United States Patent

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[54] **MOLD LEVEL CONTROL SYSTEM**
3 Claims, 3 Drawing Figs.

[52] **U.S. Cl.** **164/282,** 164/154; 226/178; 103/38
[51] **Int. Cl.** **B22d 11/12,** B22c 19/04
[50] **Field of Search** ..... 164/82, 154, 282; 226/178, 188; 103/38 (recent), 38A

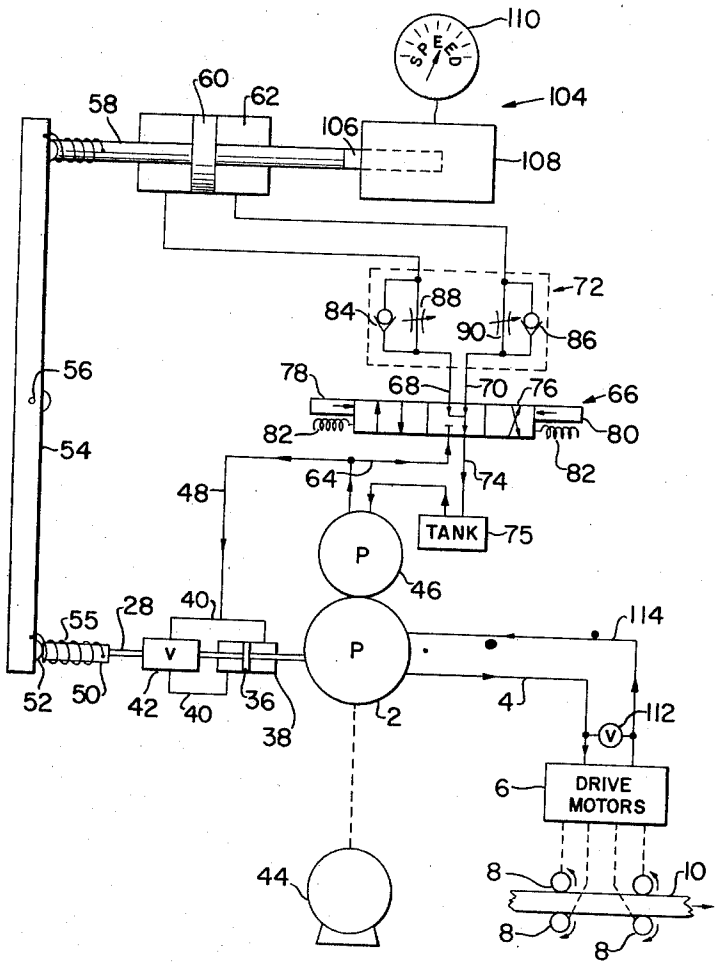
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ABSTRACT: A mold level control used with a continuous casting machine having hydraulic motors for withdrawing a cast strand from a mold. The system includes a stem servo-controlled pump supplying fluid to the motors, a piston actuating the stem to control pump output, and a four-way self-centering solenoid valve to control piston movement. Movement of a joystick up or down closes microswitches to operate the valve to decrease or increase strand withdrawal rate respectively. Between joystick movements the valve centers itself and strand withdrawal rate remains steady.



