6.2.3 FLUID COUPLINGS

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TYPES OF FLUID COUPLINGS

The term *fluid coupling* can be loosely used to describe any device utilizing a fluid to transmit power. The fluid is invariably a natural or synthetic oil because oil is capable of transmitting power, is a lubricant, and is able to absorb and dissipate heat. Manufacturers have tried water as the fluid in fluid couplings, but sealing problems (keeping water out of the bearings and oil out of the water) and corrosion have prevented its use in any standard catalog drive.

All fluid couplings may be broken down in four categories:

1. Hydrokinetic
2. Hydrodynamic
3. Hydroviscous
4. Hydrostatic

HYDROKINETIC DRIVES

Although all types of fluid couplings are used in starting and controlling pumps, the one most commonly used is the hydrokinetic machine (Figure 1).

Basic Principle In the hydrokinetic drive, commonly known as a fluid drive or hydraulic coupling, oil fluid particles are accelerated in the impeller (driving member) and then decelerated as they impinge on the blades of the runner (driven member). Thus, power is delivered in accordance with the basic law of kinetic energy:

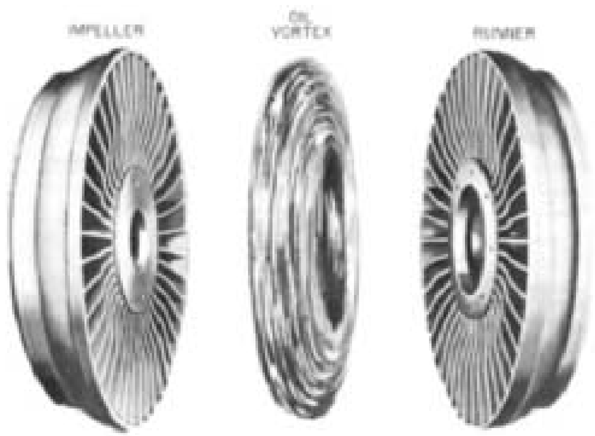


FIGURE 1 Power-transmitting elements of a hydrokinetic coupling (American Davidson)

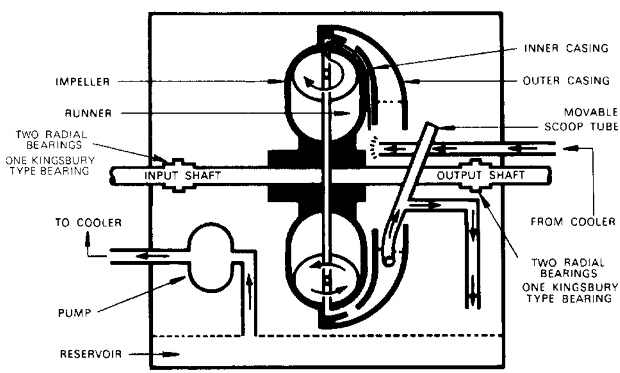


FIGURE 2 Hydrokinetic coupling, scoop-trimming type (American Davidson)

$$E = \tfrac{1}{2}M(V_1^2 - V_2^2)$$

where *F* represents energy, *M* is the mass of the working fluid, *V* is the velocity of the oil particles before impingement, and V^2 is the velocity after impingement on the runner blades.

This principle is used in traction units and, with modification, in torque converters. Neither of these offers controlled variable speed.

In variable-speed units, the mass of the working fluid can be changed while the machine is operating and infinitely variable output speed is achieved. Variation of oil quantity can be accomplished in four ways: scoop-trimming couplings, leakoff couplings, scoop-control couplings, and put-and-take couplings (Figures 2 to 5).

Components The following components are common to all the above types with few exceptions.

The housing of the fluid drive serves four purposes—as a reservoir for the nonworking oil, as a support for the bearings and scoop tube, as a guard to surround the moving parts, and as a container for oil particles and vapors that prevents their escape to the atmos-

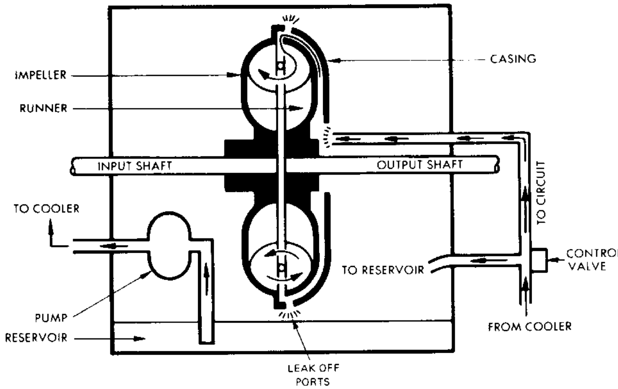


FIGURE 3 Hydrokinetic coupling, leakoff type (American Davidson)

phere. It also supports the oil pump when an internal pump is used. On small units, the housing is of end-bell construction; all others are split on the horizontal centerline to facilitate inspection and maintenance.

