

Aug. 13, 1957

T. T. BUNCH

2,802,337

HYDRAULIC DRIVE SYSTEMS

Original Filed Oct. 18, 1951

2 Sheets-Sheet 1

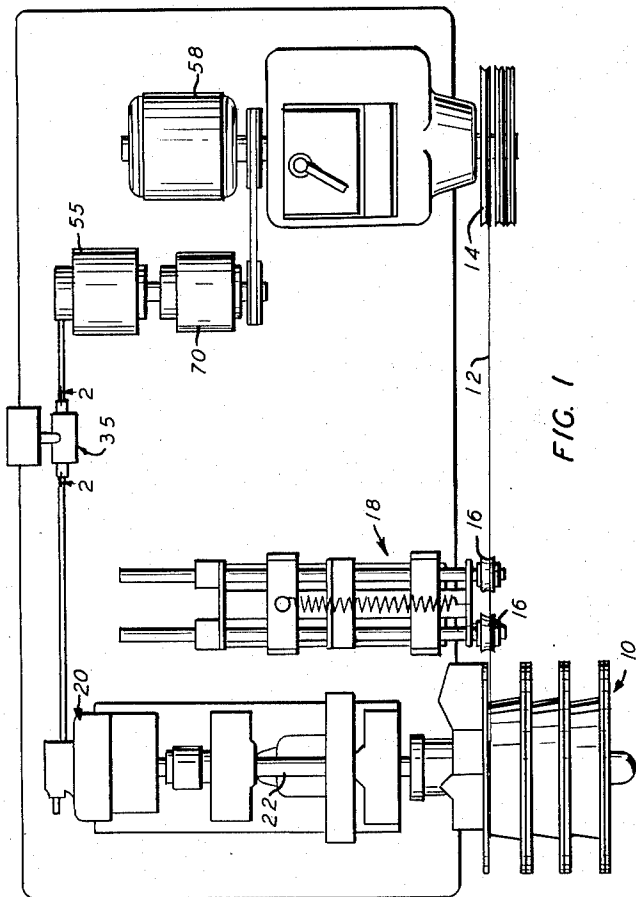


FIG. 1

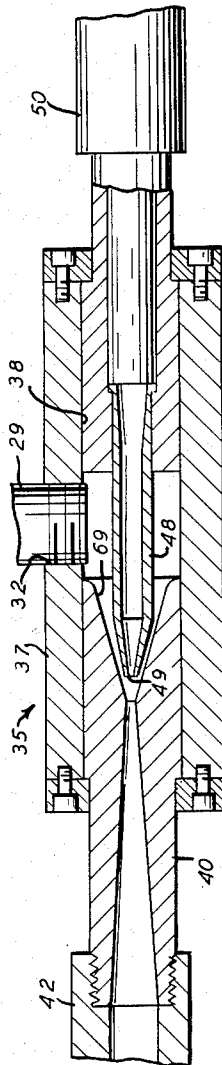


FIG. 2

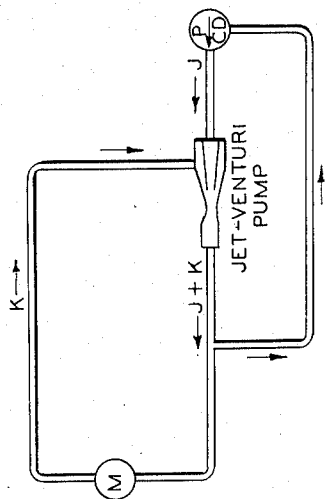


FIG. 4

INVENTOR
T. T. BUNCH
BY *T. T. Bunch*
ATTORNEY

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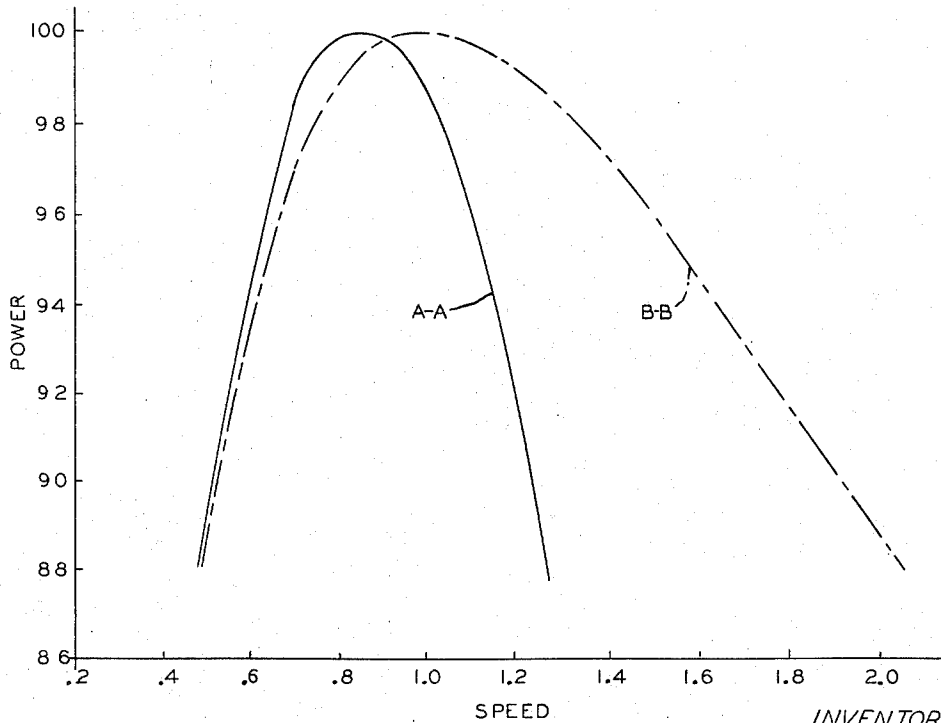
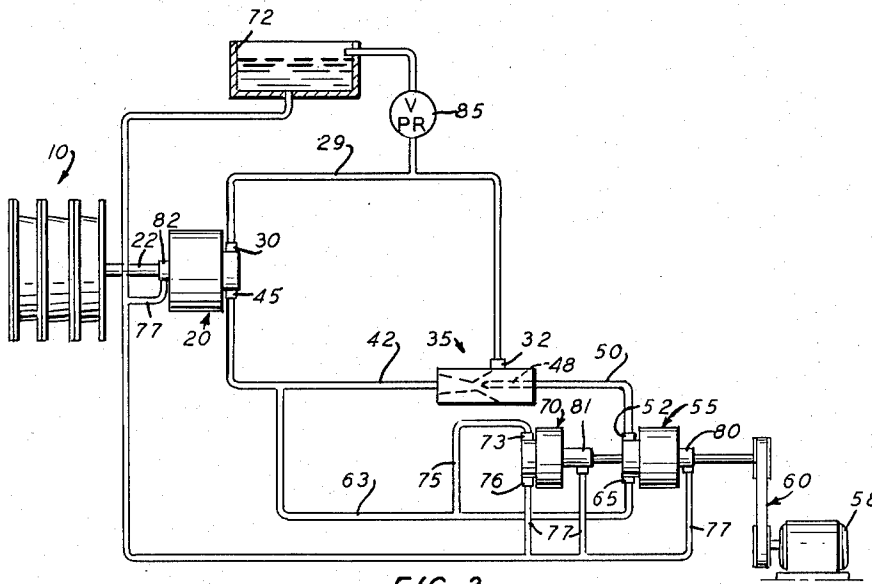


FIG. 5

INVENTOR
T. T. BUNCH
BY *Attorney*
ATTORNEY

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2,802,337

HYDRAULIC DRIVE SYSTEMS

Tillman T. Bunch, near Ashland, Md., assignor to Western Electric Company, Incorporated, New York, N. Y., a corporation of New York

Original application October 18, 1951, Serial No. 251,968, now Patent No. 2,733,869, dated February 7, 1956. Divided and this application October 1, 1953, Serial No. 383,681

10 Claims. (Cl. 60—53)

This invention relates to hydraulic drive systems, and more particularly to hydraulic drive systems associated with winding and coiling apparatus.

This application is a division of my copending application Serial No. 251,968, filed October 18, 1951, for "Apparatus for Coiling Filamentary Materials," now Patent No. 2,733,869, issued February 7, 1956.

One of the most perplexing problems encountered in designing apparatus suitable for use in a coiling operation is the problem of maintaining a constant tension on a strand being wound on a coiling head. Assuming that it is desired to maintain a predetermined constant tension on a strand which is advanced to the coiling head at a predetermined constant linear speed, it is essential that the rotational speed of the coiling head at the start of a coiling operation be relatively high and decrease proportionally with the increase in the winding diameter as a coil builds up. Since at the start of the coiling operation the winding diameter is small, the required torque is likewise relatively small. As the coiling operation proceeds, the torque must increase proportionally with the increase in the winding diameter in order to maintain the predetermined tension on the strand.

