RG ROTO-JET DESIGN
A NEW CONCEPT IN HIGH-PRESSURE PUMPS

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PUMP EVOLUTION

The pitot pump first appeared in U.S. patent history at the turn of the century. The first forms were of the open ring rotor type which had many performance limitations. During the 1920's, the basic closed rotor form was described in patents, such as shown in Fig. 1. This closed form was extensively studied in Germany in the years 1939 - 1945 (Ref. 1) for use in aircraft and rockets, and in Britain during the late 1940's. Development on this pitot pump study was stopped when it was found the design did not lend itself to being extended to flows over 5 GPM. It was also determined by this group that the pump was prone to air-locking [2] and air-bleeding methods were patented.[3] In 1959, a pitot pump study was completed and reported by the U.S. Office of Naval Research [4] in which a number of pitot pumps were built and tested. They also suggested additional research be carried out, although no research has been reported at this time. In this study, test efficiencies were reported of 25 - 30%, and head coefficient of 1.10.

In 1962, development work was started in the United States that led to the enclosed rotor spin-up passages and other concepts that form the basis of the Roto-Jet form of pitot pump. These closed rotor passages and grooved spin-up slots result in efficiency increases of 5 to 10 points and are described by Patent Nos. 3,384,024 and 3,795,459. The special diffuser construction in the pitot tube increases the efficiency by 15 points.

Another unique feature that has been developed is the ability to operate with very high inlet pressures, as the rotor can be completely pressure-balanced.

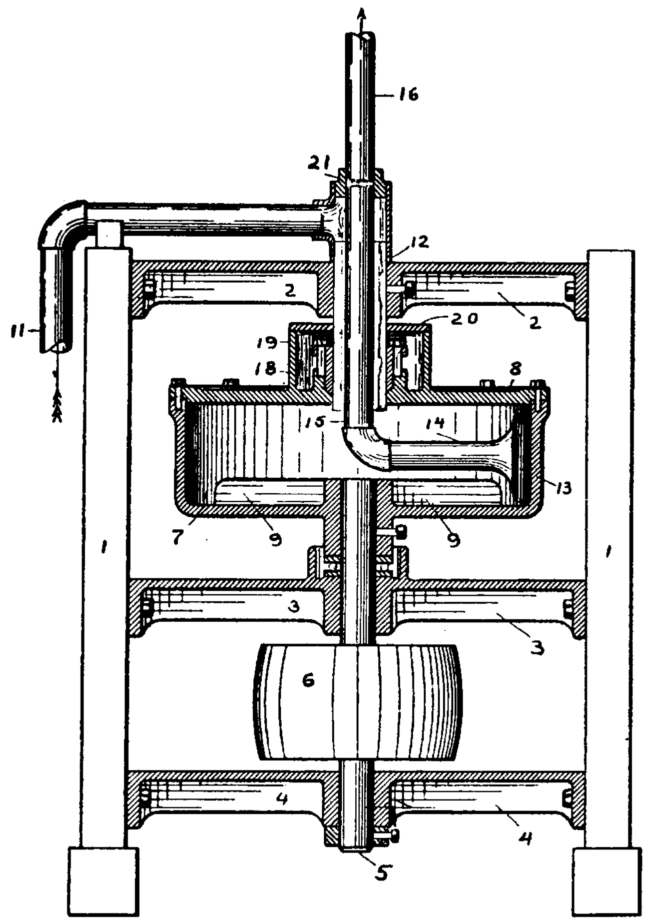

FIGURE 1

PUMP DESCRIPTION

The pitot pump, of which the Roto-Jet (Fig. 2) is one form, is a rotating fluid case (A) pump. The fluid (B) in the case is spun to the full rotational speed of the case in closed passages (I). A stationary streamlined pickup tube (C) is extended from the center (D) of the rotating case to near the inner maximum diameter (E) where its internal passage is bent (F) to impact against the flow rushing past the tube. By this arrangement, this bent end of the internal passage develops both the centrifugal force pressure of the rotating fluid and the impacted velocity pressure of the fluid rushing past the tube. The pressure developed forces the fluid down the internal passage (G) in the pickup tube and out the discharge of the pump (H).