Bearings are used to support the shafts radially and axially. In the case of smaller industrial units, ball or roller bearings are usually used; larger machinery utilizes babbitt radial bearings and Kingsbury thrust bearings. Input sleeve bearing pillow blocks often support the internal oil pump driving and driven gears. In most cases, the thrust bearings are designed to handle only the internal thrust of the fluid drive. Thrust developed by sleeve bearing driving motors can be accepted by the hydraulic couplings, but driven machines must usually have provisions to absorb their own thrust.

Shafts support the rotors and transmit driving torque to and from them. In some cases, shafts are hollow and are used to supply oil to the bearings and to the working circuit (Figures 2 to 5).

Rotors are often compared to halves of grapefruit after the meat has been removed and may be fabricated in three ways. The lightest-duty units are equipped with die-cast rotors of SAE 356 aluminum. Heavier-duty units have rotors that are machined out of 4130 or 4340 aircraft-quality steel forgings.

Inner and outer *casings* are bowl-shaped members that bolt to the front of the impeller to contain the oil in two connected areas known as the *working circuit* (Figure 2). One chamber is formed by the impeller and inner casings. The other is formed between the inner and outer casings and can be called the scoop-tube chamber. Ports in the inner casing permit oil to flow from one chamber to the other.

The *scoop tube* (Figure 2) can be moved radially or rotated inside the scoop tube chamber and is supported by sleeve or antifriction bearings. The pickup end of the tube is between the two casings facing the direction of oil rotation. Linkages permit the tube to be moved from outside the housing, and seals prevent the leakage of oil or vapors at this penetration.

An *oil pump* is provided that may be an internally mounted gear pump driven from the input shaft or an externally mounted positive displacement motor-driven pump. In cases where extreme reliability is required, emergency standby ac- or dc-driven pumps may be furnished. These pumps furnish light turbine oil to lubricate, transmit power, and remove heat from the fluid drive. In many cases, they supply lubrication to the driver, the intermediate gear boxes, and the driven machine.

Oil coolers are required on all drives rated above 3 hp (2.2 kw). These coolers remove heat dissipated by the fluid drive and other machines for which they furnish lubrication. Shell-and-tube water-to-oil exchangers are normally supplied, although finned-tube air-to-oil exchangers are utilized where water is not available or economical. On pipeline work, it is common to use in-line coolers. The product of the pipeline is put through one side of the cooler to remove heat from the fluid-drive oil system.

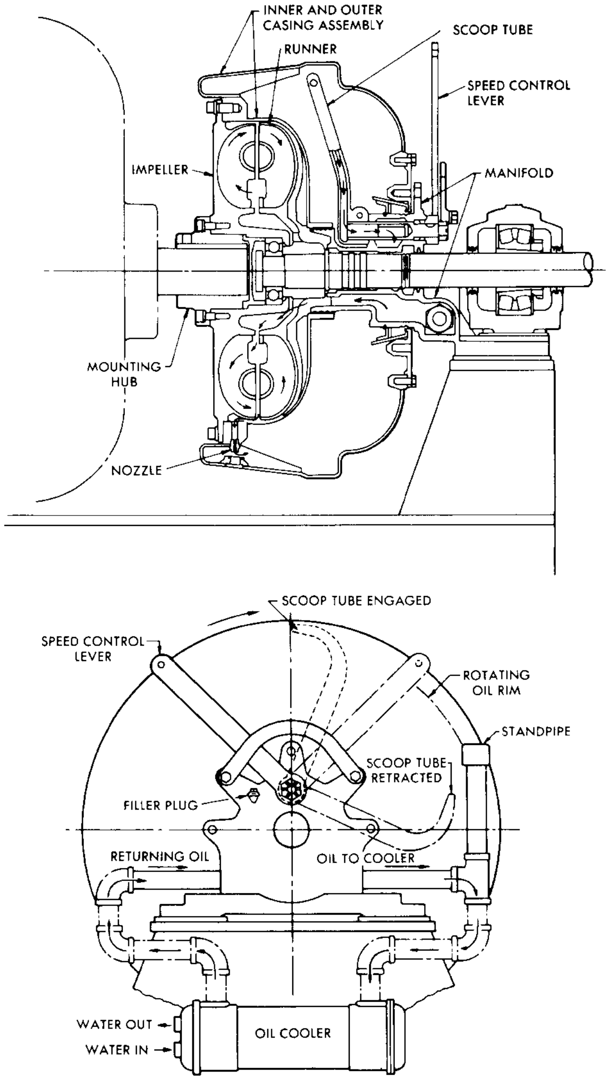


FIGURE 4 Hydrokinetic coupling, scoop-control type

Manifolds are usually used on scoop-controlled couplings in lieu of housings. They provide passages to permit oil flow to and from the working circuit and support the scoop tube and, sometimes, one bearing on the output shaft.