From the above-mentioned relationships between the torque and winding diameter, and the rotational speed and winding diameter, it is manifest that in order to maintain a constant tension on the strand under these conditions the torque must vary inversely with respect to the rotational speed. Hence, it is necessary that a drive system designed to fulfill the foregoing requirements must be capable of delivering a substantially constant power output.

It is an object of this invention to provide new and improved hydraulic drive systems.

Another object of this invention is to provide new and improved hydraulic drive systems associated with winding and coiling apparatus.

Apparatus illustrating certain features of this invention may include a fluid motor, a fluid inlet line associated with the motor, a fluid exhaust line associated with the motor, a jet-Venturi pump, and means for operating the pump to withdraw the fluid from the exhaust line and discharge it into the inlet line.

A complete understanding of the invention may be had from the following detailed description of apparatus forming a specific embodiment thereof, when read in conjunction with the appended drawings, in which:

Fig. 1 is a plan view of the apparatus;

Fig. 2 is an enlarged, fragmentary, vertical section taken along line 2—2 of Fig. 1;

Fig. 3 is a schematic diagram of an improved hydraulic drive system forming part of the apparatus;

Fig. 4 is an idealized, schematic diagram of the hydraulic drive system, and

Fig. 5 is a graph illustrating power characteristics of the hydraulic drive system.

Referring now to Fig. 1, there is shown a multi-section coiling head 10 arranged to take up a strand 12 which

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is continuously advanced at a substantially constant speed by a takeup capstan 14. Positioned immediately adjacent to the coiling head are a pair of guide sheaves 16—16 mounted in tandem and forming part of a fluid-operated stepping and distributing mechanism, indicated generally at 18. The guide sheaves 16—16 are operatively connected to the reciprocable piston of a double-acting hydraulic cylinder, the reciprocation of which is controlled automatically by a four-way valve (not shown) and an associated hydraulic pump (not shown).

The coiling head 10 is driven by a hydraulic motor 20, the coiling head being operatively connected to the motor by means of a drive shaft 22. Associated with the hydraulic motor 20 is a hydraulic drive system (Fig. 3) designed to operate the motor so as to deliver a substantially constant horsepower to the coiling head 10.

The hydraulic drive system, which is shown schematically in Fig. 3, includes a hydraulic fluid line 29 connected at one end thereof to a discharge port 30 on the motor 20 and at its other end to an intake port 32 provided on a jet-Venturi pump, indicated generally at 35.

The jet-Venturi pump, shown in detail in Fig. 2, includes a cylindrical member 37 having an axial, cylindrical bore 38, in one end of which is mounted a Venturi tube 40. The discharge end of the Venturi tube 40 is connected by a hydraulic fluid line 42 to an intake port 45 on the hydraulic motor 20. Positioned within the other end of the bore 38 is a jet 48 having a small orifice 49 at its discharge end. The intake end of the jet 48 is connected to a hydraulic fluid line 50 which communicates directly with a discharge port 52 of a constant-displacement, hydraulic pump 55. The pump 55 is driven at a substantially constant speed by a constant speed electric motor 58 through a belt and pulley arrangement, indicated generally at 60. Communicating with the hydraulic fluid line 42, at a point intermediate the discharge end of the Venturi tube 40 and the intake port 45 on the hydraulic motor 20, is a hydraulic fluid line 63 which is arranged to divert a portion of the hydraulic fluid passing through the line 42 into an intake port 65 of the hydraulic pump 55.

Referring again to the details of the jet-Venturi pump 35, as shown in Fig. 3, the jet 48 is mounted concentrically with respect to the bore 38 and the longitudinal axis of the Venturi tube 40 and extends partially into the mouth 69 at the entrance end of the Venturi tube. The jet 48 is spaced from the walls of the bore 38 and the mouth 69 of the Venturi tube to allow the fluid from the line 29 to be entrained by a high velocity fluid stream delivered by the jet. The fluid from the line 29 is accelerated prior to meeting the jet flow due to a pressure differential developed in the Venturi tube 40.