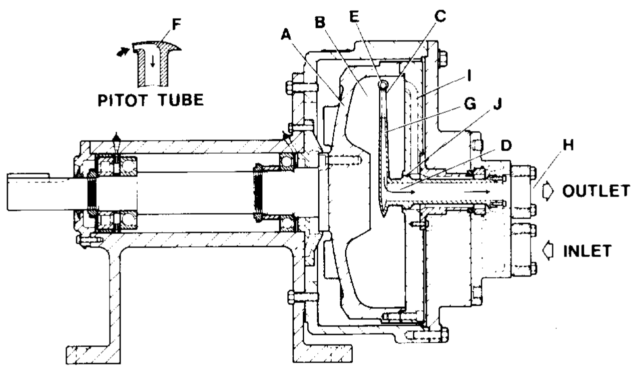

FIGURE 2

PUMP CHARACTERISTICS

Several dimensionless parameters are useful in discussing the characteristics of this pump:

Specific speed:

$$N_S = \frac{N\sqrt{GPM}}{(H)^{0.75}}$$

Suction specific speed:

$$S = \frac{N\sqrt{GPM}}{(NPSH)^{0.75}}$$

Head coefficient:

$$q = \frac{H}{U^2/2g}$$

Pump efficiency:

$$\frac{\text{Fluid horsepower out of pump}}{\text{Shaft horsepower into pump}}$$

Where:

GPM = flow rate, gal./min.
H = pump head, ft
N = rotational speed, rpm
U = maximum peripheral velocity of closed passages
g = acceleration due to gravity ft/sec^2
NPSH = minimum operating net positive suction head, ft

EFFICIENCY

Good correlation of centrifugal pump data is found when "maximum attainable efficiency" is plotted as a function of specific speed, as shown in Fig. 3. The plot was taken from AEC R&D Report AER 572. A line has been added to this curve indicating the tested performance of several production Roto-Jet pumps of various sizes. It can be seen that the unique features of this new pitot pump increase the efficiency 20 points over previous pumps in their specific speed range.

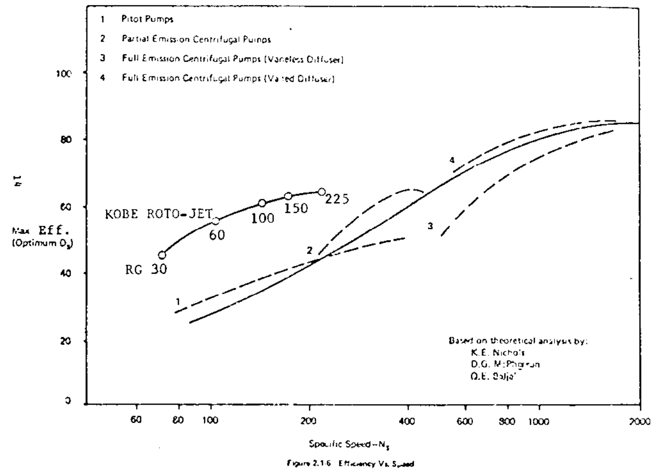

FIGURE 3

PRESSURE (VERSUS SPEED VERSUS SIZE)

For a given diametrical size and speed, the pitot pump will generate about three to four times the head of a conventional centrifugal pump. This is due to two factors:

(1) The head coefficient on the pitot pump, at maximum efficiency, is about 1.6, which is almost twice that of a standard centrifugal pump. This is the result of the fluid impacting the end of the pickup tube, causing another one-half head rise which does not occur in the standard centrifugal pump.

(2) The pitot pump does not require an external volute or radial diffuser to recover the fluid rotation or speed. The overall diametrical size of the pump is reduced by 30%, and since pressure varies as the square of the diameter, an equivalent of twice the pressure is produced for a given size. The result of this combination is approximately four times greater pressure for the pitot pump design for a given diametrical size and speed.

NPSH

The suction specific speed of the pitot pump is approximately 7500. This result compares favorably with 7900 given by Stepanoff[1] for standard single-suction centrifugal pumps. For lower inlet pressure, efficient jet pump charging is possible by use of a second shortened pickup tube in the chamber for providing jet pump power fluid as described in a recently issued patent.

AIR PURGING ABILITY

The pitot pump in its original form tends to air-lock on startup or if excessive air is contained in the water entering the pump. This finding was reported by Barske,[2] and a solution to this problem utilizing a suction pump, is shown in his patent.[3]

The closed spin-up passages of the Roto-Jet pump (I) (Fig.2) and the throttling area at (J) provide a pressurized passage of air from the main chamber into the water flowing to the pickup tube entrance. This arrangement allows the pitot pump to purge itself of air on startup. It also allows this new pitot pump to continuously pump a 10% by volume mixture of air in the water without deteriorating the pump's performance.

