 GPM (3.0 to 3.8 *L*/sec). While pumping water through the nozzles and screen into the formation, the jetting tool is slowly rotated, thus washing and developing the formation near the bottom of the well screen. The jetting tool is then raised at intervals of a few inches and the process repeated until the entire length of

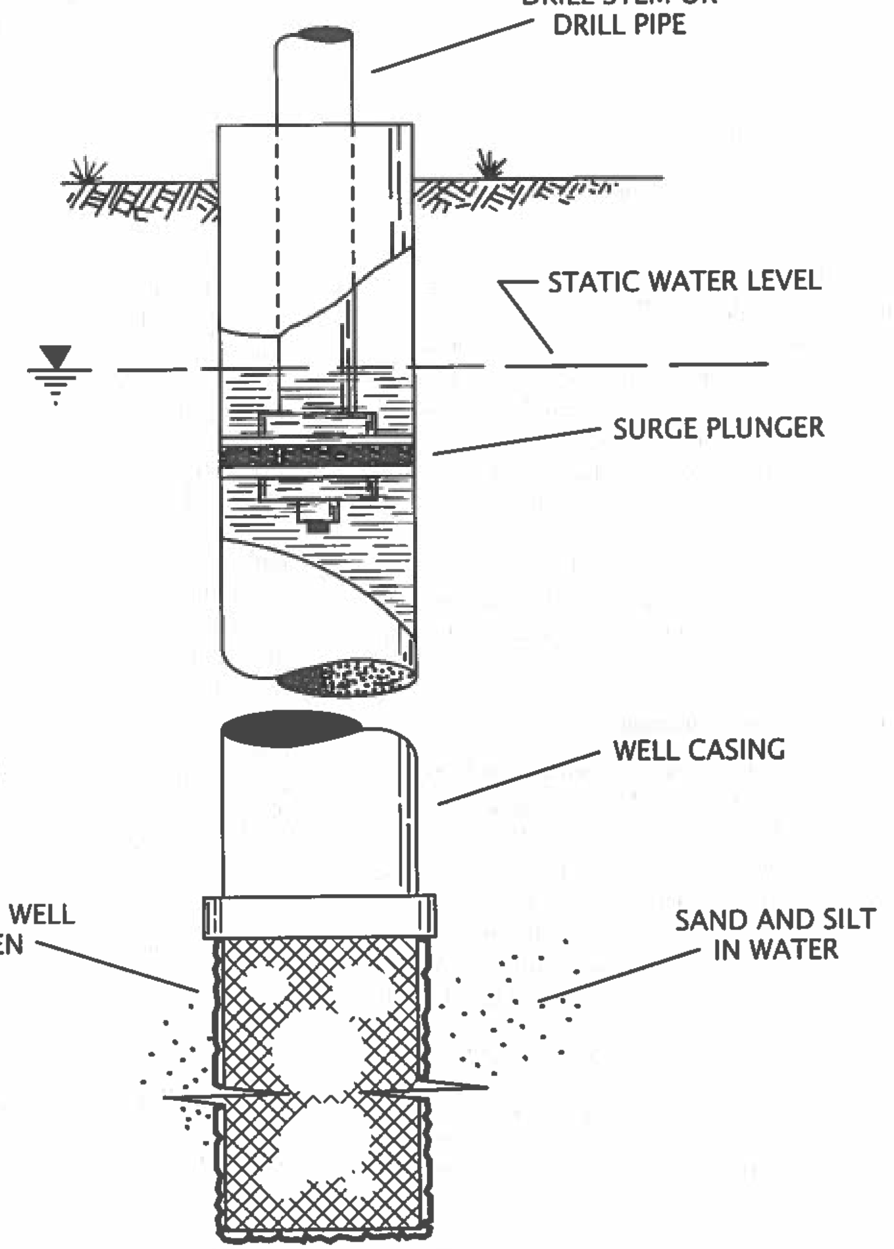


Fig. 3.13 Typical surge plunger arrangement

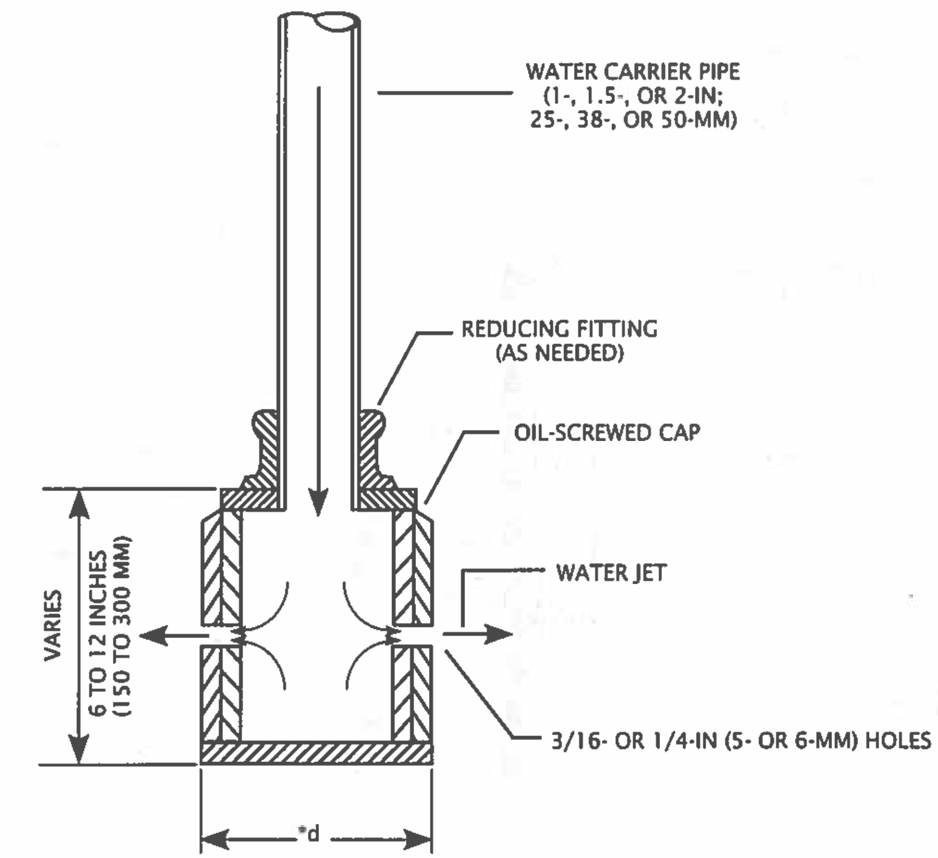


Fig. 3.14 Simple jetting tool

screen has been backwashed and fully developed. Where possible, it is very desirable to pump the well at the same time the jetting operation is in progress.

As shown in Figure 3.15, the area of concentration of the spray is very small. Because of this concentration, the jet spraying procedure becomes one of the most effective procedures for screen cleaning and well development.

3.332 *Acid Treatment*

Acid treatment may be the only effective procedure available to loosen incrustation so that it may be removed from the well casing and well. Acids normally used are hydrochloric or sulfamic. Both of these acids readily dissolve calcium and magnesium carbonate, though hydrochloric acid does so at a faster rate. Strong hydrochloric acid solutions also dissolve iron and manganese hydroxides. The simultaneous use of an inhibitor serves to slow up the tendency of the acid to attack steel casing.

The use of chemicals in a well requires the proper selection of well materials at the time of construction to avoid damage to the materials by the chemicals.

Hydrochloric acid should be used at full strength. Each treatment usually requires 1½ to 2 times the volume of water in the screen or pipe to be cleaned. This provides enough acid to fill the area to be cleaned and additional acid to maintain adequate strength as the chemical reacts with the incrusting materials. Figure 3.16 illustrates a method of placing acid in a well. Acid can be introduced into the well by means of a wide-mouthed funnel and ¾- or 1-inch (18- or 25-mm) plastic pipe. Acid is heavier than water, which it tends to displace, but with which it also mixes readily to become diluted.

