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The Selection of Vertical Turbine Pumps for *Plant Water Supply Systems*

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BEFORE a well for the plant water supply system is drilled, the probable characteristics should be obtained from available data on nearby wells. Careful attention should be given to such factors as depth, diameter, screen size, sand production, and the general perviousness or stability of the strata which might contribute to the collapsing of the well if production were excessive.

Consideration should be given to the chemical quality of the water such as the pH value and presence of carbon dioxide gas. These factors are somewhat a measure of corrosion tendencies and dictate special materials for the pump. Further, the presence of iron or surface contamination of the water affects the potability and usefulness unless there is some chemical treatment prior to its use around the plant.

The usual graphic method of plotting the log of a well in north-south and east-west planes gives at best

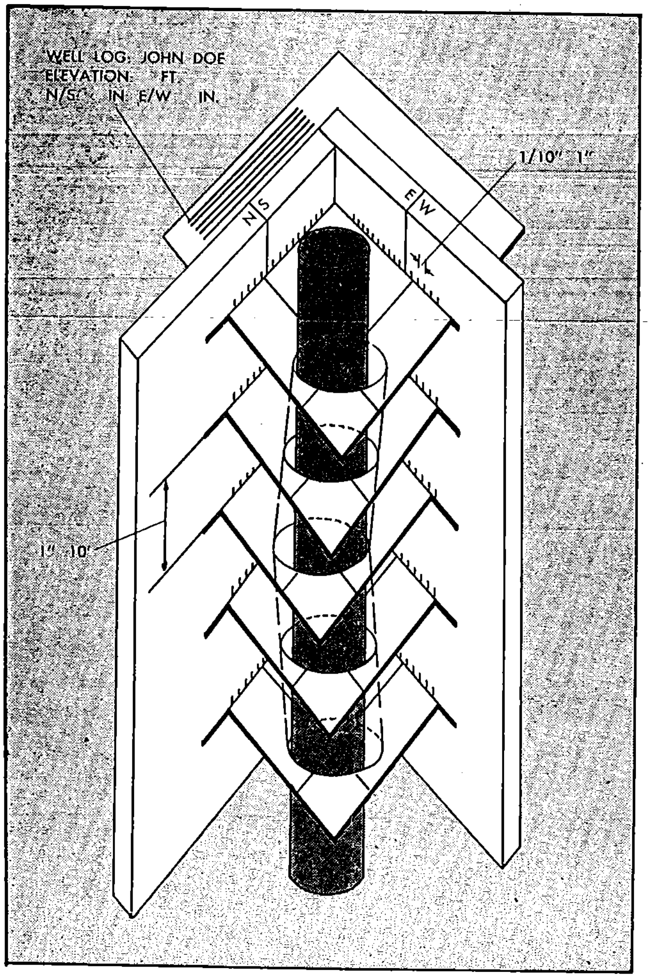


FIG. 1—THREE-DIMENSIONAL CONDITION of a well is best revealed by this slotted frame with adjustable cards instead of a graphical plot