MECHANICAL CONSIDERATIONS

The new RG pump has the bearing system opposite the fluid side of the pump. This arrangement has two major advantages:

1. Hot or cold fluids do not have a major thermal effect on bearing performance, allowing a wide fluid operating temperature range.
2. Since the fluid seal is also on this fluid side, seal leakage cannot contaminate the lubricant and bearings. Much longer operating periods are now possible, handling fluids which would otherwise be harmful to the bearings or their lubricant.

Also, the bearing capacity has been increased to provide a 200 psig inlet pressure L-10 bearing life of 35,000 hours. All rotors are two-plane, dynamically balanced to reduce pump vibration to less than 2 mils.

PUMPING LIQUIDS CONTAINING SOLIDS

A field problem encountered was the tendency of the pump to centrifuge solids out of the liquid onto the inner surface of the rotating fluid case, causing wear on the outermost surface of the pickup tube head. A new tube geometry was developed of stellite and tungsten carbide, providing a life of 3000 hours when pumping 300 ppm of sharp silica sand in oxygenated water. When pumping sandy oils, the life is several times that in water service.

CLEANING LIQUIDS CONTAINING SOLIDS, ROTO-FILTER PUMP

Out of the pitot pump's ability to centrifuge solids from a liquid came the development of the recently introduced Roto-Filter pump (RFG), (see Fig. 4). As shown in Fig. 4, solids, containing some fluid, discharge through carbide nozzles (A) which have been positioned where the solids tend to deposit. To minimize the amount of solids/fluid flow, only two discharge nozzles are used. A unique stirring vane (B) is placed to move the solids to the nozzles. The flow is split 50:1 between clean fluid and solids/fluid flow.

The clean fluid is impacted against a shortened pitot tube (C) to provide a pressurized discharge of clean fluid. The cleaning efficiency and discharge pressure of the clean fluid are shown in Fig. 5.

DESIGN SUMMARY

The Roto-Jet pump is a developed form of the pitot pump that provides a combination of several desirable features not previously possible. For the

ROTO-FILTER
pump

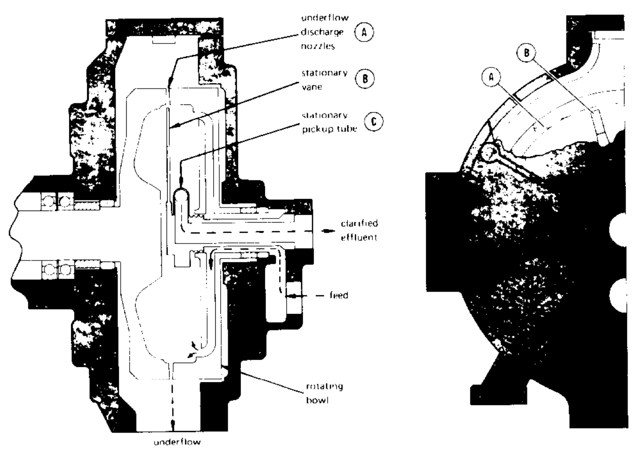

FIGURE 4

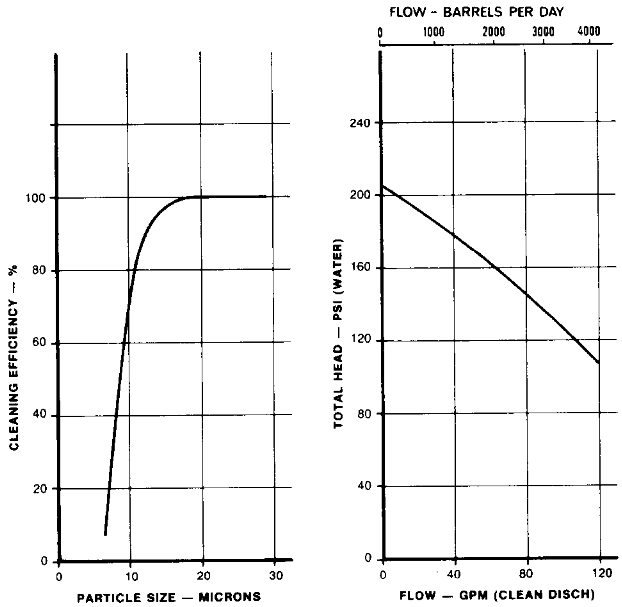

FIGURE 5

first time, the inherent *higher pressure* generating capabilities of a pitot pump are now available at *higher efficiencies* (approximately 70% greater than previous pitot pump designs) in combination with a self-air purging ability upon startup.