Operation The flow of oil in the *scoop-trimming* fluid drive is begun by the circulating pump, which is driven at constant speed by the input shaft, or external motor driver. The circulating pump moves the oil from the reservoir at the bottom of the housing to an external oil cooler (if used) and then to the rotating elements. Oil entering the rotating casing is acted upon by centrifugal force caused by the casings rotating at the input speed. This

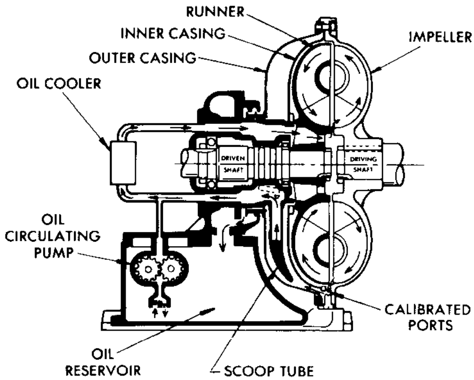


FIGURE 5 Hydrokinetic coupling, put-and-take type (American Davidson)

centrifugal force throws the oil outward against the side of the casing and into the impeller and runner, or working circuit, where it takes the form of an annular ring. Communication ports in the inner casing permit the oil level to equalize in the two chambers.

The amount of oil in the working circuit is regulated by the scoop tube acting as a sliding weir. The scoop tube removes the oil from the casing and empties it into the oil reservoir at the bottom of the housing, where it is ready to begin the cycle once more.

By either manual or automatic control, the scoop tube is moved in the casing. This, in turn, sets the level of the oil is the working circuit because the oil tends to seek the same level in the entire assembly. The scoop tube is designed to give fast response for both increase and decrease of output speed as required. In the *leakoff* type of fluid drive (Figure 3), the scoop tube and outer casings are not used. Oil flow is initiated by a pump, usually of the viscous or centrifugal type, driven by the input shaft, through a heat exchanger (if required) and to a two-way control valve. This control valve modulates between the two extreme positions: all oil to the working circuit and all oil dumped back to the reservoir. Oil in the working circuit is thrown out through orifices called *leakoff ports.* Flow is created by centrifugal head, which varies with the depth of oil in the coupling.

If oil is added to the coupling faster than it is thrown out of the orifices, the quantity of oil in the unit and the output speed increase. Obviously the converse is true as well, and if oil is put into the working circuit at exactly the same rate that it is "leaked off," the unit runs at constant speed. This type of unit lends itself well to closed-loop automatic control, which compensates for the differential flow through the leakoff ports. Manual control is questionable because oil must be added at *exactly* the rate it is discharged or output speed will drift.

In the scoop-control fluid drive, the communication ports in the inner casing are closed to form orifices and the scoop tube casing is sealed at the shaft. This breaks the unit into two separate chambers, the working circuit between the impeller and inner casing and the rotating reservoir between the inner and outer casings. The two are connected only by the orifices, or leakoff ports. Usually the housing, three bearings, and input shaft are omitted. In this configuration, the input rotor and casings are supported by the driving motor. In some cases, the mounting is accomplished through a solid hub as shown in Figure 4, and in others through a disk capable of flexing to absorb slight misalignment. The runner and output shaft are supported either by a pilot bearing and an outboard bearing or by a pilot bearing and the driven machine through a piloted flexible coupling.

Oil flow is initiated by the scoop in the reservoir acting as a pump. This flow is directed out through the manifold to the oil cooler, back to the manifold, and into the working circuit.

A portion of the oil constantly flows through calibrated nozzles in the inner casing to the outer casing, where it is held in an annular ring against the outer casing by centrifugal force. The fluid drive is initially charged with just enough oil to fill the impeller and runner and the cooler circuit so the idle oil in the outer casing is a subtraction from the working circuit. The movable scoop tube adjusts the oil quantity in the outer casing and thus regulates the oil quantity in the working circuit. The scoop tube can be fully engaged, where it skims off all the oil in the casing and thus fills the working circuit. Otherwise, it can be retracted completely so all the oil lies idle in the outer casing and the unit is "declutched." Intermediate positions regulate torque and speed of the drive.

Put-and-take couplings (Figure 5) have not been manufactured in recent years. There was, in the design of such couplings, a variation of the scoop control coupling wherein the position of the scoop tube was fixed; thus, the tube provided circulation only between working circuit and cooler. The amount of oil in the coupling itself was regulated by a gear-type pump that was operated in one direction to pump oil from a reservoir into a unit, stopped to maintain constant coupling speed, or reversed to remove oil from the drive and pump it into the reservoir. This created very unwieldy control systems having very poor response characteristics with some bunting, and the design became obsolete.

Reversibility can be obtained by reversing the driving motor, provided that the unit incorporates oil pumps that are not affected by input shaft rotations. In addition, units utilizing scoop tubes must have dual tips that can accept the flow of oil from either side.

In all fluid drives, the same fluid is utilized to transmit power, to remove absorbed heat, and to lubricate. Thus there is no requirement for internal seals, or slingers, and positive lubrication is assured. Because the power-transmitting medium is the heat-absorbing medium, there are no problems of heat transfer encountered in units utilizing oil pumps. This type of unit can be selected with the capability of dissipating 100% or more of the driving-motor rated power.

HYDRODYNAMIC DRIVES

This type of fluid coupling is occasionally used to drive pumping equipment, usually in the portable pump field (Figure 6).