An auxiliary, constant-displacement, hydraulic pump 70, operatively connected to the electric motor 58, supplies a constant predetermined quantity of hydraulic fluid from a reservoir 72 to make up gland leakage losses in the hydraulic system. Compensation for motor slippage is also made, since a portion of the fluid supplied by the pump 70 from the reservoir 72 is forced through the motor 20 before being expelled from the system. The discharge port 73 of the pump 70 is connected to the intake port 65 of the fluid pump 55 by means of a hydraulic fluid line 75. Gland leakage fluid is returned to the intake port 76 of the auxiliary pump 70 by means of leakage fluid return lines 77—77 connected to drains 80 and 81 on the hydraulic pumps 55 and 70, respectively, and a drain 82 on the hydraulic motor 20. The discharge port 30 of the hydraulic motor 20 is connected to the reservoir 72 through a pressure-relief valve 85 which is set to open at a predetermined pressure to relieve excess pressure in the line 29, thereby maintaining a desired predetermined

supercharge pressure at the discharge port of the hydraulic motor.

Operation

In operation the coiling head 10 is driven continuously by the hydraulic motor 20 to take up the strand which is advanced continuously at a predetermined uniform speed. In order to maintain a predetermined constant strand tension, it is essential that the rotational speed of the coiling head at the start of the coiling operation be relatively high and decrease proportionally as the winding diameter increases with the build-up of a coil on the head. Further, since the winding diameter is relatively small at the start of the coiling operation, the coincident torque is likewise relatively small and must increase proportionally with the build-up of the coil on the coiling head. The foregoing requirements, which are necessary to maintain a constant predetermined strand tension, are fulfilled by delivering a substantially constant power output from the hydraulic motor 20 to the drive shaft 22.

The hydraulic drive system (Fig. 3) associated with the motor 20 is designed to obtain a substantially constant power output from the motor, disregarding changes in bearing friction which by design are of a relatively small order. In operation the constant-displacement pump 55 is driven continuously at a substantially constant speed by the electric motor 58 to supply a substantially constant volume flow J (Fig. 4) under such pressure as is required to maintain the flow through the line 50 to the jet 48. The jet orifice 49 imparts a constant velocity head to the constant volume flow J so that it then possesses a constant power in the form of kinetic energy.

A flow K (Fig. 4) leaving the motor 20 is conducted to the port 32 in the jet-Venturi pump 35, wherein it is entrained in the Venturi tube mouth 69 by the jet flow J. The jet flow J imparts momentum to the entrained stream and develops a combined velocity head, which is converted substantially into a pressure head by the Venturi tube 40. The combined flow (J+K) is discharged by the Venturi tube 40 into the line 42. However, before entering the motor 20, the flow J is withdrawn by the line 63 and recirculated through the pump 55. The remaining flow K is conducted to the intake of the fluid motor 20, where its pressure head is converted into mechanical energy. The flow K is then discharged into the line 29 to be recirculated by the jet-Venturi pump 35.

A derived mathematical relationship between the two flows K and J can be expressed by the following equation:

$$\frac{E_k}{E_j} = \frac{f^2 \frac{K}{J}}{\left(1 + \frac{K}{J}\right)^2} + \frac{C_1 \left(\frac{K}{J}\right)^3 \left[\frac{(2f^2 C_2 - C_1) - 2C_1 \frac{K}{J} - C_1(1-f^2) \left(\frac{K}{J}\right)^2}{\left(1 + \frac{K}{J}\right)^2} \right]}{C_2^2 \left(\frac{K}{J}\right)^2}$$

Where:

E_k = energy delivered to motor 20

E_j = energy of the jet stream J

f = impact coefficient

D_1 = Venturi tube throat diameter

D_2 = jet orifice diameter

K = flow delivered to the motor 20

J = flow delivered to the jet 48 by pump 55

$$C_1 = \frac{4}{\pi D_1^2}$$

$$C_2 = \frac{4}{\pi D_2^2}$$

Based on the design dimensional constants of an actual

working model, where: $f=0.5$, $C_1=19.4$ and $C_2=151$, a theoretical power characteristic curve A—A, plotting power versus speed is shown in Fig. 5.

Referring again to the power characteristic curve designated A—A in Fig. 5, it may be seen that for operation in the region of the maximum power output of the system there are extremely small changes in power over a wide range of speeds. Neglecting small losses in the hydraulic motor 20 (e. g. bearing losses), the output of the motor may be considered to be substantially constant over this wide range of speeds. It will be noted, for example, that the variation in power for a speed change ratio of 1:1.5 is only approximately 2% in the region of the maximum power output (approximately .65 speed to approximately 1.0 speed). Thus, for example, a coil having an inner diameter of 12 inches and an outer diameter of 18 inches could be wound while maintaining a substantially constant strand tension.