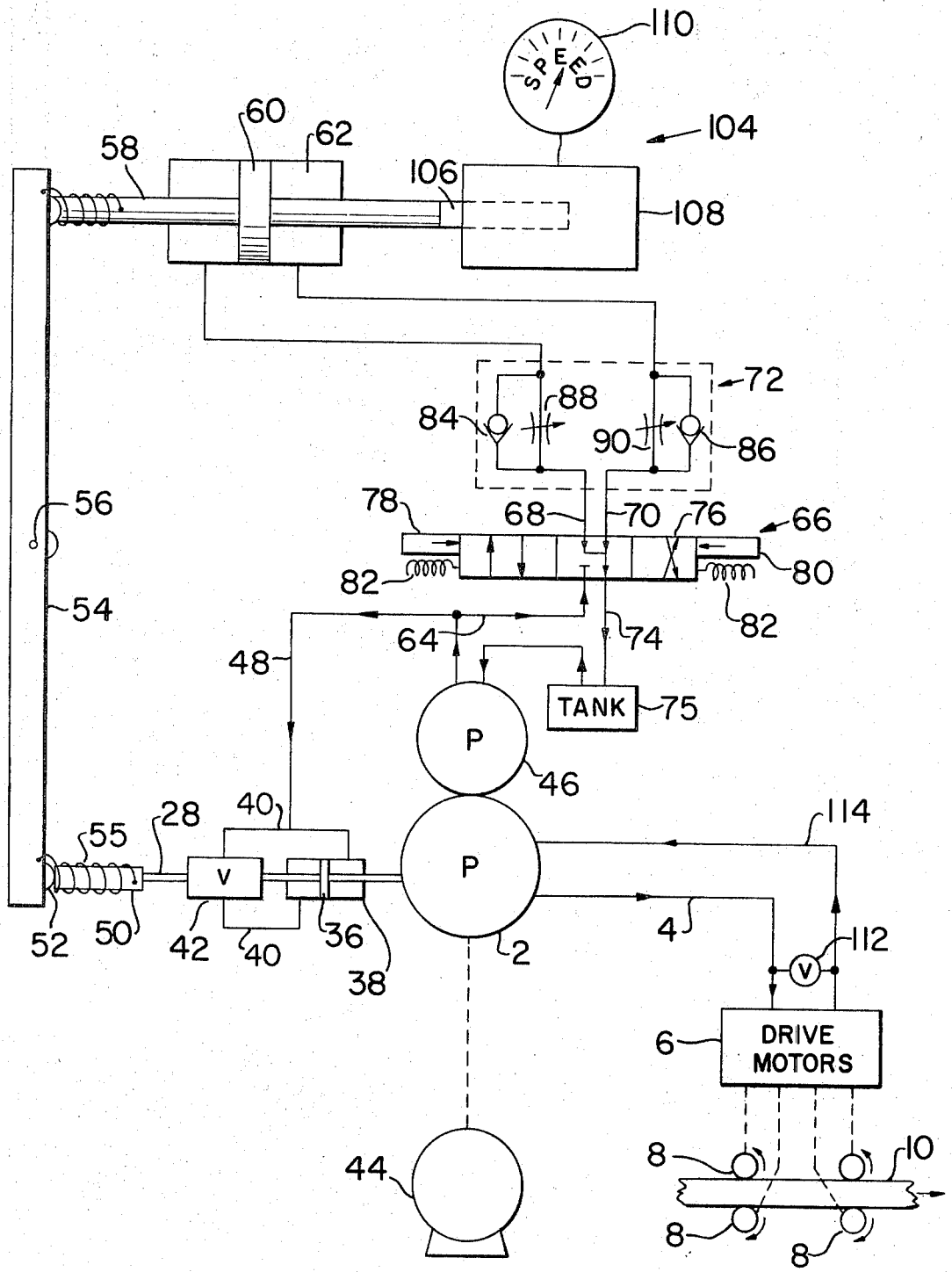


FIG. 1

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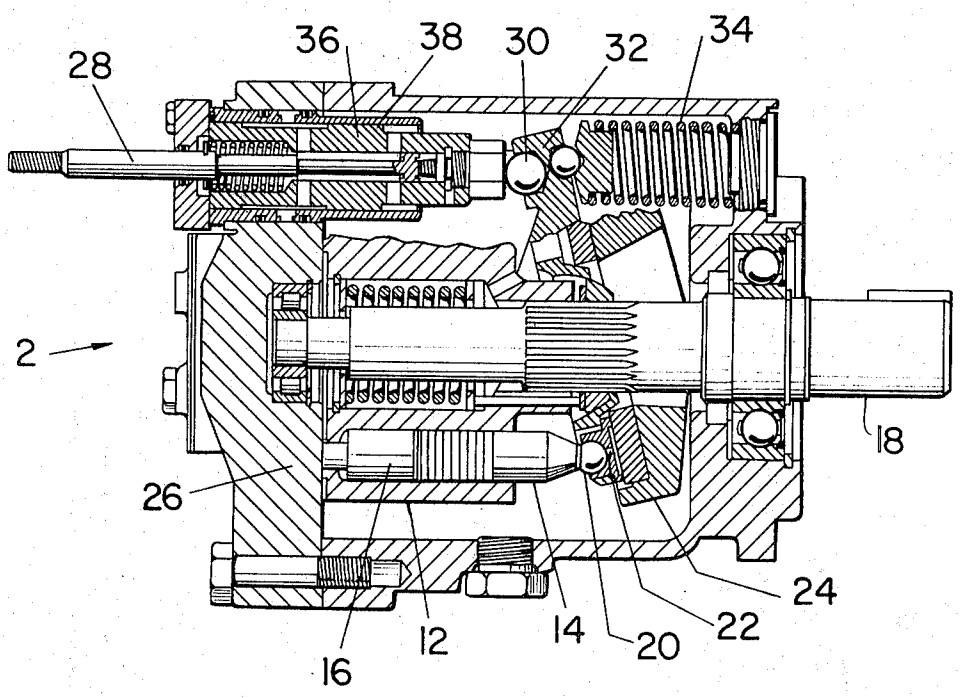


