Centrifugal Versus Plunger Pumps for High Pressure Water Injection

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Several unique conditions existed which influenced Gulf Oil Corporation's selection of multi-stage centrifugal pumps over multi-plunger pumps at its Goldsmith (5600 ft.) Water Injection Plant in Ector County, Texas. However, the factors taken into consideration in this particular case are applicable to the design of any high volume, high pressure water injection plant.

Before selecting the type of pumps to be used, certain assumptions must be made. The volume of fluid and the pressure at which the fluid is to be pumped must be estimated. The initial design conditions were estimated to be 100,000 BWPD at 1200 psi discharge pressure. The ultimate conditions were estimated to be 150,000 BWPD at 2000 psi discharge pressure. With these discharge volumes and pressures established, an economic study of the 2 different types of pumps can be made.

There are many factors that influence the selection of high pressure water injection pumps. The most important of these are as follows:
(1) environment; (2) choice of prime movers; (3) flexibility of operation; (4) pump efficiencies; (5) space requirements; (6) operating and maintenance expense; (7) installation cost; (8) initial pump cost, and (9) expected life of injection plant.

ENVIRONMENT

The quality of the water used for injection has a great deal to do with pump selection. The nature of water used dictates what precautions should be taken. At the Goldsmith Injection Plant, initially Hendrick Reef water would be used. Later in the life of the flood, a combination of produced water and Hendrick Reef water would be used. Analyses of these different waters were made to determine their physical and chemical characteristics. It was determined that the water source in this case was highly corrosive, primarily because of its hydrogen sulfide or H_2S content. The results of the analysis also indicated that a closed system should be used. This would be accomplished by use of combination oil and gas blankets. This blanket would eliminate a highly corrosive condition by preventing oxygen from entering and dissolving in the water.

Corrosion is one of the most expensive and annoying factors in water flooding today. The usual methods of combating corrosion in high pressure water injection pumps are by the use of corrosion resistant materials and by the injection of chemical compounds into the water prior to entry into the pump. In this case, economics indicated that corrosion resistant materials should be used.

Centrifugal pumps have a distinct design advantage over plunger pumps, due primarily to the size of the pump per bbl. of water moved. Being of much smaller size, naturally the amount of corrosion resistant materials needed is less in centrifugal pumps. However, either pump can be designed to resist corrosion attack in high pressure water injection. Of the two types, it appears that the centrifugal pump would be more easily protected by the use of corrosion resistant materials. The selection of materials is dependent on the type of water and conditions encountered.

CHOICE OF PRIME MOVERS

Before the pumps can be selected, a choice of prime movers should be made. In this case, variable speed, 2-shaft gas turbine engines were selected as the prime movers. The selection of these prime movers was based on the availability of low cost fuel and ease of automating. The turbine horsepower rating was in the 1000 horsepower range with a maximum speed of 22,300 RPM. The unitizing of the gas turbine with a high RPM centrifugal pump could be accomplished much easier than with a slower RPM plunger pump. This factor influenced the selection of centrifugal pumps which rotated at a maximum speed of 3870 RPM. The centrifugal pumps selected were horizontal, split-case, double-volute, 6-stage pumps rated at 33,500 BWPD at 1200 psi discharge pressure. The pump cases were designed for 2000 psi working pressure. This pressure can be obtained by installing 2 pumps in series.

Other prime movers under consideration were electric motors and piston-type gas engines. Electric motors are available in the 1000 HP range. The most common are 1800 and 3600 RPM motors. Other speeds are available upon special request. Piston type engines are available in this horsepower range in the high, medium, or slow speed range.

FLEXIBILITY OF OPERATION

Centrifugal pumps, by design, possess a high degree of flexibility. Normally in a high pressure water flood, the initial pressures are low and the volumes are high for reservoir fill-up. This fill-up period normally covers a period from 2 to 3 years, depending upon reservoir voidage. As can be seen from the volume head curve in Fig. 1, the centrifugal pump possesses this type of flexibility. Flexibility in multi-stage centrifugal pumps can also be obtained by changing speed, destaging, or trimming impellers. For this plant, 6-stage centrifugal pumps were purchased but with only 5 stages installed. The 5 stages should satisfy requirements for the first 3 to 4 years of operation. When additional head is required, the additional stage can be installed.

