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Grout Pump Selection Process for the Transportable Grout Facility

**D. McCarthy
R. L. Treat**

January 1985

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GROUT PUMP SELECTION PROCESS
FOR THE TRANSPORTABLE GROUT
FACILITY

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Richland, Washington 99352

SUMMARY

Selected low-level radioactive liquid wastes at Hanford will be disposed by grouting. Grout is formed by mixing the liquid wastes with solid materials, including Portland cement, fly ash, and clay. The mixed grouts will be pumped to disposal sites (e.g., trenches and buried structures) where the grout will be allowed to harden and, thereby, immobilize the wastes.

A Transportable Grout Facility (TGF) will be constructed and operated by Rockwell Hanford Operations to perform the grouting function. A critical component of the TGF is the grout pump. A preliminary review of pumping requirements identified reciprocating pumps and progressive cavity pumps as the two classes of pumps best suited for the application. The advantages and disadvantages of specific types of pumps within these two classes were subsequently investigated. As a result of this study, the single-screw, rotary positive displacement pump was identified as the best choice for the TGF application. This pump has a simple design, is easy to operate, is rugged, and is suitable for a radioactive environment. It produces a steady, uniform flow that simplifies suction and discharge piping requirements. This pump will likely require less maintenance than reciprocating pumps and can be disassembled rapidly and decontaminated easily.

If the TGF should eventually require discharge pressures in excess of 500 psi, a double-acting duplex piston pump is recommended because it can operate at low speed, with only moderate flow rate fluctuations. However, the check valves, stuffing box, piston, suction, and discharge piping must be designed carefully to allow trouble-free operations.

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1.0 INTRODUCTION

A Transportable Grout Facility (TGF) Project (B-475) was initiated under the management of Rockwell Hanford Operations (RHO) to dispose of selected low-level radioactive liquid wastes by grouting. The TGF mixes liquid wastes with grout-forming solids to form a grout slurry, which is subsequently pumped to on-site disposal locations. Low-level radioactivity is immobilized when the grout slurry hardens. Grout-forming solids include Portland cement, fly ash, and clays. Disposal locations may include buried culvert vaults and large open trenches, depending on the hazards and costs involved.

The TGF is currently scheduled for operation in May, 1986. Design efforts recently initiated defined the need to select the type of pump to be used. A preliminary review of candidate pumps identified reciprocating pumps and progressive cavity pumps as the two classes of pumps best suited for the application. Pacific Northwest Laboratory (PNL) subsequently evaluated the advantages and disadvantages of these two classes of pumps and recommended one for TGF service.

2.0 THE PUMP SELECTION PROCESS

The pump selection process integrates the requirements of the application with the operating characteristics of pumps available in the marketplace. The process results in the selection of a pump that will meet the design requirements for the application.

The selection decision should be based on criteria defined in advance. The decision criteria for this evaluation included only non-economic (technical) considerations (e.g., ease of operation, maintenance requirements, suitability for a radioactive environment, ruggedness, and flexibility).

2.1 THE APPLICATION

Dry grouting materials will be mixed with low-level radioactive wastes in the TGF. The TGF (see Figure 1) will contain a pump to transfer the grout slurry to a disposal site. The fluid characteristics of the slurry and the hydraulics of the pump system will define the operating environment of the pump.

The characteristics of the slurry will depend on the physical and chemical properties of the dry powder feed and the liquid low-level radioactive wastes that are mixed to create the slurry. The design properties of the dry grouting materials are summarized in Table 1. The dry grout consists of a mixture of fine materials, including fly ash, Portland cement, clay and other additives.

The low-level liquid radioactive wastes may exhibit the properties indicated in Table 2. The properties may change as more information about the waste becomes available. The waste will be alkaline, with few suspended solids, and will contain a wide variety of radionuclides.

The grout slurry is expected to exhibit the properties listed in Table 3. The mixture is a non-Newtonian fluid that can display pseudoplastic, Bingham plastic and thixotropic flow behavior. This fluid will exhibit a variety of rheological properties and must be pumped at a nominal 50 gpm (30 - 70 gpm range) against a discharge pressure of 165 psig (50 - 350 psig range).