The Roto-Jet pump can now pump *abrasive fluids* or *obnoxious fluids* with excellent component life.

The new Roto-Filter pump has been developed from the Roto-Jet pump. It can clean solids from various liquids with flows up to 4000 BPD and provide the clean fluid at 100 psi. This product serves applications such as the cleaning of power fluid, waste and injection water, and oil processing and separation.

FUNDAMENTAL MARKETING SITUATION

Early market studies preceding the development of the new pitot pump indicated that 600 psi was a key performance point. Most important application areas were moving into pressure requirements for 600 psi and beyond, and at this performance level, multistage centrifugal pumps required too many stages to stay competitive with a single-stage pitot pump design. Consequently, the need to generate 600 psi at 3550 rpm (2-pole, 60 Hz) dictated a 16-in. diameter pitot pump design.

Existing production hardware covers the following performance range: flows of 700-11,000 BPD; pressures of 400-1200 psi. In the lower performance regions (up to 1700 BPD and 700 psi), significant competition with other existing pump designs is encountered. In this application area, the final "usage decision" will probably be determined by some of the auxiliary features and benefits relating to reliability and simplicity rather than any fundamental technical or economic performance advantage. Above 1700 BPD and 700 psi, the improved pitot pump becomes unique in its ability to reliably and economically provide desired flows and pressures. Multistage centrifugals become quite costly (when compared with a single-stage design) for generating pressures of 700 psi and above. Positive displacement designs become relatively expensive when flows in excess of 1700 BPD are needed; and they produce other inherent technical disadvantages such as pulsating flow, the need for extensive relief valving, packing replacement, etc. Initial acceptance of the Roto-Jet has, therefore, been greatest in those specific applications requiring flows and pressures above 1700 BPD and 700 psi.

APPLICATION IN THE OIL INDUSTRY

Initial oil industry market penetration and applications have indicated significant potential for this new pump in applications discussed in the following sections.

Crude Oil Transfer

A major oil producer used the RS-30 Roto-Jet pump pictured in Fig. 6 for crude oil transfer at a West Coast pumping station. The pump displaces 1029 BPD at a discharge pressure of 400 psi in a

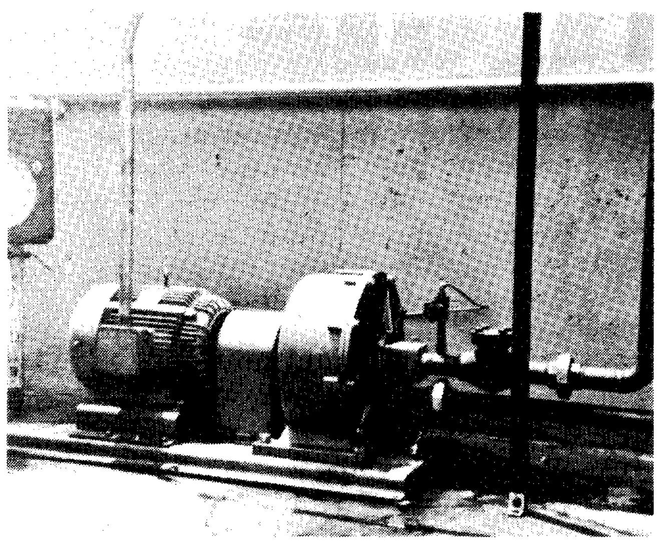

FIGURE 6

continuous duty cycle. Satisfaction with this pump led the user to purchase a second, larger pump for the same service.

Water Disposal

The Roto-Jet pump has been applied to fresh and salt water disposal at a number of installations in this country and Canada at flows ranging from 700 BPD to 7000 BPD and pressures to 900 psi. Application of the pump to this service for several years makes disposal one of the more mature Roto-Jet oilfield commitments.

Steam Generation

A 20-million BTU generator set in a California thermal flood operation equipped with an RS-60 Roto-Jet pump is shown in Fig. 7. The pump displaces 1371 BWPD at 825 psi to the generator boiler, and is only one of four applied successfully to the same service in California.

