SOUTH CAROLINA IRRIGATION GUIDE
CHAPTER 6. IRRIGATION SYSTEM COMPONENTS

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SOUTH CAROLINA IRRIGATION GUIDE

CHAPTER 6. IRRIGATION SYSTEM COMPONENTS

GENERAL

In order to have an irrigation system operate as designed and function effectively, consideration of many irrigation components is necessary. This chapter will attempt to identify some of the components and briefly discuss them.

It is important to consider in the design, components that affect pressure losses and also those that affect control of operations. The characteristics and operation requirements of components may vary depending on the designs of different manufacturers. It is very important that the designer has the necessary data for all system components utilized in an irrigation system. This information needs to be secured from literature available from the manufacturer. Each designer should collect this information for all irrigation system components utilized in his area. Additional data on components is also available from technical manuals, publications on irrigation, and from National Engineering Handbook, Section 15 - Irrigation. Conveyance components for surface systems are discussed in NEH, Section 15.

The SCS Technical Guide provides minimum standards and specifications for many of the components to be discussed in this chapter.

PUMPING PLANT

SELECTION OF THE PUMPING PLANT

General

The pumping plant selected must be capable of delivering the required capacity at the designed operating pressure. Economy of operation is also a primary consideration. More detailed discussion of pumping plants is contained discussion of pumping plants is contained in Chapter 8 of the SCS National Engineering Handbook, Section 15 - Irrigation. It may be necessary to contact manufacturer's representatives to assure that the pumping plant selected can perform in accordance with the system requirements.

The function of an irrigation system pumping plant is to perform the work of moving water at the rate needed and at the pressure required to meet the requirements of the irrigation system. A pump operates best at the specific head and at the specific pump speed for which it was designed. The operating conditions should therefore be determined as accurately as possible. If there is a variation in operating head, both the maximum and the minimum should be determined and furnished to the manufacturer to permit selection of the most satisfactory pump. With the use of accurate data, the system planner can make proper selection of pumping equipment and assure the user a satisfactory performance of his system.

Pumps

Centrifugal, turbine, and propeller pumps are commonly used for irrigation pumping. Each type of pump is adapted to a certain set of conditions under which it will give efficient service.

Centrifugal Pumps

Centrifugal pumps are built in two types--the horizontal centrifugal and the vertical centrifugal. The horizontal type has a vertical impeller connected to a horizontal shaft. The vertical centrifugal pump has a horizontal impeller connected to a vertical shaft.

Both types of centrifugal pumps draw water into their impellers, so they must be set only a relatively few feet above the water surface. In this respect the vertical type has an advantage in that it can be lowered to the depth required to pump water and the vertical shaft extended to the surface where power is applied. The centrifugal pump is limited to pumping from reservoirs, lakes, streams, and shallow wells where the total suction lift is not more than approximately 20 feet.

The horizontal centrifugal (Figure 6-1) is the one most commonly used in irrigation. It costs less, is easier to install, and is more accessible for inspection and maintenance; however, it requires more space than the vertical type. To keep the suction lift within operating limits, the horizontal type can be installed in a pit, but it usually is not feasible to construct watertight pits more than about 10 to 15 feet deep. Electrically driven pumps are best for use in pits because they require the least cross-sectional area.

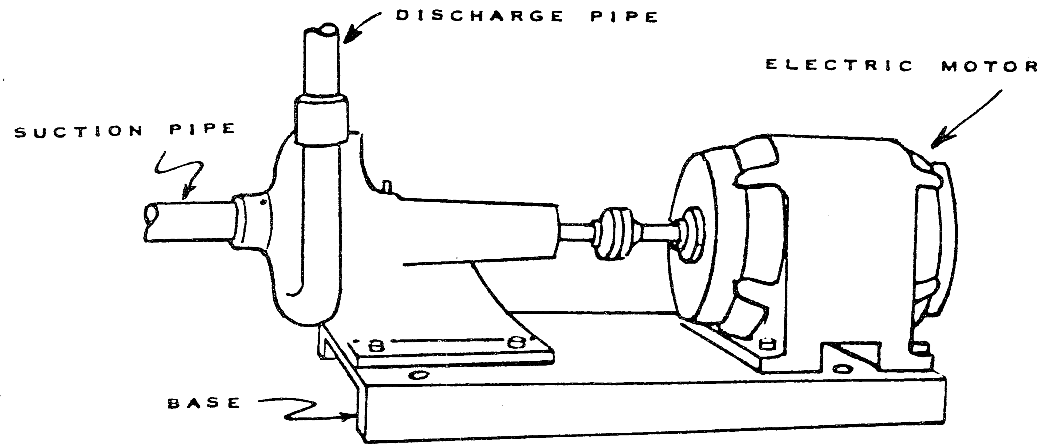
The vertical centrifugal pump may be submerged or exposed. The exposed pump is set in a watertight sump at an elevation that will accommodate the suction lift. The submerged pump is set so the impeller and suction entrance are under water at all times. Thus, it does not require priming, but maintenance costs may be high as it is not possible to give the shaft bearings the best attention. Pumps of this kind usually are restricted to pumping heads of about 50 feet.

Turbine Pumps

The deep-well turbine pump is adapted for use in cased wells or where the water surface is below the practical limits of a centrifugal pump.

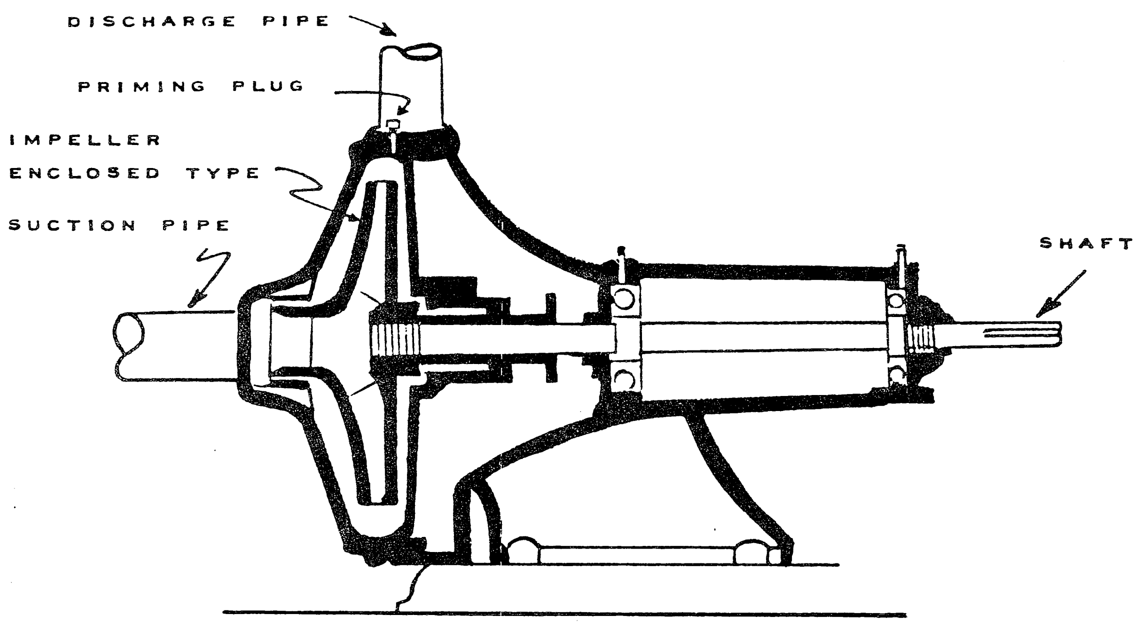
To insure the proper selection of a turbine pump the following must be known:

1. Depth of well
2. Inside diameter of casing
3. Depth of static water level
4. Drawdown/yield relationship curve
5. Depth of screen section
6. Pump capacity requirements



DIRECT CONNECTED HORIZONTAL CENTRIFUGAL PUMP

INTERNAL COMBUSTION OR ELECTRIC MOTOR MAY BE USED



CROSS SECTION OF MODERN HORIZONTAL CENTRIFUGAL PUMP

SINGLE SUCTION ENCLOSED IMPELLER

Figure 6-1. Horizontal Centrifugal Pump

All this is essential in selecting a pump that will fit inside the well, deliver the required amount of water at the desired pressure, and to assure that the bowls are submerged during operation.

Turbine pumps are equipped with impellers that are fitted inside a bowl-appearing case. Each of these units is known as a stage. Stages are added to develop additional head. You can determine the number of stages needed for a pump installation by the amount of water required and the pressure at which it is to be delivered.

Turbine pumps may be either oil-lubricated or water-lubricated. The oil-lubricated pump has an enclosed shaft that oil drips into, thus lubricating the bearings. The water-lubricated pump has an open shaft. The bearings are lubricated by the pumped water. If there is any fine sand being pumped, select the oil-lubricated pump because it will keep the sand out of the bearings. If the water is for domestic use, it must be free of oil. So you should use the water-lubricated pump.

Turbine pumps are available with either semi-open or enclosed impellers. The semi-open impeller will tolerate more sand than the enclosed impeller and it can be adjusted. The enclosed impeller claims to retain high efficiency without adjustment. Figure 6-2 shows a typical deep-well turbine pump.

The submersible pump is simply a turbine pump close-coupled to a submersible electric motor attached to the lower side of the turbine. Both pump and motor are suspended in the water, thereby eliminating the long-line shaft and bearing retainers that are normally required for a conventional deep-well turbine pump. Operating characteristics are the same as for deep-well turbine pumps. Figure 6-3 shows a typical submersible pump.

Propeller Pumps

Propeller pumps are chiefly used for low-lift, high-gallonage conditions. There are two types of propeller pumps, the axial-flow or screw type, and the mixed-flow. The major difference between the axial-flow and the mixed-flow propeller pumps is in the type of impeller (Figure 6-4).

The principal parts of a propeller pump are similar to the deep-well turbine pump in that they have a head, an impeller, and a discharge column. A shaft extends from the head down the center of the column to drive the impeller. Some manufacturers design their pumps for multi-stage operation by adding additional impellers where requirements demand higher heads than obtainable with single-stage pumps.

Where propeller pumps are adapted, they have the advantage of low first cost and the capacity to deliver more water than the centrifugal pump for a given size impeller. Also, for a given change in pumping lift, the propeller pump will provide a more nearly constant flow than a centrifugal pump. Their disadvantage is that they are limited to pumping against low heads.