FIGURE 1. Transportable Grout Facility Process Flow Diagram

TABLE 1. Physical Properties and Values of Dry Grouting Materials

Property	Definition of Property	
	Typical Value	Range of Values
Constituents		
Fly Ash	50 wt%	30-80 wt%
Portland Cement	40 wt%	20-50 wt%
Various Clays	10 wt%	0-10 wt%
Additives	Nominal	Nominal
Size Distribution		
% less than 325 mesh	80	80
Shape		
Spherical	Fly Ash	Fly Ash
Angular	Others	Others
True Density		
Fly Ash	2.3 g/cc	
Portland Cement	3.2 g/cc	
Various Clays	2.5 g/cc	
Bulk Density		
Fly Ash	1.0 g/cc	
Portland Cement	1.6 g/cc	
Various Clays	0.7 g/cc	

TABLE 2. Properties and Approximate Values of Low-Level Liquid Waste

Property	Approximate Value
Radionuclide Concentration	0.0005 - 2 Ci/L
Suspended Solids	Less than 20 wt%
Size Distribution of Solids	Most less than 325 mesh
Temperature	15° to 45°C
Viscosity	Less than 20 cp
Density	Less than 1.3 g/cc
pH	About 12

TABLE 3. Properties and Values of the Grout Slurry

Property	Definition of Property	
	Typical Value	Range of Values
Suspended Solids	50 wt%	40-60 wt%
Density	1.4 g/cc	1.3-1.7 g/cc
Temperature	25°C	10°-40°C
pH	13	12-14
Rheology		
Apparent Viscosity	50 cp	10-100 cp
Power Law Fluid Coefficients		
n'	0.50	0.35-0.77
k'	0.02	0.0035-0.05
Gel Strength	40 lb/100 ft ²	22-56 lb/100 ft ²
Abrasiveness	High	Very High

2.2 SURVEY OF AVAILABLE PUMPS

Many kinetic and positive displacement pumps are available in the market-place. Each pump class is designed to provide a specific range of pump capacities and discharge pressures. The energy transferred to the liquid in a kinetic pump is kinetic energy that is nonuniformly imparted to the liquid with subsequent distribution throughout the liquid. A positive displacement pump causes liquid to flow in volumetric proportion to an alternating increase and decrease of the volume in the pumping chamber (AIChE 1960).

Types of available kinetic and positive displacement pumps are shown in Figure 2. The TGF application was considered during the review of these pumps in the literature and in present industrial practices.

A useful guide to the selection of common process pumps was published by W. H. Stindt (1971). Stindt prepared a nomograph that gives pump capacity and power as a guide for pump selection (Figure 3). The specific TGF criteria of 70 gpm and 350 psig falls within the capacity of positive displacement pumps.

FIGURE 2. Types of Pumps

FIGURE 3. Pump Selection Chart

Many positive displacement pumps are identified in the literature (Pump 1971, Dalstad 1977, Nearkin 1974). They are listed in Figure 2. A survey of 28 vendors revealed that a variety of positive displacement pumps including: reciprocating positive displacement; piston, plunger and diaphragm pumps; and the rotary single screw pump; have been successfully applied in similar grouting applications.

3.0 RECIPROCATING POSITIVE DISPLACEMENT PUMPS

Reciprocating pumps can be characterized as steam, power, or controlled volume pumps (Hydraulics 1983). A steam pump is driven by a reciprocating steam engine. A cross-section of a steam pump is depicted in Figure 4. Compressed air or natural gas can be used in place of steam to move the piston or plunger.

A power pump is a reciprocating pump driven by power from an outside source applied to the crankshaft of the pump. A reciprocating power pump is a controlled-volume pump used to displace a predetermined volume of fluid in a specified time period. It is driven by power from an outside source applied to the pump mechanism. It includes a mechanism for adjusting the effective plunger, piston or diaphragm displacement (Hydraulics 1983).

3.1 OPERATING CHARACTERISTICS

Piston, plunger and diaphragm pumps rely on the reciprocating motion of a rod to effect fluid flow. Plunger and piston pumps each have suction valves, discharge valves and a stuffing box that will contact the motive fluid

FIGURE 4. Cross-Section of a Steam Pump

(Figure 5). The fluid enters through the suction valves as the reciprocating element retreats. As the element advances the fluid forces the suction valves closed and applies pressure to the discharge valves. The discharge valves open and the fluid exits the liquid end of the pump. The reciprocating element retreats and the cycle is repeated (Poynton 1979).