Offshore Potable Water

Reverse osmosis systems used on offshore platforms to convert sea water to potable water will soon be equipped with Roto-Jet pumps. The compact, quiet and reliable Roto-Jet operating at pressures to 1000 psi and flows to 3425 BPD is ideally suited to the stringent demands of this kind of platform service.

Hydrocarbon Transfer

The RS-100 Roto-Jet pump illustrated in Figs. 8

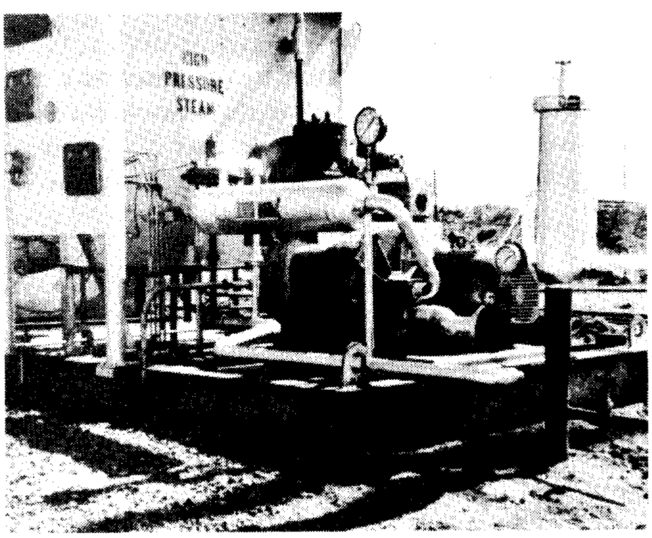

FIGURE 7

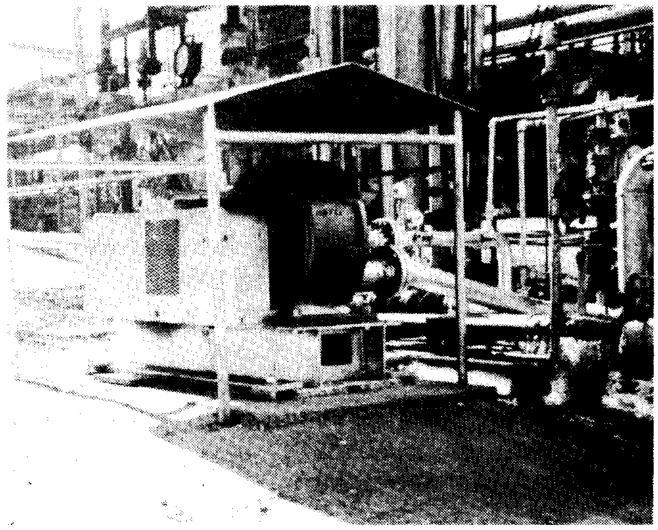

FIGURE 8

and 9 transfers 2400 BPD of hydrocarbons at 575 psi from the column in the right foreground to the fractionating tower in the left background. In service for a year, the pump has required little maintenance, and has been characterized by operating personnel as "500% better" than the pump it replaced.

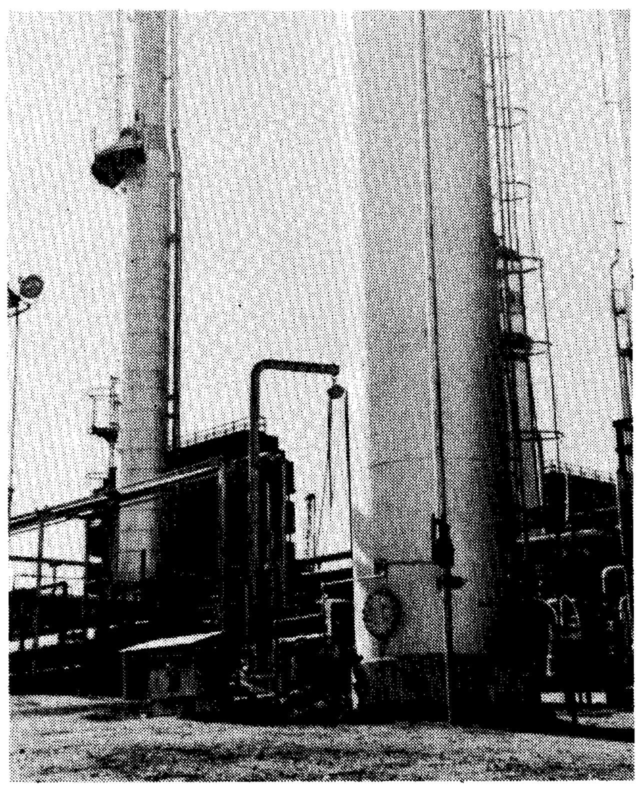

FIGURE 9

Natural Gas Refining

Two Roto-Jet pumps are presently committed to the pumping of an amine/water solution in Canadian gas plants. A solution of approximately 80% water and 20% monoethanolamine is used to strip hydrogen sulfide from natural gas. The Roto-Jets used in this service displace approximately 1025-2055 BPD at pressures to 1000 psi.