Basic Principle In the most common forms of hydrodynamic drives, planetary gear trains utilize some components as oil pumps. Throttling the discharge of these pumps creates back pressure and increases drive torque.

Components The input shaft, supported by a bearing either on an independent bearing pedestal or on a packaged subbase assembly, drives the housing, endplate, manifold, and planetary gear shafts. These planet gears are partially surrounded by the manifold, which forms a pump cavity. The sun gear drives the output shaft. The control yoke moves the internal valve.

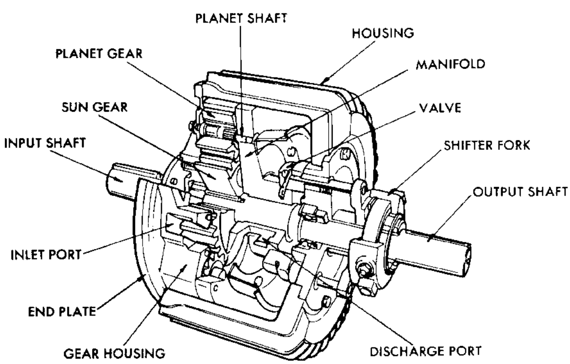


FIGURE 6 Hydrodynamic coupling (American Davidson)

Operation When the driver is started, oil flow is initiated by planet gears rotating against the sun gear. With the control yoke in the low-speed position, the mixing valve is positioned to admit air mixed with oil, the pump discharge valve ports are wide open, and the pump-developed head is approaching zero. The force on the pump gear teeth approaches zero, and the output speed is minimum. As the control yoke is moved, the pump discharge valves begin to close, less air is admitted, and the discharge pressure rises. This develops resistance to pump rotation and imparts a force on the sun gear, and the output shaft begins to rotate. If the oil discharge ports are closed, theoretically the pump pressure will rise until the pump gear is locked to the sun gear. This would rotate the output shaft at exactly input speed. In practice, leakage permits the pump to rotate and the output shaft turns at a slightly lower speed than the input shaft. Reversibility can be achieved simply by reversing the driving motor.

HYDROVISCOUS DRIVES

Hydroviscous drives are relatively new in commercial use. There are several manufacturers in the United States who are marketing this type of drive for a wide range of pump applications (Figure 7).

Basic Principle Hydroviscous drives operate on the basic principle that oil has viscosity and energy is required to shear it. More energy is required to shear a thin film than a thick one. The hydroviscous drive varies its torque capability by varying the film thickness between driving and driven members.

Components The following components are common to all hydroviscous drives. The primary variations from one manufacturer to another are in the mechanics of control, the numbers of disks, and the support of the rotors.

The *housing* serves the same purpose as in other fluid drives, supporting bearings, guarding moving parts, and containing oil and vapors. In addition, one manufacturer uses

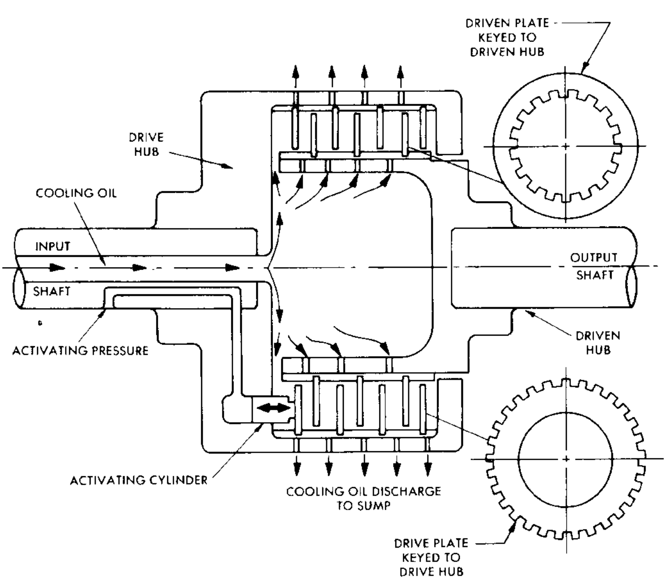


FIGURE 7 Hydroviscous coupling (American Davidson)

cored passages in the housing to introduce water to remove heat from the working fluid. Bearings are usually of the antifriction type in small machines, with sleeve and Kingsbury bearings available in large units. Shafts support rotors, transmit driving torque, and, in most cases, are hollow to supply cooling oil and control oil.

The *rotors* have the driving hub keyed on the inside to driving disks and the driven hub keyed at its inner diameter to the driven disks.

The *disks* are made of various materials and are usually grooved with some type of pattern to direct cooling oil flow.

Pistons are hydraulic. When moved by control hydraulic oil, they force the disk stack closer together.

Oil pumps are usually motor-driven, but sometimes are driven by the input shaft of the coupling. It is not uncommon to have two separate pumping systems, one providing high-pressure control oil and the other lower-pressure cooling oil.

Oil coolers are usually shell-and-tube water-to-oil heat exchangers, although air-to-oil exchangers can be furnished and, as mentioned earlier, cored housings can sometimes be used.

