6.3.2 HYDRAULIC PUMP AND MOTOR POWER TRANSMISSION SYSTEMS

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The use of fluid (hydraulic pump and motor) power transmission systems to drive water pumps is a relatively recent development. The first units of any size were first marketed in the late 1960s and early 1970s and were utilized primarily for construction dewatering purposes because they can be driven by diesel engines or electric motors located well away from construction site cave-ins without the inconveniences of priming and suction hoses and with no limitation on suction lift or capacity (Figure 1).

COMPONENTS

A typical unit consists of a submersible axial-flow water pump with a hydraulic motor mounted in the pump bowl (Figure 2). The thrust bearings, shaft, and hydraulic motor are all sealed to operate under water. The hydraulic motor is driven by oil fed from a hydraulic pump under a pressure of approximately 2500 lb/in^2 (170 bar[1]). Water flowing past the hydraulic motor acts as a heat exchanger and keeps the system cool. Plumbing extends from the hydraulic motor out through the pump bowl and connects to the hydraulic oil conduits leading to the hydraulic pump driver. Quick-coupling hose connections are generally supplied on each end of the hydraulic hoses. The quick couplings contain spring-loaded hall valves that prevent the oil from leaking from either side when the couplings are disconnected (Figure 3).

The hydraulic pump is driven by the prime mover, which is generally a diesel engine or electric motor. The hydraulic conduits may be steel-reinforced rubber hoses or steel pipe or a combination of both (Figure 4). Sometimes it is desirable to utilize a combination of steel pipe and flexible hose as the conduits. This is particularly true when the drive units

[1]1 bar = 10^5 Pa.

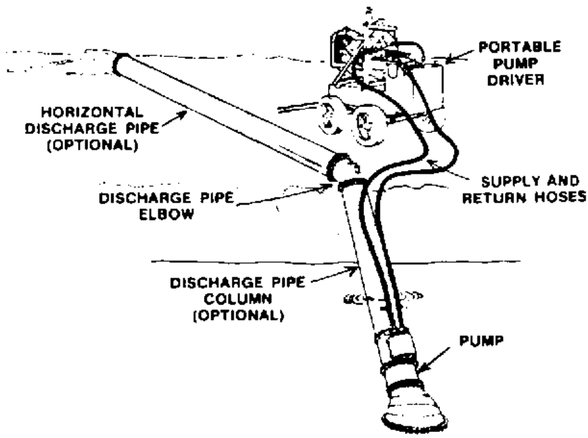

FIGURE 1 Typical portable hydraulically driven water pump with diesel prime mover (M & W Pump)

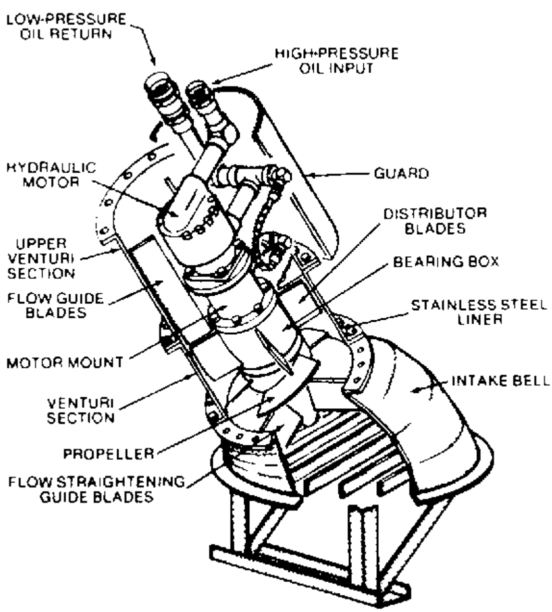

FIGURE 2 Interior of a hydraulically driven axial-flow water pump (M & W Pump U.S. Patent No. 3, 907, 463, other patents pending)

are to be located a considerable distance from the water pump. When steel pipe is used, it is highly desirable to weld all joints. After welding, the pipes should be thoroughly cleaned and tested up to maximum expected operating pressures and inspected for leaks. The pipes should then be painted with an asphalt-base enamel or epoxy, depending upon the surrounding environment.