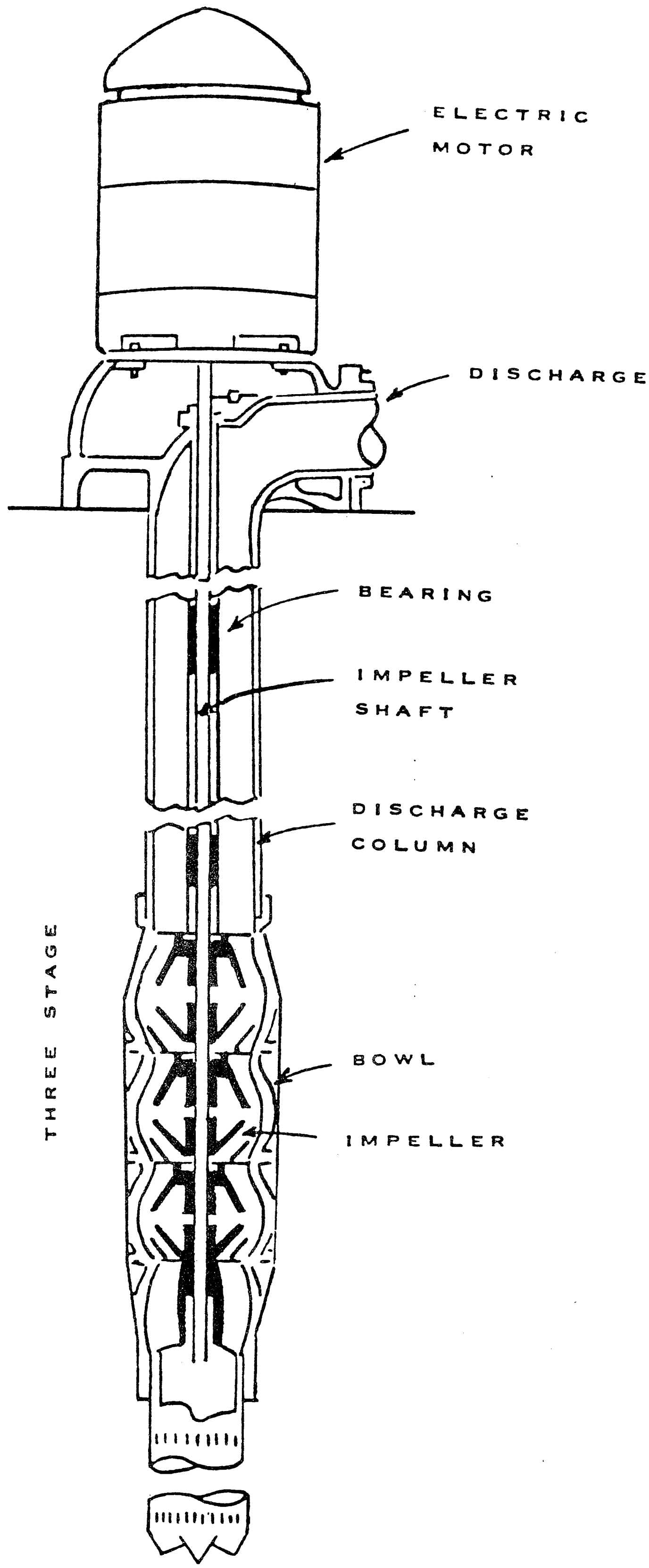


Figure 6-2. Deep-well Turbine Pump

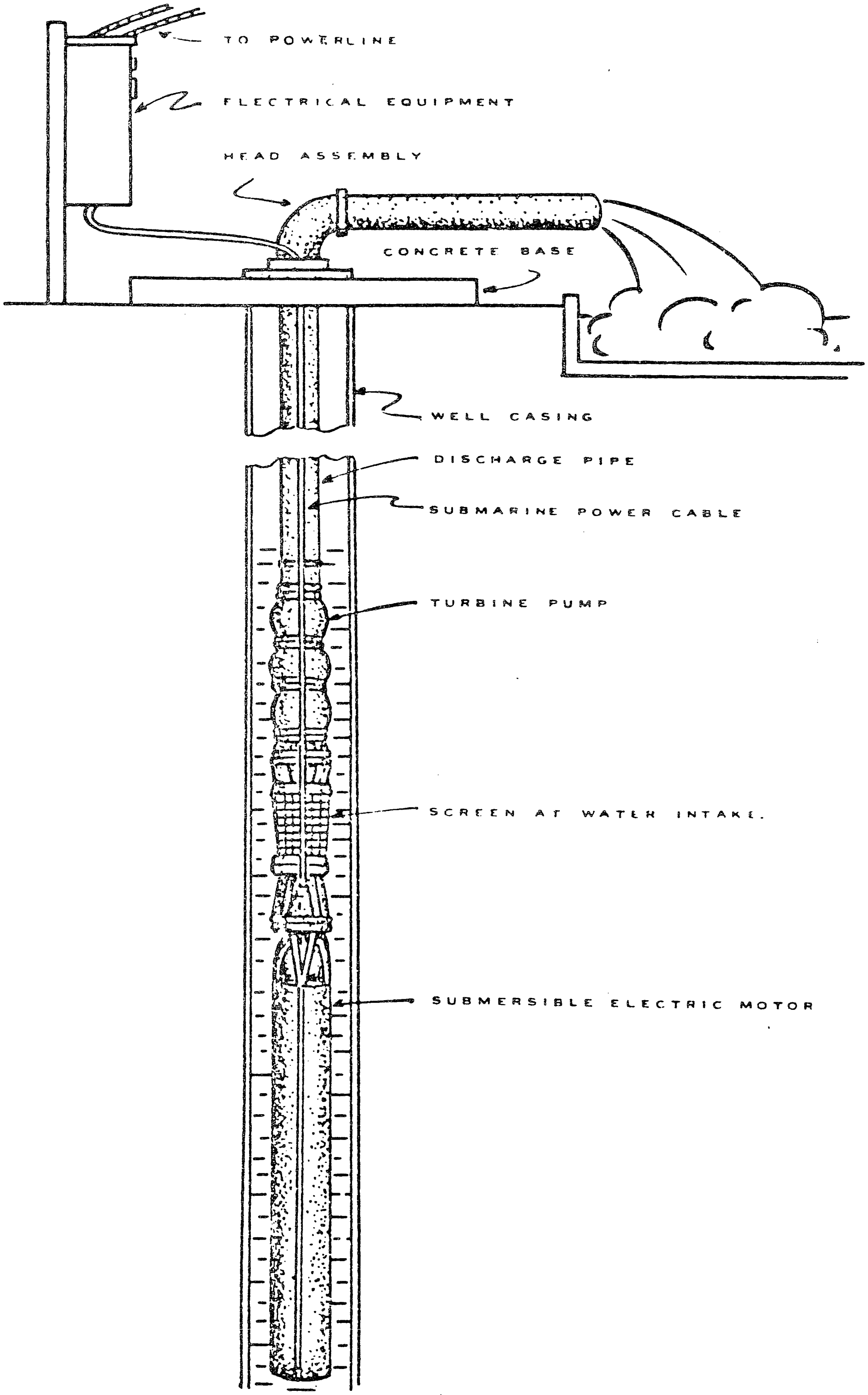


Figure 6-3. Submersible Pump

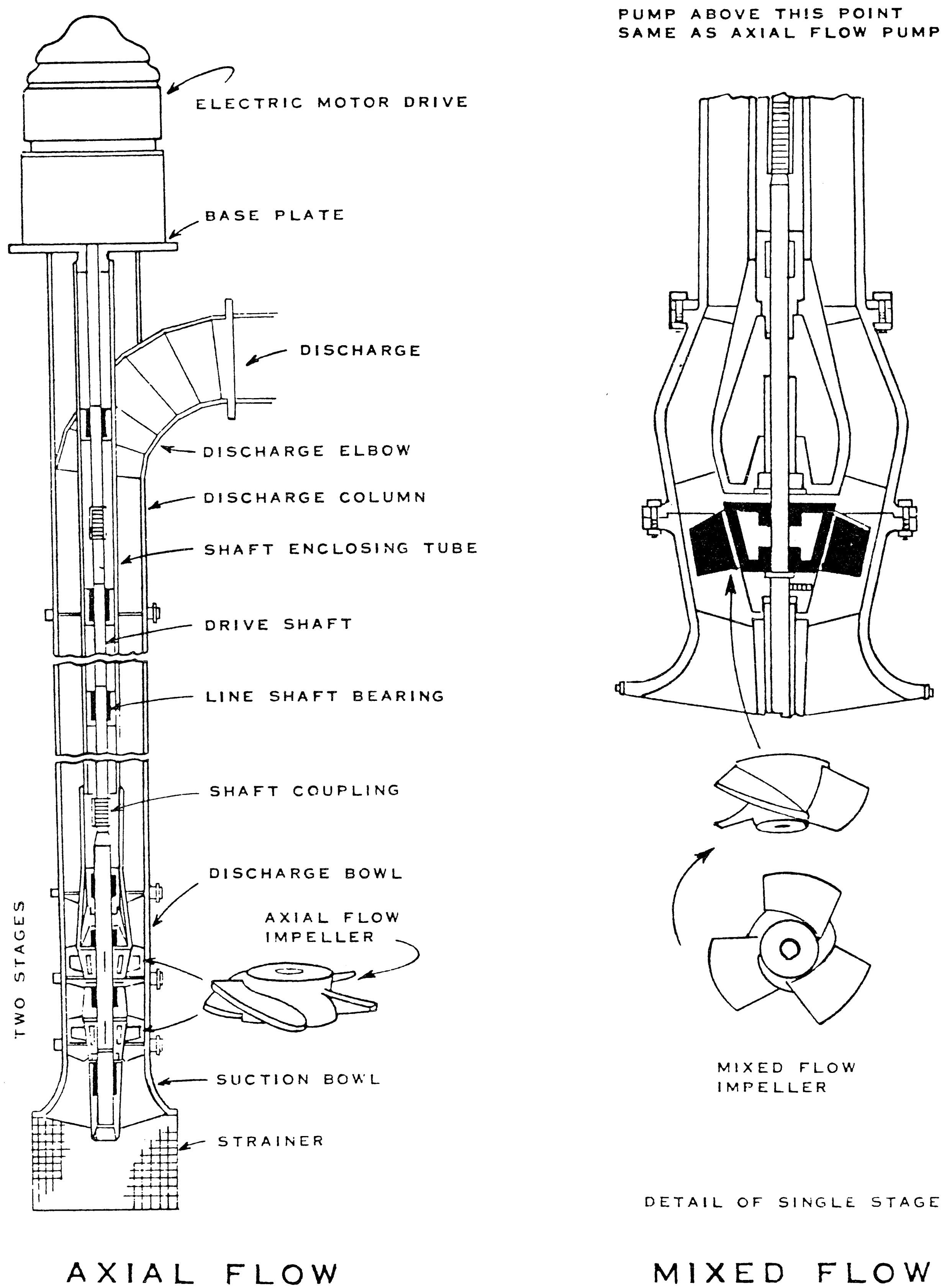


Figure 6-4. Propeller Pumps

Axial-Flow Pumps

The axial-flow single stage propeller pumps are limited to pumping against heads of around 10 feet. By adding additional stages, heads of 30 to 40 feet are obtainable. These pumps are available in sizes ranging from 8 to 48 inches. The impeller has several blades like a boat propeller. The blades are set on the shaft at angles determined according to the head and speed. Some manufacturers have several propellers for the same size of pump, thereby providing for different capacities and heads. The water is moved up by the lift of the propeller blades and the direction of flow does not change as in a centrifugal pump. A spiral motion of the water results from the screw action, but may be corrected by diffusion vanes.

Mixed-Flow Pumps

The mixed-flow propeller pump is designed especially for large capacities with moderate heads. The smaller size single-stage pump will operate efficiently at low heads of from 6 to 26 feet. The multiple stage and large size pumps will handle heads up to approximately 125 feet. They are generally built in sizes ranging from 10 to 30 inches. The mixed-flow pump uses an open vane curved blade impeller which combines the screw and centrifugal principles in building up the pressure head. They have a capacity range of from 1,000 gpm to approximately 50,000 gpm depending on size, stages, and heads. The mixed-flow pump operates more efficiently against higher heads than the axial-flow propeller pump.

Table 6-1 lists the advantages and disadvantages of commonly used irrigation pumps.

Pump Characteristic Curves

The importance of pumping efficiency cannot be over emphasized. Anyone buying a pump should insist on seeing the pump curves before making a decision.

There are four different characteristic curves that are most commonly provided by the manufacturer. Some manufacturers use tables, but the most common approach is to use graphs. The four types of curves are illustrated in Figure 6-5.

Total Dynamic Head Versus Discharge

This curve is often referred to as the TDH-Q curve and relates the head produced by the pump as a function of the discharge. Generally these curves will dip downward to the right although there are some pumps which will have multiple humps. The most common curves for irrigation pumps have a shape similar to the one in Figure 6-5.

The curve usually shows the head for only one stage for multi-stage pumps. It is usually necessary to use more than one stage to create the required pumping head with one stage discharging directly into another. The head produced by such a pump is directly proportional to the number of stages; that is, for a given capacity, a two-stage pump will produce twice the head of a single-stage pump, etc.

Table 6-1 Advantages and Disadvantages of Commonly Used Irrigation Pumps

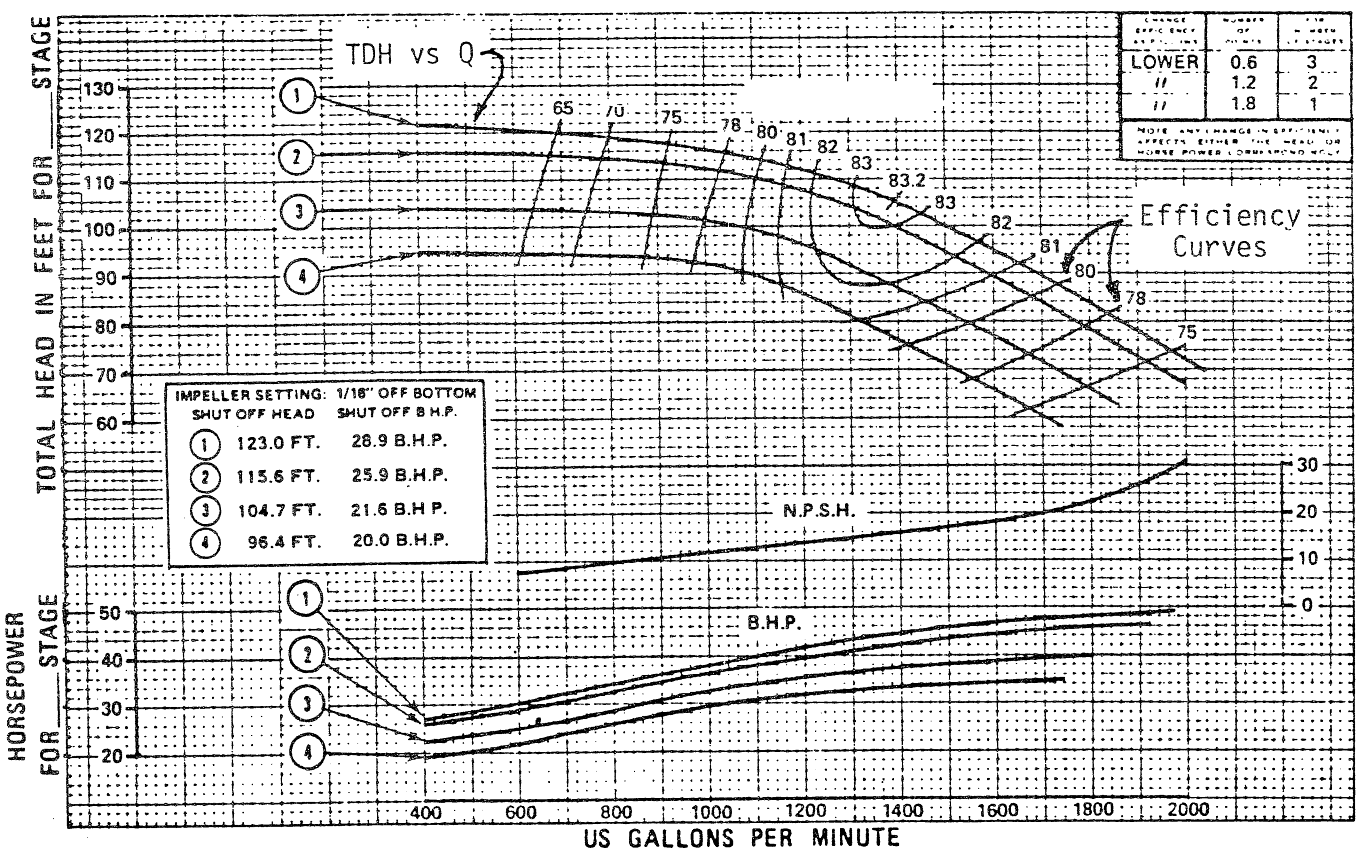
HORIZONTAL CENTRIFUGAL PUMPS	
Advantages	**Disadvantages**
High efficiency is obtainable.	Suction lift is limited, should be within 20 feet of water surface.
Efficiency remains high over a range of operating conditions.	Requires priming.
Adaptable to a range of operating conditions.	Loss of prime can damage pump.
Simple and economical.	May overload if head is decreased.
Easy to install.	Available head per stage is limited.
Does not overload with increased head.	
Produces a smooth even flow.	