FIG. 2

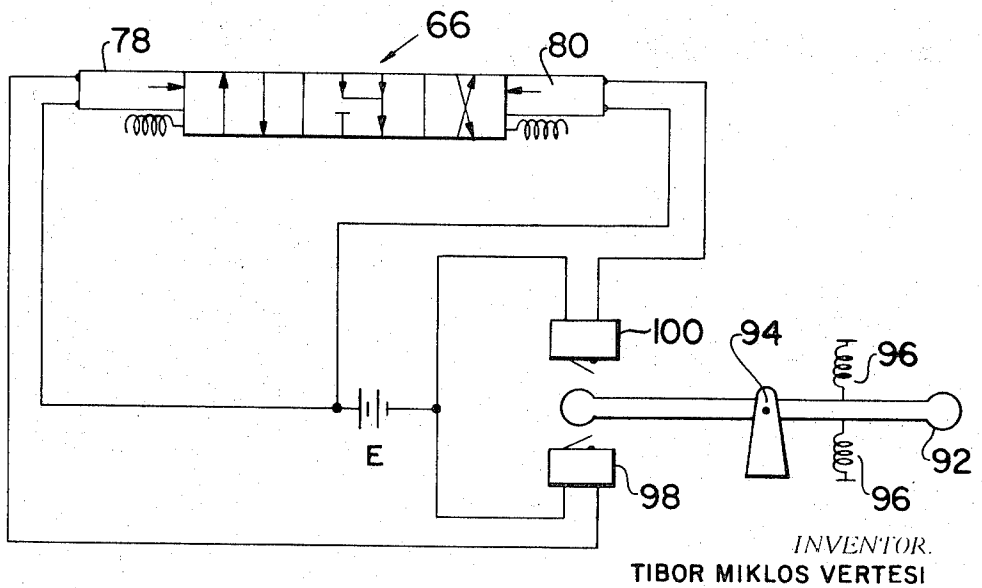


FIG. 3

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MOLD LEVEL CONTROL SYSTEM

This invention relates to continuous metal casting apparatus, and more particularly, it relates to a relatively simple mold level control for continuous casting apparatus.

Apparatus for producing continuous metal castings usually includes a mold into which metal is poured and from which a metal strand is withdrawn at a controlled rate. The rate at which molten metal is poured into the mold is usually not easily controlled to close tolerances and therefore the rate at which the metal strand is withdrawn from the mold must be controlled to keep the metal level in the mold relatively constant. A constant liquid level in the mold is desirable because it allows uniform heat removal in the mold, helping to insure a uniform shell thickness for the newly formed cast metal strand. In addition, control of the liquid metal level in the mold prevents overflow of the mold, and also ensures that metal is not withdrawn from the mold at such a rapid rate that the mold is emptied thus causing a break in the strand.

The cast metal strand withdrawn from the mold is normally propelled by drive rollers acting on the strand. In the past, such drive rollers have usually been driven by variable-speed direct current motors. Complex speed control equipment has been provided so that the speed of the drive motors can be continuously varied, so that an operator will have continuous control of the withdrawal speed of the strand. These prior art speed control mechanisms have been costly and sometimes unreliably complicated.

Accordingly, it is an object of the present invention to provide relatively simple apparatus for controlling the withdrawal rate of the metal strand to keep the metal level in the mold relatively constant. The mold level control of the invention is intended for use with a continuous casting machine of the type including hydraulic drive motors for withdrawing a cast metal strand from said mold, and the mold level control typically comprises:

a. a pump for supplying power fluid to said drive motors to operate said motors, said pump being controllable to vary the power level of said power fluid,
b. piston and cylinder means coupled to said pump and operable to vary the power output of said pump,
c. a source of control fluid for said piston and cylinder means,
d. valve means coupled between said source of control fluid and said piston and cylinder means said valve means being actuable to selectively operate said piston and cylinder means in a desired sense when said valve means is actuated, said valve means having a neutral position in which said piston and cylinder means remains stationary, and including means biasing said valve means to said neutral position,
e. and control means coupled to said valve means to actuate the same to operate said piston and cylinder means.