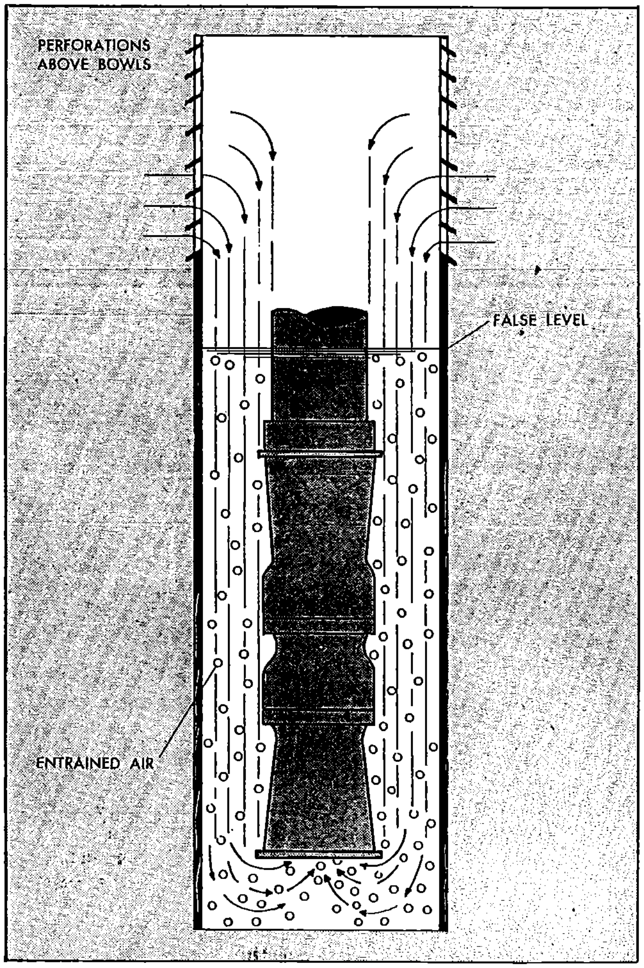
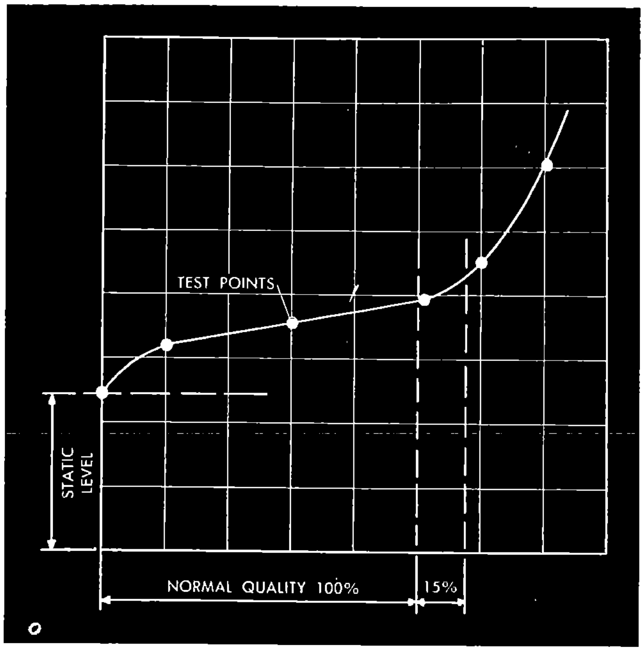


FIG. 2—FALSE DATA on water level occurs when there are perforations above the pump bowls



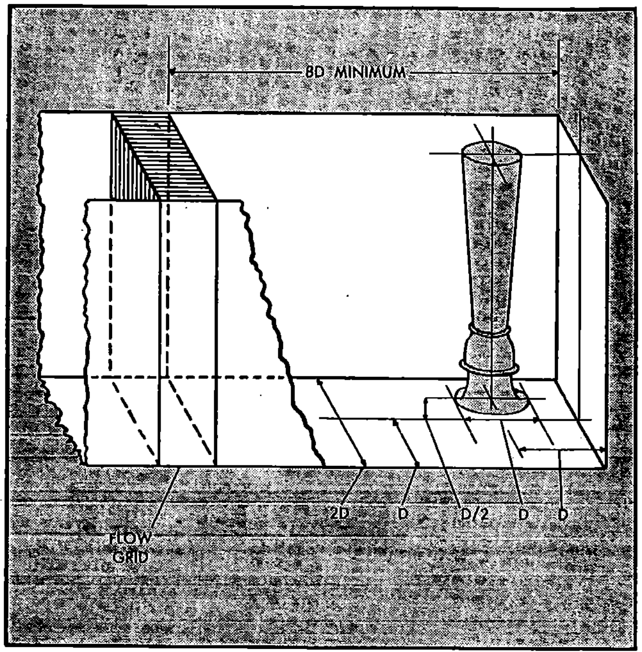


FIG. 3—PUMPING SYSTEM PERFORMANCE is aided by a well production graph, and **FIG. 4**—Recommended form and dimensions for pump sump

a distorted view of the crookedness or vertical misalignment. The use of a slotted frame, Fig. 1, having adjustable cards will show the three-dimensional condition of a well. The usual log data is used and the card representing the well opening at various elevations can be kept on file. A piece of wooden dowel of proper scale to represent the maximum pump and column can be inserted through the series of card openings and points of interference directly determined. On this basis the proper location of column aligning spiders can be fixed to assure the straight line-shaft.