VERTICAL CENTRIFUGAL PUMPS	
Advantages	**Disadvantages**
May be exposed or submerged	Maintenance costs may be high to the shaft and bearings.
Submerged pump does not require priming.	Usually restricted to pumping heads of no more than 50 feet.
	May overload if head is decreased.
	More expensive than horizontal centrifugal.

TURBINE PUMPS	
Advantages	**Disadvantages**
Adapted for use in wells.	Higher initial cost than centrifugal.
Adapted for use where water surface fluctuates.	Requires closer setting than centrifugal pumps.
Can be adapted for high heads and large discharges.	Efficient over narrower range of operating conditions than centrifugal pumps.
Small chance of losing prime.	Not adaptable to change in speed.
	Requires additional stages for larger heads.
	Difficult to install and repair.

PROPELLER PUMPS	
Advantages	**Disadvantages**
Simple construction.	Not suitable for suction lift.
Adaptable to high flow against low heads (0-25 feet for axial-flow pump) (6-45 feet for mixed-flow pump)	Requires proper clearances between walls and bottom of pump.
Efficient at variable speeds.	
Can pump some sand with water.	
Needs no priming.	

Figure 6-5. Typical Pump Performance Curve



14LD Curve No. 4805999 Impeller No. 2634705 1760 RPM

If a pump is operated against a closed valve, the head generated is referred to as the shut-off head. Shut-off head is shown in Figure 6-5. Note that the efficiency of the pump at this point is zero because the pump still requires energy to drive it. For turbine or centrifugal pumps it is necessary to know the shut-off head. The pipe on the discharge side must be capable of withstanding the shut-off head in case a valve is accidently closed on the discharge side.

For a turbine pump the manufacturer's reported efficiency is for a specific number of stages. If, for a specific application, the number of stages differs, then it is necessary to adjust the reported efficiencies upward or downward depending on the number of stages. Figure 6-5 indicates that efficiency values as graphed must be lowered 1.8 percentage points for only a single stage pump, lowered 1.2 percentage points for a two-stage pump, lowered 0.6 percentage point for a three-stage pump, and would remain unchanged for more than three stages.

Efficiency Versus Discharge

The efficiency discharge relationship is drawn as a series of envelope curves upon the TDH-Q curve in Figure 6-5. There is generally only one peak efficiency which is related to a specific discharge. If the pump can be operated at this discharge then for a given amount of energy input to the pump, the output work will be maximized.

Efficiencies vary between types of pumps, manufacturers and models. Generally, the larger pumps have higher efficiencies. The efficiency also is related to types of materials used in construction, the finish on the castings or machining, and the type and number of bearings used. For example, enameled impellers, which are smoother than bronze or steel, will result in a higher efficiency.

Efficiency is defined as the output work divided by the input work. See Chapter 8 for discussions on pumping plant efficiency.

Input Power Versus Discharge

The input power if referred to as the brake horsepower required to drive the pump. The curve is commonly called bhp-Q curve. It should be noted that even at zero discharge when the pump is operating against the shut-off head, an input of energy is needed.

The shape of the bhp-Q curve can take several different forms. The most common form for irrigation pumps is similar to the curve of Figure 6-5. In other instances the bhp-Q curve will have the highest horsepower demand at the lowest discharge rate and the required input power will continue to decline as Q increases. The shape of the bhp-Q curve is a function of the TDH-Q and Eff-Q curves.

Net Positive Suction Head Versus Discharge

The fourth characteristic curve is the net positive suction head required, NPSHR, versus discharge relation. The NPSHR is the amount of energy required to move the water into the eye of the impeller and is a function of the pump design. This characteristic also varies for different types of pumps, manufacturers and models. Its value is determined by the manufacturer from laboratory tests. The NPSHR is a function of pump speed, impeller shape, liquid properties, and the discharge rate. If sufficient energy is not present in the liquid on the intake side of the pump to move the fluid into the eye of the impeller, then the liquid will vaporize and pump cavitation will occur.

Theoretically, if a pump could be designed to produce a perfect vacuum at its center and it was being operated at sea level, the atmospheric pressure of about 14.7 psi acting downward on the surface would force water up the suction line to the pump a distance of 34 feet (14.7 psi x 2.31 ft/psi). In practice this is impossible first because a perfect vaccum cannot be created at the center of the impeller and second because there are losses due to friction created by the flow through the suction line and losses due to turbulence at the entrance to the suction line and at the entrance to the impeller.

To assure that the required energy is available, an analysis must be made to determine the net positive suction head available, NPSHA. The available head is a function of the system in which the system operates and can be calculated for all installations. If the NPSHA does not exceed the NPSHR then the pump will cavitate. The equation for computing NPSHA is as follows:

$$NPSHA = 144 \frac{Pa - Pv}{w} - h_f + z$$

where Pa = pressure, psia, on a free water surface, atmospheric

Pv = vapor pressure, psia, of the water at its pumping temperature

hf = friction loss in the suction line, ft of water

z = elevation difference, ft (suction lift) between pump center line and water surface. If the suction water surface is below the pump centerline, z is negative.

w = unit weight of water, lb/ft3

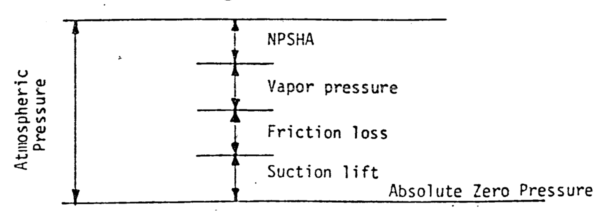


Figure 6-6 Schematic for NPSHA Versus Atmospheric Pressure, Suction Lift, Friction and Vapor Pressure

A person should keep in mind that there are many pump manufacturers and many pump models. If the first pump investigated does not fit the needs, then the designer should investigate other pumps. There should be pumps available to meet the particular situation. Also, do not expect a pump to maintain its peak efficiency over the years. Select a pump capable of filling the demands at a little less than its peak design efficiency.

Power Units

The power required to pump depends on (1) the quantity of water, (2) the total head or pressure against which it is pumped, and (3) the efficiency of the pump. See Chapter 8 for computing horsepower requirements of power units.

Many types of power units can be used for operating pumps. An old automobile engine belted to the pump may do the job at low initial cost, but operating cost is likely to be high and service unreliable. Money is often wasted by investing in old inefficient engines not suited to the job.

It must be remembered that a farm tractor used to furnish power will not be available for other farming operations and may require modification of the cooling system. Farm tractors are not built for continuous operation such as is needed to power an irrigation pump. If a tractor is used, it should be large enough so that it is not necessary to operate the engine at full throttle. Also, the motor should be equipped with safety devices.

Where available at reasonable rates, electricity is usually the most satisfactory source of power for irrigation pumping. Electric motors offer high efficiency, reliability, compactness, and low maintenance cost; which makes them especially desirable for operating pumping plants.

Internal combustion engines are most widely used where electric power is not available or where it is too expensive. These include gasoline and diesel engines. The former type may be adapted to burn natural gas, kerosene, or distillages. Proper cooling is very important when internal combustion engines are used for irrigation pumping.

Gasoline engines cost less initially than diesel engines and are better adapted to smaller loads and shorter operating hours. Diesel engines are best for heavy duty and generally give longer service. The choice of an internal combustion engine for a given job depends on the size of load, length of operating periods, and the required life of the engine.

Table 6-2 lists some of the advantages and disadvantages of various types of power units.

Table 6-2 Advantages and Disadvantages of Various Power Units

DIESEL

Advantages	Disadvantages
Variable speed allows variation of pumping rate and horsepower.	Service may be a problem.
Moderate depreciation rate.	High initial cost.
Can be moved from site to site.	
Fuel costs are usually lower than gasoline or LP.	

GASOLINE

Advantages	Disadvantages
Variable speed allows variation of pumping rate and horsepower.	High depreciation rate.
Parts and service are usually available locally on short notice.	High maintenance cost.
Can be moved from site to site.	Fuel costs may be high.
	Fuel pilferage may be a problem.

NATURAL GAS

Advantages	Disadvantages
Variable speed allows variation of pumping rate and horsepower.	Requires natural gas pipeline.
Moderate depreciation rate.	Not easily moved from site to site.
Low energy costs if gas is available at favorable rates.	

LP GAS

Advantages	Disadvantages
Variable speed allows variation of pumping rate and horsepower.	Special fuel storage must be provided.
Parts and service are usually available locally on short notice.	Fuel costs may be high.
Moderate depreciation rate.	

ELECTRIC MOTOR

Advantages	Disadvantages
Long life, low depreciation.	Constant speed, pumping rate can be reduced only by increasing head on system.
Low maintenance.	Requires three-phase power or phase converter.
Easily adapted to automatic controls.	Not easily moved from site to site because of the necessary electric service.
High operating efficiency.	Electrical storms may disrupt service, sometimes many miles from the site.
Easy to operate.	
Requires no fuel storage.	

Irrigation pumping plants often operate for long periods without attention. For this reason, power units should be equipped with safety devices to shut them off when changes in operating conditions occur that might cause damage. Such changes include when: (1) oil pressure drops, (2) coolant temperature becomes excessive, (3) pump loses its prime, (4) the discharge pressure head drops, or (5) oil level drops.

Pumping Plant Head

For proper pump and power unit selection the total dynamic head (TDH) must be computed. A knowledge of certain terms is necessary to compute the TDH and in discussing pumping plant head requirements.

Pressure-Pressures are usually measured with a gauge. When water in a container is at rest, the pressure at any point consists of the weight of water above the point (i.e., water weighs 62.4 pounds per cubic foot or 0.433 pounds per square inch (psi). The column of water is referred to as head and is expressed in feet. Head can be converted directly to pressure in evaluating systems by multiplying head by 0.433. Conversely, pressure can be converted to head by multiplying pressure by 2.31.

Dynamic Head - An operating sprinkler system has water flowing through the pipes. Thus, the head under which the system is operating is dynamic. Dynamic head is made up of several components as follows:

1. Static Head - Static head is a vertical distance. It is the distance through which the pump must raise the water.

   Where the water source is below the pump centerline, the distance from the water surface to the pump centerline is called the static suction lift or head. For centrifugal pumps, friction losses in the suction pipe and fittings should be included.

   The elevation difference between the centerline of the pump and the point of discharge is referred to as the static discharge head.

   Total static head is the summation of the static suction lift or head and the static discharge head.

2. Pressure Head - Sprinkler operating pressure converted to head is termed pressure head. The sprinkler converts pressure head to velocity head which carries the water out into its trajectory.

3. Friction Head - The friction caused by water flowing through a pipe decreases pressure in the pipe. The pump must overcome this loss which is termed friction head which is a function of size, type, condition and length of the pipe and water velocity in the pipe. Similar losses are incurred by water flowing through pipe fittings. Losses through specific fittings can be stated as an equivalent length of pipe of the same diameter and can be taken from Appendix C.

Losses in fittings and valves can also be computed by the formula:

$$h_f = \frac{Kv^2}{2g}$$

Where: h_f = friction head loss in feet

K = resistance coefficient for the fitting or valve

$\frac{v^2}{2g}$ = velocity head in feet for a given discharge and diameter

Values of the resistance coefficient K may be taken from Appendix C.