Further objects and advantages of the invention will appear from the following disclosure, taken together with the accompanying drawings, in which:

FIG. 1 is a diagrammatic view showing a mold level control system according to the invention;

FIG. 2 is an elevation, in section, showing a stem servo-controlled variable displacement pump for use with the invention; and

FIG. 3 is a side view showing a joystick control handle connected to actuate a valve of the FIG. 1 apparatus.

Referring to FIG. 1, there is shown in block form a stem servo-controlled variable displacement pump 2. The pump 2 is a standard pump and supplies hydraulic fluid through a line 4 to hydraulic drive motors indicated in block form at 6. The hydraulic drive motors are connected to drive rollers 8 which turn in the direction indicated by the arrows to withdraw a metal strand 10 from a mold (not shown).

Since the pump 2 is standard and well known, it will be described only to the extent necessary for understanding of its role in the mold level control system. The pump 2 (FIG. 2) includes a rotating cylinder block 12 containing pistons 14 which are free to move in and out of their bores 16. A typical pump suitable for use with the invention, made by the Vickers-Sperry Co. under model No. PVB-45, has nine cylinder bores and nine pistons. A drive shaft 18 is connected to the cylinder block so that rotation of the drive shaft causes rotation of the pistons and the cylinder block at the same speed.

Each piston terminates in a ball 20 fitted in a ball-shaped groove 22 extending around a swash plate 24. The swash plate 24 is fixed against rotation and is oriented at an angle with respect to the drive shaft 18.

Rotation of the drive shaft 18 and hence of the cylinder block causes the pistons to move in and out of their bores. The stroke length of the piston, and therefore the pump output, depends on the angular position of the swash plate 24. As each piston moves outward, fluid is drawn in through a valve plate 26 (via conduits not shown), and on the return stroke, fluid is forced out through the valve plate under pressure.

The angle of the swash plate may be changed by any of several different types of control methods. One of these methods, and the method illustrated here, is the stem servocontrol method, which utilizes a stem 28 protruding through the valve plate 26. The stem extends all the way through to the swash plate and terminates in a ball 30 located in a socket 32 of the swash plate. The socket 32 is located outside the groove or track 22 so as not to interfere with the rotary movement of the pistons. The swash plate is biased against the stem 28 by a spring 34.

The stem 28 is hydraulically locked in any position in which it is set by a double-acting piston 36 in a cylinder 38. Oil lines 40 (FIG. 1) from each side of the cylinder 38 are connected together through a valve mechanism diagrammatically indicated at 42 (FIG. 1) and actuated by the stem 28, the valve mechanism 42 being such that oil lines 40 are connected together only when the free end of stem 28 is moved. This is a standard feature of stem servo-controlled variable displacement pumps.

The variable displacement pump 2 is driven by a motor 44. Motor 44 also drives a smaller fixed displacement pump 46 used to supply make-up hydraulic fluid to the closed loop system containing drive motors 6 (pumps 2 and 46 are normally sold as a package and are internally connected) and to supply pressurized fluid for the mold level control system. A fluid line 48 from pump 46 supplies control fluid for cylinder 38.

The stem 28 is moved in and out by an extension 50 screwed to the end of the stem and riding on a ball surface 52 located at the tip of a yoke 54. The yoke 54 and extension 50 are held together by an extension spring 55. If desired, a different type of connection, such a pin and slot, could be used instead.

The yoke 54 is pivoted at 56, and its other end is connected to a piston rod 58 of a double-acting piston 60 located in a cylinder 62. As the piston 60 moves back and forth, it drives yoke 54 to push stem 28 in and out, thereby controlling the power level of the output fluid of pump 2. When a Vickers-Sperry model PVB-45 variable displacement pump 2 is employed, the typical maximum travel of stem 28 from one extreme to the other is about thirteen-sixteenths inch, with only a few pounds pressure required to achieve this travel. The yoke 54 is then typically about 7 inches in length, and cylinder 62 is typically a 1 inch diameter cylinder supplied with fluid at a pressure of about 100 p.s.i.