When the well perforations are above the pump bowls, there will be objectionable air entrainment and false water level datum will be registered including the velocity head and friction losses around the pump bowls. (Fig. 2.)

The production characteristics of the well are as important as those of the pump and sufficient test data should be taken to define the various pumping levels from the static through the normal range and into the "breakdown" region. Such a graph, Fig. 3, will greatly aid in the efficient performance of the pumping system. A good well is costly and demands proper use to avoid over-pumping which may result in sanding or collapsing.

For supply sources such as rivers and lakes, there is small change in the pumping levels but the sump becomes an important component which should be designed on the basis of scale model tests. The use of a screen or trash rack is sometimes required and allowance must be made for periodic cleaning and inspection. Fig. 4 shows a suggested form and preference is for one pump per sump.

The choice of the pumping unit is important in several aspects and use should be made of the engineering resources and experience of a reliable and well-established manufacturer.

Pump performance characteristics must be carefully fitted into the total plant's requirements which vary widely in applications for industry. The steep head-capacity curve may be quite suitable for use with fluctuating well levels, but the system-head of a processing plant may require the flat type of curve for which the pressure would not be excessive when valves are closed.

Usually, the bowl diameter has

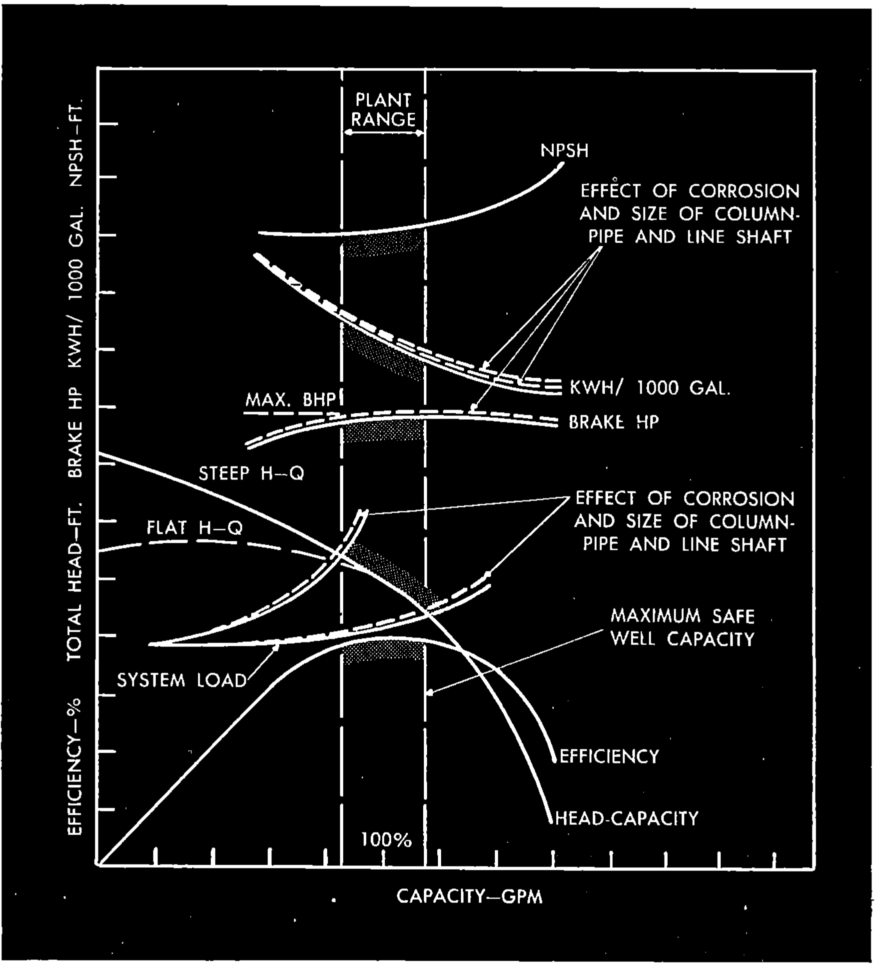


FIG. 5—Effects of variables on pump performance, a help in determining the range limits