Diaphragm pumps also rely on a reciprocating element to effect fluid motion (Bristol 1981). However, the reciprocating element is designed to avoid contact with the fluid being pumped. The element contacts a hydraulic fluid or air which in turn contacts a diaphragm. The diaphragm imparts motion to the fluid (Figure 6). The fluid is separated from the reciprocating element and the stuffing box in a diaphragm pump.

The volume pumped by a reciprocating pump is a function of the speed of the reciprocating element, the area of the plunger, piston or diaphragm, and the length of the plunger, piston or diaphragm stroke. This relationship is depicted in Figure 7. The theoretical volume pumped must be corrected for mechanical inefficiencies and fluid slip.

The capacity of a reciprocating pump operating at a constant speed is independent of the pressure at the pump discharge (see Figure 8). The pump will deliver its rated capacity until the pressure increase at the pump discharge causes the pump motor to exceed its rated capacity. This pressure-capacity characteristic must be considered when reciprocating pump systems are

FIGURE 5. Plunger and Piston Power Pumps

FIGURE 6. Hydraulically-Actuated Diaphragm Pump

FIGURE 7. Reciprocating Pump Operating Principles

FIGURE 8. Pump Performance at Constant Speed

designed. The motor must be sized carefully and the discharge piping must be equipped with a pressure relief system in each reciprocating pump installation. The pressure relief system recommended by the Hydraulics Institute is included in Figure 9.

The capacity of a reciprocating pump will increase linearly with speed for a given discharge pressure as shown in Figure 10. This characteristic allows reciprocating pumps to function effectively as metering pumps. The change in speed can be accomplished with mechanical gearboxes, hydraulic drives or variable frequency alternating current (AC) speed controllers. The means of speed control selected will depend on the application. If high start-up torques are likely, mechanical gearbox speed controllers are usually specified.

Schematic for Pumps with Single Discharge Connection

Schematic for Pumps with Dual Discharge Connections

FIGURE 9. Schematics of Liquid By-Pass Systems

FIGURE 10. Pump Performance at Constant Pressure

Reciprocating pumps deliver a pulsating flow of fluid. The degree of pulsation will depend on the design of the pump. Single-acting, simplex (one pump head) pumps will create variations in velocity that can vary from 1 to 100 percent of the design velocity. As the number of pump heads attached to the drive end of a single-acting pump increases, the velocity variations created will decrease (Table 4).

Double-acting piston pumps (Figure 5) deliver fluid with fewer pulsations than are created by similarly configured single-acting pumps (Pump 1971). The velocity of liquid entering and leaving a single-acting pump falls to zero twice per pumping cycle. The resulting flow velocity for a duplex double-acting pump is almost constant. The flow discharged from one side of the pump begins before the flow from the other side has ceased. The resulting overlap in discharge flow results in a relatively smooth (± 10 percent) flow in both the

TABLE 4. Velocity Variations of Power Pumps

<u>Single Acting Pumping Elements (number)</u>	<u>Type of Pump</u>	<u>Velocity Variation (%)</u>
1	Simplex	200
2	Duplex	160
3	Triplex	25
5	Quintuplex	7
7	Septuplex	4
9	Nonuplex	2

Source: Henshaw, 1981.

suction and discharge lines. The relatively smooth flow profile in double-acting duplex piston pumps has helped this pump design become the pump of choice in many grouting applications.

Substantial flow fluctuations can make flow monitoring and control difficult, induce cavitation, lead to solids deposition in pipe runs and pipe fittings, and cause other problems. To reduce the severity of problems caused by pulsating flow, the Hydraulics Institute and the American Petroleum Institute (API) recommend the installation of pulsation dampeners on the suction and discharge side of reciprocating pumps. Three common pulsation dampener designs are depicted on Figure 11. Each design is a wide spot in the line that allows

FIGURE 11. Three Common Pulsation Dampener Designs

velocity fluctuations to stabilize (Ekstrum 1981). Figure 11a shows a typical pulsation dampener, consisting of a shell (A) which is connected into the line to or from the pump by the connections (D). The vessel is charged with a gas (B) through the connection (E) to a predetermined pressure. Figure 11b shows a pulsation vessel that has a polished finish and connections suitable for food applications. Figure 11c shows an alternative design for food applications that has a single connection to the pipeline and the gas is contained in a rubber bag. Some residual solids in grout slurries may be deposited in the pulsation dampeners, which could hamper the process.