The acid solution in the well should be agitated by means of a surge plunger or other suitable means for 1 to 2 hours. Following this, the well should be bailed until the water is relatively clear. The driller usually can detect an improvement in the yield

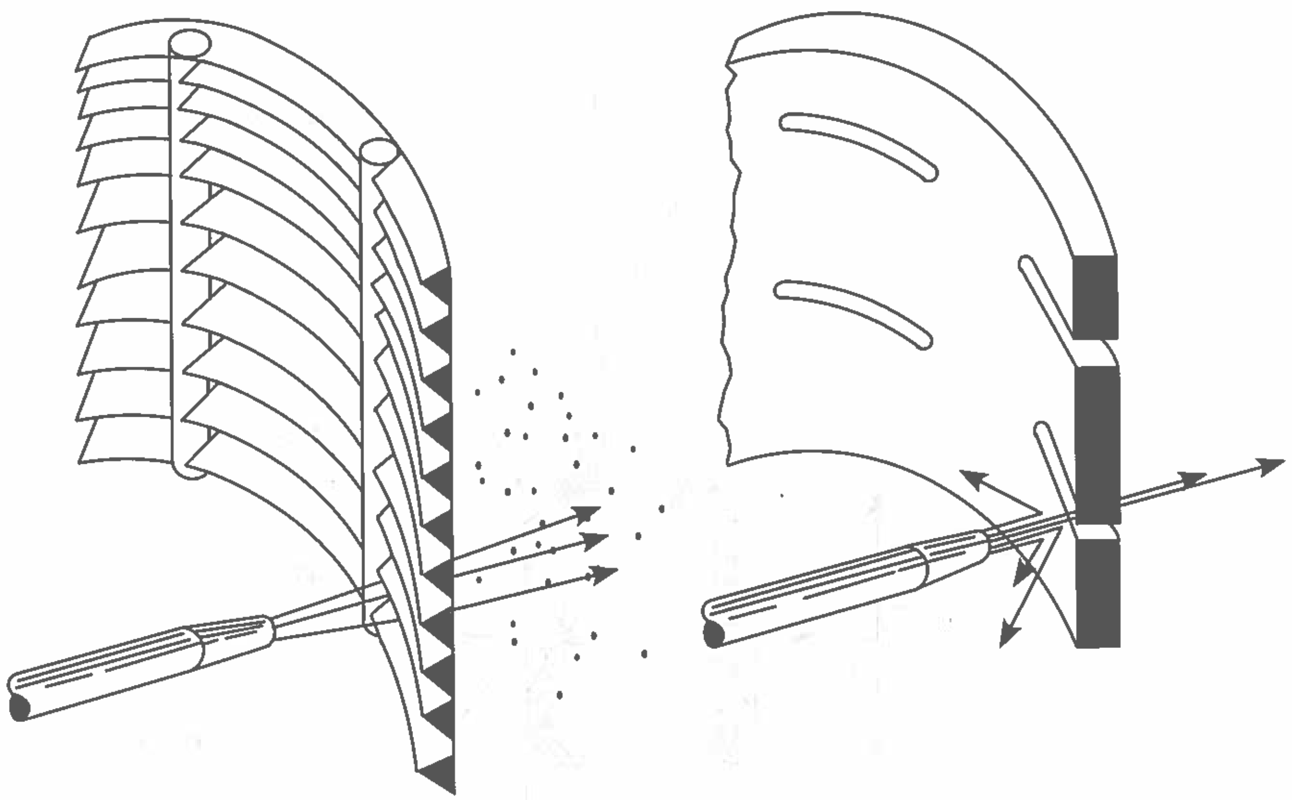


Fig. 3.15 *Use of jet spray on well screen*

of the well while running the bailer. The well may, however, be pumped to determine the extent of improvement. If the results are less than expected, the treatment may be repeated using a longer period of agitation before bailing. Additional treatment may even be undertaken.

