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VARIABLE PRESSURE SLIP CLUTCH WITH SLIP TORQUE FLUCTUATION AT A FRACTIONAL LEVEL OF THE VARIATION IN FRICTION COEFFICIENT

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A clutch was needed for a power transmission to transmit torque up to a definite level and dissipate through friction the energy applied above that level. The commonly used clutches operate at constant pressure and have a high variation in torque capacity due to the inherent high fluctuation in the characteristics of the friction materials. The clutch torque is determined by the equation:

$$T = \mu F_P R_C N$$

See definition of terms on page 2.

The coefficient of friction, μ, may vary during operation by one hundred per cent or more. This made such a clutch unsuitable for applications where the slip torque must be maintained at a nearly constant level.

A new clutch was designed which uses the same friction materials and is similar in construction to the common clutch, however, it operates under variable pressure in such a way that the variation in the coefficient of friction is instantly compensated by a change in pressure to maintain the clutch torque capacity nearly constant.

In a regular slip clutch, the hub is normally made of one piece. In this variable pressure slip clutch the hub is made of two parts: one, called the hub, is engaged with the disks by a spline (part 1 on Fig. 1), and the second, called the cam, is engaged with the output shaft by a spline (part 2 on Fig. 1). Several matched sets of ramps are facing each other on the hub and cam transmitting the torque from one member to another by the aid of steel balls (see Fig. 1). A piston (part 3 on Fig. 1) provides a constant force that is counter-acted by the clutch plates and the hub. In this clutch the force is provided by a washer spring and hydraulic pressure.

The reduction in slip torque variation results from the interaction between the clutch forces which is as follows:

a. At any instant of time the torque is equal at the input shaft, clutch plates, ball and ramp, and the output shaft.

$$T_{in} = \mu F_{CP} R_C N = RF_B \operatorname{Tan} \alpha = T_{out} \qquad (1)$$

b. The separating force at the ball and ramp acting on the hub (1) and cam (2) is always proportional to the torque.

$$T = RF_B \operatorname{Tan} \alpha \qquad (2)$$

c. There are three forces acting on the piston as follows (see Fig. 3):

$$F_P = F_{CP} + F_B \qquad (3)$$

d. When the friction characteristics at the clutch plates vary, the torque transmitted through the clutch varies. The variation in torque level creates a proportional variation in the ball-ramp separating force (F_B). Since the clutch force (F_{CP}) is the difference between the constant piston force (F_P) and the varying ball-ramp separating force, it varies inversely proportional to the torque.

The inverse relationship between the clutch force and torque results in a smaller variation in torque for a given variation in the coefficient of friction.

For example, when the coefficient of friction increases, the torque transmitted through the clutch increases. The higher torque increases the ball-ramp force (F_B). Since the piston force (F_P) is constant and now a greater ball-ramp force acts against it, the force available at the piston (F_{CP}) is decreased. Thus, an increase in friction coefficient is compensated by a decrease in clutch force resulting in a torque increase that is smaller than the increase in the coefficient of friction.

The mathematical expression for the slip torque, determined from equations 1, 2, and 3, is as follows:

$$T = \frac{F_P}{\frac{1}{\mu R_C N} + \frac{1}{R \tan \alpha}}$$

T	=	Slip Torque
F_P	=	Piston Force (constant)
F_B	=	Ball and Ramp Separating Force (proportional to torque)
F_{CP}	=	Clutch Compressive Force
μ	=	Coefficient of Friction
R_C	=	Mean Clutch Radius
N	=	Number of Friction Surfaces
α	=	Ramp Angle
R	=	Distance from Shaft Center to Ramp

Tests performed under identical conditions on a constant pressure clutch and a variable pressure clutch which used the same friction disks and separator plates showed that the variable pressure clutch can transmit torque that varies only a fraction of the variation in the coefficient of friction.