Plunger pumps have flexibility as shown by the chart in Fig. 2. In plunger pumps, the head and volume can be varied to satisfy almost any condition by changing RPM and the size of the plungers.

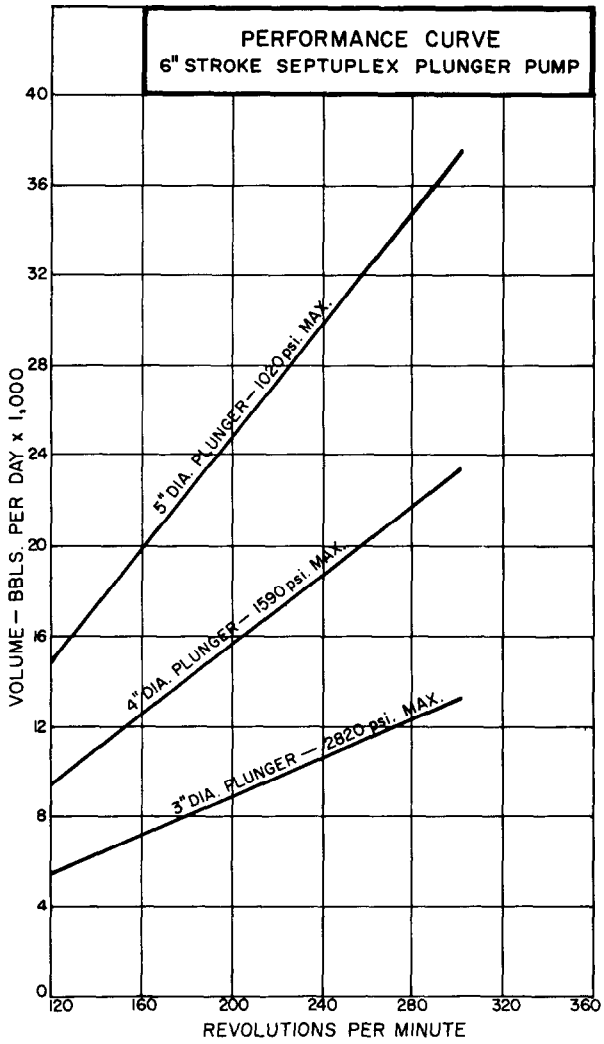

FIG. 1

PUMP EFFICIENCIES

The greatest single disadvantage of centrifugal pumps is their low efficiency. In low volume ranges, efficiencies of 50 to 75% can be expected. As the volumes increase above 10,000 BPD, efficiencies range from 75 to 85%. This inherent low efficiency requires greater horsepower than do higher efficiency plunger pumps. This additional horsepower in operating cost can be calculated.

Taking a specific point of 37,500 BPD at 1250 psi discharge pressure on the curve in Fig. 1, the horsepower requirement for the centrifugal pump, with an efficiency of 79.5%, is 1000 hp. The horsepower requirement for a plunger pump for the same conditions, at an efficiency of 90%, is only 885 hp. Using a fuel consumption rate of 11.0 cu. ft. per brake horsepower hour for the gas turbine, the fuel cost difference due to efficiency can be determined. Using a gas cost of 16 cents per MCF, with a gas heating value of 1000 BTU per cu. ft., cost to operate the gas turbine with a centrifugal pump is approximately $1270 per month. The cost to operate the gas turbine with a plunger pump under the same conditions is only $1120 per month. This is a saving of $150 per month as a result of the efficiency of the plunger pump over the centrifugal pump.

Most water flood projects are designed to operate for periods ranging from 8 to 18 yr. Using an average life of 13 yr., a saving of $23,400 in operating expense would be realized.

SPACE REQUIREMENT

In the West Texas and New Mexico area, space requirement of pump installations is not a significant factor. In congested areas and on off-shore installations, space is of major concern. In cases such as these, centrifugal pumps would probably be more satisfactory. This is due to their smaller size and lighter weight. In this installation, space requirements were not considered.

OPERATING AND MAINTENANCE EXPENSE

Operating and maintenance expenses are normally considered in one topic. However, operating expense has been previously shown by a specific example when considering pump efficiency.

Maintenance expense of pumps should be a prime consideration in selecting the type of pump to be used. Centrifugal pump maintenance was estimated to be 65 cents per installed horsepower yr. The maintenance on the plunger pump was estimated to be $1.75 per installed horsepower yr. These figures are based on past experience in the West Texas Area.