Petrochemical Services

Figure 10 is one example of several applications of the Roto-Jet pump in the petrochemical industry. The pump injects 125 BPD of a catalyst into a process stream at 625 psi.

High - Pressure Power Fluid

A future generation of the Roto-Jet capable of pumping against 3500 psi will suit the pump to oilfield power fluid applications. The ease of operation and maintenance inherent in the design simplicity of the Roto-Jet will make it particularly attractive for this service.

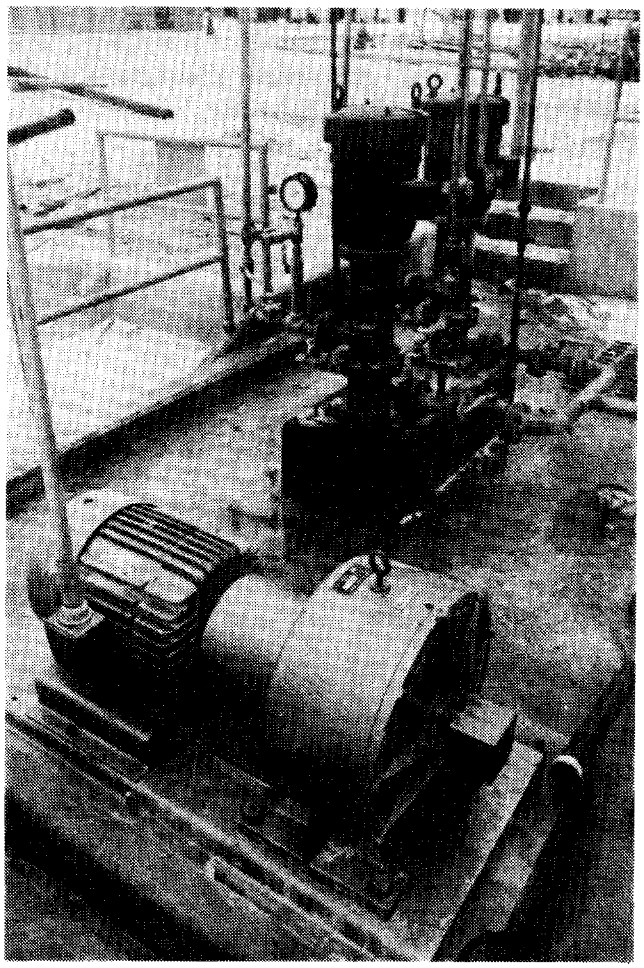

FIGURE 10

DESIGN CONSIDERATIONS

Existing designs provide flow: 700-11,000 BPD; pressure: 400-1200 psi; power: 300 hp maximum. Figures 11 through 15 at the end of the paper show performance characteristics.

New designs are under development which will expand performance to flows up to 18,000 BPD, and pressures up to 3500 psi. These innovations will tremendously increase the impact of the new pitot pump design upon the oil industry.

The Roto-Filter, a combination centrifugal pump-cleaner, will provide the oil industry with exceptional cleaning ability at minimum size and cost.

UNIQUE FEATURES AND BENEFITS

Exclusive of pressure, flow, and initial cost considerations, the simplicity and uniqueness of the pitot pump provide additional operational benefits. As noted previously, these become even more important in evaluating its applicability in lower flow and pressure applications where there is greater direct competition with other available pump designs.

Ease of Maintenance

The simplicity of this unique single-stage pump, with no close clearance bushings or wear rings in the pumped fluid, all but eliminates maintenance. All internal parts are readily accessible without the need to disconnect or move the driver. No special adjustments or shimming operations are required.

Performance Flexibility

The wide range of performance obtained with only one single-stage pump case offers the user a new concept in standardization. Changes in system pressure requirements are met by merely using different sheaves.

Dependable Mechanical Seal

A single, inside balanced-type mechanical seal prevents undesirable or costly fluid leakage and eliminates routine stuffing box adjustment and maintenance. Since the seal operates at low inlet pressure, it has unusually long life.