4. Velocity Head - Flowing water represents energy and work must be done by the pump to impart motion to the water. The resistance to movement by the water is similar to friction. Velocity head is computed by squaring the velocity and dividing by two times acceleration due to gravity or

$$H_v = \frac{v^2}{2g}$$

Velocity is measured in feet per second and can be computed from:

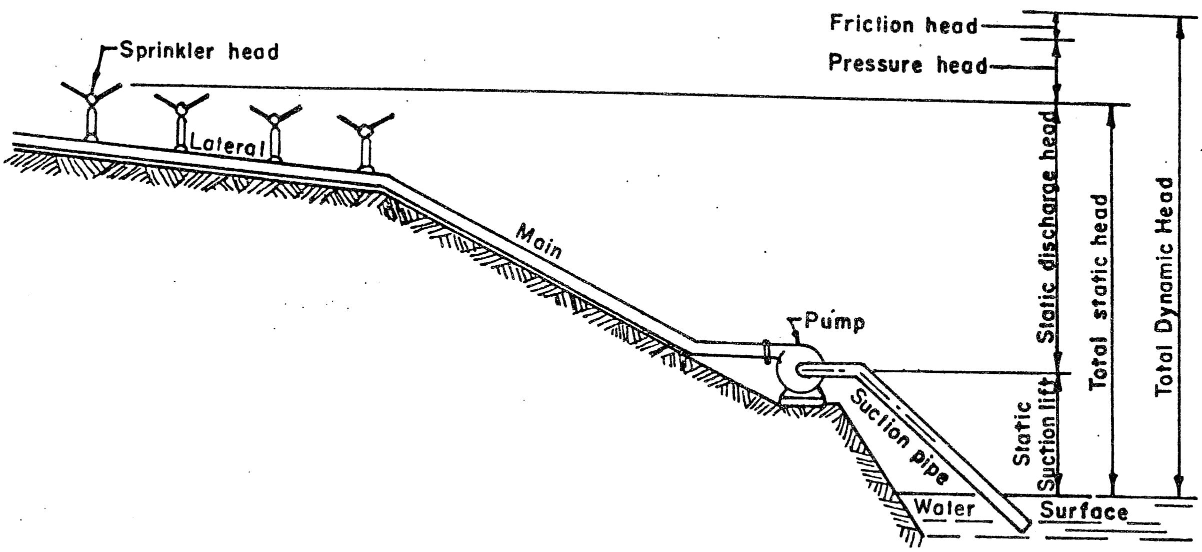
$$V = \frac{0.408 \times gpm}{D^2}$$

Where gpm is discharge in gallons per minute and D is inside diameter of the pipe. Hv values are small and usually negligible unless large volumes are pumped through small diameter pipes.

Total Dynamic (TDH) - As mentioned, this is a very important factor in selecting the pumping unit. An accurate estimate is necessary to assure a satisfactory pump performance. First calculate the components discussed in the preceding paragraphs and add them together:

Total dynamic head = total static head + pressure head + friction head

See Figure 6-7 for a sketch showing the above terms. NEH Section 15, Chapter 8, Figures 8-19, 8-20, and 8-21 give examples of computing TDH for centrifugal pumps, turbine pumps, and propeller pumps, respectively.



TDH = total static head + pressure head + friction head

Where

1. Total static head = static discharge head + static suction head or lift

   a. Static discharge head is the difference is elevation between the centerline of the pump and the elevation of the sprinkler orifice or other point of use.

   b. Static suction lift is the difference in elevation between the water surface elevation being pumped and the centerline of the pump.

2. Pressure head is the average operating pressure for the lateral.

3. Friction head is pressure loss due to friction in the main, lateral suction pipe, and fittings and valves.

Figure 6-7 Elements of A Pumping Plant and the Corresponding Elements of Total Dynamic Head Used In Calculating Pump and Power Requirements

SELECTION

When selecting the distribution pipelines, both the annual installation cost and the annual operating cost should be considered. The installation cost of smaller diameter pipelines is less, but the operating cost (pumping power cost to overcome pipeline friction) will be more than for larger diameter pipelines. The most economical size would be the one with the smallest sum of annual installation and operating costs. This requires the comparison of the sum of installation and operating costs of the various pipeline sizes being considered.

The annual installation cost is computed by multiplying the initial installed cost by the appropriate amortization factor. The amortization factor can be found from Chapter 9, Table 9-1. Use the same life expectancy and interest rate that will be used in the economic evaluation.

The annual operating cost of a pipeline essentially consists of only the pumping power fuel cost to overcome pipeline head loss (friction) since the total static head and pressure (operating) head remains constant when comparing pipeline sizes, only the friction and velocity head change. The annual fuel cost can be found by using the following formulas.

$$\text{Fuel cost per yr} = \frac{\text{bhp} \times \text{hr/yr} \times \text{cost/unit of fuel}}{\text{bhp-hr/unit of fuel } \underline{1}/}$$

Where $$\text{bhp} = \frac{\text{TDH} \times \text{Q}}{3690 \times \text{pump eff.} \times \text{drive eff.}}$$

bhp = brake (dynamometer) horsepower

TDH = total dynamic head, feet

Q = capacity in gpm

1/ bhp-hr/unit of fuel is shown in Chapter 8, Table 8-1.

The annual operating cost should be computed for each pipeline size evaluated in order to determine which has the lowest annual operating cost. Chapter 8 contains an example showing the calculations for determining pipeline operating costs.

DESIGN CONSIDERATIONS

Water Hammer

Possibly the most detrimental factor contributing to pipe failures in distribution pipelines is water hammer or surge. What causes "water hammer?" In a pipe containing a column of moving liquid, energy is stored in the fluid due to its mass and velocity. When a value is quickly closed, the velocity is suddenly stopped. Since liquids are nearly incompressible, this energy cannot be absorbed, and the momentum of the fluid causes a shock called "water hammer." This may represent excessively high momentary pressures. The shutting down of a pump and then restarting it before the system comes to rest is also a cause of excessive surge pressure. Four factors that greatly influence the magnitude of water hammer (surge pressure) are:

1. Length of pipeline (the longer the line, the greater the shock)
2. Velocity
3. Closing time of valves
4. Diameter of pipe

Minimum valve closing times, pressure relief valves, and thrust blocks are utilized to help minimized and/or control surge pressures. Since velocity is the primary factor contributing to excessive surge pressure, the velocity of pipelines generally should be limited to five feet per second. Also, irrigators should be advised against quick closing of valves and restarting pumps before the system returns to static rest. Another factor that influences surge is the instantaneous stopping of electric motors whereby a backlash condition is created and higher than normal pressures occur.

When pipeline working pressures and velocities exceed the limits generally recommended in the SCS technical guide standards, special considerations should be given to protect the pipeline for flow conditions and the total pressure generated during a surge condition. Measures utilized may include pressure-relief valves with control of valve opening and closure times. The total pressure subjected to the mainline pipe during a surge condition is equal to:

$$P\ Total = Po + Ps$$

where P Total = total system pressure during a surge (psi)

Po = the operating pressure at the time of the surge(psi)

Ps = the surge pressure: an increase in pressure over and above the existing operating pressure at the time of the surge(psi)

The approximate magnitude of the surge pressure (Ps) for gradual closure conditions may be calculated by the following formula (reference - Rainbird Design Guide For Turf and Ornamental Irrigation Systems 1976, p. 54)

$$Ps = \frac{V \times L \times .07}{t}$$

where V = original velocity of flow at time of surge (ft/sec)

L = the length of the straight mainline pipe which extends between the water source and the point in the mainline (valve or pump location) where the flow was stopped (feet).

t = the approximate time required to stop the flow of water (i.e. time to close the valve - seconds)

Closure is considered instantaneous whenever t is less than 2 L/U where U is the velocity (fps) of a pressure wave in the pipe as follows:

$$U = (E/R)^{0.5} \quad (1/(1+ED/EpT))^{0.5}$$ [1]

where E = modulus of elasticity of water, 43.2×10^{6} psf

R = density of water, 1.94 lb sec^{2} per ft^{4}

D = diameter of pipe, ft

Ep = modulus of elasticity of pipe material, 57.6×10^{6} psf for Type 1, Grade 1 or 2 PVC pipe

T = thickness of pipe wall, ft

For instantaneous closure the maximum surge pressure may be calculated as follows:

$$Ps = RUV$$ [1]

where Ps, R, U, and V are as defined above.

[1] Reference - Standard Hbk. for Civil Eng. by F.S. Merritt McGraw-Hill, Inc. Page 21-33.

If it is not practical to keep the total pressure during a surge equal to or less than the working pressure rating of the pipe, the total system pressure during the surge should be less than 75 percent of the burst pressure rating of plastic pipe. The burst pressure rating of plastic (PVC) pipe is approximately 3.0 times the nominal working pressure rating (PVC 1120, 1220, & 2120, see ASTM D 2241)

Safety Devices

Figure 6-8 illustrates many of the devices that enhance the water delivery process and protect the pipeline investment. The relative location of each of these devices is important and alteration of their location should be reviewed carefully.

Manual Valves

Manual valves are principally used to isolate sections of a system for irrigation, for purpose of repair and for manual drain valves. The valves should be gate valves rather than globe valves to keep friction loss to a minimum. Generally, cross handles are preferred as the access to gate valves is through valve sleeves. A sprinkler control valve key is used to open them. Non-rising stems are often required.

Occasionally a gate valve is used as a flow control, but its use is limited to hydraulically simple systems.

Check Valves

Check valves are used to limit water flow to one direction. Check valves are utilized at the pump discharge to prevent the backflow water into the well and are required to prevent chemicals from flowing back into the ground water formation when chemical injection is used.

Check valves can be of the swing-check variety (which depends on its own weight to close against a backflow), spring loaded variety (which is closed against a backflow by a retracting spring), or the float variety (in which a float is pushed out of the way by regular water flow but pressed into the upstream opening by backflow).

Pressure Reducing Valve

The pressure reducing valve provides control over the downstream flow rate and/or pressure. These control valves are often used to prevent rapid buildup of line pressures during pump start-up.

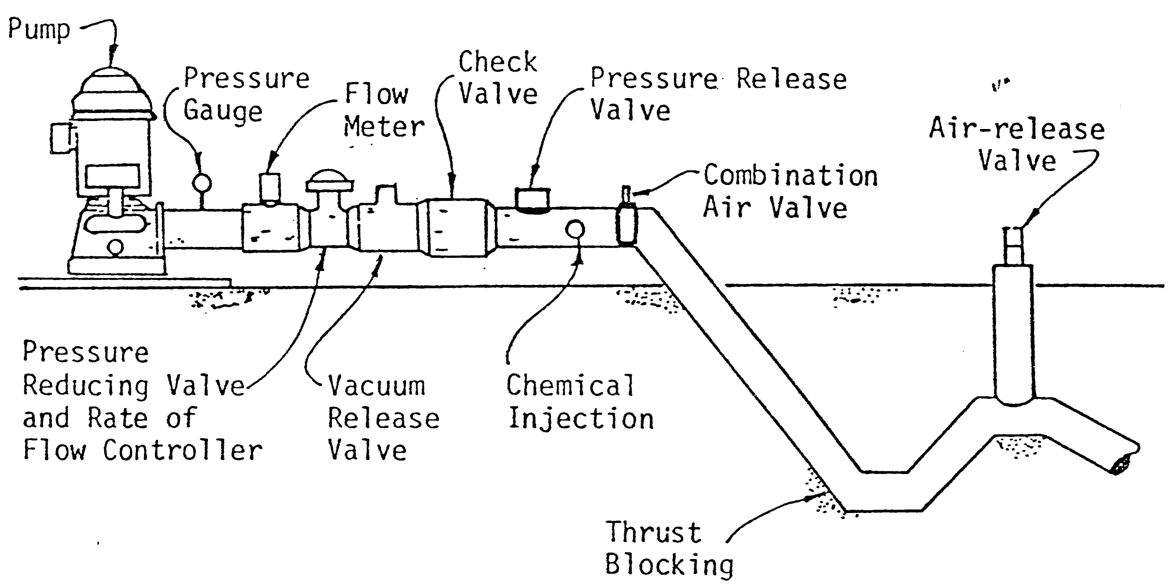


Figure 6-8. Illustration of Valve Location

Anti-Syphon or Backflow Prevention Units

South Carolina passed legislation June 6, 1986 (SC Code of Laws, Section 46-1-140) requiring installation of an anti-syphon or backflow prevention device on any irrigation system designed or used for the application of fertilizers, pesticides or other chemicals. Effective June 6, 1988, all irrigation systems must be in compliance with this new law. An anti-syphon device could consist of the following components:

(a) Functional Check Valve. Such valve shall be equipped with replaceable disc and shall be serviceable with conventional tools. This valve shall be located in the irrigation supply line between the irrigation pump and the point injection of fertilizer, pesticide or chemical. This valve, when installed, shall be on a horizontal plane and level.

(b) Low Pressure Drain. Such drain shall be at least three-fourths inch in diameter. It shall be located on the bottom of the horizontal pipe between the functional check valve and the irrigation pump. It must be level and must not extend beyond the inside surface of the bottom of the pipe. The outside opening of the drain shall be at least two (2) inches above grade.

