Water Flooding Equipment and Injection Station Piping

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INTRODUCTION

The correct application of equipment on waterflood projects has become difficult and confusing to the waterflood operator during the past several years due to the multitude of equipment available which will perform the same function. This paper is being presented to pass on information that might help eliminate a portion of this confusion. It is based on observations and past experience of the writer.

WATER SUPPLY WELL PUMPS

Three basic types of equipment are available for lifting water from the source water wells. These are,

(1) Beam pumping units,
(2) Turbine type centrifugal pumps, and
(3) Submersible type centrifugal pumps.

Beam pumping units should always be considered where the volume requirements are 1000 barrels per day or less, regardless of the well depth. A beam pumping system can be operated cheaper than any other means of pumping and will have less down time than any other system as it can be serviced by almost all oil field personnel. In addition, replacement parts are generally available from the closest oil field supply store for any segment of a beam pumping system.

Turbine type centrifugal pumps, which have their centrifugal pumping elements suspended from the surface, should be considered where the volume requirements are greater than 1000 barrels per day and the fluid level does not exceed 1000 feet. This type pump can be driven by any electric motor, gas, gasoline or diesel engine and the prime mover can be serviced without pulling the pump. Initial and operating cost on turbine type centrifugal pumps will generally run considerably less than on a submersible type pump.

Submersible pumps, which have their motors and centrifugal pumping elements both submerged in the water, must be used where the volume requirements are greater than 1000 barrels per day and the fluid level is below 1000 feet. These pumps should also be considered for crooked holes as the entire assembly is run into the hole and there is no shaft wear, due to the deflection in the well.

There are two types of submersible pumps available. One can be run into small casing regardless of the horsepower requirements, while the other requires larger casing as the horsepower requirement increases. The pump which can be run into small diameter casing syncronizes additional rotors and stators of the same diameter, as the horsepower requirements increase. The other pump utilizes only one rotor and stator but increases the diameter as the horsepower increases. The latter is highly efficient and almost trouble free; however, it generally requires a larger casing size.

The hydraulic friction losses are low in submersible pumps as there is no shaft to reduce the flow area in the eduction pipe. Also, with the motor close coupled to the pump, there are no mechanical power losses in the shaft bearings such as are encountered in turbine type pumps. The disadvantage of this type pump is the large power loss in the cable between the surface and the pump. This generally results in a step up voltage transformer being installed in the system.

FILTERS

The two most common methods used today for filtering oil field brines are diatomaceous earth filters and pressure type sand filters.

Diatomaceous earth filters are recommended for filtering water that has not been treated, is relatively clear, and is free of any particles which tend to flocculate. This type filter will do an excellent job of filtration regardless of the flow rate used or the turbidity of the water; however, it requires backwashing very frequently and the flow rate must be adjusted according to the length of time desired between backwash cycles.

There are two types of diatomaceous earth filters available. One type consists of several vertical elements, or leaves, suspended in a horizontal or vertical tank. The elements are made of stainless steel, monel, carborundum, or some other suitable material and each element is precoated with diatomaceous earth prior to putting the filter on stream. After a sufficient coating is built up, the water is passed through the elements to the filter outlet.

The difficulty with this type filter is that a pressure differential must exist for the diatomite to remain on the elements. When the differential ceases to exist, such as when an inlet or outlet valve is closed instantaneously, the filter cake falls off the elements. When the filter is then restarted, it is necessary to precoat the elements again, discharging the water to the drain until a sufficient filter cake is built up. If this is not done the diatomaceous earth will be pumped through the injection pumps and to the injection wells.

The other type diatomaceous earth filter consists of several horizontal trays mounted in a vertical tank. Installed in each tray is a perforated plate which supports a non rigid foundation of discrete material, generally silica sand and gravel, covered by a tough water and chemical resistant synthetic fabric disc. A coating of diatomite rests on the synthetic fabric. The diatomaceous earth is not lost in this type filter when the filter is shut down, as a pressure differential is not required to precoat the tray.

Pressure Type Sand Filters

Pressure type sand filters are recommended where the water entering the filter has been chemically treated to allow particles to flocculate or where the water has a high content of suspended particles that must be removed. In addition to sand, these filters may be used with other types of filter media such as anthracite or graphitic ore; however, due to the particle shapes of these materials they are not as effective for filtering as sand.

When using these other materials the entire bed is required for filtration. This bed becomes dirty very rapidly resulting in an effluent that is no longer clear. In sand media, due to the closeness of the particles, only the top few inches are used for filtering, which results in a clear effluent as long as the beds are intact. For this reason, most states now allow only sand as a filter media in their municipal water supply filters. Coagulant feeders should not be used in conjunction with this type filter as the fast flow rate will not allow sufficient time for particle flocculation before passing through the filter and this material can cause trouble in the injection well.