Economical Installation

Relatively small, the pitot pump requires a minimum of floor space and support. The need for associated equipment such as pulsation dampeners, relief valves and special piping is eliminated.

Seize - Proof

A pitot pump will not seize if run dry by loss of suction or if operated against a closed discharge valve.

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4. Sundstrand Corp., USN Contract NONR 2292 (00) No. NR 094 343, "Study of Turbine and Turbopump Design Parameters," Vol. IV, S/TD No. 1735, Nov. 1959.
5. Stepanoff, A.J.: "Centrifugal and Axial Flow Pumps," 2nd Ed., Wiley, New York. May, 1967.

KOBE ROTO-JET PUMP
MODEL RG30

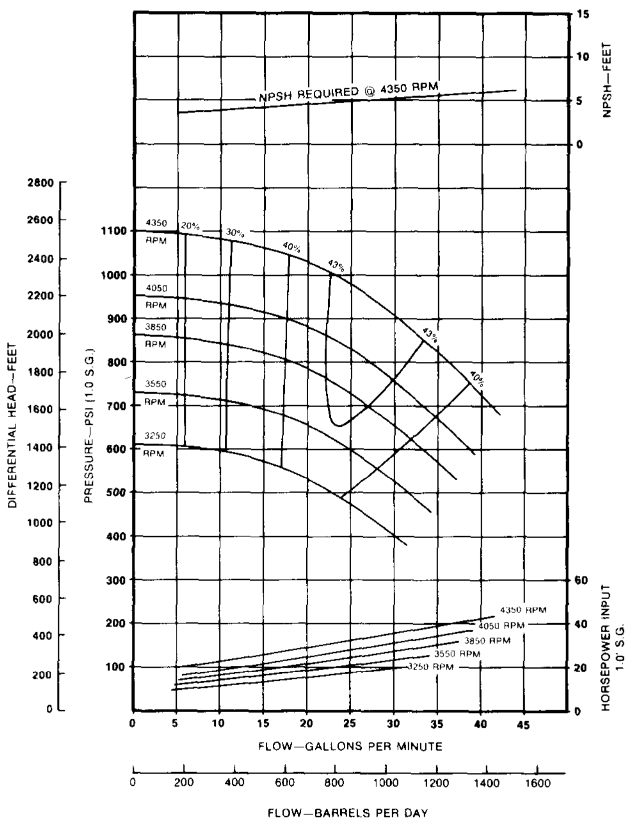

FIGURE 11

KOBE ROTO-JET PUMP
MODEL RG60

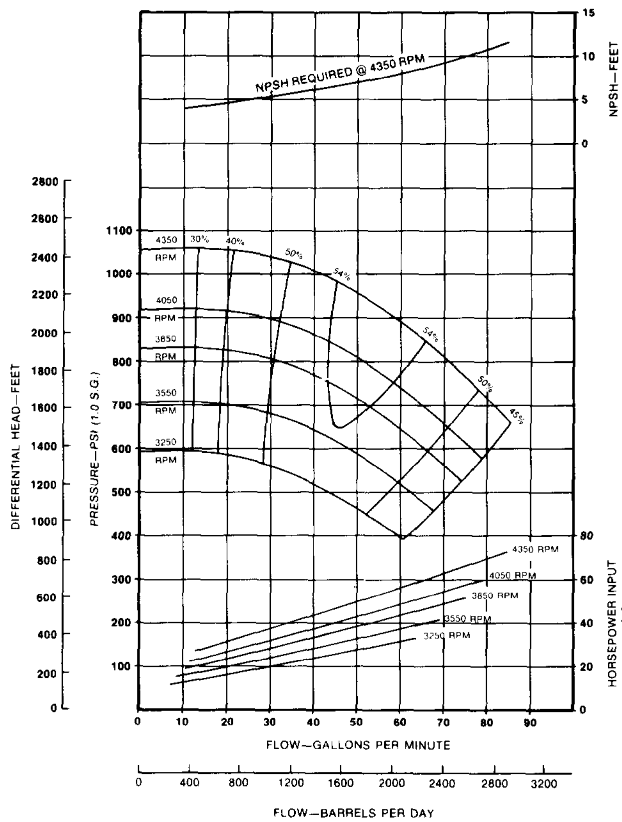

FIGURE 12

KOBE ROTO-JET PUMP
MODEL RG100

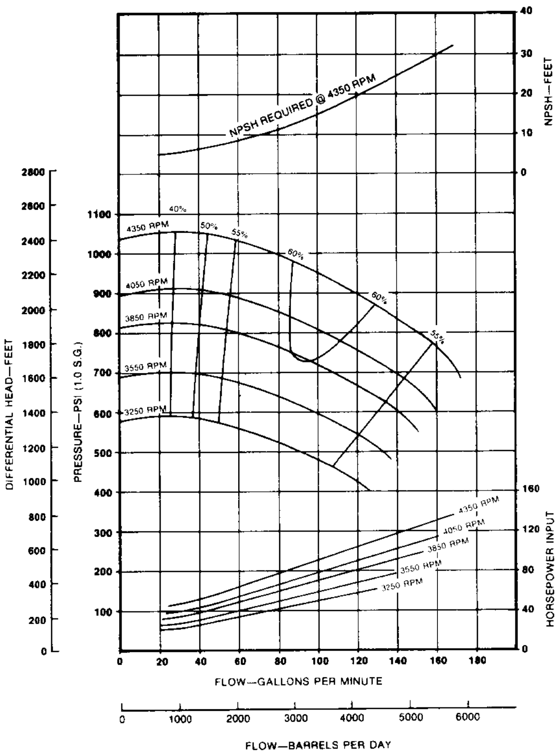

FIGURE 13

KOBE ROTO-JET PUMP
MODEL RG150

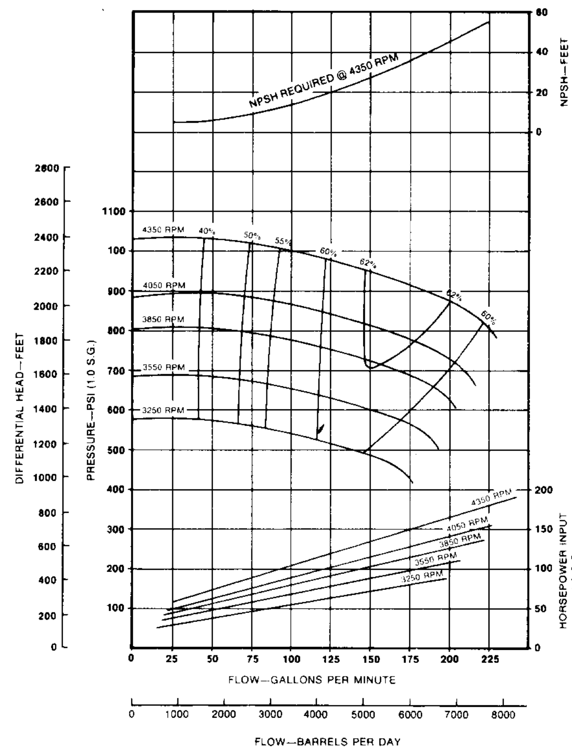

FIGURE 14

KOBE ROTO-JET PUMP
MODEL RG225

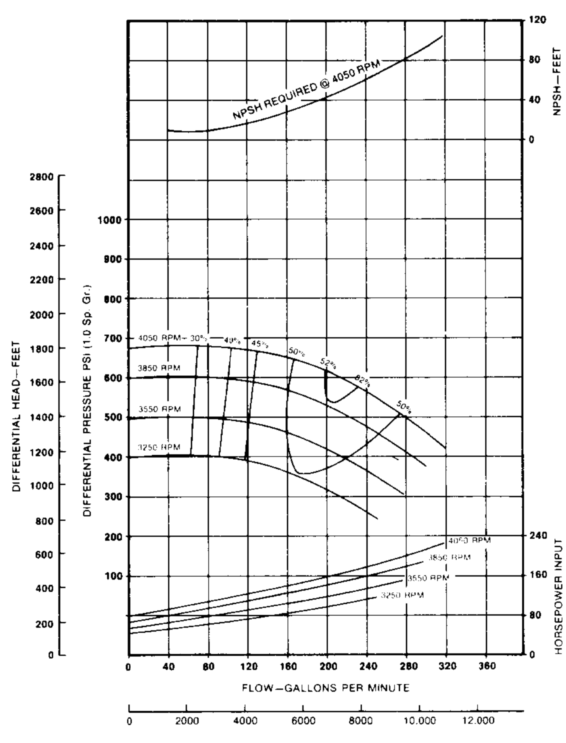

FIGURE 15