(c) Vacuum Relief Valve. The low pressure drain shall include a vacuum relief valve as a component part, or shall be complemented with a separate vacuum relief valve. The separate vacuum relief valve shall be at least three fourths inch in diameter and shall be located on the top of the same horizontal pipe section in which the low-pressure drain is located.

Drain Valves

Drain valves can be either manual or automatic and are used to drain the water from pipe lines. Manual drain valves are usually used on distribution lines which are continually under pressure. When the system is winterized, the valve is opened and the water is drained out of the pipes. Often pressurized air is also introduced at other points of the system to clear out any pockets of water caused by low pipe lines. Manual drain valves are normally located at lower points of the system and should be an angle valve which incorporates a flexible and replaceable seat.

Automatic drain valves are usually a spring and ball combination and are used in lateral lines which are under pressure only when the sprinklers are operating. When the water pressure in the pipe reduces, the spring is relieved of the pressure contracting it, it expands, pushing the ball off the seat to allow water to flow through it to the atmosphere.

Pressure Regulating Valves

Pressure regulating valves have an automatic internal throttling action to reduce high upstream pressures to a constant downstream pressure. Within limits, a pressure regulator can throttle a wide range of higher pressures to deliver the constant downstream pressure. There is always an inherent loss through the regulator itself due to friction, in addition to the throttling action. They cannot increase pressure. A given pressure regulator can deliver a constant downstream pressure at several flow rates. If a pressure regulator is placed upstream of a gate valve, the flow rate through the combination can be varied by opening or closing the gate valve. However, at all flow rates the maximum discharge pressure of the regulator will be the same. A pressure regulator only creates a constant, desired pressure immediately downstream of itself. Further downstream the pressure will be different.

Pressure-Release Valves

Pressure-release valves are attached to a pipeline and exhaust water from the pipeline into the atmosphere when the pressure in the pipeline exceeds a set value. They are located where high pressures will occur, such as at the bottoms of hills. They are also located immediately upstream of valves which could create sudden pressure buildups if closed quickly. Pressure relief valves do not prevent pressure fluctuations; they do prevent water pressures in the line from exceeding set valves.

Air Valves

General

There has been confusion in the industry as to the difference between an air-release valve, air-and-vacuum valve and a combination air valve. First it must be stated that these valves are for liquid systems and not for air or gas systems. To clarify the difference between these valves, the following will describe the specific purpose, function and operation of each valve.

Air-Release Valves

An air-release valve can be described as a device which will automatically release accumulated small pockets of air from high points in a system while that system is in operation and under pressure.

If we stop to consider some of the problems associated with air in a system, we can better understand how air-release valves can be utilized to eliminate those problems.

First of all, as a function of nature, some of the air entrained in a system will settle out of the liquid being pumped and collect at high points within that system. If no provision is made to remove this air from the high points, a small pocket of air will grow in size as additional pockets of air accumulate. This action will progressively reduce the effective area available to the flow of liquid and create a throttling effect as would a partially closed valve. The degree to which the flow is reduced and some of the ensuing problems are described in the following paragraphs.

In many instances, the liquid flow velocity will be sufficient to partially break up an enlarging pocket of air and flow a portion of it downstream to lodge at yet another high point. This ability of the flow velocity to trim back the size of an air pocket, as it grows larger, may prevent the flow rate from being drastically reduced. However, as a result of the throttling effect caused by the presence of this remaining air, the flow rate will always be less than intended and power consumption will be increased.

This type of problem is difficult to detect and if allowed to go uncorrected, constitutes a constant drain on system efficiency and will thereby increase operating costs.

In more extreme instances, it is actually possible for an enlarging pocket of air collecting at a high point or a series of high points within a system, to create a restriction to such a degree that the flow of liquid is virtually stopped or at the least greatly reduced. In a severe situation such as this, the problem is more easily identified and the installation of air release valves at high points in the system should be taken as a corrective measure to remove the restrictive pockets of air, thereby restoring system efficiency.

Of a more serious nature is the factor that sudden movements of these air pockets can result in a rapid change in the velocity of the liquid being pumped. The dyanmics involved in this change of velocity can be substantial and can lead to high pressure surges and other destructive phenomenon. As we can see, the problems associated with air in a system can range from mild but costly to severe and potentially destructive. The ideal situation is of course to anticipate those problems as outlined earlier and prevent the accumulation of air through the installation of air-release valves at all high points within a system, thereby avoiding the negative consequences described.

<u>Operation of Air-Release Valves</u>

First of all, consider the valve installed at a high point within the system, filled with liquid and under system pressure.

Now, during system operation, as small amounts of air enter the valve from the system, they will displace the liquid within the valve and lower its level relative to the float. When the liquid level has been lowered to the point where the float is no longer buoyant, the float will drop. This action opens the valve orifice and allows the air which has accumulated in the upper portion of the valve body to be released to the atmosphere. As this air is released, the liquid level within the valve once again rises, lifting the float and closing the valve orifice. This cycle automatically repeats itself as often as necessary. The ability of the valve to open and release accumulated air under pressure is achieved through the use of a leverage mechanism. When the float is no longer buoyant, this mechanism produces a greater force to open the valve than the system pressure produces against the valve orifice, which attempts to hold the valve closed. Accordingly, for a given air-release valve, the higher the system pressure, the smaller the orifice diameter must be to allow the valve to open and release accumulated air. Conversely, in the same valve, the lower the system pressure, the larger the orifice diameter that can be used to release accumulated air.

It should be noted, an air-release valve is intended to release pockets of air as they accumulate at high points during system operation. It will not provide vacuum protection nor will it vent large quantities of air quickly on pipeline fill, air-and-vacuum valves are designed and used for the purpose.

Air-release valves when needed should be installed at high points in the system where air can accumulate or on the discharge side of the pump having a suction lift, and should be as close to the pump check valve as possible.

Air-and-Vacuum Valves

An air-and-vacuum valve (also referred to as air-vacuum-release and air-vent-and-vacuum release) can be described as a float operated device, having a large discharge orifice equal in size to its inlet port, which will automatically allow a great volume of air to be exhausted from or admitted into a system as circumstances dictate.

If we consider its use on pipeline service, we would find the following conditions prevail:

Prior to filling, a pipeline is thought to be empty. But this is far from true, for in reality it is filled with air and the presence of this air must be taken into consideration when filling the pipeline. It must be exhausted in a smooth and uniform manner to prevent pressure surges and other destructive phenomenon from taking place.

In addition, air must be allowed to re-enter the pipeline in response to a negative pressure in order to prevent a potentially destructive vacuum from forming. It should also be noted that even in those instances where vacuum protection is not a primary concern, some air re-entry is still necessary to properly drain a pipeline.

To perform those functions as outlined above, air-and-vacuum valves are installed wherever there is a high point or a change in grade. They should be installed on the discharge side of pumps having a suction lift and should be as close to the check valve as possible. They should also be used on the water source side of check valves for well systems to allow for breaking vacuums at the end of pumping.

Operation of Air-and Vacuum Valves

As the line is filled, the air present in the pipeline is exhausted to the atmosphere through air vacuum valves mounted at high points in the system. After all the air has been exhausted, water from the pipeline will enter the valve, lift the float and close the valve orifice. The rate at which air is exhausted is a function of a pressure differential which develops across the valve discharge orifice. This pressure differential develops as water filling the pipeline compresses the air sufficiently to give it an escape velocity equal to that of the incoming fluid. Since the size of the valve controls the pressure differential at which the air is exhausted, valve size selection is a very important consideration.

At some time during system operation, should the interal pressure of the pipeline approach a negative valve due to column separation, draining of the pipeline, power outage, pipeline break, etc., the float will immediately drop away from the orifice, and allow a flow of air to re-enter the pipeline. This action will minimize the potential vacuum and protect the pipeline against collapse or other related damage. The size of the valve will dictate the degree to which the vacuum is minimized, therefore, valve size selection is once again a very important consideration.

The valve, having opened to admit air into the pipeline in response to a negative pressure, is now ready to exhaust air as the need arises. This cycle will automatically be repeated as often as necessary.

One additional point must be made. While the system is in operation and under pressure, small amounts of air may enter the valve from the pipeline and displace the fluid. Even though the entire valve may eventually fill with air, the air-and-vacuum valve will not open. The system pressure will continue to hold the float against the valve orifice and keep the valve closed. To reiterate, an air-and vacuum valve is intended to exhaust air during pipeline fill and to admit air during pipeline drain. It will not open and vent air as it accumulates at high points during system operation, air-release valves are designed and used for that purpose.

Combination Air Valves

As the name implies, this valve combines the operating features of an air-and vacuum valve and air-release valve.

It is utilized at high points within a system where it has been determined that the functions of air-and-vacuum and air-release valves are needed to properly vent and protect a pipeline.

The valve is available in two body styles, the single housing combination and the custom built combination.

The single housing combination air valve is utilized when compactness is preferred or when the potential for tampering exists due to accessibility of the installation. This style is most popular in the 1", 2" and 3" sizes with the 4" and 6" sizes used to a lesser degree.

The custom built combination air valve is a standard air-release valve piped with a shut off valve to a standard air-and-vacuum valve. It has greater versatility than the single housing style because many different model air-release valves with a wide range of orifice sizes can be utilized. This style is most commonly used in sizes 4" through 16".

When there is doubt as to whether an air-and-vacuum valve or a combination air valve is needed at a particular location, it is recommended that the combination air valve be selected to provide maximum protection.

Thrust Blocks

Thrust blocks are important components of irrigation water conveyance systems. They are required at abrupt changes in pipeline grade or alignment or changes in size to protect certain type pipelines from failure due to axial thrust of the pipeline. The thrust block should be designed in accordance with instructions contained in the appropriate Technical Guide for Irrigation Water Conveyance, Code 430. As a guide for horizontal thrust control, minimum thrust block thickness recommended is 1.0 feet whereas for vertical thrust control, minimum thickness recommended is .5 feet.

Accessories

Booster Pumps

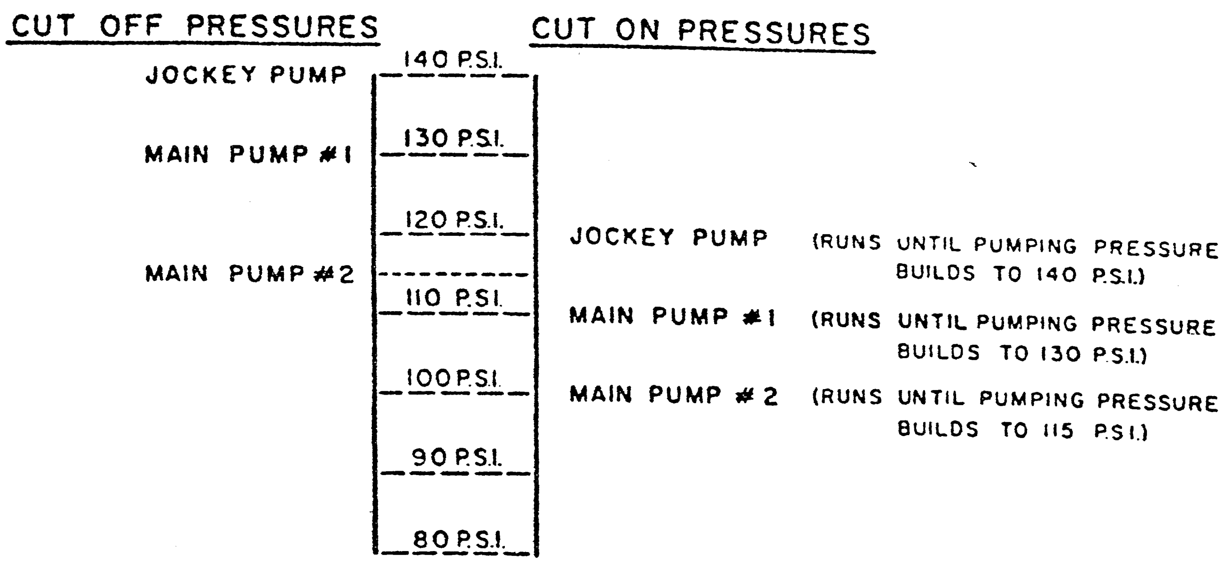
The booster pump can be used in a large irrigation system where compensations are necessary for pressure losses due to elevation. Booster pumps usually are of the centrifugal type which produce pressure by forcing movement of water. A booster does as its name implies, boosts the pressure. If the pressure at a certain point in a system is 30 psi at 20 gpm and the system requires 50 psi at 20 gpm at that point, a booster pump rated at 20 psi at 20 gpm can be installed in the line.

Pressure Tanks

Pneumatic pressure tanks are often used where a wide variance of gallonage requirements exists. The pressure tank will relieve the pump from kicking on for a short period of time when a low gallonage demand is made. The tank acts as a pressurized reservoir of water with expanding air forcing water out of the tank to fulfill low and infrequent water demands. Often times a small "jockey" pump is used to replenish the tank if low demands exist for a period longer than that for which the tank can provide.