After almost 39,000 pump hr. of operation of the 3 centrifugal pumps at the Goldsmith Plant, 4 mechanical seals and 2 bearings have been replaced. Therefore, in this particular installation, the estimate of 65 cents per installed horsepower yr. may prove to be somewhat high. Maintenance expense may increase as the pumps get older.

As an example, consider the horsepower requirements used in the pump efficiency topic and project maintenance cost for a period of 13 years. The horsepower requirements were 1,000 for the centrifugal pump and 885 for the plunger pump. Using the above maintenance figures for an average 13 yr. period, the centrifugal pump indicated a savings of $11,500 over the plunger pump.

There are other factors under operating and maintenance expense which have no fixed value. Two of these are down-time and water leakage.

Down-time of high pressure water injection plants should be avoided. Some ideas have been formulated as to how much value should be allowed for down-time. Where allowable is determined on a voidage replacement formula, the advantages of a low down-time centrifugal pump installation can easily be seen.

Centrifugal pumps with mechanical seals provide an installation with minimum leakage. The plunger pumps, on the other hand, are very difficult to pack-off. In most plunger pumps, leakage will be present around the plungers. This creates a maintenance problem in clean-up and allows corrosion on external surfaces.

Operations are much smoother with centrifugal pumps because pulsation and vibration are reduced to a minimum. Plunger pumps in most cases require the installation of pulsation dampeners. In some installations where pulsation dampeners were not used on plunger type pumps, maintenance and down-time became prohibitive. This was caused by water hammer which resulted in piping and pump part failures.