The pulsating flow characteristic of reciprocating pumps can complicate the design of pump suction piping. Energy must be expended to accelerate the liquid flow in the suction side of the pump to prevent cavitation in the suction pipe and in the pumping chamber. This acceleration head is a component of the net positive suction head (NPSH) required by each reciprocating pump. The NPSH is defined as the difference between suction pressure and the vapor pressure of the liquid being pumped, measured at the pump suction nozzle when the pump is running. The NPSH is the energy required to push the suction valve(s) from its seat, overcome pipe friction losses, and accelerate liquid in the suction piping. The NPSH required by reciprocating pumps exceeds the head required by rotary screw pumps. Most reciprocating pump vendors recommend that the available NPSH be at least 5 psia. This requirement decreases as the pump speed decreases.

To increase the available NPSH, vendors recommend enlarging the diameter of suction piping, reducing the length of suction piping, installing a suction stabilizer (reduces acceleration head), elevating the level of the liquid in the suction feed tank, reducing the temperature of the liquid, and reducing the speed of the pump. The Hydraulics Institute has incorporated these suggestions in its recommended suction piping design for reciprocating pumps (Figure 12).

Pulsating flow can induce cavitation in reciprocating pumps. Some liquid may vaporize to fill the cavities created during a low flow pulse. The collapse of vapor bubbles as they reach a region of higher pressure within the pump causes cavitation (Budris 1980). Cavitation can reduce capacity, damage

FIGURE 12. Suggested Piping System for Power Pumps

pump components, increase sound and vibration levels and exacerbate flow and pressure pulsations at the pump discharge.

The TGF will employ a continuous mixer for mixing dry grouting solids with the liquid low-level waste. The mixer is likely to entrain some air in the slurry it produces. This entrained air will cause problems similar to those created by cavitation. Pump vendors advised that the amount of entrained air in reciprocating pumps be kept to less than 0.5 to 1.0 percent of the volume pumped.

3.2 STUFFING BOX DESIGN

The stuffing box of a reciprocating pump is a cylindrical cavity through which the plunger or piston rod reciprocates and in which liquid leakage is controlled by means of packing. The stuffing box contains a flexible packing material and the hardware necessary to assure a good seal between the packing and the reciprocating element (plunger, piston rod, piston). The packing is used to control the leakage of fluid from the wet end to the drive end of the pump.

Packings for piston pumps are installed between the piston rod and cylinder head (Figure 5) and between the piston and the cylinder wall (Figure 13). Packings are expendable, reducing wear on more costly parts, flexible to conform to the shape of adjacent parts, and usually relatively soft (Rothman 1973, Hayle 1978). Packing is installed to permit adjustment for the best balance between leakage and wear of both the packing and the parts it contacts.

A typical stuffing box design for a piston pump application is depicted in Figure 14. The interlocking packing gland - bushing-follower ring arrangement is used to guide the piston rod as it reciprocates and to adjust the packing as it wears over time.

The stuffing box depicted in Figure 14 does not contain a lantern ring. A lantern ring is placed in a stuffing box to provide an annular space for the introduction of a barrier fluid as a lubrication. The holes in the center of the lantern ring permit free circulation of fluid or lubricant around the piston rod on both sides of the ring. The pressure of the fluid or lubricant applied to the packing must be adjusted to a level that exceeds the pump discharge pressure to prevent process fluid leakage past the packing.

It may be possible to design a packing that will operate without external lubrication. A non-lubricated packing would be easier to incorporate into the TGF design. The design of an effective non-lubricated packing will be difficult to accomplish, however. Packings are usually braided fabrics impregnated with tetrafluoroethylene (TFE), graphite or other solid lubricants, or with oil or grease. Heat and friction will cause packings to degrade over time. Non-lubricated packings will wear out at a faster rate than lubricated packings.