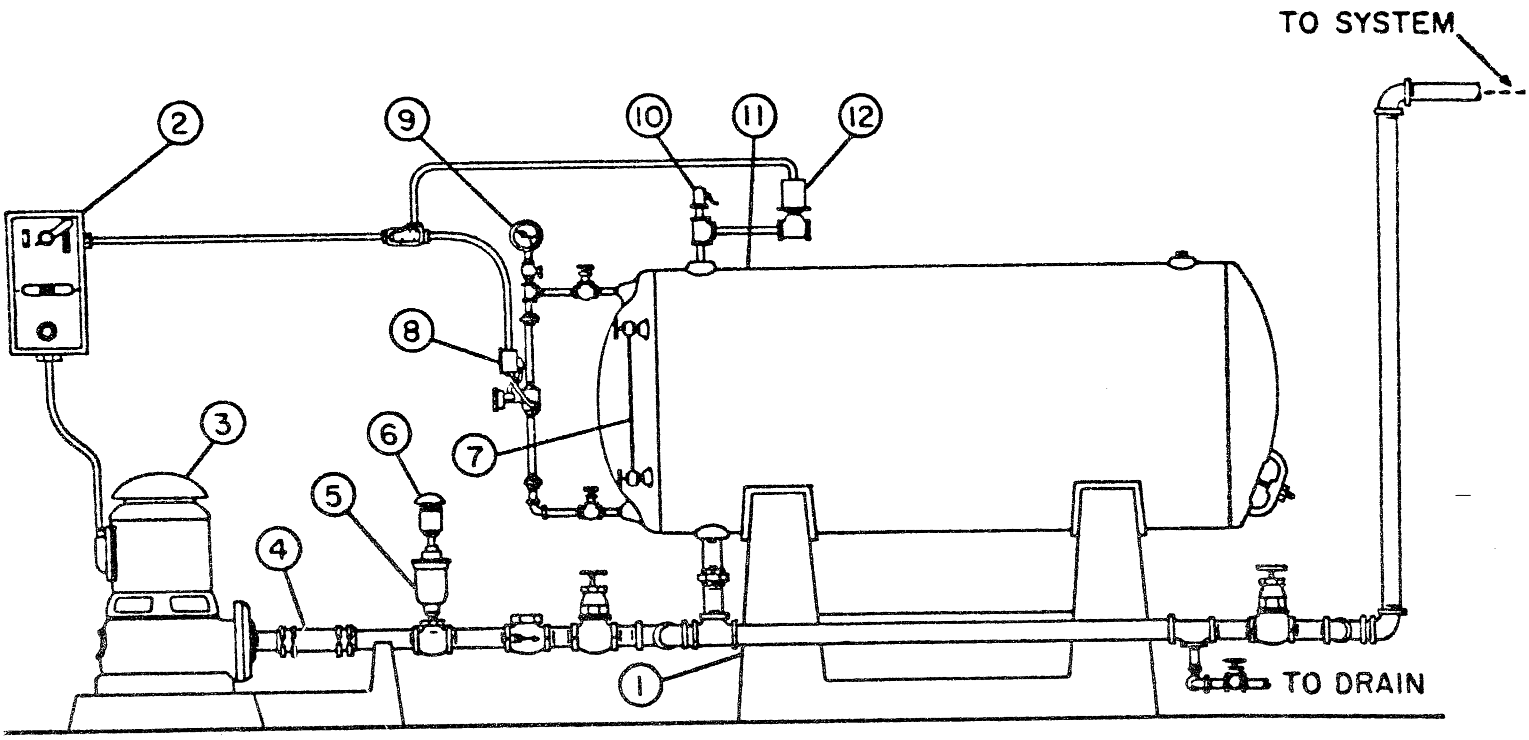
An example for the above case would be to have the "jockey" pump activate, by way of a pressure switch, at 120 psi. It would continue to run until pressure tank is replenished to 140 psi. If the demand was greater than the jockey pump, the pressure would continue to decrease until it reached the low limit of the pressure switch of the main supply pump. At that point the main pump would activate. If more than one main pump is used, they would be activated in turn as the pressure continued to drop. See the sketch on the following page.

If the pressure tank is too small for low gallonage demands, it will cause frequent and repetitive start-up of the pumps. This can also happen it the tank becomes waterlogged (the air is absorbed in the water causing a loss of the volume of air.)



An alternative for a pressure tank in a system where the demand varies widely is recirculation using a "dump" valve. Recirculation means to take the water supplied by the pump in excess of the water demanded of the system and dump it back into the supply. The dumping should be back into the reservoir as just repiping it back to the inlet can cause severe heating of the water when the demand is small, making the recirculated water volume large. A pressure relief valve is used to control the amount of water to be recirculated. Pressure tanks and the related equipment necessary for proper operation can become a maintenance headache so should be designed by an expert in the field of pumps and tanks.

Figure 6-9 is a typical system using a deep well pump with a pneumatic pressure tank. This system has an automatic air replenishing feature which can't normally be used when pumping from a reservoir using horizontal centrifugal pumps.



1—TANK SADDLES
2—COMBINATION STARTER
3—DEEP WELL PUMP
4—RUBBER HOSE CONNECTION
5—FLOAT VENT VALVE
6—AIR FILTER
7—WATER GAUGE
8—AUTOMATIC DUAL PRESSURE AND LEVEL CONTROL
9—PRESSURE GAUGE
10—PRESSURE RELIEF VALVE
11—PRESSURE TANK
12—SOLENOID VALVE

The water in the pump column (3) drains back into the well after each pumping cycle, replaced by air entering through the float vent valve (5). When the pump is started again, some of the air is forced into the tank, replenishing the air supply there. Excess air is vented to atomsphere by the float operated level control valve (8) opening the solenoid valve (12). The float in the control valve (8) will close the solenoid valve when the level is proper, readying the system for the next pumping cycle.

Figure 6-9. Typical System Using A Deep Well Pump With A Pneumatic Pressure Tank

Pressure Gauges

Pressure gauges are desirable to have in a system so that the operator can operate the system in accordance with the system design. The system efficiency is often dependent upon operating pressures.

Flow Meters

Information from flow meters should decide the duration of pumping for many systems. A flow meter is indispensable in order to have efficient and economical irrigation operations. It will often reflect water supply problems from wells or other sources and provide data that will indicate repairs and maintenance needs in water supply equipment.

Chemical Injectors

A chemical injector is a device which injects a metered amount of liquid chemical (fertilizer, herbicides, pesticides, etc.) into the irrigation system. Three principal methods used in the injection of fertilizers and chemicals into irrigation systems are pressure differential, venturi vacuum, and metering pumps. Injectors are available to match most system needs and should be installed in the system ahead of the filter so that any undissolved chemicals will be filtered out before they enter the lines. If the injector is a pump which pumps chemicals from a tank into the system, it will not contribute any system pressure losses; however, when considering an injector, it is necessary to size it so that it will inject at a higher pressure than the main pump.

When chemicals are injected into irrigation systems there is a possibility of contamination of the water supply if the injection system is not carefully designed and safely managed. In many cases, the irrigation water supply is also a drinking water supply. The irrigator has the responsibility of protecting water quality. Water contaminated by chemicals could affect the health of other users of the water supply. If not properly used, chemigation exposes an irrigator to possible liability. Safety equipment exists which will protect both the water supply and the chemical purity in the storage tank. The possible dangers in chemigation include backflow of chemicals into the water source and water backflow into the chemical storage tank. Backflow to the water source will contaminate it. Backflow to the storage tank can rupture the tank or cause overflow, contaminating the area around the tank, and perhaps indirectly contaminating the water source. Once these problems are solved, the risk of liability in chemigation is not substantially greater than the liability which arises from the field use of agricultural chemicals utilizing other modes of application. For technical reasons such as reduced wind drift, rapid movement into the soil, and high dilution rates, chemigation could result in less risk of liability than the traditional methods of chemical application if proper backflow preventors are used.

Safety features recommended for internal combustion and electric irrigation pumping plants are shown in Figures 6-10 and 6-11. The safety equipment package consists of the following items which should be in good operating order before chemigation of any type.

1. A check valve must be installed between the pump and the chemical injection point on the irrigation pipe. This will prevent water from flowing from a higher elevation in the irrigation system back into the well or surface water supply. Thus water contaminated with chemicals will not flow back into the water source.

2. A vacuum breaker must be installed on the irrigation pipe between the pump and the check valve. This will allow air to enter the pipe when pumping stops so that water flowing back to the pump will not create a suction, pulling additional water and chemicals with it.

3. A low pressure drain should be provided to allow the irrigation pipe to empty without flowing back into the water source.

4. If chemical injector pumps are used, power supplies must be interconnected so that the injector pump cannot operate unless the irrigation pump is also operating. If the injector pump is mechanically driven, such as by a belt from the drive shaft of an internal combustion engine (Figure 6-10), this is not a problem. In this case, the power supplies are interconnected and, when the internal combustion engine stops, the injector pump will also stop. If, however, the chemical injector pump is electrically driven (Figure 6-11), then its electrical circuit must be interconnected with the irrigation pump circuit to assure that it stops when the irrigation pump stops. This precaution will assure that the chemical injector pump does not continue to inject into an empty irrigation pipeline, or worse, backwards into the water supply.

5. If chemical injector pumps are used, a check valve on the chemical injection line must be used to prevent water flow backwards from the irrigation system through the chemical injector pump and into the chemical storage tank. This will prevent dilution of the chemical by the irrigation water. It will also prevent possible rupture or overflow of the chemical storage tank and pollution of the surrounding area.

   Chemical injection line check valves are typically spring-loaded and require a large pressure to allow fluid to flow through them. These valves thus permit flow only when that flow is a result of the high pressure generated by a chemical injector pump. When the injector pump is not operating, chemicals will not leak due to the small static pressures created by the chemical level in the storage tank.

6. A valve must be provided for positive shutoff of the Chemical supply when the injection system is not in use. This may be a

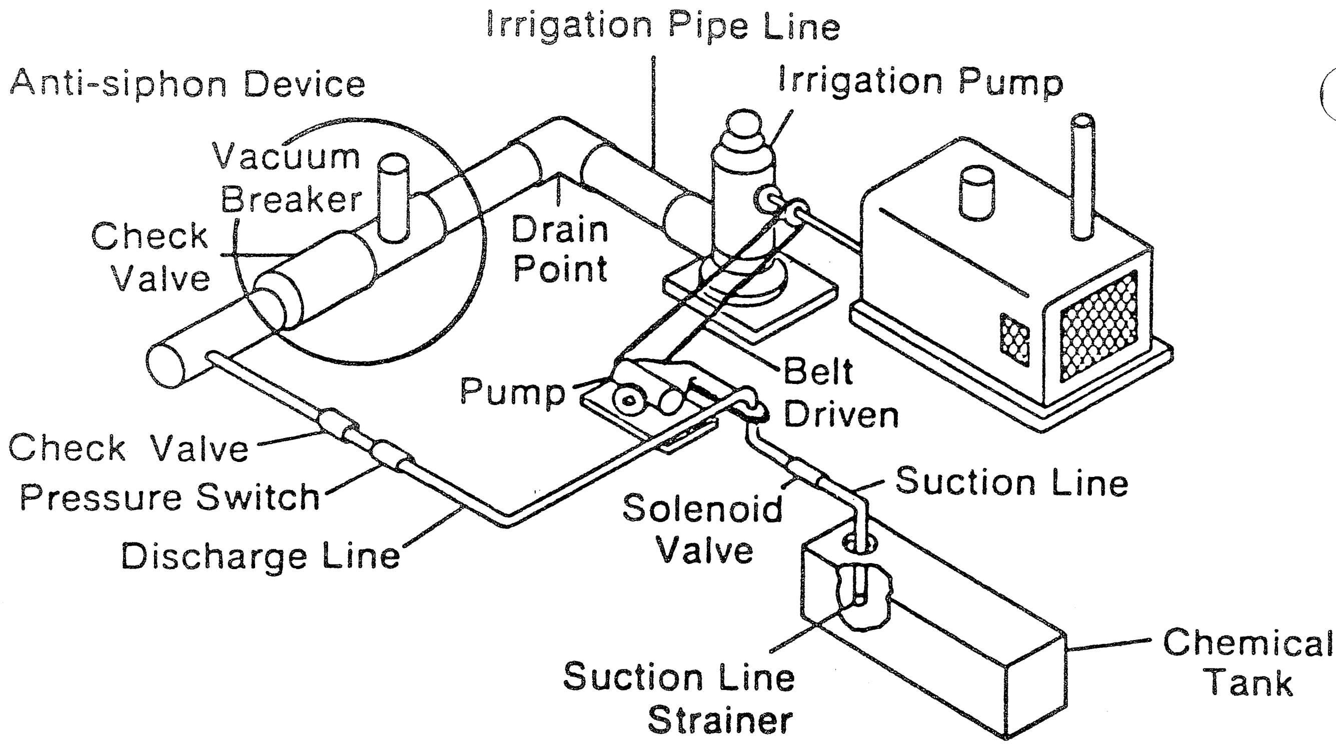


Figure 6-10. Chemigation safety equipment for internal combustion engine irrigation pumping plant.