Pressure surges through sand filters should be avoided as the particles filtered out of the water, which are embedded in the top few inches of sand, will be forced down through the bed. For this reason, positive displacement pumps should never take their suction directly from a filter as this type pump has a definite surge characteristic on its suction side. Likewise, the source pump should not discharge directly into the filter if it has a tendency to surge.

Many types of automatic backwash systems have been devised for filters although few have been successful. These systems have mostly been based on a time cycle which is unsatisfactory. The characteristics of the water change periodically and the sand can lose its effectiveness after it has been put into service. These changes effect the time and frequency required for backwashing. In addition, if the wrong valve is opened or the valves are opened too fast the filter bed becomes disrupted and the filter is no longer effective. For these reasons, automatic backwashing is not recommended.

INJECTION PUMPS

There are two basic classes of pumps used for water injection. These are centrifugal and positive displacement.

Centrifugal pumps should be considered where the volumes' requirements are high and the pressure requirements do not exceed 125 psi. The initial cost of this type pump is low in comparison with the positive displacement pump; however, it is relatively inefficient and should not be considered in its upper pressure range without also considering the size prime mover required and its cost of operation. Fluid ends are available for this type pump in all iron, bronze trim, all bronze, and many other special alloys.

Positive displacement pumps may be either piston or plunger type. The piston type pumps, either simplex or duplex, should be used for pressures up to 500 psi. The plunger type pumps, triplex, quintuplex, and septuplex, should be used for pressures in excess of 500 psi.

The above figures are based on generalities; for pressure requirements varying slightly from those given above, both types of pumps should be investigated.

Pumps should never be selected without first investigating the prime movers required to operate the pumps and their initial and operating costs. Where gas engines are to be used as prime movers for pumps requiring 150 horsepower or above, a batter of smaller pumps should always be considered from an engine operating cost standpoint. A considerable savings will generally be apparent. In addition to the economic saving that can be realized by using several small gas engine driven pumps in place of one, a considerable amount of operating flexibility is made available and standby equipment is on hand when a portion of the plant is down for repair.

Positive Displacement Pumps

Positive displacement pumps are available from most manufacturers with all iron, bronze trim, or complete bronze fluid ends. The all bronze end, generally an aluminum bronze, is the most widely used as it is more corrosive resistant to the majority of the oil field brines being used for water injection today.

Although a considerable saving can be made by purchasing the all iron or standard fitted bronze trim pump initially, the additional expenditure for a bronze fluid end can easily be justified if operating expenses are considered. Most major operators who have kept records of operating cost on their water injection pumps over the past several years will consider nothing but aluminum bronze fluid ends on their pumps, regardless of the degree of corrosiveness of the water.

Many types of plungers are available for the plunger type positive displacement pumps. These include solid ceramic, ceramic lined, bronze, stainless steel, chrome plated, colmonoy coated and many others for special services. If plunger alignment can be maintained within the pump, the solid ceramic plunger is the most satisfactory against corrosion and abrasion. In addition, the ceramic plunger will carry sufficient water within its pores to keep the packing lubricated. These plungers, however, are extremely brittle and must be handled with extreme care when installing in the pump.

Positive displacement pumps handling corrosive water should be shut down as little as possible to prevent build up between the plungers or pistons and the cylinders within which they are working. For this reason gas engines, where they can be economically justified, lend themselves very well as prime movers for injection pumps as the engine speed can be automatically controlled by injection pressures, injection volumes, or by fluid levels within storage tanks.

This prevents on-off operation such as is prevalent when electric motors are used. Also, the build up between the plungers and cylinders within which they are working is kept to a minimum. Pumps handling corrosive water which are subjected to on-off operation should be equipped with stuffing box lubricators to minimize this build up.

INJECTION STATION PIPING

The most important factor to be considered in the design of any water injection system is the injection station piping. Poor piping design can bring on cavitation in the injection pumps, water hammer or fluid pound, pulsations, horsepower loss, and many other factors related to any hydraulic system.

Along with proper piping, a positive suction head should always be maintained on the suction side of the injection pumps. Although the theoretical correct head on the suction side of a positive displacement pump varies with the fluid velocity, type of pump, length of line, pump speed, and the acceleration head, a good rule of thumb is to maintain a minimum of 3 psi at the suction inlet of the pump.

The flow through the suction piping should not be greater than three feet per second. Flow can be determined by the formula below:

$$V = \frac{GPM}{D^2 \times 2.45} \quad \text{Feet/Second}$$

Where D = Inside diameter of pipe in inches

The suction line between the clear water storage and the injection pumps should be as close to the injection pumps as possible, regardless of the size pipe used. Single suction lines should be used for each pump whenever possible. Long suction lines can result in negative heads being produced, due to the pulsating nature of a positive displacement pump. As the plunger velocity changes, acceleration of the fluid in the line is present. To have acceleration, a differential pressure must exist between the two ends of the pipe.