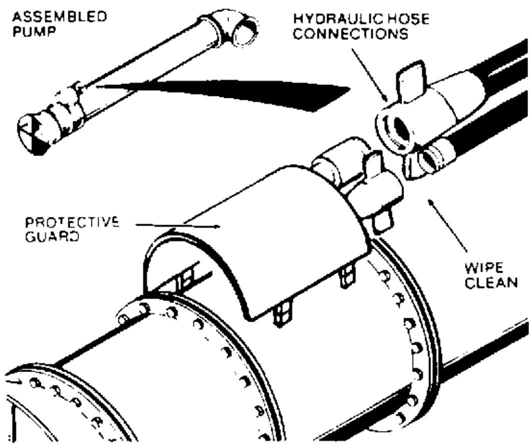

FIGURE 3 Quick couplings are used to fasten hydraulic hoses to the water pump

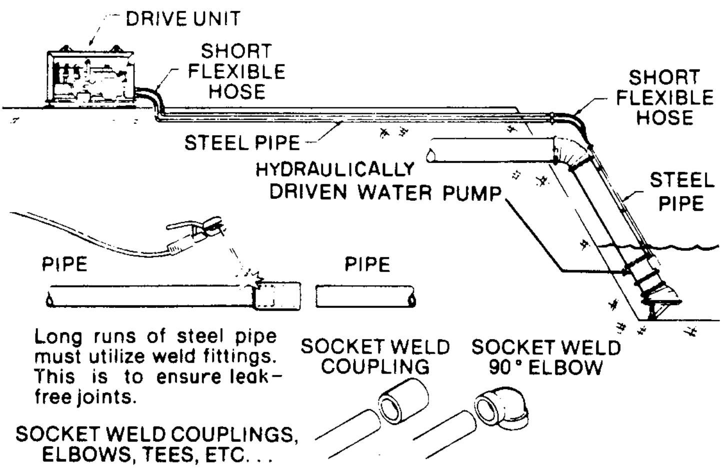

FIGURE 4 For permanent installation, steel pipes with welded joints are generally used for the hydraulic oil conduits instead of hoses.

Hydraulic pump and motor drives can be adapted to centrifugal volute pumps. Figure 5 illustrates a portable nonclogging-impeller trash or sewage pump so driven.

ADVANTAGES

Although the original users of hydraulically driven water pumps were contractors, farmers, and open pit miners using mostly portable pumps, the system described here offers the advantage of permanent pump stations, such as might be used for municipal storm drainage (Figure 6) or massive irrigation or drainage works.

The system is very simple. The power source can be located close to the pump or in a more accessible or protected area. Other advantages include the ability to vary the speed

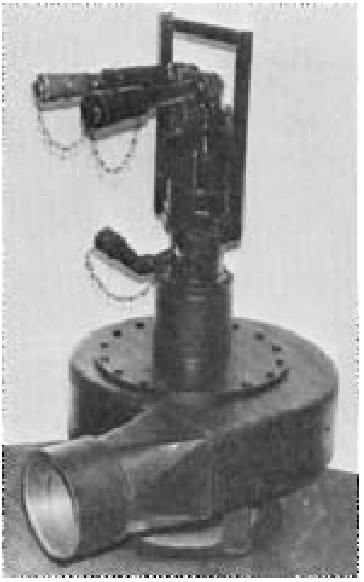

FIGURE 5 Portable centrifugal volute trash pump driven by hydraulic motor (M & W Pump)

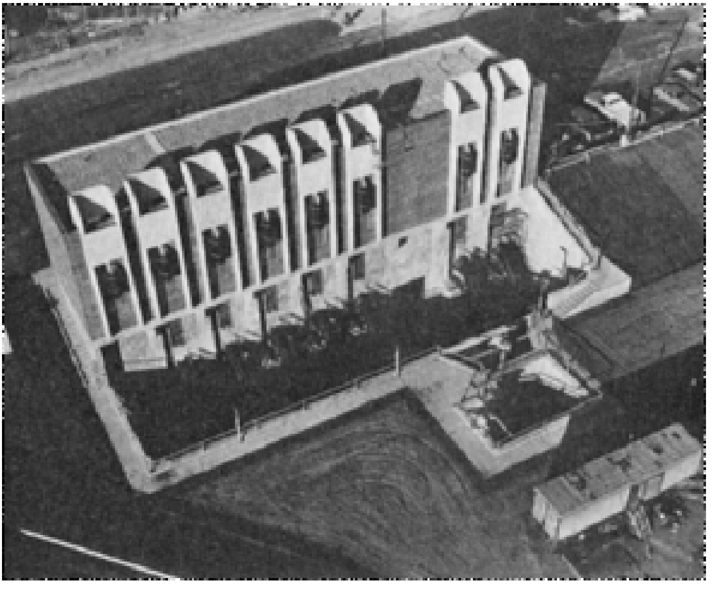

FIGURE 6 A 350,000-gpm (79,500-m^3/h) municipal pump station for combination storm drainage and final sewage effluent (M & W Pump)