FIGURE 13. Available Piston Configurations

The packing between a piston and the cylinder wall reduces the "slip" of process fluid past the piston during the piston discharge stroke. The piston design recommended for "grout" service is the slush piston depicted in Figure 13.

A typical stuffing box design for a plunger pump is depicted on Figure 15. This stuffing box arrangement includes a packing ring, gland and bushing, similar in design to those found in a piston pump. A lantern ring was included on Figure 15 since pump manufacturers recommend packing lubrication for plunger pumps. This recommendation stems from the fact that the plunger element is in direct contact with the abrasive grout mixture and the packing.

FIGURE 14. Stuffing Box Design for a Piston Pump Application

The plunger introduces solid particles to the surface of the packing. If these particles are not flushed away, abrasion of the seal face and plunger can be severe.

The flushing fluid or lubricant supplied to the lantern ring must be free of suspended solids, chemically compatible with other stuffing box materials of construction, and at a cool temperature. The fluid or lubricant must be delivered at a pressure that is higher than the discharge pressure of the pump to assure that it will be properly distributed at the shaft-packing interface and limit the penetration of solids into the seal/shaft contact area. The delivery pressure must be adjusted as necessary to mimic changes in the pump discharge pressure. A high delivery pressure will result in excess lubrication and subsequent dilution or contamination of the process fluid. A low delivery

FIGURE 15. Stuffing Box Design for a Plunger Pump

pressure will prevent proper lubrication and could allow process fluid to flow from the liquid end to the drive end of the pump.

Industrial standards for packing have been established by the fluid Sealing Association (FSA), the National Fluid Power Association (NFPA) and the American Society of Lubrication Engineers (ASLE).

3.3 CHECK VALVE DESIGN

The suction and discharge valves on the liquid end of a reciprocating pump are opened by the liquid passing through them, and closed by gravitational forces and the action of a spring. Pump manufacturers usually recommend the wing or the disc valve designs depicted in Figure 16 for grout applications.

The specific design of the valve, seat and spring is usually established by experience for each application. The materials of construction, spring tension, and valve-seat clearance for each valve are critical to its performance in grout applications. The valve materials must withstand the abrasive and corrosive grout environment. This environment will induce wear on the valve

FIGURE 16. Wing and Disc Valve Design

and valve seat and impair the performance of the pump. Worn valves can lead to pump priming difficulties, mechanical damage and loss of capacity. The spring tension must be adjusted to allow the valve to open completely and close fully. The appropriate spring tension is usually established during operation.

The maximum size particle that will flow freely through the valve is limited by the the valve-seat clearance when the valve is fully opened. The pump vendors contacted agreed that one-eighth inch is the maximum particle dimension that will flow through reciprocating pumps sized for the TGF application. This limitation makes it likely that hardened grout particles or other debris will lodge in the valve mechanism from time to time. The frequency and duration of these valve obstructions will have to be determined empirically. Oak Ridge National Laboratory has had success in reducing the frequency of obstructions by increasing spring tension. Another method of freeing obstructions is to increase the capacity of the pump. The increased fluid velocity in the valve may dislodge the obstruction. If this procedure fails, the pump must be flushed with clean liquid or solvent. If flushing fails to dislodge the particles, then the valves must be removed and cleaned.

4.0 ROTARY SCREW PUMPS

A rotary pump is a positive displacement pump consisting of a chamber containing gears, cams, screws, vanes, plungers or similar elements actuated by the rotation of the drive shaft or casing, and which has no separate inlet and outlet valves (Hydraulics 1983). Rotary pumps are usually identified by the type of pumping element utilized. The various types of rotary pumps are identified in Figure 2, and illustrated in Figure 17.

Rotary pumps have been used in a variety of applications (Nearkin 1980, McKelvey 1976). However, only the single screw rotary pump appears capable of handling 70 gpm of grout at 350 psig.

4.1 OPERATING CHARACTERISTICS

Rotary single screw pumps (also known as progressive cavity pumps) have a rotor with external threads and a stator with internal threads (Figure 18). The rotor threads are eccentric to the axis of rotation. The rotor turns eccentrically within a double-threaded helical stator of twice the pitch, forming a series of sealed cavities 180 degrees apart. These cavities progress from suction to discharge as the rotor turns. As one cavity diminishes, the opposite cavity is increasing at exactly the same rate. The result is a constant, uniform, non-pulsating flow between the cavities and thus through the pump.