The procedure is sometimes varied to alternate acid treatment and chlorine treatment. The chlorine helps to remove the slime deposited by iron bacteria. Sulfamic acid offers a number of advantages over hydrochloric acid as a means of treating incrustation in wells. Sulfamic acid can be added to a well in either its original granular form or as an acid solution mixed on site. Granular sulfamic acid is nonirritating to dry skin and its solution gives off no fumes except when reacting with incrusting materials. Spillage, therefore, presents no hazards and handling is easier, cheaper, and safer. Sulfamic acid also has a markedly less corrosive effect on well casing and pumping equipment. Sulfamic acid dissolves calcium and magnesium carbonate compounds to produce very soluble products. The reaction is, however, slower than that using hydrochloric acid and a somewhat longer contact period in the well is required. Again, agitation must be provided by some sort of plunger. The quantity of acid added in this case should be based on the total volume of water standing in the well—not on the volume of just the part of the well to be cleaned (as is the case if the acid is applied in solution form). A little extra granular sulfamic acid may be added to keep the solution up to maximum strength while it is being used up through reaction with the incrusting material. The addition of a low-foaming, nonionic wetting agent improves the cleansing action to some extent.

A number of precautions must be exercised in using any strong acid solution. Goggles and waterproof gloves should be worn by all persons handling the acid. When preparing an acid solution, *always pour the acid slowly into the water.* In view of the variety of gases, some of them very toxic, produced by the reaction of acid with incrusting materials, adequate ventilation must be provided in pump houses or other confined spaces around treated wells. Do not allow personnel to stand in a pit or depression around the well during treatment because some of the toxic gases (such as hydrogen sulfide) are heavier than air and will tend to settle in the lowest areas. After a well has been treated, it should be pumped to waste to ensure the complete removal of all acid (measure pH) before it is returned to normal service.