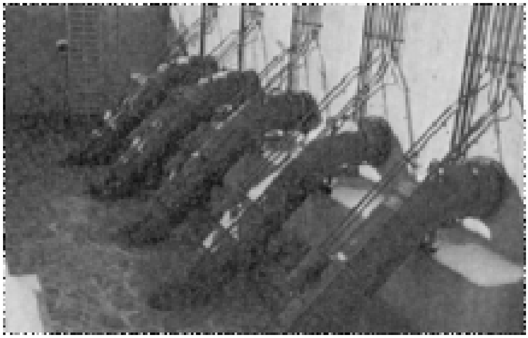

FIGURE 7 Five 42-in (107-cm) double-staged hydraulically driven water pumps with design flows automatically varying from 0 to 50,000 gpm (0 to 11,550 m^3/h) (M & W Pump)

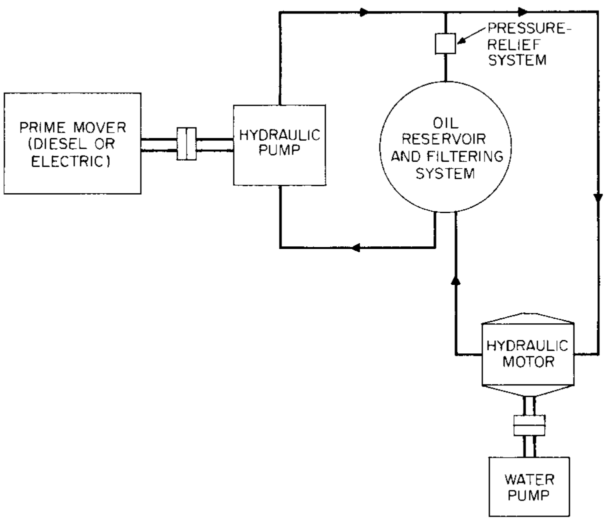

FIGURE 8 Hydraulic drives are much simpler than other types of electromechanical equipment and provide a wide speed range, variable-speed and reversing capability, and shock resistance at a relatively low cost.

of the water pump by regulating the amount of hydraulic oil sent to the motor, the ease of automation for automatic or remote control, and safety because there is no high-voltage electricity in the water (Figures 7 and 8).

FIXED VERSUS VARIABLE FLOWS

A fixed displacement hydraulic pump is used to drive the fixed-displacement hydraulic motor when a fixed water pump flow is desired. The drive shaft of a fixed-displacement vane pump (see Figure 9) is keyed to a rotor and revolves with it. Rectangular varies fit into slots in the rotor. As the rotor turns, the vanes are forced out by centrifugal force to

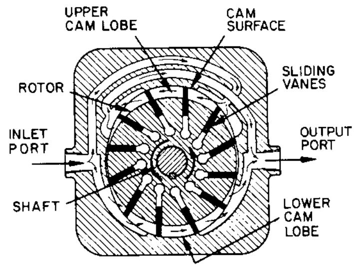

FIGURE 9 Principle of fixed-displacement balanced-vane pump

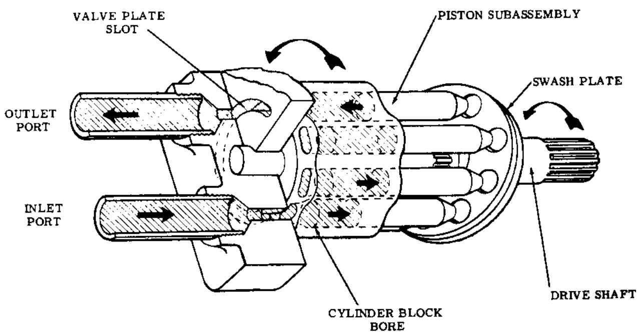

FIGURE 10 Principle of variable-displacement piston pump

make continuous contact with the cam surface. Because of the kidney shape of the cam surface, the space between a vane passing top dead center and the vane ahead of it starts closing down, increasing pressure and forcing oil out through the outlet port. Simultaneously, the vanes on the pump inlet side are passing through the cam kidney-shaped area, which is increasing in size, thus creating a vacuum that pulls oil in through the pump inlet.