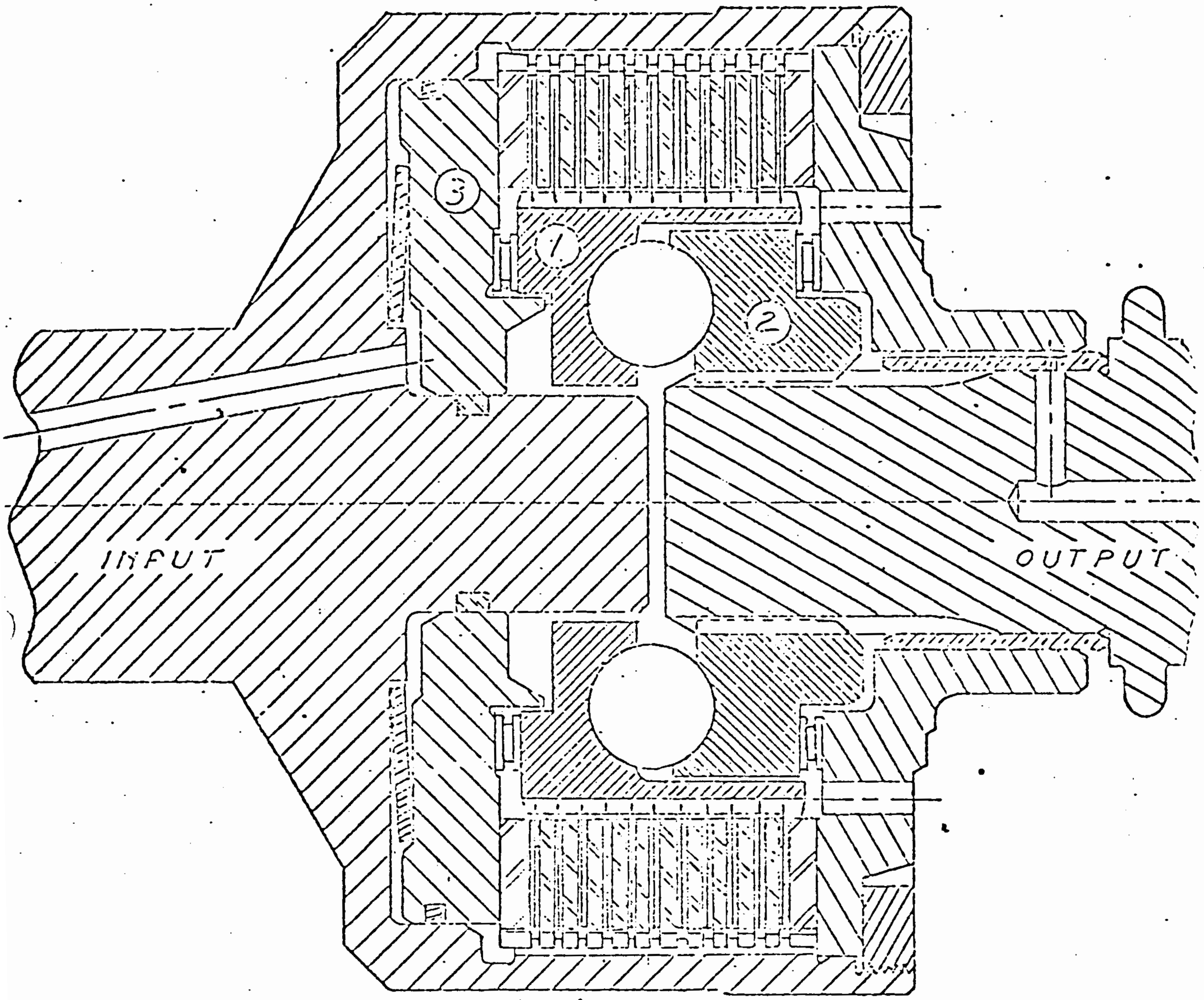


FIGURE - 1

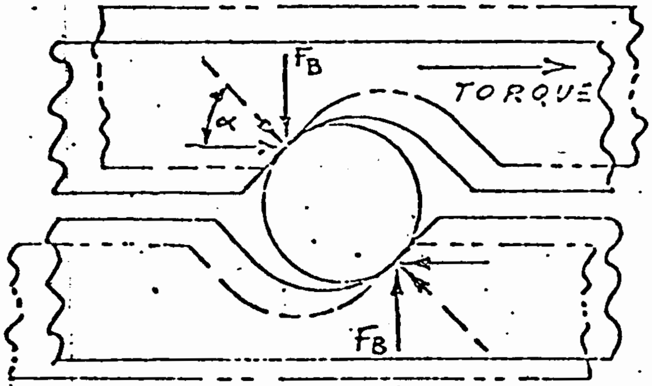