The capacity of a rotary pump is equal to

$$Q = \frac{DN}{231} - S \quad (1)$$

where: Q = capacity, gpm

D = displacement, in³/revolution

N = revolutions/minute

S = slip, gpm

The displacement of a rotary pump is the volume displaced per revolution of the rotor. It may be calculated from the physical dimensions of the pumping elements, or it may be determined empirically as the volume of fluid pumped per

FIGURE 17. Rotary Pumps

revolution at zero differential pressure. The slip, S , is the quantity of fluid which leaks through internal clearances of a pump per unit time. Slip is dependent upon internal clearances, differential pressure, the characteristics of the fluid handled, and in some cases, on the speed (Hydraulics 1983).

FIGURE 18. Rotary Screw Pump

The capacity of a rotary pump varies directly with rotational speed (Figure 10) and is relatively independent of pressure (Figure 8). The discharge pressure attained by a rotary pump can affect fluid slip. Slip tends to increase as pressure increases and viscosity decreases. Prudent rotary pump designers empirically define the capacity-rotational speed relationships for individual pumps during performance tests that simulate the environment that the pump will encounter.

A rotary pump will deliver its rated capacity until the pressure increase at the pump discharge causes the pump motor to exceed its rated capacity. This pressure-capacity characteristic must be considered when rotary pump systems are designed. The motor must be sized carefully and the discharge piping may require a pressure relief system in each rotary pump installation. The pressure relief system recommended by the Hydraulics Institute was described in Figure 9.

The linear speed-capacity relationship allows rotary pumps to function effectively as metering pumps. The change in speed can be accomplished with mechanical gearboxes, hydraulic drives or variable frequency alternating current (AC) speed controllers. The means of speed control selected will depend on the application. Mechanical gearboxes are specified in most rotary pump metering applications.

Rotary pumps deliver a uniform, nonpulsating flow of fluid. This constant volume characteristic reduces flow monitoring and control difficulties, eases suction piping restraints, and makes rotary pumps relatively easy to operate. Rotary pumps are not as sensitive to entrained air as reciprocating pumps. Single screw rotary pumps employed in grouting applications are frequently equipped with an "open throat" design. This design allows grout to fall directly into the suction port of the pump. Air entrained in the grout is pumped along with it. The entrained air reduces the net amount of grout pumped but does not adversely affect the operation of the pump.

4.2 MECHANICAL SEAL DESIGN

The stuffing box of a rotary pump is a cylindrical cavity in which the rotor shaft rotates and in which fluid leakage from the wet end to the drive end of the pump is controlled. Mechanical seals are usually employed to minimize or prevent leakage in single screw rotary pumps.

A mechanical seal consists of rotating and stationary elements with opposed seal faces. A typical mechanical seal design for a rotary screw pump is included as Figure 19. One rotating primary element is fastened and sealed to the shaft. A second primary element is mounted or sealed to the end plate or body of the pump or stuffing box. Primary seal faces are often highly lapped surfaces of materials selected for low friction and for resistance to corrosion and erosion by the fluid being pumped. Secondary seals prevent leakage around the primary seals. Mechanical hardware is used to maintain the proper degree of contact between seal elements.

Mechanical seals may fail because of installation errors or poor seal design (Hawk 1980, Jones 1980). Installation problems can occur as a result of dirt (rust) on seal faces, damaged faces, worn shaft bearings or a poorly aligned stuffing box. Most improper seal designs can be traced to springs or elastomers that are unable to compensate for shaft fluctuations. As the fluctuations occur, the seal begins to leak. As leakage continues, the soft primary element faces erode. As faces erode, leakage increases until failure occurs.

FIGURE 19. Mechanical Seal Design for a Rotary Screw Pump

Lubrication is usually applied to mechanical seals in grouting applications to keep abrasive and corrosive materials away from seal parts. A solids-free, cool liquid is usually employed. The liquid must be delivered at a pressure greater than the pressure at the suction side of the rotary screw pump. A delivered pressure of 15 - 20 psig will be adequate in most instances.