been determined by the manufacturer for the nominal well size with proper respect to sufficient clearance to allow free entry, but in extreme cases it may be advisable to choose the next lower nominal size, which is indicated by deformities in the well or because some of the inflow is above the bowls. There may be a further limitation due to the restrictive production of the well suggesting a lower capacity pump. The initial cost and efficiency of two pump sizes should be compared over the amortization period in terms of power cost.

The graph, Fig. 5, shows the usual pump performance in terms of capacity. The choice of the normal pump quantity (100%) should be made with respect to the normal well quantity which is about 15% below the beginning of the "Breakdown" region. It is desirable to have the maximum horsepower of the pump near the normal quantity. In the case of high capacity pumps where the shutoff horsepower is higher than at normal quantity, the engine or motor must be sufficiently oversize or protected by devices to stop the pump or bypass the flow.

Since the head or pressure of the pump is usually more directly indicated by gauges, it is sometimes more useful to the plant operator to have the efficiency of the pump and total system plotted against head instead of the usual coordinate of capacity. In this way the effects of wear and corrosion, as well as the loss of efficiency is more visual.

As an example of operating costs in terms of changing plant efficiency, assume an amortizing period of five years (21,600 hours at 12 hrs/day) a power cost of 1½c/KWHR and a nominal pump load of 100 BHP. With a 91% motor the plant requires 1,773,000 KWHR at a cost of $26,600.00. If the plant efficiency lowers from 75% to 74%, the operating power cost would be increased $350.00 for this one point drop. Such an index could be used in the proper multiples to decide the best point to make repairs or the replacement of obsolete equipment. If Federal power allocation and conservation should be applied, such a check of changing performance would be quite valuable.

For engine operation it is advisable to choose a pump which has nearly constant efficiency at normal capacity for the expected speed range. Selection of engine with adequate service factor for continuous duty is of extreme importance.

To enable the plant operator to limit the range over which any one pump of a group should be allowed to run, it is suggested that the power quantity of KWHRS per 1000 gallons or the equivalent fuel consumption be plotted for various capacity rates and heads, Fig. 5.

Some applications require the pump to be capable of reverse rotation without excessive speed. From studies on the transient behavior of pumps, the run-away speed can be determined and for the common pump types generally is not sufficiently high to damage either pump or motor. In passing it is noteworthy that modern pumps are nearly as efficient when operated as turbines.

Consideration must be given to the cavitation characteristics of the pump if safe operation is expected for restricted suction conditions. If the operating range of the plant could be narrowly controlled, it would be possible to choose the pump which would run near the threshhold of cavitation with maximum efficiency. As previously mentioned, Fig. 2, wells which have some or all of the perforations above the bowls are a distinct handicap to a pump since the apparent water level is decreased by the velocity head and friction losses, all of which tend to aggravate suction conditions and induce cavitation. For unusual requirements due to volatile liquids, hot water, or high lifts, the pump manufacturer should furnish the NPSH curve for the pumps, NPSH is the net positive suction head (absolute) above the vapor pressure of the liquid pumped or is equal to the atmospheric head less the vapor pressure plus or minus the suction head. The sign of addition or subtraction depends upon whether there is suction head like submergence or suction lift respectively.