Operation Oil flow is initiated by the oil pumps, which force cooling oil through the disk stack, draining into the sump. With the control set at minimum speed, the disks are at maximum spacing and the coupling transmits minimum torque. As pressure is applied to the piston, the disks are forced together. This decrease in film thickness between disks increases the force transmitted from one plate to the next. At maximum piston pressure, the spacing between plates is zero and the output shaft is driven at input shaft speed. In the full-speed condition, this device is actually a lockup mechanical clutch; at reduced speeds, it is an oil shear coupling; and in a narrow band between these two points of operation, it must be looked upon as an oil-cooled mechanical clutch. Reversibility can be accomplished by reversing the driving motor if oil pumps are driven by separate motors.

HYDROSTATIC DRIVES

Basic Principle There are many variations of hydrostatic variable-speed drives, but in one form or another they invariably use positive displacement hydraulic pumps in conjunction with positive displacement hydraulic motors.

In some cases, varying amounts of fluid are bypassed from the pump discharge back to the pump suction. This provides a controllable variable flow to the positive displacement motor and therefore a variable output speed. This system has no particular advantages over the more common variable-speed drives. The higher-than-average first costs and above-average maintenance required explain why this type of hydrostatic system is seldom used.

In other cases, the hydrostatic drive system uses variable-flow positive displacement pumps that may be of the sliding vane type or axial piston type (Figure 8). Reducing the discharge flow on the hydraulic pump reduces output speed; increasing pump flow increases output speed. This type of variable-speed drive is offered in package form with pump, piping, and motor mounted in a common housing. It offers the capability of torque multiplication, maintains a relatively constant efficiency regardless of speed, has excellent control characteristics, and is widely used in the machine tool and other industries. The output shaft can be reversed by valving (without changing motor rotation). This design has inherently high first cost and maintenance requirements, precluding significant use as a pump driver.

CAPACITY

Hydrokinetic Drive Being centrifugal machines, fluid drives follow very familiar laws: power varies as speed raised to the third power (Figure 9), as diameter to the second power, and directly as the density of the working fluid.

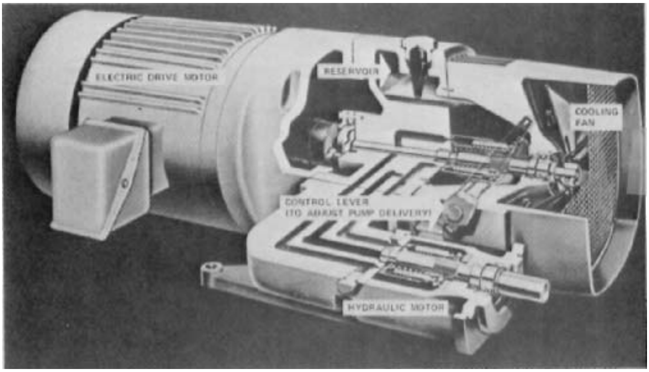


FIGURE 8 Typical package hydrostatic drive (Sperry Vickers)

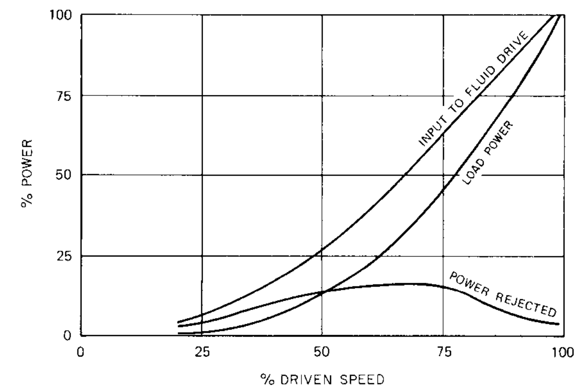


FIGURE 9 Load power varies as speed cubed. This figure represents a pump operating in a system where all the head is frictional, or where head varies as flow squared. In this system, the driven pump operates at only one point on its characteristic curve, and therefore the shape of the pump curve is academic. Although the rapid loss of hydraulic coupling efficiency at reduced speeds is quite obvious, the dramatic decrease in pump power requirements results in a total system power that is most acceptable. Note that the heat rejection requirements in the fluid drive are maximum at about 18% of the total load power.

Thus hydraulic capacity is governed by speed, diameter, and operating fluid; mechanical capability is governed by the structural design of housing, bearings, shafts, rotors, and casings; thermal capacity is limited by the capacity of the oil pumps, the specific heat and thermal conductivity of the oil, and the ability of the heat exchanger to dissipate heat.

It should be noted that in scoop-trimming couplings, the oil pumps are usually sized solely for heat dissipation. In the leakoff coupling, the orifices are sized to permit enough oil flow to dissipate heat, and the pumps must handle this plus enough to fill the coupling in a reasonable time. The scoop-control coupling has limited flow and pressure because both are generated by the scoop tube. This may preclude its uses in certain positive displacement pumping applications or where installation of coolers at a remote location is required.