When it is desirable (as for final sewage effluent pumping), water pump flow rate can be easily varied through a large range by regulating the amount of oil going to the hydraulic motor in the water pump bowl. Because the hydraulic motor has a fixed displacement, its speed is a direct function of the amount of oil supplied to it by the hydraulic pump connected to the prime mover. Assuming a constant-speed prime mover, the rate of oil flow can be changed easily by utilizing a variable-displacement piston hydraulic pump (Figure 10). In this type of pump, the pistons are moved into and out of the cylinder block by a swashplate rotating cam whose angle can be changed either manually or automatically. When the cam is set at zero angle, the piston does not move and no oil is pumped. As the cam angle is increased, the pistons begin to reciprocate and oil is pumped. The amount of oil pumped is directly related to the angle of the swashplate. For automatic systems, the swashplate angle can be regulated by a servo-control valve attached to the hydraulic pump. This valve is simply an apparatus that converts an electric signal to a mechanical force. A typical system would utilize a 0- to 20-mA signal coming from a sensor in the pump sump.

The sensor could be a sonic, air bubbler, or float device measuring the wet-well sump level and sending a proportional electric signal back to the servo-control valve on the hydraulic pump. If the sump level is rising, for instance, the electric signal may increase, which would cause the servo to stroke the hydraulic pump swashplate to a greater angle, increasing the amount of oil being pumped. This in turn would speed up the hydraulic motor and the water pump propeller, and the water pump flow would increase. Thus a relatively small water-pump sump can be utilized, and pumped water outflows can be regulated to match highly varying gravity inflows.

EFFICIENCY

The main criticism of hydraulic power transmission systems for water pumps is that power is lost through the hydraulic system. There is obviously a power loss in the hydraulic pump, the hydraulic motor, and the plumbing. However, when evaluating efficiencies against those of other types of power transmission systems, such as gears, belts and pulleys, and direct-connected shafts, it is important to make meaningful comparisons.

Water pump manufacturers typically publish performance curves for their wet-pit pump bowls *only,* and these curves do not include power losses for *any* type of power transmission system. This is done because the pump manufacturer does not know the shaft lengths for all possible extended-shaft pumps. Therefore, there is no way the manufacturer can include the losses for the shaft, bushing and bearing supports, couplings, and other transmission parts. Consequently, a user must add to the evaluation the losses resulting from the extended shafting and other transmission parts.

For example, a typical extended-shaft pump may have a column shaft 30 ft (9 m) long. An additional power requirement of 10 to 15% above that of the pump alone would not be unusual for an extended-shaft pump with a gear or belt drive. By comparison, a hydraulically powered pump would typically have a power transmission loss of 20 to 25%—or in other words, would require 10 to 15% more power than an equivalent extended-shaft pump. Thus, a hydraulically powered pump may require, for example, a 30-hp (22-kW) motor rather than a 25-hp (19-kW) motor or diesel prime mover. However, the additional cost of this larger motor should be weighed against the savings in civil works costs and engineering and installation time and the savings resulting from the versatility and automatic operation possible with the hydraulic system.

AVAILABLE SIZES

Hydraulic pump and motor transmission systems are available for almost any speed output, from 100 to 3000 rpm for power outputs up to 500 hp (370 kW). For larger power drives, speed selection is more limited.

Table 1 illustrates readily available standard pump and hydraulic drive sizes from one manufacturer.

TABLE 1 Standard pump sizes readily available with hydraulic drives

Discharge diameter, in (cm)	Capacity range, gpm (m^3/h)		Total head range, ft (m)[a]
4 (10)	475–1,025	(110–280)	8–10 (2–12)
6 (14)	700–1,450	(160–330)	18–50 (5–15)
8 (20)	1,400–2,300	(820–520)	5–23 (1.5–7)
12 (89)	2,500–4,000	(570–910)	5–45 (1.5–14)
16 (41)	4,000–8,000	(910–1,800)	5–28 (1.5–7)
18 (46)	5,000–9,000	(1,100–2,000)	18–45 (5–14)
20 (51)	7,000–12,000	(1,600–2,700)	5–20 (1.5–6)
24 (61)	12,000–17,000	(2,700–3,900)	5–22 (1.5–7)
30 (76)	23,000–27,000	(5,200–6,100)	5–22 (1.5–7)
36 (91)	24,000–35,000	(5,400–7,900)	5–19 (1.5–6)
42 (107)	45,000–53,000	(10,000–12,000)	5–16 (1.5–5)
60 (152)	100,000–120,000	(23,000–27,000)	5–16 (1.5–5)

[a]Most units can be double-staged to accomplish twice the heads shown.