Hydraulic fluid to power the piston 60 is supplied by the fixed displacement pump 46 through a line 64. The line 64 is connected to a four-way directional valve 66 from which lines 68, 70 extend through a choke block 72 to each side of the cylinder 62. A drain line 74 also extends from valve 66 to a tank 75 and then back to the fixed displacement pump 46.

The valve 66 is a conventional valve having a valve spool diagrammatically indicated at 76. The spool 76 has three positions, namely a first or neutral position in which both lines 68, 70 from cylinder 62 are connected together and to the drain line 72 and pressure line 64 is blocked off, a second position in

which pressure and drain lines **64**, **74** are connected to lines **68**, **70** respectively, and a third position in which the pressure and drain lines **64**, **74** are connected to lines **70**, **68** respectively.

The valve spool **76** is actuated by two solenoids **78**, **80**. When solenoid **78** is actuated, spool **76** is moved to its first position (in which lines **64**, **74** are connected to lines **68**, **70**) and when solenoid **80** is actuated, spool **76** is moved to its second position (in which lines **64**, **74** are connected to lines **70**, **68**). The arrows on the solenoid blocks indicate the direction in which they move the valve spool when they are actuated. When neither solenoid is actuated, springs diagrammatically indicated at **82** return the valve spool to its neutral position.

The choke block **72** contains check valves **84**, **86**, one for each line **68**, **70**, and adjustable orifices **88**, **90**, one connected in parallel with each check valve.

The adjustable orifices **88**, **90** are typically screwdriver operated and are provided to control the response of the system.

The solenoids **78**, **80** are actuated by a joystick control handle shown at **92** in FIG. **3**. Joystick **92** is pivoted at **94** so that its axis is located in a horizontal plane, and it is normally held in this position by biasing springs diagrammatically indicated at **96**. The free end of joystick **94** is a shaped to cooperate with the switch elements of fixed microswitches **98**, **100** mounted to cooperate with the joystick. Microswitch **98** is connected to a source of electrical power E to operate solenoid **78**, while microswitch **100** is connected to source E to operate solenoid **80**.

The overall operation of the apparatus described is as follows. Assume that the strand **10** is being withdrawn from a mold and that the strand is being withdrawn too slowly, so that the level of metal in the mold is rising and will overflow if the trend continues. The operator then pushes joystick **92** downwardly, i.e. in the direction that he would like the level of the metal to go. This closes microswitch **98**, actuating solenoid **78**.

Solenoids **78** then moves valve spool **76** out of its neutral position to its second position in which lines **64**, **74** are connected to lines **68**, **70** respectively. This moves piston **60** to the right as shown in FIG. **1**, thereby moving stem **28** to the left as shown in FIG. **1** (i.e. pulling the stem out from the pump **2**). This increases the angle of swash plate **24**, increasing the displacement of pump **2** and hence increasing the power level of its fluid output. The strand **10** is then withdrawn at a faster rate, the amount of the increase depending on the length of time for which microswitch **98** is held closed. The operator can push joystick **92** down for a brief interval, observe the effect on the mold level, and then push down the joystick for further brief intervals as required.

Similarly, if the level of metal in the mold is falling too rapidly, the operator can push joystick **92** upwardly. This closes microswitch **100** to actuate solenoid **80**, thereby connecting lines **64**, **74** to lines **70**, **68** respectively. This moves piston **60** to the left as shown in FIG. **1**, pushing stem **28** in to reduce the angle of swash plate **24** and decreasing the power level of the output from pump **2**. This reduces the rate of withdrawal of strand **10**, causing the mold level to rise as desired.

The response of the system will typically be adjusted (by adjustment of orifices **88**, **90**) so that the time required for piston **60** to travel from one extreme to the other is about 8 seconds. However, this time can be adjusted from about 22 seconds to about 0.2 seconds by control of the orifices. Movement of piston **60** from one extreme to the other (i.e. from a position in which stem **28** is fully pushed in to a position in which stem **28** is retracted to its limit) will typically change the withdrawal speed of strand **10** between zero and 300 inches per minute.

It may be noted that the present invention basically provides, not a speed control, but a mold level control. The operator is not normally concerned with the speed of the strand, but only with the mold level, which is the only process information that he need observe in order to make his decision as to whether to push the joystick **92** up or down. However, when the strand withdrawal from the mold is initially commenced, it is usually desirable to preset a rate of strand withdrawal that will approximately match the rate at which it is anticipated that metal will be poured into the mold. Therefore, a speed indicator generally indicated at **104** is connected to the free end of piston rod **58**.