The amount and type of lubrication that will be required in the TGF application must be determined empirically. Grease or oil lubrication rates as low as 0.01 gpm may be possible. It may be possible to operate the seal without lubrication for the two week TGF operating cycle. It would be prudent to install a backup mechanical seal if the no-lubrication option is pursued. Primary seal elements are likely to erode due to heat and abrasion if they are not lubricated. The backup seal may afford some protection if the first mechanical seal fails.

The selection of a mechanical seal or a packing for the rotary pump application will ultimately depend on empirical evidence collected during TGF run simulations or actual runs. The design of the facility would be simplified if lubrication can be avoided. Mechanical seals are probably more amenable to nonlubricated operation than dry packings due to the pressure compensating properties inherent to springs.

5.0 CONCLUSIONS AND RECOMMENDATIONS

The pump selection process integrates the requirements of the application with the operating characteristics of the pump class being evaluated. In this instance, only non-economic considerations are of interest. The non-economic factors that must be considered include simplicity of design, ease of operation, maintenance requirements, ruggedness, operating flexibility, and suitability for a radioactive environment.

These factors, positive or troublesome, are summarized in Tables 5 and 6. The troublesome attributes of the positive displacement pumps arise primarily

TABLE 5. Suitability of Reciprocating Pumps for the Transportable Grout Facility Application

<u>Positive Attributes</u>	<u>Potential Troublesome Attributes</u>
High pump discharge pressure at low piston/plunger speeds (less abrasion)	Pulsating flow ($\pm 10\%$ for a double acting piston; $\pm 25\%$ for a single-acting triplex plunger; pulsation dampeners needed)
High mechanical efficiency (lower power requirements)	Pump suction requirements (more than 1% entrained air will cause pump to fail; pump priming is required, suction piping design is critical)
Capacity is a function of speed, not discharge pressure (easy to control capacity)	Disassembly is time consuming
Discharge pressures above 10,000 psig are possible	Will require periodic maintenance of check valves, stuffing box, drive-end hydraulic fluid
Many fluid heads can be driven off one drive assembly (redundancy)	Stuffing box lubrication is recommended
Power source can be separated from the drive/liquid end of pumps	Seal water delivery pressure must be adjusted to remain above the pump discharge pressure, as the pump discharge pressure fluctuates.
Self priming	Flush cleaning may not be possible
	Difficult to disassemble and decontaminate
	Maximum particle size that will pass through the valve is 1/8 inch diameter

TABLE 6. Suitability of a Rotary Single Screw Pump for the
Transportable Grout Facility Application

<u>Positive Attributes</u>	<u>Potential Troublesome Attributes</u>
Quick disassembly <ul style="list-style-type: none"> - Rotor-stator assembly can be replaced in 10-30 minutes 	Maximum discharge pressure attainable with standard designs is 500 psig
No check valves	Rotor-stator abrasion increases as discharge pressure increases
Mechanical seals can be used. <ul style="list-style-type: none"> - lower lubrication requirements - non-lubricated option 	Fluid slip increases as discharge pressure increases
Seal water, if required, can be delivered at a constant pressure as low as 10 psig	Only one vendor is available
Pump suction requirements <ul style="list-style-type: none"> - self priming - no air entrainment problems - open throat design (hopper) acceptable 	Solids can accumulate in the quiescent zone of the inlet chamber of the pump
Constant flow - no pulsations	
Constant volume <ul style="list-style-type: none"> - no dead spots likely to develop 	
Curved external surfaces, easy to decontaminate	
One inch diameter particle will pass through	

from mechanical complexity and the need for maintenance to reduce problems caused by air entrainment, cavitation, check valve plugging and stuffing box lubrication. The rotary, progressive cavity pump, by comparison, is relatively simple in design and easy to operate and maintain. It provides the same operating flexibility as other positive displacement pumps.

The primary limitation of the pump lies in its inability to effectively generate discharge pressures higher than 500 psig. Fluid slip and abrasion can be significant at higher discharge pressures.

At the present time, the TGF application requires a maximum discharge pressure of 350 psig. At this pressure, the rotary single screw pump appears to be the best pump for the application. However, if the TGF should eventually require pressures in excess of 500 psi, a double-acting duplex piston pump is recommended because it can operate at low speed, with only moderate flow rate fluctuations. However, the check valves, stuffing box, piston, suction, and discharge piping must be designed carefully to allow trouble-free operations.

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