Large velocity changes require high acceleration, therefore, large pressure differences. The longer the supply line, the larger the pressure difference. This pressure difference is obtained because the plunger tends to leave a void in the cylinder on its suction stroke. If the suction head is not sufficient to prevent the pressure in the pump cylinder from falling below the vapor pressure of the liquid being pumped, an implosion or cavitation will take place within the fluid end of the pump. The resultant gas in the pump block or cylinder, when compressed on the discharge stroke, sets up a definite shock wave which is also detrimental.

There should be a minimum of sharp turns in both the suction and discharge lines. Where turns are necessary, always use long radius elbows, preferably 45 degree if space allows.

Suction Air Chambers

Suction air chambers should be installed in the suction line or manifold to help reduce the possibility of cavitation within the pump fluid end. Air chambers are also useful for quieting pipe line vibration and hydraulic noise. The suction air chamber should be a closed vessel equipped with an air charging valve and a liquid sight glass.

The vessel should be partly filled with water so that when the pump cylinder pressure starts to fall below average supply pressure the air will expand, forcing some of the water in the vessel into the pump chambers, thereby reducing the possibility of cavitation. The suction air chamber should have a capacity of 3.5 times the displacement per stroke of the pump equipped with the largest piston or plunger. A typical suction air chamber is shown in Fig. 1

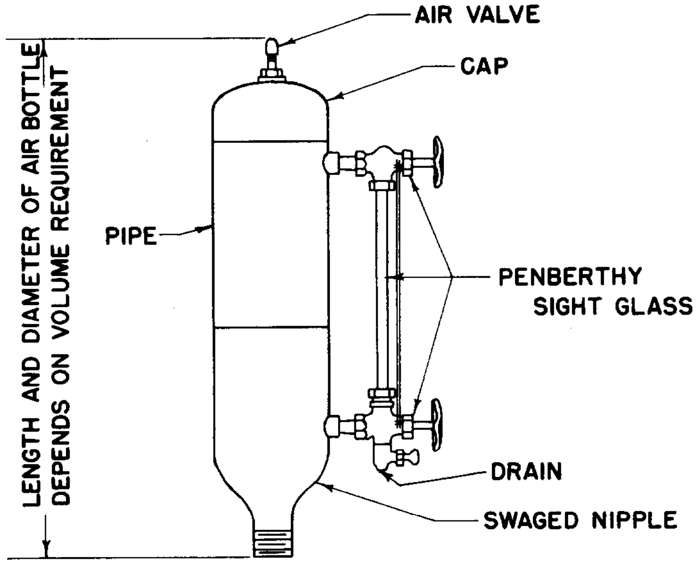

Fig. 1

On the discharge side of the pump, a short run of pipe should always be installed between the discharge connection and the first elbow. This will prevent damage to the pump's fluid end which can be caused by high pressure surges which are set up when an elbow is connected directly to the pump discharge. These high pressure surges can far exceed the working pressure of the pump.

The use of 45 degree elbows and laterals on the discharge side of the pump in place of 90 degree elbows and tees will help reduce the possibility of water hammer and the resultant vibration. This vibration, common to most discharge systems, can be reduced further by the installation of bladder type pulsation dampeners. This type dampener is particularly desirable on large stroke multiple pump hook ups.

Bypass arrangements on the discharge side of pumps should be discharged to the storage tank, not to the suction line. Undesirable flow characteristics are set up by water returned to the suction line and water continually bypassed will have a considerable temperature rise.

All injection pumps should be equipped with a shear relief valve located between the discharge of the pump and the first valve downstream from the pump discharge.

Suction and discharge piping should always be rigidly anchored and supported so that the pipe is not dependent on the machinery to which it is connected for support. Piping dependent on fluid ends for support will result in a fatigue failure of the fluid end.

A heavy concrete foundation, having a minimum foundation weight to pump weight ratio of 3:1, is desirable so that the natural vibrations of the machine will be absorbed and not transmitted to the piping.

CAUSES OF CAPACITY LOSS

If the foregoing piping suggestions are followed, only normal routine maintenance will be required on any injection pumps.

Should an injection pump lose capacity or become noisy after being in operation the following should be checked:

1. Poor piping design
2. Worn or hung up valves
3. Air in the suction line or pump
4. Worn packing
5. Worn gaskets
6. Insufficient suction head
7. Insufficient speed
8. Worn piston rings
9. Poor foundation
10. Misalignment
11. Broken valve springs
12. Foreign matter in pump
13. Too much crosshead clearance
14. Worn bearings.