FIGURE 2

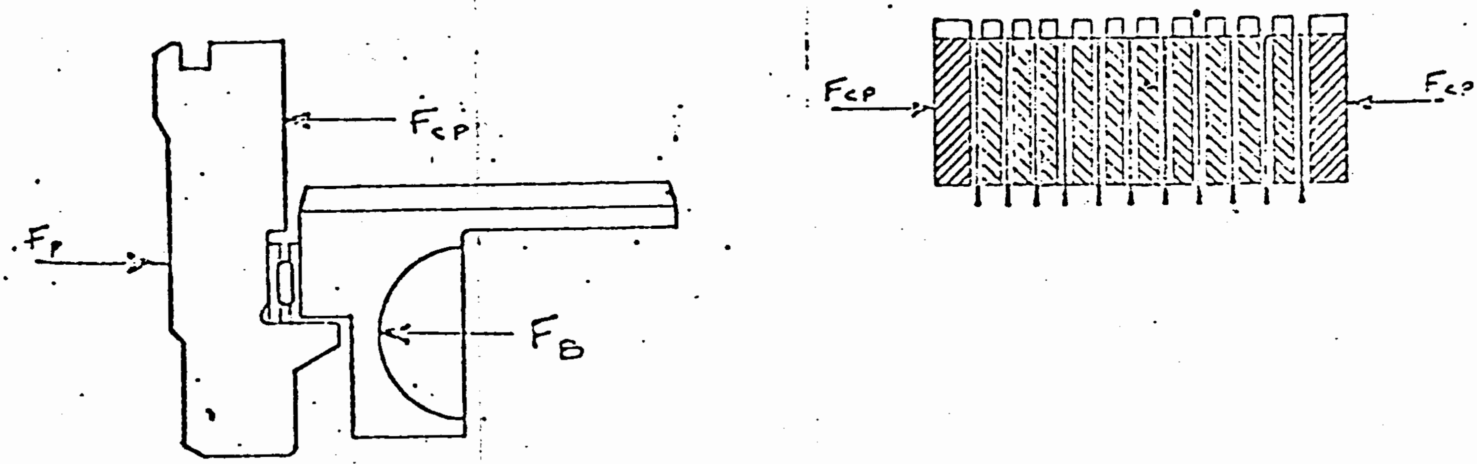
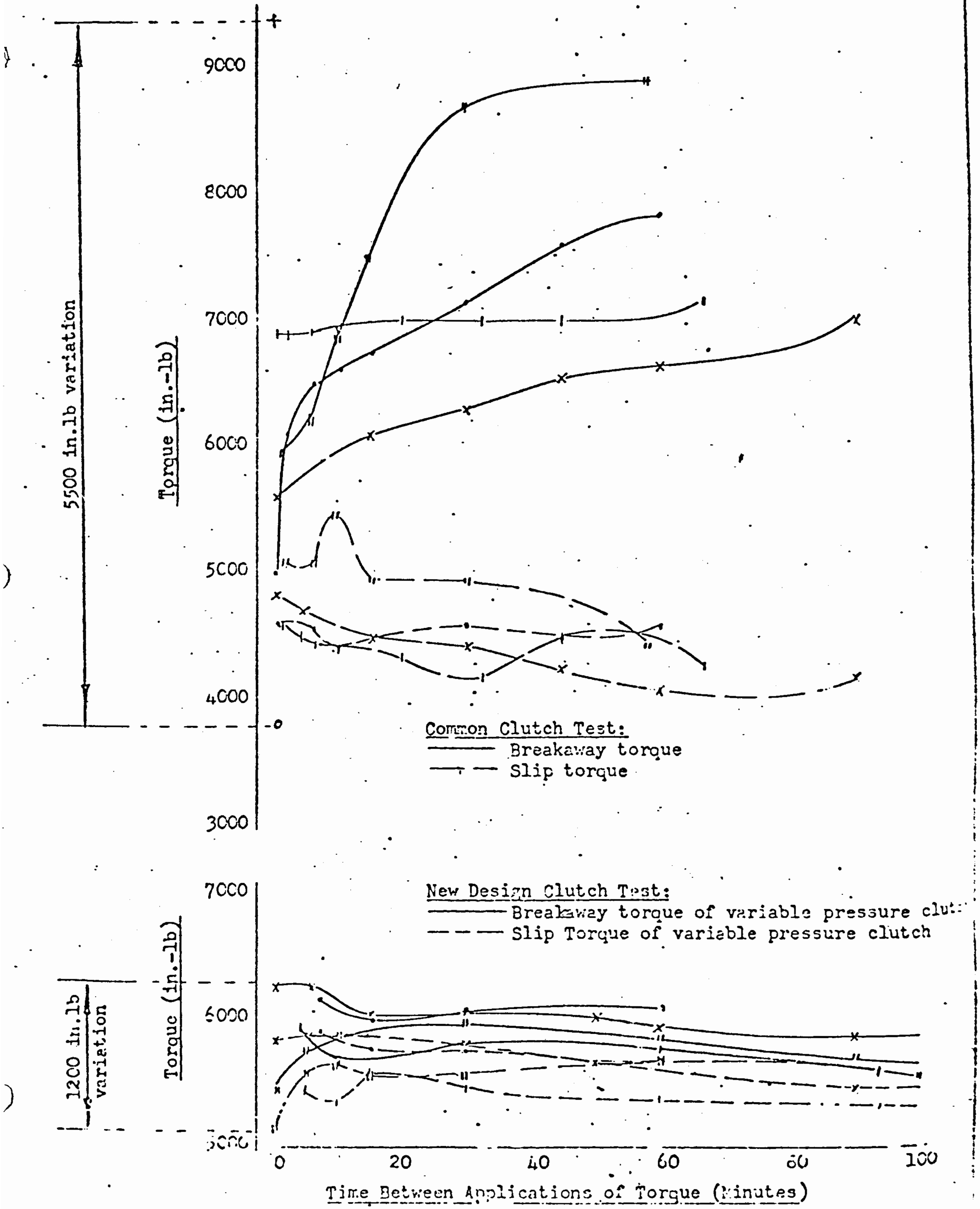