Hydrodynamic Drive This type of coupling varies so much in configuration that it is impossible to establish similar laws. Because any given machine has a definable torque limitation, we can state that power varies directly with speed.

Because standard units have no provision for removal and replacement of the working fluid, all cooling must be provided on the exterior surfaces of the rotating housing. This becomes a decided limitation if the unit is to be used with constant-torque loads and has limited the available sizes to some degree.

Hydroviscous Drive As would be expected, this device also follows the centrifugal laws: power varies as speed raised to the third power and as diameter raised to the second. However, the density of the working fluid has little or no effect; instead, capacity varies directly with viscosity. Thus, hydraulic capacity varies with speed, diameter, and viscosity. Mechanical capability is a relatively simple matter of structural design. However, thermal design is critical. Because power-transmitting capability varies with viscosity, which in turn varies with temperature, disk design is most important. Free area available for cooling oil flow varies with disk spacing, output speed, and heat load.

REGULATION

The output speed of all fluid couplings (hydrostatic drives are not being considered) is affected, to some degree, by changes in load. Although this may be significant in cases of single-cylinder, low-speed reciprocating pumps, it is insignificant on multicylinder reciprocating and all centrifugal pumps. In these cases, 1% speed regulation is considered normal. In special cases, regulation has been guaranteed at 0.3%.

TURNDOWN

Standard catalog hydrokinetic and hydroviscous units offer the regulation described above over a 5-to-1 turndown on centrifugal machines and 4-to-1 turndown when driving positive displacement pumps on constant-pressure systems. Specially designed fluid drives have been sold that give stable control at 10-to-1 turndown. Hydrodynamic units are limited primarily by heat dissipation capabilities and range from turndown values of 100 to 1 to 1.2 to 1.

Figure 10 is typical of a boiler-feed pump where a high percentage of the developed head is relatively constant. In this case, this fixed head is the boiler pressure. The figure demonstrates the savings in pressure and power realized when this system is used rather than a feedwater regulating valve.

Figure 11 assumes that a positive displacement pump is working on a system where pressure is constant. Although this type of system is seldom found, it is shown here to demonstrate that the rapid reduction in fluid drive efficiency does not require overmotoring the pump. Although system efficiency is much poorer than that of a bypass valve, fluid drives are used to provide no-load starting, isolation of torsional vibrations in reciprocating pumps, and elimination of the bypass valve in slurry systems where erosion is severe.

Response It must be recognized that all fluid couplings being discussed here are slip devices. Thus, any demand speed change cannot be accomplished in microseconds or milliseconds. However, the time required to change the torque applied varies from one type of unit to another.

Hydrokinetic Drive In the scoop-trimming fluid drive, response speed is affected by many factors. The speed with which oil can be added to the working circuit (a factor of the size of the oil pumps) or removed from it (a factor of the size of the scoop tube) influences response capability.

In the leakoff unit, the size of the leakoff ports determines how quickly the unit will empty. However, the oil pumps must be sized to replace this oil and have additional capacity to fill the coupling in a reasonably short time.

Scoop-control units are limited by the ability of the scoop tube to pump oil from the reservoir into the working circuit and by the ability of the leakoff ports to return it to the

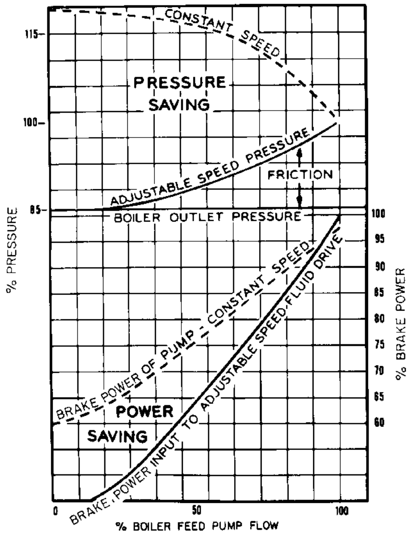


FIGURE 10 Comparison of adjustable-speed and constant-speed pressure and power characteristics for a typical centrifugal boiler-feed pump

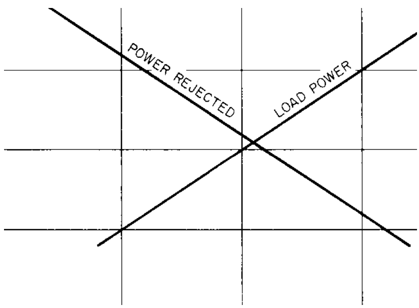
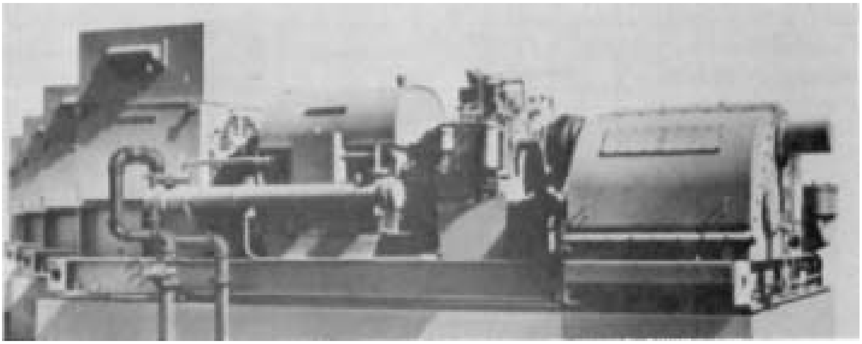