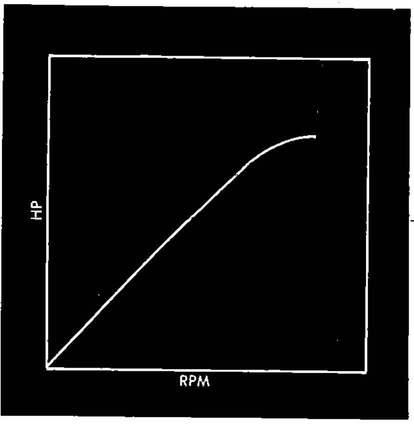


FIG. 6—Steam turbine horsepower rises with shaft speed

The choice of mechanical features in the pump unit should be made from the basic considerations which clearly show functional advantages or disadvantages.

The fully enclosed type of impeller is well-known for its general stability during extended wear, hydraulic balance which is more favorable to thrust bearing, and for being insensitive to axial adjustment over the normal pumping range.

The semi-open impeller allows careful finishing of the passages but is quite dependent upon close running clearance at the mating surface to minimize circulation losses. The clearance is subject to fluctuation as the head changes over the range and necessitates adjustment for the maximum head with subsequent penalty of circulation loss for the minimum head. The by-passing of part of the normal capacity of the pump to lower the quantity of power does so at the expense of KWHRS/1000 gals. since the efficiency is correspondingly lowered as the circulation losses increase.

The further feature of raising the semi-open impellers to develop a well during the sanding phase and reseating after this or after normal sand wear is offset by the spiral type of erosion in the mating surface which is not fully resurfaced by readjustment except at the expense of impeller port width. This loss of capacity registers in the increase in KWHRS/1000 gals.

In the choice of the pump column two general types of construction should be considered. The enclosed line shaft with proper seals at the bowl connection can be lubricated with oil and supported in close fitted bronze or phenol-plastic bearings. This separation from sand and water, together with the protective oil film, adds to the life of the shaft and bearings. The open line shaft is usually supported in rubber bearings at which point the shaft may have a journal sleeve of special alloys which is intended for water lubrication and can handle suspended sand due to the fluted bearing construction and materials.

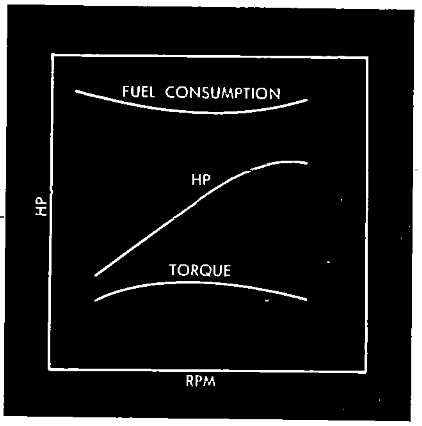


FIG. 7—Speed effects on three variables in a gas engine

It should be noted that running clearances are much greater than with bronze bearings so that the magnitude of vibration is somewhat higher. There is some question that the natural damping quality of rubber effectively suppresses the vibration due to general misalignment or to critical speed. Exposure to corrosion of the shaft, which is usually low carbon steel, results in tuberculation and increasing shaft horsepower loss reflected in possible slightly higher cost of power (KWHRS/1000 gals.). (Fig. 5.)

The correct size of the column pipe should be determined by comparisons on the basis of initial cost and power

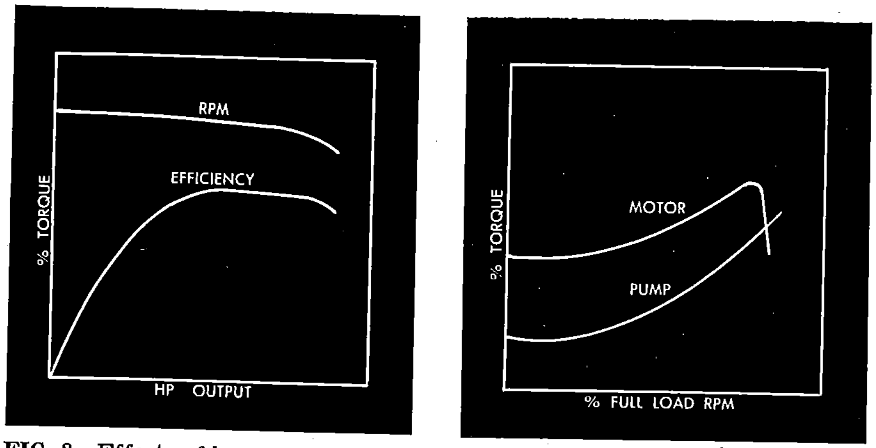


FIG. 8—Effects of horsepower and % full load speed on electric motor variables

cost (KWHRS/1000 gals.) due to the change in friction losses. (Fig. 5.)