Plunger pumps require large oil reservoirs for

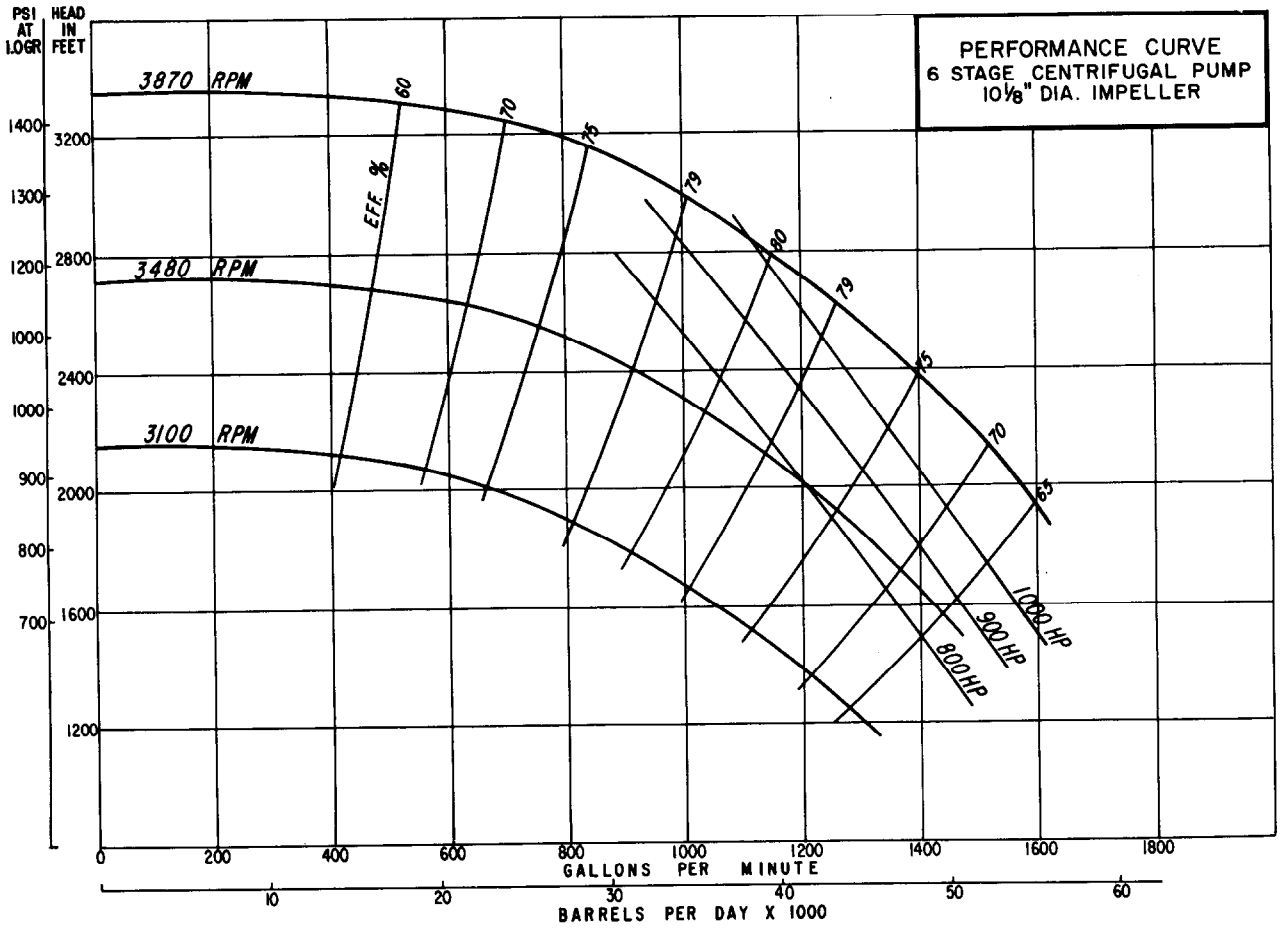

FIG. 2

the lubrication of the many moving parts. Centrifugal pumps, on the other hand, require very little oil for their lubrication system.

INSTALLATION COSTS

In this installation, both the prime mover and the pump were installed concurrently with plant construction; therefore, their cost cannot be separated from the total plant cost.

A heavy concrete foundation, having a minimum foundation-weight to pump-weight ratio of 3 to 1, is desirable so that the natural vibrations of the machines will be absorbed and will not be transmitted to the piping. Weight of the plunger-type pump is approximately 6 times greater than the centrifugal pump; therefore, foundation costs for plunger pumps would be much greater.

Centrifugal pumps are easily adapted to outdoor installations. Fig. 3 is a view of the Goldsmith high pressure water injection pumps showing the arrangement of pumps, turbines, etc. This is essentially an outdoor installation, with only the controls housed in a small building. The centrifugal pumps have been unitized with gas turbines and mounted on oil field skids. Foundations for the pumps consist of a small concrete slab approximately 18 in. thick. Provision has been made for future expansion by the installation of additional units to be connected in series with the existing units to obtain plant pressure of 2000 psi.

Several different high pressure water injection plants are shown by Figs. 4, 5, 6, and 7.

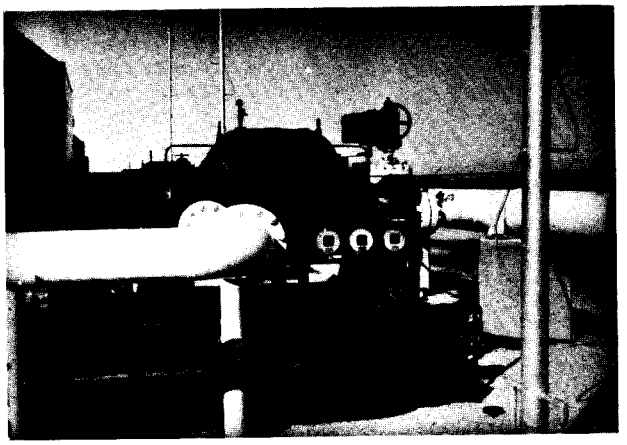

FIG. 3
Centrifugal pumps supply high pressure water for injection into the Goldsmith (5600') Lease, Ector County, Texas. These pumps are driven by 1000 horsepower gas turbine engines.

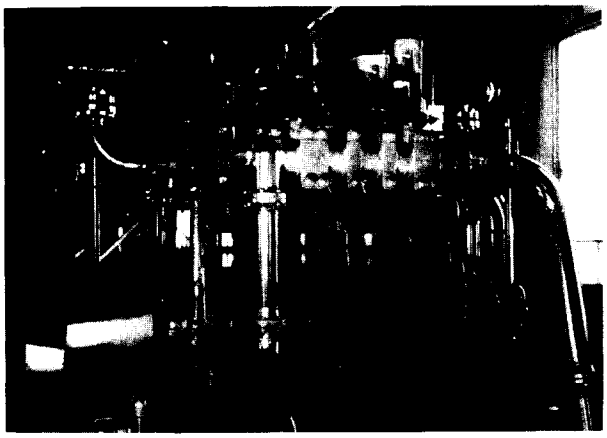

FIG. 4
A plunger pump installation that supplies high pressure water for injection. These pumps are driven by 514 horsepower piston type gas engines.