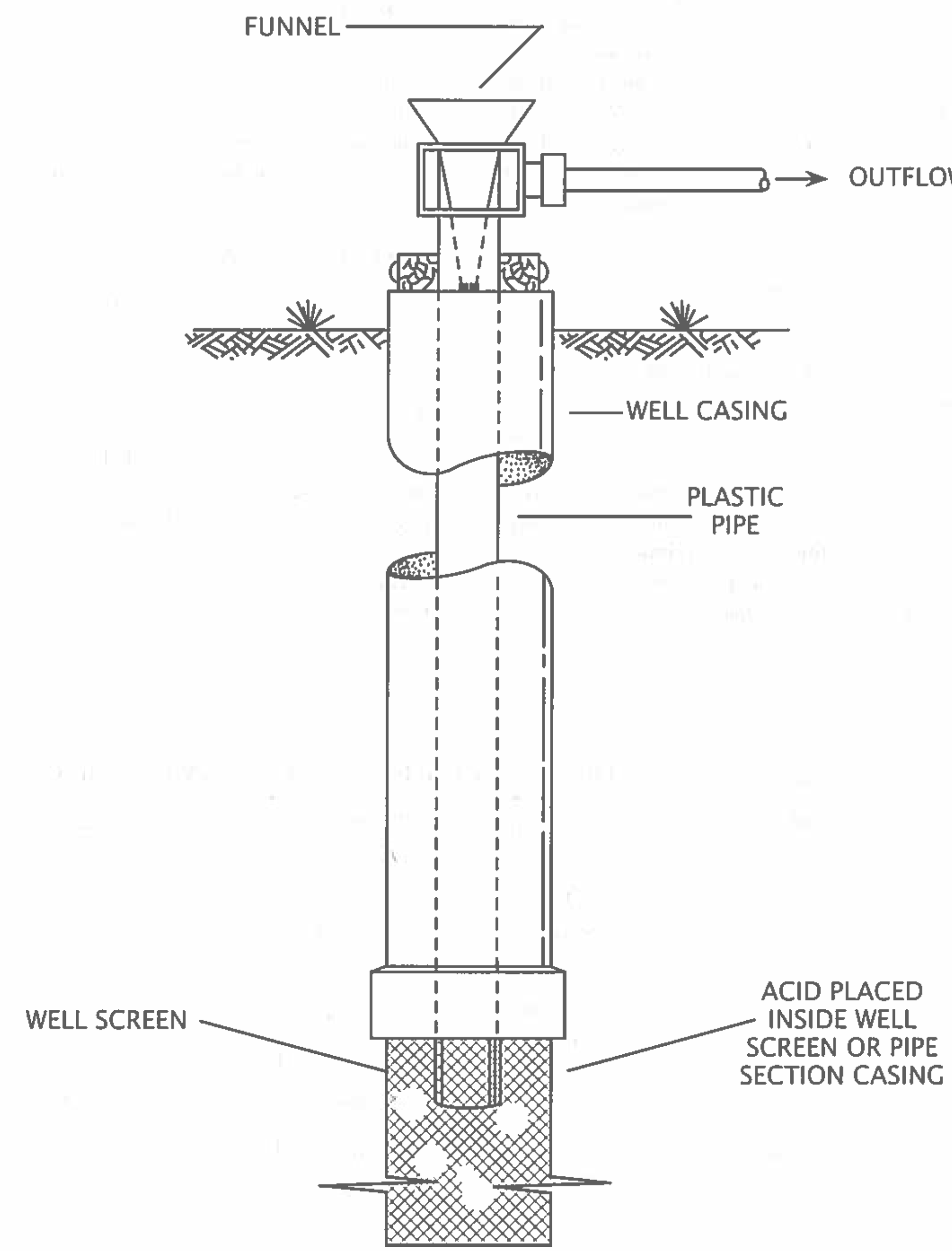


Fig. 3.16 *Procedure for introducing acid into well for purpose of cleaning incrustations from screen and casing*

Table 3.5 provides a summary of the characteristics of common well cleaning acids. Always store and handle acids in accordance with the supplier's recommendations.

3.333 *Chlorine Treatment*

Chlorine treatment of wells is more effective than acid treatment in loosening bacterial growths and slime deposits, which often accompany the deposition of iron oxide. Because of the very high concentrations required, 100 to 200 mg/L of *AVAILABLE CHLORINE*,[37] the process is often referred to as "shock treatment" with chlorine. Calcium hypochlorite or sodium hypochlorite may be used as the source of chlorine.

> **NOTE**
>
> Either calcium hypochlorite or sodium hypochlorite can be used. They are never used together. Extreme heat or an explosion could occur.

The chlorine solution in the well must be agitated. This may be done by using the high-velocity jetting technique or by surging with a surge plunger or other suitable technique. The recirculation provided with the use of the jetting technique greatly improves the effectiveness of the treatment.

The treatment should be repeated 3 or 4 times in order to reach every part of the formation that may be affected. This treatment may also be alternated with acid treatment, but use the acid first.

3.334 *Polyphosphates*

Polyphosphates, or glassy phosphates as they are commonly called, effectively disperse silts, clays, and the oxides and hydroxides of iron and manganese. The dispersed materials can be easily removed by pumping. In addition, the polyphosphates are safe to handle and are often used in the chemical treatment of wells.

3.335 *Explosive Charges*

Small explosive charges have been used to clean plugged well screens. Experts in this field should be consulted before attempting this procedure.

3.336 *Summary*

Although many forms of well cleaning and maintenance have been discussed here, you are cautioned to exercise care in the application of any of these. Always observe manufacturers' recommendations. Obtain expert advice if you are not sure which chemical to use, how to apply the chemical, or how to remove it from the well.

TABLE 3.5 CHARACTERISTICS OF COMMON WELL CLEANING ACIDS

Characteristic	Sulfamic	Hydrochloric	Phosphoric	Hydroxyacetic	Citric
Corrosiveness to:					
• Metals	Moderate	Very High	Slight	Slight	Slight
• Skin	Moderate	Severe	Moderate	Slight	Slight
Reactivity vs:					
• Carbonate Scale	Very Good	Very Good	Very Good	Poor–Fair	Poor
• Sulfate Scale	Good	Good–Poor	Good–Poor	Very Poor	Very Poor
• Fe/Mn Oxides	Fair	Very Good	Good	Good	Chelates
• Biofilm	Poor	Poor	Poor	Moderately Good	Poor
Pounds of Acid (100%) Required to Dissolve 1 lb of Calcium Carbonate	2.0	.73	.65	4.5	4.0

Source: *CHEMICAL CLEANING, DISINFECTION, AND DECONTAMINATION OF WATER WELLS*, John H. Schnieders, 1st Edition, 2003. Published by Johnson Screens, Inc., PO Box 64118, St. Paul, MN 55164-0118. ISBN 978-09726750-0-0. Reprinted with permission of Johnson Screens / a Weatherford Company and by permission of the author, Dr. John H. Schnieders, Ph.D., CPC.