The motive power is another important element of the system and deserves careful thought. The horizontal or vertical steam turbine can be used where the range of head capacity dictates extremes of speed. The turbine and pump have similar torque characteristics and are effectively coupled. A typical graph of the horsepower versus RPM of a steam turbine is shown in Fig. 6.

For less speed range the gas or diesel engine has useful flexibility and both vertical and horizontal types are available. This type of drive requires a suitable clutch which can be supplemented to advantage by hydraulic couplings or gears. See Fig. 7 for general performance characteristics.

Probably the more common drive which is more readily adaptable to full automatic control is the electric motor—either the induction or synchronous type. As with the other drives the pump torque characteristics are easily adapted. Note from Fig. 8 that the motor efficiency in terms of output horsepower is broad and combines to advantage with the turbine pump for extreme changes of head capacity even though the choice of speeds may be more restricted. Efficiency and power factor can be improved by the use of the synchronous motor, but there is a low limit of horsepower below which it is not economical.

The delivery piping with the various fittings and flow devices completes the load system and warrants thorough investigation.

Dimensional data such as elevations, lengths, and tentative diameters should be represented in suitable graphic form which can be considered with such other factors as shock and friction losses and the effects of age or deposits on the total investment and operating expense. Thus, an oversize pipe system may be a saving when properly amortized.

For most demands, a net quantity (gallons or cubic feet) of water is the useful form and any added power to develop pressure or velocity is intangible. For example, a plant which delivers large quantities at low levels and maintains simultaneously a small quantity at an extreme high elevation or pressure reflects serious waste of power due to the large quantity and high pressure. An auxiliary plant for this small quantity would be preferred.

Controls

The well and pump should be protected and guided by floats or other level detectors. Lubrication controls should be provided for the shaft bearings and in the case of open line shaft type of column, the device should pre-lubricate and post-lubricate during the starting, stopping, and reversing phases. The anti-reverse ratchet can be used to some advantage if no reversal can be permitted.

Speed controls are necessary for drives other than electric motors of the induction or synchronous type and should be coupled with suitable pressure devices for stabilizing the system. Overload protection is provided for the electric drive for such typical conditions as sand locking or interference due to sticks, stones, or other obstructions at the impeller. Whether any of these devices should be fully automatic or manual depends upon the size, location or use of the plant.

Valuable supplements to the pumping plant are recording devices for the flow, quantity and rate, discharge pressure and other levels and power measurements. These will aid the supervisor in decisions affecting the total plant.

The total plant becomes a serviceable unit when the components are combined to operate within the prescribed limits. The factors of quantity, pressure, power, time and materials are summarized for the economical range and safe operation as shown in Fig. 5. The use of the system beyond these limits clearly shows the waste of the power dollar (KWHRS/1000 GPM) and the possible abuse of the well, pump or drive.

Constructive supervision of such an investment requires judgment and experience. It is greatly augmented by carefully kept records of the pumping quantities, time, cost and the man-hours required for repair or replacement. This information should be supplemented by a sort of current library having books, notes, papers, sketches and drawings pertaining to the components. From this background a thoughtful decision can be made, for example, to add more units instead of overloading the existing ones or when to repair the old equipment or to replace with modern improvements.

Successful operation of the pumping plant implies an obligation to Management, to the investor and to the consumer. This means a proper choice of equipment based on sustained high performance and due regard for the basic features of design.

Conclusion

The object of this limited article has been to offer some general factors for supplementing the plant operator's practical experience with the water supply and kindred pumping units, and to promote further study and continued analysis of a given system so he may most efficiently utilize present facilities, and take advantage of new techniques and more efficient equipment available today.

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