FIGURE 11 Positive displacement pump with constant discharge head



-**FIGURE 12** Thirteen fluid drives driving reciprocating pumps on a coal pipeline. The fluid drive absorbs a large percentage of the pulsations created by the reciprocating pumps and controls their speed to provide proper pipeline flow (American Davidson).

reservoir. Some special marine couplings utilize quick-dumping valves, but these are seldom, if ever, used with pump drives.

Obviously the speed at which the scoop tube is moved is also significant. Large polar moments of inertia (*WK*² values) of the driven equipment will increase response time.

The scoop-trimming coupling offers the best overall response characteristics of the hydrokinetic drives, and standard catalog machines have normal fill times ranging from 10 to 15 s. They will accomplish 90% of a 10% step speed change in the 40 to 100% speed

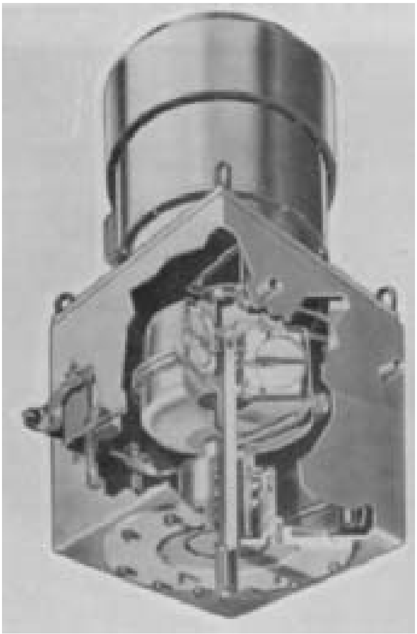


FIGURE 13 Cutaway view of vertical fluid drive suitable for operation with vertical pumps. Note the NEMA P pump flange and output shaft (American Davidson)

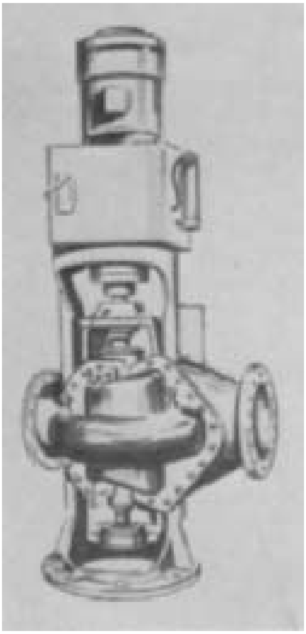


FIGURE 14 Fluid drive of Figure 13 mounted on a vertical-shaft pump (American Davidson)

range in 7 to 20 s if coupled to a "normal load inertia." Special units are in operation where this change is accomplished in 2 to 6 s.

Hydrodynamic and Hydroviscous Drive Both hydrodynamic and hydroviscous couplings respond very quickly to a change in demand for torque output. Both require a mechanical motion (change in valve position or change in spacing between disks) followed immediately by a change in pressure or in film thickness.

In most cases, the torque available for speed change and the WK^2 values involved are of such a magnitude that the major portion of the response time is caused by inertial effects rather than by the time required to change torque. This is particularly true in the deceleration of centrifugal pumps. Unless auxiliary brakes are built-in, none of the hydrokinetic, hydrodynamic, or hydroviscous drives can provide dynamic braking. On a demand to decrease speed, they can at best reduce driving torque to zero. Under these circumstances, the only retarding force to slow the inertia of the driven machine is the load it developed. In the case of centrifugal pumps on fixed systems, this load would fall off as the cube of speed, and below 40% of full speed, such pumps have an almost insignificant braking effect.

EFFICIENCY

There are two kinds of losses present in hydrokinetic, hydrodynamic, and hydroviscous couplings. First, we will consider what are termed circulation losses. They are made up of bearing friction, windage, and the power required to accelerate the oil in the rotor. On internal pump units, the power required to drive the oil pump is included. As an average, these losses represent approximately 1.5% of the unit rating, and for most purposes these losses may be considered as being constant, regardless of output speed.

Second are *slip losses*. As is the case on similar slip machines such as mechanical clutches and eddy-current couplings, the torque on the input shaft equals the torque on the output shaft. Therefore any reduction in the speed of the output shaft has a directly related power loss inside the machine. In other words,

$$\text{Slip efficiency} = \frac{\text{output speed}}{\text{input speed}} \times 100$$

The total fluid drive losses are the sum of the two inefficiencies. The complete energy formula is

In USCS units

$$\text{Fluid drive input horsepower} = \frac{\text{output horsepower}}{\text{output speed/input speed}} + \left(\begin{array}{c}\text{circulation horse-}\\\text{power losses}\end{array}\right)$$

In SI units

$$\text{Fluid drive input kilowatts} = \frac{\text{output kilowatts}}{\text{output speed/input speed}} + \left(\begin{array}{c}\text{circulation}\\\text{kilowatt losses}\end{array}\right)$$

At maximum designed operating speed (which is usually about 98% of driven speed), the total coupling efficiency is approximately 96.5%, with 1.5% of the losses being circulation losses and 2% being slip losses. The hydroviscous unit can be operated at 100% driven speed, but under these conditions it is not a fluid coupling.

