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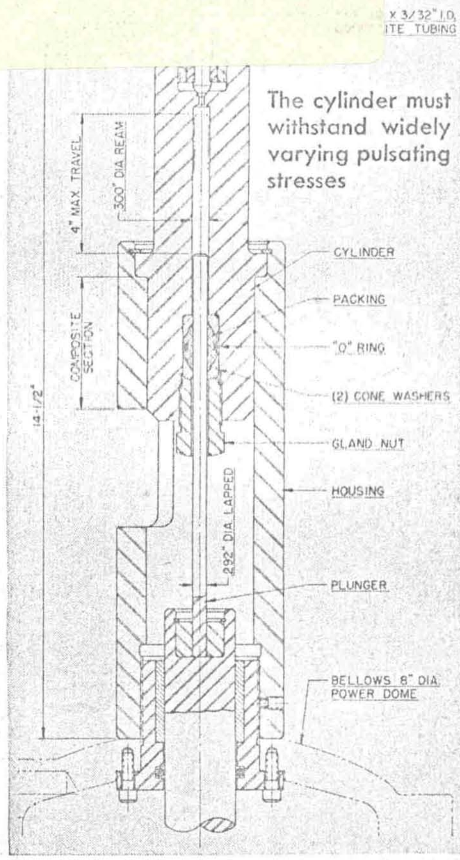
A High Pressure Air-Driven Pump

This design method produced a successful pump made to operate at 60,000 pounds per square inch



The cylinder must withstand widely varying pulsating stresses

Although many problems and considerations are involved in designing for research work a liquid pump for attaining pressures of 60,000 pounds per sq. inch, those discussed here are chosen to illustrate basic approaches applicable to all pressure apparatus.

In developing this pump, it was necessary to subdivide the over-all design into its essential components: type of drive mechanism suitable for safety, adjustability, operational ease, maintenance, and plunger size and design.

These components were based on two major considerations—proper functioning during operation and maximum safety commensurate with good design. Perhaps most difficult was a check valve to provide positive action without leakage at operational pressures.

In designing the plunger and cylinder, available driving forces and adaption to the driving mechanism had to be considered. Then a packing gland had to be devised, capable of sealing against the high liquid pressures involved, which are not constant but rather pulsate from atmospheric to 60,000 pounds per sq. inch with each stroke of the pump. This widely fluctuating pressure produces hazardous pulsating stresses in the cylinder which was partly solved by using a composite cylinder.

Drive Mechanism

Safety was the major factor in selecting the drive mechanism and the air cylinder was chosen for two reasons. First, the output pressure of the pump is directly dependent on air pressure applied to the air cylinder—e.g., if desired output pressure is 50,000 pounds per sq. inch, the air pressure determined from test curves is 94 pounds. Thus, when this setting has been made on the air control valve, the pump will automatically stop when output pressure reaches 50,000 pounds. Of course, a constant output pressure can be maintained by properly adjusting air pressure to the cylinder. The second reason an air cylinder was chosen is because it contains no electrical devices to spark an explosion in the presence of highly volatile substances.

Also, an air drive can easily change the length of stroke and speed of operation without complicated and costly control devices. The cylinders, having a power dome eight inches in diameter and made by the Bellows Co., are readily available and adaptable to high pressure apparatus.

Sizing of Pump Plunger

Air pressure of 100 pounds per sq. inch, readily available in most laboratories, was used to provide an output of 60,000 pounds per sq. inch. The first assumption was used here—from previous experience in pumping at high pressures, an efficiency loss of approximately 20% caused by friction, air leakage, and operational losses from a suitable check valve design was assumed. Using this assumption, the theoretical diameter of the plunger was calculated as 0.288 inch: the effective area of the air cylinder piston is

$$A_a = 0.785\,(D_a^2 - d_a^2)$$

$$A_a = 0.785\,(8^2 - 1.5^2) = 48.5 \text{ sq. inches}$$

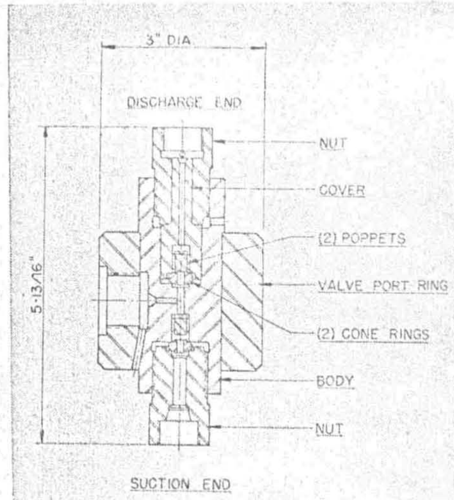
where in square inches A_a effective area; D_a is diameter of piston; and d_a is diameter of shaft, inches.

If the pump is 80% efficient, it can be assumed that 80 of the 100 pounds of pressure applied is actually transmitted to the cylinder.

Thus,

$$A = \frac{A_a P_a}{P}$$

$$A = \frac{(48.5)(80)}{60,000} = 0.0646 \text{ sq. inch}$$



This check valve presented the most difficult problem in designing the pump

Setting forth basic principles for guidance in designing high pressure equipment is increasingly needed. The problem is attacked here by inductive reasoning—in developing a particular pump, solutions to problems encountered, which can be applicable to all high pressure apparatus, are selected for discussion