An idealized power characteristic curve B—B (Fig. 5) neglecting the design constants C_1 , C_2 and f has been plotted to the same scale as the curve A—A. It is possible by design to select proper values for the constants C_1 , C_2 , f , E_j and J to obtain a relation that approaches the following equation:

$$\frac{E_k}{E_j} = \frac{JK}{(J+K)^2}$$

where the effect of the second term in the precise mathematical equation is small enough to be neglected. It will be noted that the curve B—B (Fig. 5) is much "flatter" than the curve A—A which is drawn for particular constants of the working model.

The auxiliary pump 70 which is a constant displacement pump driven at a constant predetermined speed supplies a predetermined calculated amount of fluid to augment the flow supplied from the Venturi tube 40, which flow (Fig. 4) has been designated as the combined flow (K+J). This predetermined augmentive quantity of fluid is calculated to compensate for fluid losses by leakage in the glands of the pumps 55 and 70 and the hydraulic motor 20 and for fluid slippage past the operating elements of the hydraulic motor. As a result, the flow delivered to the motor 20 is somewhat greater than K to allow for their losses.

Another adaptation of this system might operate within a speed range wherein the slope of the power characteristic curve is principally negative. This would provide compensation for any increased bearing friction caused by the increased weight of the loaded coiling head, if the magnitude of the friction became such that it could not be neglected. Likewise, the system might be made to operate within a speed range where the slope of the applicable power characteristic curve is principally positive.

It will be understood that the present invention is not limited to the embodiment herein described, but may be incorporated in various modifications and applications within the spirit and scope of the invention.

What is claimed is:

1. A pumping system for supplying fluid under pressure with preselected regulation of power versus volumetric delivery, which comprises a jet pump having a jet and an intake chamber, a constant displacement type hydraulic pump means for passing hydraulic fluid at a substantially constant rate independently of the intake pressure thereof through the jet of the jet pump, the fluid discharged from the jet in the jet pump entraining fluid from the surrounding intake chamber of the jet pump at a variable rate in a preselected range and adding a substantially constant amount of momentum to the momentum of the entrained fluid for obtaining a velocity head within a preselected range of values in the combined fluids, a diverging Venturi means communicating with the fluids discharged by the jet pump for converting the velocity head of the combined fluids substantially all

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into a pressure head, means communicating with the fluids discharged from said Venturi means for extracting fluid at a constant rate substantially equal to the rate at which fluid passes through the jet of the jet pump, and means for supplying fluid to the intake chamber of the jet pump adjacent to the intake of the Venturi means at a variable rate in response to the rate of flow of the fluid supplied by the pumping system and for advancing the fluid within the chamber into contact with the fluid discharged from the jet of the jet pump, any variation in the rate at which the fluid is being entrained by the fluid discharged from the jet being substantially equal to any variation in the flow of the fluid supplied by the pumping system, whereby the hydraulic fluid is supplied by the pumping system at a variable rate of flow and at a pressure responsive to any variation in the rate of flow to produce a substantially constant value of power.

2. The pumping system defined by claim 1 wherein the output thereof is connected to the intake of a constant displacement type fluid motor and the discharge from said motor is connected to the intake chamber of the jet pump adjacent the intake of the Venturi means.

3. A pumping system for supplying fluid under pressure with preselected regulation of power versus volumetric delivery, which comprises a jet pump having a jet and an intake chamber, a variable speed constant displacement type hydraulic pump means for passing hydraulic fluid at a variable rate within a preselected range independently of the intake pressure thereof through the jet of the jet pump, the fluid discharged from the jet in the jet pump entraining fluid from the surrounding intake chamber of the jet pump at a variable rate in a preselected range and adding a variable amount of momentum within a preselected range to the momentum of the entrained fluid for obtaining a velocity head within a preselected range of values in the combined fluids, a diverging Venturi means communicating with the fluids discharged by the jet pump for converting the velocity head of the combined fluids substantially all into a pressure head, means communicating with the fluids discharged from said Venturi means for extracting fluid at a rate substantially equal to the rate at which fluid passes through the jet of the jet pump, and means for supplying fluid to the intake chamber of the jet pump adjacent to the intake of the Venturi means at a variable rate in response to the rate of flow of the fluid supplied by the pumping system and for advancing the fluid within the chamber into contact with the fluid discharged from the jet of the jet pump, any variation in the rate at which the fluid is being entrained by the fluid discharged from the jet being substantially equal to any variation in the flow of the fluid supplied by the pumping system, whereby the hydraulic fluid is supplied by the pumping system at a variable rate of flow and at a pressure responsive to any variation in the rate of flow to produce the desired preselected regulation of power.