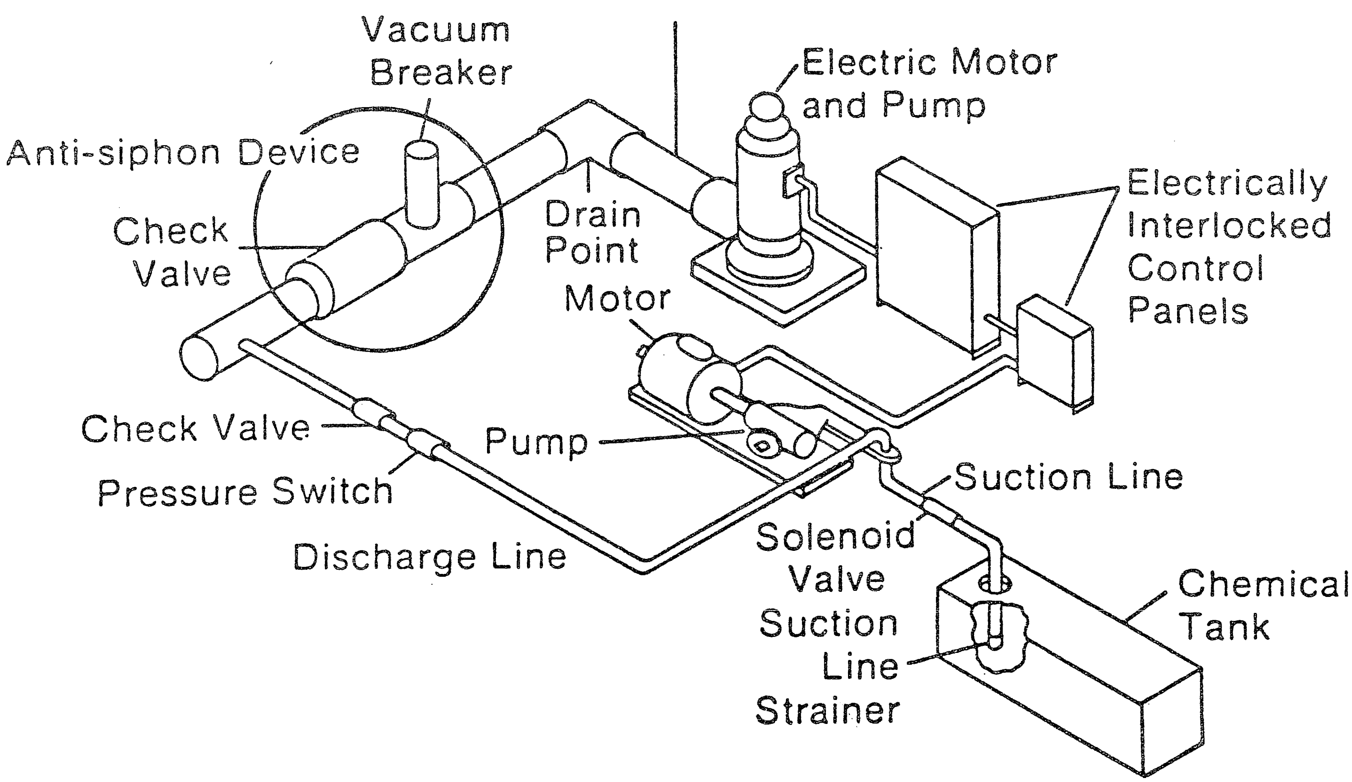


Figure 6-11. Chemigation safety equipment for electric motor irrigation pumping plant.

manual gate valve, ball valve, or a "normally off" solenoid valve. This valve must be installed near the bulk chemical storage tank. It must be open only when the injector pump is operating. It must be constructed of materials resistant to chemical corrosion. A disadvantage of the solenoid valve is that corrosive chemicals may cause the valve to fail to operate after only a short period of time. A PVC ball valve will be less affected by corrosion. However, it will require manual operation.

7. Chemical storage tanks must be located remote from the well site or surface water supply. Tanks should be located at a site sufficiently remote and sloped so that contamination of the water supply will not occur if the tank ruptures or it a spill occurs while it is being filled.

Chlorine Injection

Chlorine injection into trickle systems is the most effective and inexpensive treatment for bacterial slimes. The chlorine can be introduced at low concentration, 1 ppm, or as slug treatments at intervals as necessary at concentrations of 10 to 20 ppm for only a few minutes at a time. Slug treatments are generally favored. Sodium hyperchlorite or chlorine gas may be used. Sodium hyperchlorite is usually more economical and safer to use.

Filters

Filters are a necessary component of irrigation systems when the water source is not clean enough to allow for proper operation of the system. Filters are usually needed for pumping for channels or reservoirs and for trickle systems. As a guide to filter sizing, allow 20 GPM per square inch of filter (verbal communication, Charlie Privette Clemson University.)

When water is supplied from a reservoirs, ditch or lake, a series of box screens should surround the intake of the water line to prevent debris, plants and even fish from ending up in the irrigation system. Slotted PVC pipe can often be used as a pump intake screen. The type filter chosen for system design needs to provide the needed capacity and provide for head loss through the filtering process. Manufacturer's information is vital in this design aspect. Pressure gauges installed prior to filtering and following filtering are vital to determine pressure losses and when back washing is needed. Refer to the manufacturer's recommendations.

Sand Filters

Sand filters are classified in many ways, but in general, have the following features:

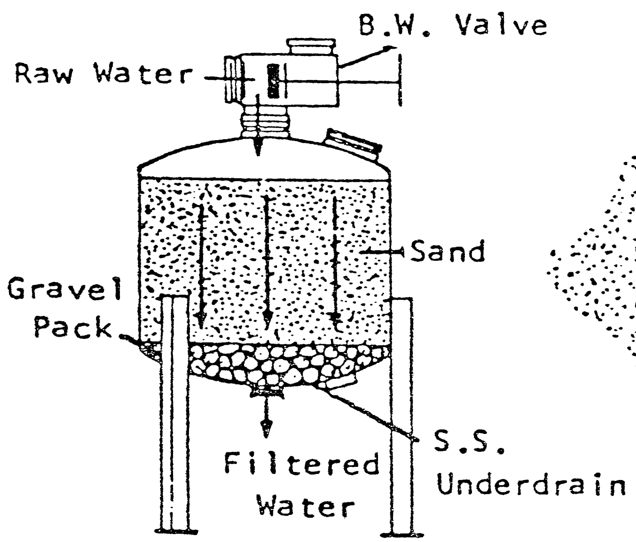
1. Enclosure - to house the filtration media(s) and store the raw water until it is passed through the filtration media(s).

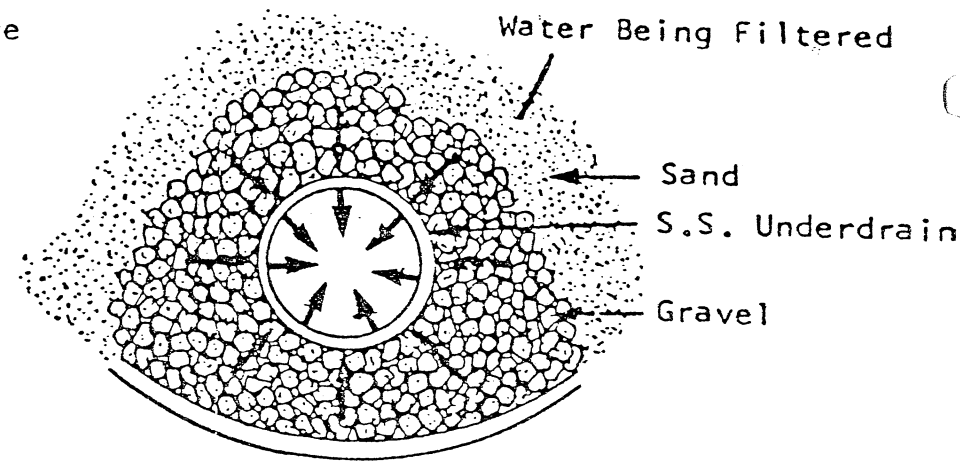
2. Raw water distributor - spread raw water over filtration media.

3. Filtration media - material used to trap the particulate material in the raw water.

4. Underdrain - to collect filtered water and retain filtration media in the enclosure.

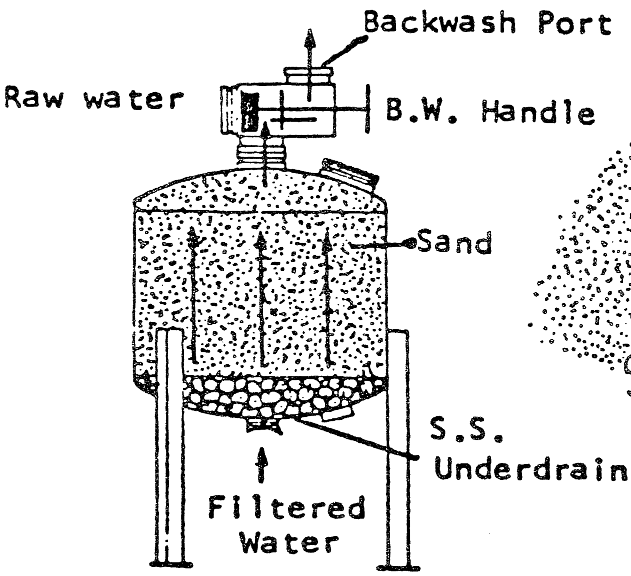
5. Clean out port - removal of filtration medial from the enclosure.

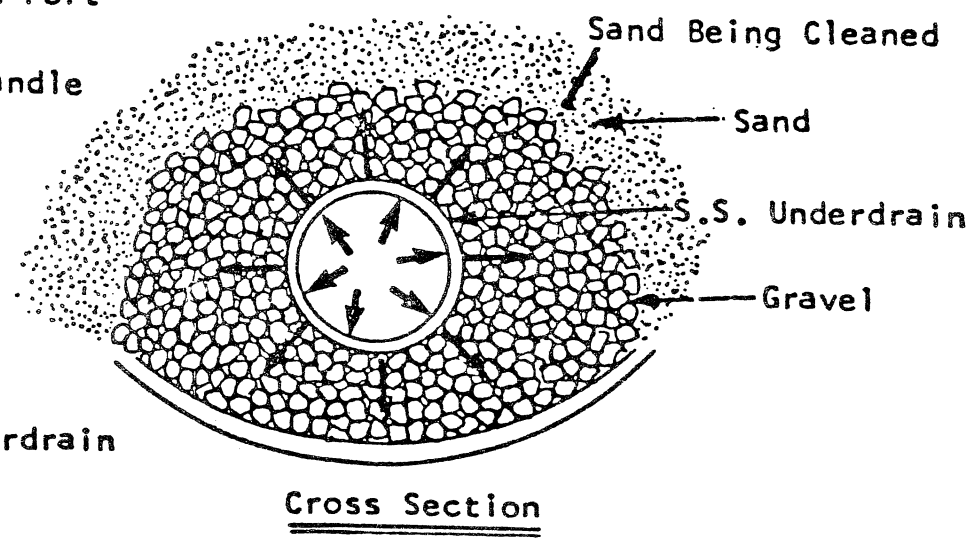




Cross Section

Filtration Operation - Raw water enters filter through the backwash valve, over the water distributor, through the sand bed, deposition of the particulate material, and the filtered water is collected through the stainless steel underdrain and discharged out the bottom.



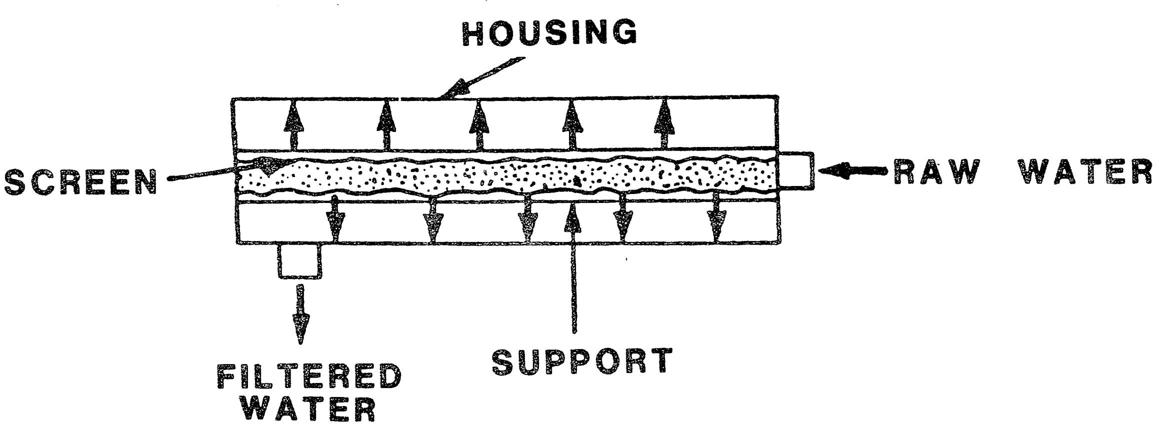


Backwash Operation - The backwash is initiated by screwing the backwash handle forward. This shuts off the incoming raw water and opens the backwash port to a near atmospheric condition. The pressurized filtered water from the adjacent filter(s) is forced through the stainless steel underdrain, upward through the gravel pack, expanding the sand bed and forcing the lighter particulate material out the backwash port and down the backwash line. Screwing the backwash handle in the reverse direction puts the sand filter back into the filtration operation.