FIGURE 3

TORQUE LIMIT CLUTCH

Torque Applied by Hydraulic Cylinder



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CLUTCH

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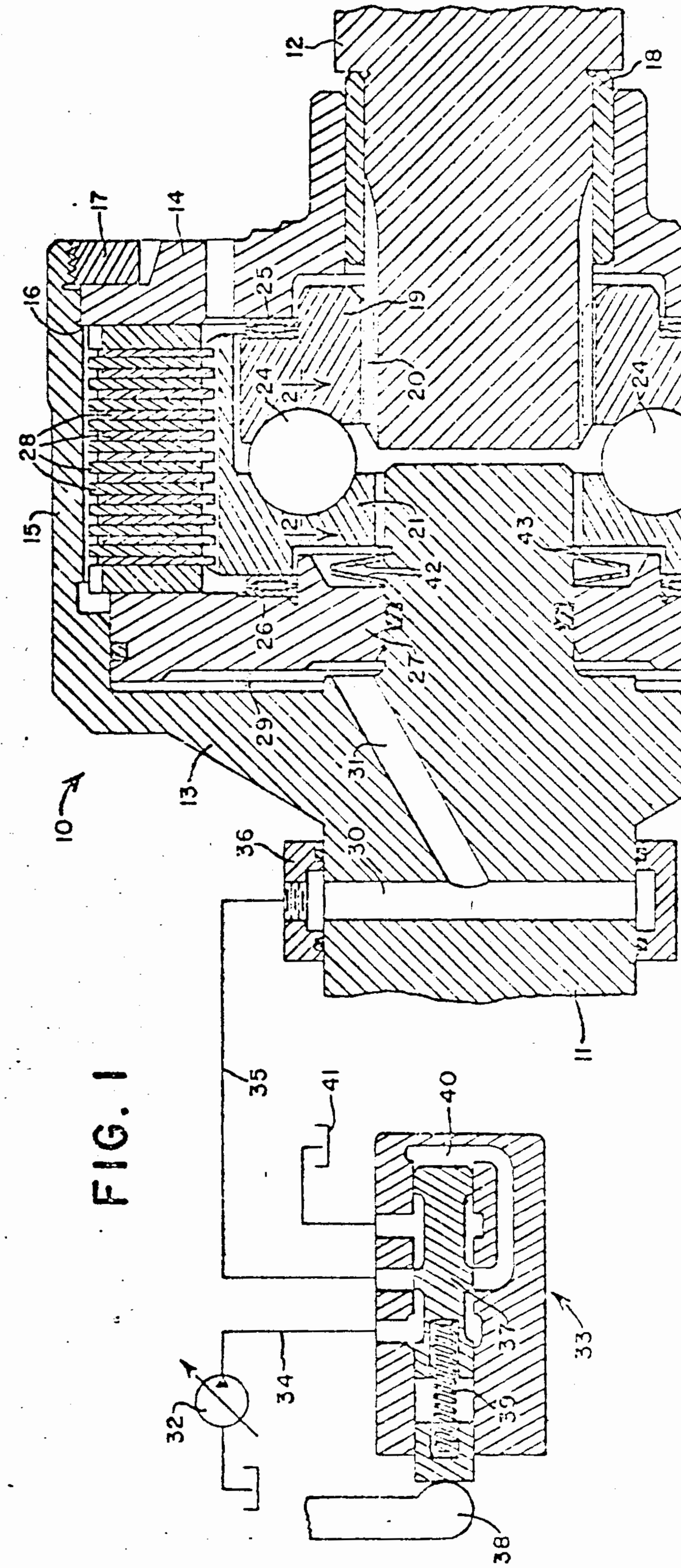

FIG. 1

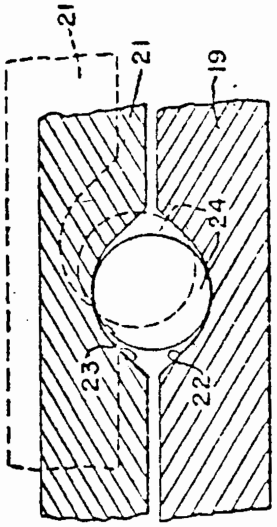

FIG. 2

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