[37] *Available Chlorine.* A measure of the amount of chlorine available in chlorinated lime, hypochlorite compounds, and other materials that are used as a source of chlorine when compared with that of elemental (liquid or gaseous) chlorine.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 139.

3.3F What records should be kept regarding a well?

3.3G What is the purpose of surging?

3.3H How can the pores in a well screen and the gravel pack around the screen be cleaned?

3.3I How can incrustation be removed from the well casing and well?

3.3J How can bacterial growths and slime deposits be removed from well screens?

3.34 Water Quality Monitoring

Well performance can be affected by the quality of the groundwater. Similarly, water quality, both physical and chemical, is a good indicator of existing or potential problem areas and should be monitored regularly for clues to problems. For example, excessive sand production indicates problems with the well completion procedure and will produce excessive pump wear. The chemical quality of groundwater indicates the type of dissolved minerals in the groundwater and will help in the design of a maintenance program if mineral deposition is suspected to be a cause of decreased well performance.

3.35 Downhole Video Inspection

Downhole video inspection can aid in well maintenance. Cameras take both still photographs and motion pictures of the well with the pumping equipment removed. The tape-recorded video log of the well can then be reviewed as an aid in designing a maintenance or rehabilitation program. Specific problem areas, such as mineral deposition or other incrustation, corrosion of screen perforations or casing, and mechanical collapse or other failure, can be identified, permitting more precise procedures to correct problems.

3.36 Troubleshooting

3.360 *Decline in Yield*

The yield of any water supply well depends on three factors: the aquifer, the well, and the pump. A decline in yield is due to a change in at least one of these factors, and correction of the problem depends on identification of the factor that is involved. This identification in many cases can be made only if data are available on the depth to the water level in the well and the pumping rate. Inability to identify reasons for a decline in yield frequently results in discontinuing the use of the groundwater and developing more expensive supplies from either groundwater or surface water sources. Table 3.6 is a summary analysis of the causes of declines in well yields and potential corrective actions.

The "specific capacity test" is a measure of the adequacy of an aquifer or well. Specific capacity of a well is determined by measuring the yield of a well in gallons per minute per unit of drawdown during a specific time period, usually 24 hours. For example, if a well yield was 150 GPM and the drawdown was 15 feet, the specific capacity would be 150 GPM/15 ft or 10 GPM/ft of drawdown. Specific capacity generally varies with the duration of pumping; as pumping time increases, specific capacity decreases. Also, specific capacity decreases and discharge increases in the same well.

3.361 *Changes in Water Quality*

Deterioration in water quality may result from changes in the quality of water in the aquifer or changes in the well. These changes may affect the biological quality, the chemical quality, or the physical quality of the water. Deterioration in biological and chemical quality generally results from conditions in the aquifer, whereas changes in physical quality result from changes in the well. Both the biological and chemical quality of water from new public water supply wells must be analyzed before the wells are placed in use to determine if the water meets drinking water standards and, if it does not, what treatment is required. Table 3.7 is a summary analysis of the causes of changes in water quality and possible corrective actions.

TABLE 3.6 ANALYSIS OF DECLINES IN WELL YIELDS[a]

Symptom	Cause	Corrective Action
Decline in available drawdown, no change in specific capacity.	The aquifer, due to a decline in groundwater level resulting from depletion of storage caused by decline in recharge or excessive withdrawals.	Increase spacing of new supply wells. Institute measures of artificial recharge.
No change in available drawdown, decline in specific capacity.	The well, due to increase in well head loss resulting from blockage of screen by rock particles or by deposition of carbonate or iron compounds; or reduction in length of the open hole by movement of sediment into the well.	Redevelop the well through the use of a surge block or other means. Use acid to dissolve incrustations.
No change in available drawdown, no change in specific capacity.	The pump, due to wear of impellers and other moving parts or loss of power from the motor.	Recondition or replace motor, or pull pump and replace worn or damaged parts.

[a] *BASIC GROUNDWATER HYDROLOGY*, United States Geological Survey (USGS) Water Supply Paper 2220.