Because the circulation losses become relatively insignificant at reduced speeds, approximate calculations may be made using the formula

$$\text{Efficiency} = \frac{\text{output speed}}{\text{input speed}}$$

CONTROLLERS

Of the hydrokinetic devices, the scoop-trimming and scoop-control units require that a mechanical motion be imparted to the scoop tubes for control, and some device must be furnished to provide this motion. This may be a hand crank on a manual control system. Simple mechanical systems are often used—a typical example is a weighted float with a rope connected to the scoop tube, controlling level in a tank. However, most installations utilize electric, electrohydraulic, hydraulic, or pneumatic actuating devices. It is not surprising that the pipeline and refinery industries use electrohydraulic actuators similar to those used on valves. The electric utility industry prefers pneumatic or electric damper operators. The only criterion for actuator selection is compatibility with the other elements of the control system.

The leakoff devices require a signal to the control valve. At present, this is standardized as a hydraulic-pressure signal, although special transducers would permit the use of other types of signals. The hydrodynamic devices are available with manual level control (which could be adapted to actuators) or with closed-loop constant-pressure or constant-temperature systems. All hydroviscous drives utilize oil pressure applied to a piston to “clamp” or vary the spacing of the disks. This hydraulic pressure may be varied by almost any type of signal, provided that the proper servos are utilized. Thus the signal may be electric, hydraulic, or pneumatic.

CAPACITIES AVAILABLE

Standard catalog variable-speed fluid couplings are available from one or more manufacturers in the speeds and powers shown in Table 1. Special designs are available for higher power ratings.

DIMENSIONS

To give some idea of physical dimensions, Table 2 lists approximate dimensions for hydrokinetic drives of one U.S. manufacturer. These feature a scoop-trimming coupling and are probably the largest unit for a given speed and power.

SELECTION AND PRICING

Because of variations in fluid coupling design for different sizes and speeds, it is virtually impossible to develop rule-of-thumb methods of estimating costs. The price list of one major fluid drive manufacturer indicates that prices can range from $60 per horsepower for sophisticated machines down to $25 per horsepower for others (in 1984 dollars). Fluid couplings prices can be increased dramatically by specific requirements for exotic controls, backup pumps and heat exchanger equipment, and other accessories. Because of this fact, it is recommended that the manufacturers be contacted to obtain even budget prices.

TABLE 1 Variable-speed coupling capacities

	Hydrokinetic			
Input speed, rpm	Min/max input hp for horizontal-shaft units[a]	Max input hp for vertical-shaft units[a]	Hydrodynamic min/max input hp[b]	Hydroviscous min/max input hp[b]
720	40,000–45,000	. . . .	. . . .	3,000–8,000
900	1,000–7,500	6,000	1–25	3.000–10,000
1,200	1,000–14,000	17,000	1–30	3,000–15,000
1,800	1,000–14,000	18,000	1–60	3,000–20,000
3,600	1,000–30,000	29,000	. . . .	3,000–20,000

[a]1 hp = 0.746kW
[b]Horsepowers apply to either horizontal or vertical units.

TABLE 2 Hydrokinetic drive dimensions

Power at 1800 rpm, input hp (kW)	Length, in (cm)	Width, in (cm)	Shaft height, in (cm)
5 (3.73)	24 (61.0)	15 (38.1)	$11\frac{1}{2}$ (29.2)
20 (14.9)	39 (99.1)	18 (45.7)	$12\frac{1}{2}$ (31.7)
50 (37.3)	38 (96.5)	28 (71.1)	19 (48.3)
100 (74.6)	38 (96.5)	28 (71.1)	19 (48.3)
1000 (746)	74 (188)	50 (127)	30 (76.2)
4000 (29811)	102 (259)	62 (157)	42 (107)

The basic information required by the manufacturer for selection and pricing is as follows:

1. Speed and type of driver
2. Power required by the driven machine at, or at least, one operating point
3. Character of driven machine-smooth or pulsating load; how torque requirements change with speed
4. Cooling medium available and temperature of medium
5. Control type
6. Accessories
7. Special specification requirements

Reasonable budget figures can usually be obtained with items 1 to 3 only.

CONCLUSION

Fluid couplings are utilized to drive pumps in virtually all pump applications requiring variable flow or pressure. They are used primarily to improve efficiency and controllability, to permit no-load starting, and to reduce pump and system wear. They are standardized to the degree that units are available to handle most pumping applications. Most manufacturers stand ready to develop new designs as the requirements of the marketplace change.