The speed indicator **104** includes a metal core **106** which moves to a varying degree into the windings of a transformer **108** as the piston **60** moves in and out. This changes the coupling between the transformer coils (in a conventional manner) and the output of the transformer **108** is read on a meter **110** calibrated to indicate the strand withdrawal rate. The meter **110** in fact reads the position of piston **60**, but this is a measure of strand withdrawal rate because of the connection of piston **60** to stem **28** of the pump **2**.

As shown in FIG. **1**, there will normally be a relief valve **112** leading from the pressure line **4** from pump **2** to drive motors **6**, to a return line **114** back to the pump. The startup procedure for withdrawal of the strand **10** is then as follows. Firstly, with the relief valve **112** open (so that drive motors **6** do not operate), the motor **44** is started, and the joystick **92** is moved until the speed indicator meter **110** reads a desired speed of strand withdrawal. The pouring of metal into the mold (not shown) is then initiated, and after the mold is partly filled, relief valve **112** is closed, at which time the drive motors **6** automatically accelerate to their preset speed. The operator observes the process, and after the preset speed of withdrawal is reached, he may vary this speed as necessary.

The speed of withdrawal will then remain relatively constant except when the joystick is depressed or raised to actuate one of the solenoids **78**, **80**. The apparatus shown, with its impulse type of speed variation, reduces the capital cost of the equipment, is uncomplicated, and is reliable in use.

I claim:

1. In a continuous casting machine of the type having a mold, and hydraulic drive motors for withdrawing a cast metal strand from said mold; a mold level control system comprising:

a. a variable displacement pump for supplying power fluid to said drive motors to operate said motors, said pump having a stem projecting therefrom to control the displacement of said pump and hence the power level of said power fluid,

b. a double-acting piston and cylinder,

c. a yoke connected to said double-acting piston and to said stem, and means pivoting said yoke, so that movement of said double-acting piston in one direction moves said stem to increase the power level of said power fluid, and movement of said double-acting piston in the other direction moves said stem in a direction to decrease the power level of said power fluid,

d. a source of control fluid, and a four-way directional valve connecting said source to said double-acting piston and cylinder, said valve including a valve member having a first position in which said control fluid is disconnected from said cylinder, so that said piston and stem remain stationary, a second position in which said control fluid is connected to said cylinder in a direction to move said piston at a predetermined rate in said one direction, and a third position in said control fluid is connected to said cylinder in a direction to move said piston at a predetermined rate in said other direction,

e. said valve further including first and second solenoids selectively actuable to move said valve member to said second or third positions respectively, and spring means biasing said valve member to said first position in the absence of actuation of said solenoids so that the power level of said fluid remains constant in the absence of actuation of said solenoids, and

f. control means for said valve, said control means including a joystick, means mounting said joystick in an orientation

with its its axis substantially horizontal, for up and down movement of said joystick from a neutral horizontal position to a raised position or to a lowered position, a first switch mounted for actuation by said joystick when said joystick is in its lowered position and being off when said joystick is in a position other than its lowered position, a second switch mounted for actuation when said joystick is in its raised position and being off when said joystick is in a position other than its raised position, and means connecting said switches with said solenoids so that when said first switch is actuated, said first solenoid is actuated and when said second switch is actuated, said second solenoid is actuated,

whereby movement of said joystick to its lowered position increases the speed of said drive motors to increase the rate of strand withdrawal from said mold, and movement of said joystick to its raised position decreases the speed of said drive motors to decrease the rate of strand withdrawal from said mold, and when said joystick is in its neutral position, said double-acting piston remains stationary and the power level of power fluid supplied to said drive motors remains fixed.

2. Apparatus according to claim 1 including adjustable choke means connected between said valve and said cylinder for controlling the speed of movement of said piston upon actuation of said valve and consequent movement of said valve member to said second or third position.

3. Apparatus according to claim 2 including speed indicating means for presetting the power level of said power fluid, said speed indicating means including an indicator coupled to said piston to indicate the position of said piston, and display means associated with said indicator and graduated for various positions of said indicator to indicate various speeds of withdrawal of said metal strand, whereby said valve may be actuated in advance of connection of said power fluid to said drive motors to move said piston until a desired power level of said power fluid is reached, so that said drive motors will accelerate to a desired speed upon application of said power fluid thereto.