TABLE 3.7 ANALYSIS OF CHANGES IN WATER QUALITY[a]

Change in Quality	Cause of the Change	Corrective Action
Biological	Movement of polluted water from the surface or near-surface layers through the *ANNULAR SPACE*.[b]	Seal the annular space with cement grout or other impermeable material and mound dirt around the well to deflect surface runoff.
Chemical	Movement of polluted water into the well from the land surface or from shallow aquifers.	Seal the annular space. If sealing does not eliminate pollution, extend the casing to a deeper level (by telescoping and grouting a smaller diameter casing inside the original casing).
	Upward movement of water from zones of salty water.	Reduce the pumping rate or seal the lower part of the well.
Physical	Migration of rock particles into the well through the screen or from water-bearing fractures penetrated by open-hole wells.	Remove pump and redevelop the well.
	Collapse of the well screen or rupture of the well casing.	Remove screen, if possible, and install new screen. Install smaller diameter casing inside the original casing.

[a] *BASIC GROUNDWATER HYDROLOGY*, United States Geological Survey (USGS) Water Supply Paper 2220.

[b] Annular (AN-yoo-ler) Space. A ring-shaped space located between two circular objects. For example, the space between the outside of a pipe liner and the inside of a pipe.

3.37 Summary

Maintenance operations should not be put off until problems become serious. When this happens, rehabilitation of a well becomes more difficult and sometimes impossible or impractical. Incrustation not treated early enough can so thoroughly clog the well screen and the formation around it that it becomes extremely difficult (and even impossible) to diffuse or circulate a chemical solution to all affected points in the formation. At this point, any attempts at rehabilitation would most likely prove unsuccessful.

No methods have yet been developed for the complete prevention of incrustation in wells. Various steps can be taken to delay the process and reduce the magnitude of its effects. Among these are the proper design of well screens and the reduction of pumping rates, both aimed at reducing entrance velocities into screens and drawdown in wells. For example, it may be worthwhile to share the pumping load among a larger number of wells in order to reduce the rate of incrustation. However, the ultimate or final solution will be in a regular cleaning program. Incrusted wells are usually treated with chemicals, which either dissolve the incrusting deposits or loosen them from the surfaces of the well screen and formation materials so that the deposits may be easily removed by bailing. Corkscrew-shaped brushes have been rotated in wells to remove incrustations.

Recordkeeping is a must. Only with data on the well's performance can problems be identified or predictions be accurately estimated. Start a recordkeeping program when a well is constructed. If such steps were not taken at the time of construction, they should be started as soon as possible.

3.38 Additional Reading

1. AWWA Standards on Storage. D102-06. *COATING STEEL WATER-STORAGE TANKS.* Obtain from American Water Works Association (AWWA), Bookstore, 6666 West Quincy Avenue, Denver, CO 80235. Order No. 44102. Price to members, $46.50; nonmembers, $68.50; price includes cost of shipping and handling.
2. *CHEMICAL CLEANING, DISINFECTION, AND DECONTAMINATION OF WATER WELLS*, John H. Schnieders, 1st Edition, 2003. Published by Johnson Screens, Inc., PO Box 64118, St. Paul, MN 55164-0118. ISBN 978-09726750-0-0. Price, $96.00, plus shipping and handling.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 139.

3.3K How does the chemical quality of groundwater influence a well maintenance program?

3.3L How can the inside of a well be inspected for incrustation or corrosion of a well screen?

3.3M When the yield of a water well declines, what three factors should be investigated to determine the cause?

End of Lesson 2 of 4 Lessons on WELLS

Please answer the discussion and review questions next.

DISCUSSION AND REVIEW QUESTIONS

Chapter 3. WELLS

(Lesson 2 of 4 Lessons)

Write the answers to these questions in your notebook. The question numbering continues from Lesson 1.

11. What could happen if the check valve on a well pump station fails?
12. What is the relationship between system pressure and the flow delivered to the system by a pump?
13. What problems may be caused by sand entering a distribution system?
14. What items would you include in your well maintenance program?
15. What procedures are available for cleaning a well screen?
16. What problem might cause a change in the biological quality of well water and how would you correct the problem?