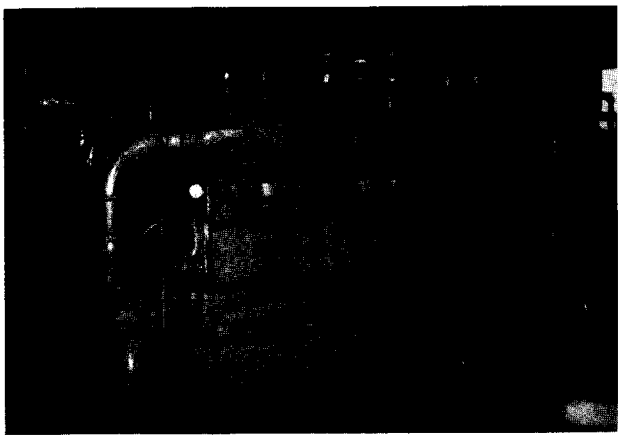

FIG. 6
A plunger pump installation that supplies high pressure water for injection. These pumps are driven by 287 horsepower piston type gas engines.

FIG. 5
A centrifugal pump installation that supplies high pressure water for injection. These pumps are driven by 700 horsepower electric motors.

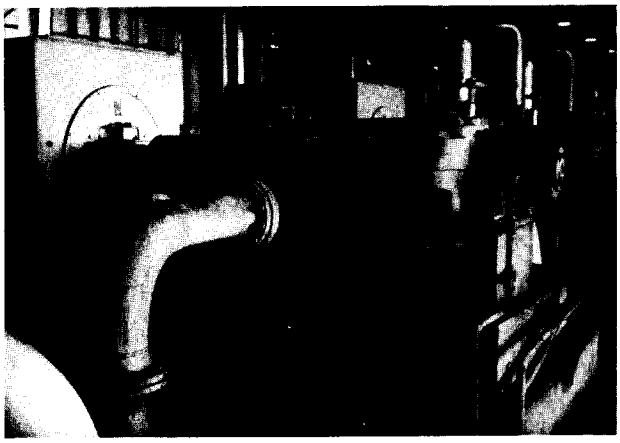

FIG. 7
A centrifugal pump installation that supplies high pressure water for injection. These pumps are driven by 300 horsepower electric motors.

INITIAL COST

The initial cost of a 6-stage centrifugal pump, rated at 37,500 BPD at 1250 psi, with premium metallurgy, ranges from $15,000 to $20,000. This consists of a pump with all water-wetted parts constructed of alloys such as 316 stainless steel, Monel, etc.

The initial cost of a similar capacity plunger pump with non-corrosive metals is approximately $40,000 each. The difference in initial cost shows a savings of $20,000 per pump by using the centrifugal type.

LIFE OF INJECTION PLANT

The expected life of the injection plant should be considered when selecting the type of pump to be used. In an average case of 13 yr. expected life, a salvage value of 10% of the initial cost of the pumps appears reasonable.

Using the initial cost figures stated in the previous topic, the salvage value would be $2,000 and $4,000, respectively, for the centrifugal pump and the plunger pump. Assuming the useful life of both pumps the same, it can be seen that the life of the injection plant influences the pump selection based on the salvage value.

CONCLUSION

It is felt that where low cost power is available for prime movers, which was true in this case, centrifugal pumps comprised a more economical and more flexible high pressure water injection installation. Centrifugal pumps normally require less attendance

than do plunger pumps. In this case, a high RPM prime mover was selected; therefore, the ease of unitizing a high RPM pump was effected. The centrifugal pump indicated a direct saving of $6,000 per pump based on an average 13 yr. life.

Centrifugal pumps can be designed for almost any condition of high pressure water injection, but there are certain conditions where plunger pumps are more economical. When the volumes are low and the head high, plunger pumps are usually more economical.

This paper does not include all the considerations in selecting high pressure water injection pumps; however, it calls attention to most of the major factors. It is intended to point out the items that might be of assistance in the selection of high pressure water injection pumps.

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