4. The pumping system defined by claim 3 wherein the output thereof is connected to the intake of a constant displacement type fluid motor and the discharge from said motor is connected to the intake chamber of the jet pump adjacent the intake of the Venturi means.

5. A pumping system for supplying fluid under pressure with preselected regulation of power versus volumetric delivery, which comprises a jet pump having a jet and an intake chamber, a constant displacement type hydraulic pump means for passing hydraulic fluid at a substantially constant rate independently of the intake pressure thereof through the jet of the jet pump, the fluid discharged from the jet in the jet pump entraining fluid from the surrounding intake chamber of the jet pump at a variable rate in a preselected range and adding a substantially constant amount of momentum to the momentum of the entrained fluid for obtaining a velocity head within a preselected range of values in the combined fluids, a diverging Venturi means communicating with

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the fluids discharged by the jet pump for converting the velocity head of the combined fluids substantially all into a pressure head, means communicating with the fluids discharged from said Venturi means for extracting fluid at a rate substantially equal to the rate at which fluid passes through the jet of the jet pump, means for adding fluid at a preselected rate to the fluids discharged from said Venturi means for substantially compensating for the rate of losses resulting from leakage in the pumping system, and means for maintaining a preselected supercharge pressure in the fluid entering the intake chamber of the jet pump adjacent to the intake of the Venturi means for supplying fluid thereto at a variable rate in response to the rate of flow of the fluid supplied by the pumping system and for advancing the fluid within the chamber into contact with the fluid discharged from the jet of the jet pump, any variation in the rate at which the fluid is being entrained by the fluid discharged from the jet being substantially equal to any variation in the flow of the fluid supplied by the pumping system, whereby the hydraulic fluid is supplied by the pumping system at a variable rate of flow and at a pressure responsive to any variation in the rate of flow to produce a substantially constant value of power.

6. The pumping system defined by claim 5 wherein the output thereof is connected to the intake of a constant displacement type fluid motor and the discharge from said motor is connected to the intake chamber of the jet pump adjacent the intake of the Venturi means, and wherein said means for maintaining the preselected supercharge pressure in the fluid entering the intake chamber is a pressure regulating valve.

7. The combination defined by claim 6 wherein said means for adding fluid at a preselected rate to the fluid discharged from said Venturi means is of sufficient size as to more than compensate for leakage in the pumping system so as to compensate for motor leakage and slippage.

8. A pumping system for supplying fluid under pressure with preselected regulation of power versus volumetric delivery, which comprises a jet pump having a jet and an intake chamber, a variable speed constant displacement type hydraulic pump means for passing hydraulic fluid at a variable rate within a preselected range independently of the intake pressure thereof through the jet of the jet pump, the fluid discharged from the jet in the jet pump entraining fluid from the surrounding intake chamber of the jet pump at a variable rate in a preselected range and adding a variable amount of momentum in a preselected range to the momentum of the entrained fluid for obtaining a velocity head within a preselected range of values in the combined fluids, a diverging Venturi means communicating with the fluids discharged by the jet pump for converting the velocity head of the combined fluids substantially all into a pressure head, means communicating with the fluids discharged from said Venturi means for extracting fluid at a rate substantially equal to the rate at which fluid passes through the jet of the jet pump, means for adding fluid at a preselected rate to the fluids discharged from said Venturi means for substantially compensating for the rate of losses resulting from leakage in the pumping system, and means for maintaining a preselected supercharge pressure in the fluid entering the intake chamber of the jet pump adjacent to the intake of the Venturi means for supplying fluid thereto at a variable rate in response to the rate of flow of the fluid supplied by the pumping system and for advancing the fluid within the chamber into contact with the fluid discharged from the jet of the jet pump, any variation in the rate at which the fluid is being entrained by the fluid discharged from the jet being substantially equal to any variation in the flow of the fluid supplied by the pumping system, whereby the hydraulic fluid is supplied by the pumping system

at a variable rate of flow and at a pressure responsive to any variation in the rate of flow to produce the desired preselected regulation of power.

9. The pumping system defined by claim 8 wherein the output thereof is connected to the intake of a constant displacement type fluid motor and the discharge from said motor is connected to the intake chamber of the jet pump adjacent the intake of the Venturi means, and wherein said means for maintaining the preselected supercharge pressure in the fluid entering the intake chamber is a pressure regulating valve.

10. The combination defined by claim 9 wherein said means for adding fluid at a preselected rate to the fluid discharged from said Venturi means is of sufficient size as to more than compensate for leakage in the pump-

ing system so as to compensate for motor leakage and slippage.

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