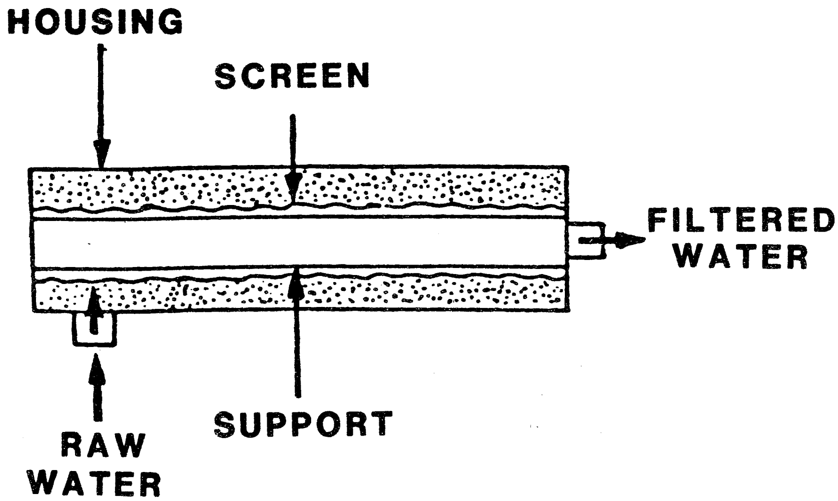
Screen Filters

Screen filters have many different configurations but are basically classified as:

1. Flow from inside out - Raw water enters interior of screen cartridge and filtered water exits along housing body. the support structure for the screen material is the inside of some type cylinder or the cylinder itself is the screen.



2. Flow from outside in - Raw water enters along housing body and through exterior of screen cartridge. Filtered water exits through interior of screen and out the bottom of the housing. The support structure for the screen material is the outside of some type cylinder or the cylinder itself is the screen.



AUTOMATION

Automation is a term applied to processes which reduce or eliminate human labor. A fully automated irrigation system would be one that would sense the crops need for irrigation, turn on and operate the system and turn off the system after the proper amount of water has been applied. Few systems are fully automated, but solid-set and self propelled big gun, boom, lateral move and center pivot sprinkler systems and trickle irrigation systems have reduced human labor requirements for irrigation. Most are manually turned on and operated. Mechanical or electronic controllers can be used to activate automatic valves for automatic operation of the system. The controllers are usually programmed by the irrigator. Moisture sensing equipment that will signal controllers to start and stop irrigation is still in the developmental state.

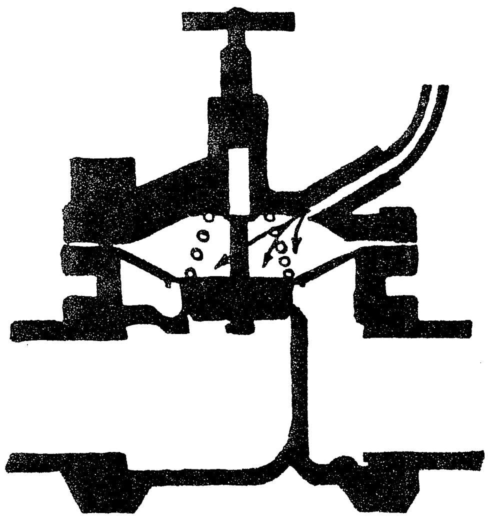
AUTOMATIC VALVES AND CONTROLLERS

This type system provides advantages for many irrigation systems and greatly facilitates proper system management.

The system's operational sequences are programmed into the controller. The controller directs the opening and closing of automatic valves as needed to accomplish the operational sequences. The controller can be mechanical or electrical. The possibility of failure from weather, etc., makes it necessary to have manual operable arrangement as well as having means for quick repairs. Valves are hydraulically or electrically operated.

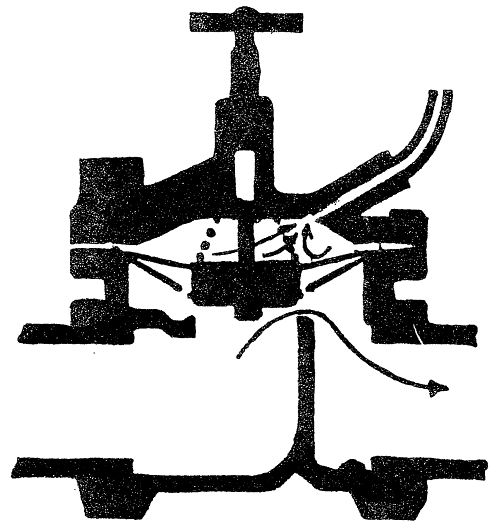
The following sketches explain in greater detail the automatic valve operation.

1. Normally Open Hydraulic - If, with a normally open valve, pressurized water is introduced at the inlet of the valve, the water will pass through the valve when there are no external connections to the valve mechanism. Pressure has to be applied to the inside of the diaphragm or piston of the valve to close it.



CLOSED

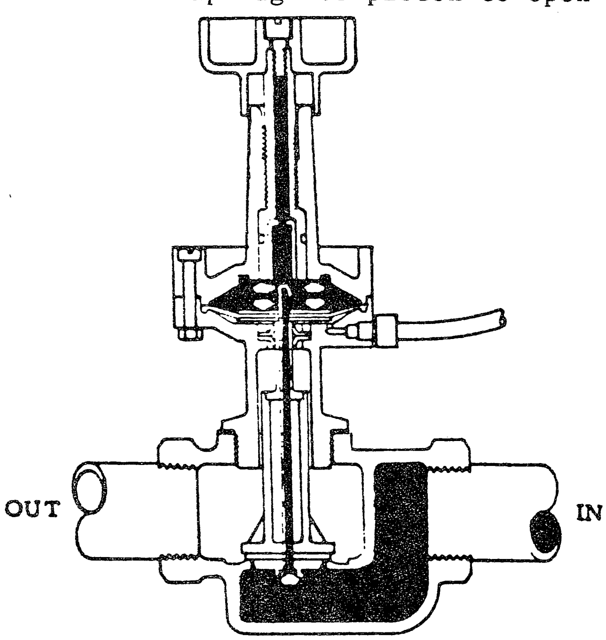
Pressure applied to top of diaphragm from control tubing causes closure of valve.



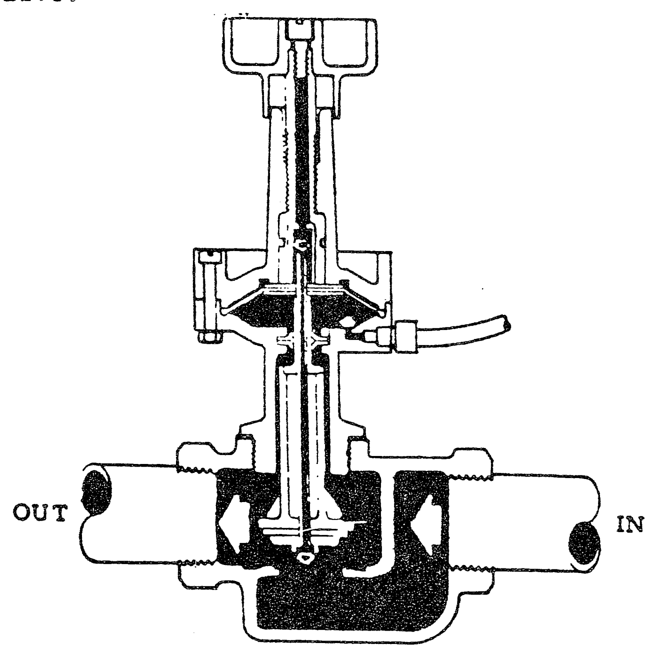
OPEN

Pressure on top of diaphragm is relieved through control tubing allowing valve to open.

2. Normally Closed Hydraulic - If, with a normally closed valve, pressurized water is introduced at the inlet of the valve, the water cannot pass through the valve when there are no external connections to the valve mechanism. Pressure has to be applied to the diaphragm or piston to open the valve.

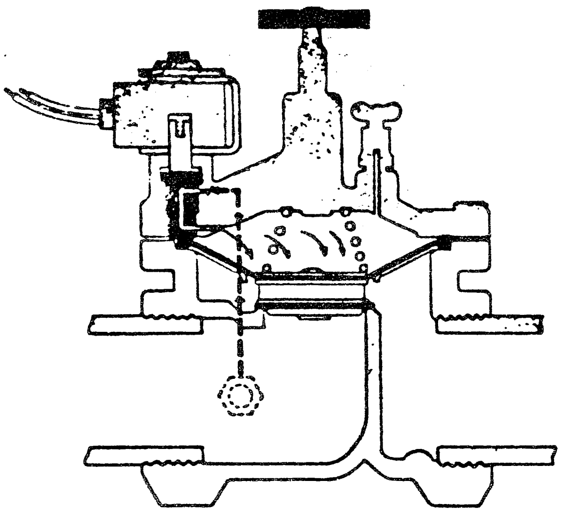


Pressure applied to top side of diaphragm through stem causing closure of valve.



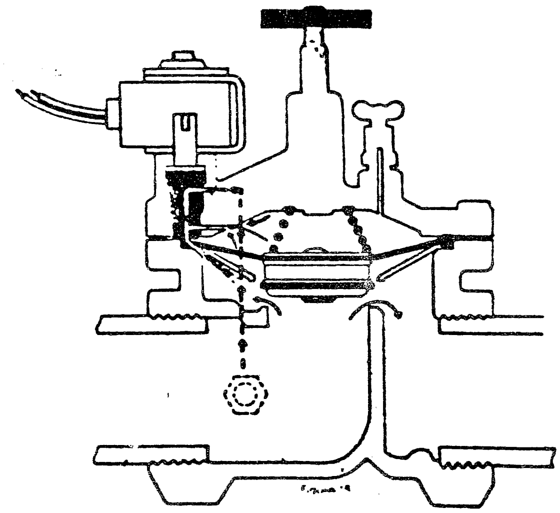
Pressure applied to lower side of diaphragm through control tubing causing water on top side to be displaced through valve and allowing valve to open.

3. Electric - Electric valves are controlled by electric current from the controller, whereas the previously mentioned types are hydraulically controlled by the control mechanism. Electric valves are generally of the normally closed types with current supplied to open the valve. Most electric valves are actually hydraulic valves electrically operated. The current energizes a solenoid which clears a passage for water to flow to or from the diaphragm or piston allowing the valve to open.



CLOSED

Pressure applied to top of diaphragm through screened inlet causes closure of the valve.



OPEN

Pressure on top of diaphragm is relieved through solenoid assembly to downstream side of valve allowing valve to open.

Desirable features on controllers include:

1. Infinite time adjustments on each station. (For precise control of watering time.)

2. No time lag between stations. (To eliminate wasted watering time.)

3. Weather-resistant locking cabinet. (To prevent weather and vandal damage.)

4. Program dial for up to 14 days is desirable. (To allow the maximum in programming flexibility.)

5. Easily set day and hour programming. (To allow the maximum in programming to be made quickly and simple.)

6. Sufficient stations on the controller for the area being covered. (Usually a minimum of 11 stations to avoid the requirement of too many controllers.)

7. Pump Circuit. (To enable a controller to kick on the pump starter circuit when the controller begins its watering cycle.)

8. Readability of controls. (To enable the manager to understand and decipher what he needs to know.)

9. Freeze resistance in hydraulic controllers. (To prevent damage due to freezing in areas where the controller mst remain functional even though nighttime temperatures drop below freezing.)

10. U.L. listing. (To qualify for specification on federal, state, and municipal projects.)

11. Manual override switch. (To allow checking of system without disturbing watering program.)

12. Off master switch. (To manually cancel the automatic watering program without disturbing program settings.)

13. Fuse protection of the timing mechanism, electric controllers, the transformer. (To protect against damage to the timing mechanism and transformer in the event of a circuit short.)

14. Easily removable timing mechanism. (So non-field repairs can be made on controller.)

15. Manual operating capability if timing mechanism is removed. (To have continuous operations if timing mechanism is removed for repair.)

16. Filtered supply line on hydraulic controllers. (To protect the pilot valve from plugging.)

Desirable features on valves include:

1. Low friction loss. (To allow pressure to be used in the pipes and sprinklers.)

2. Smooth opening. (To avoid hydraulic ram conditions.)

3. Smooth closing. (To avoid water hammer conditions.)

4. High pressure rating. (To avoid equipment failure at high pressures.)