July 30, 1957 H. A. PANISSIDI 2,800,885

HYDRAULIC CONTROL APPARATUS

Filed Dec. 31, 1954 3 Sheets-Sheet 1

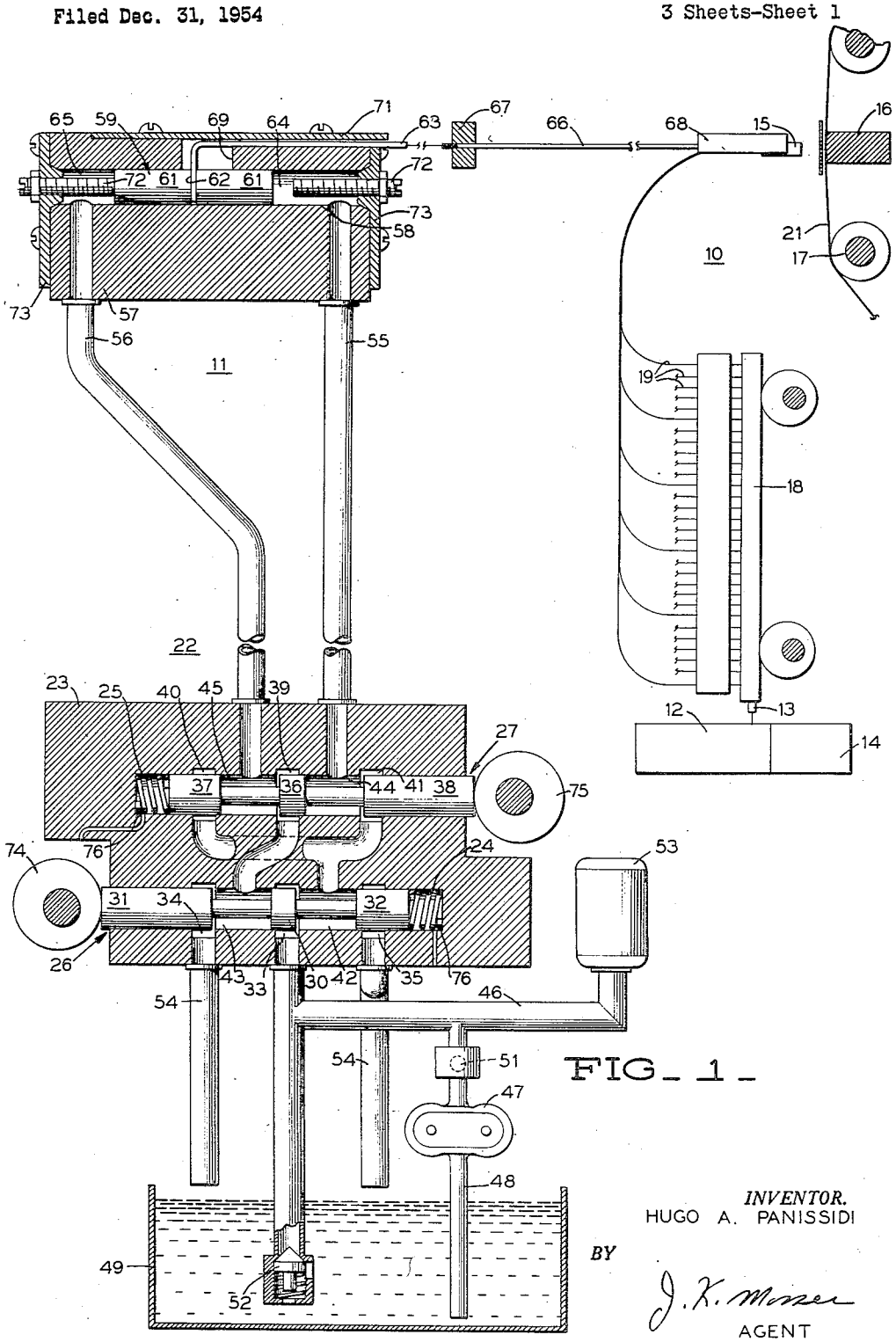


FIG. 1.

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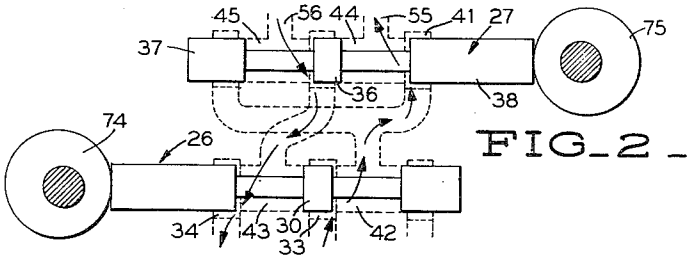


FIG_2_

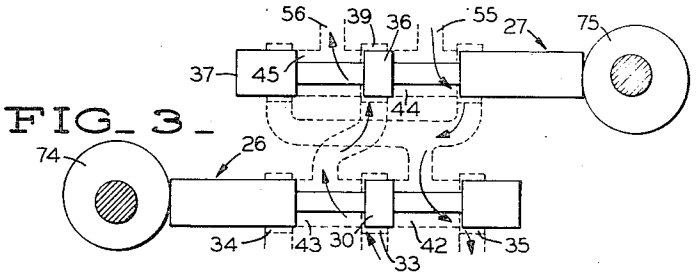


FIG_3_

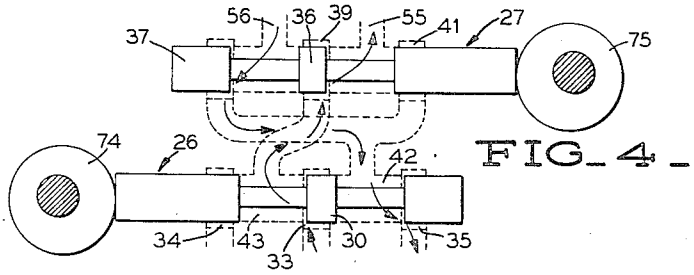


FIG_4_

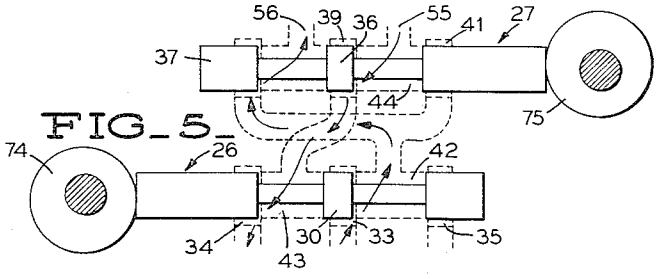


FIG_5_

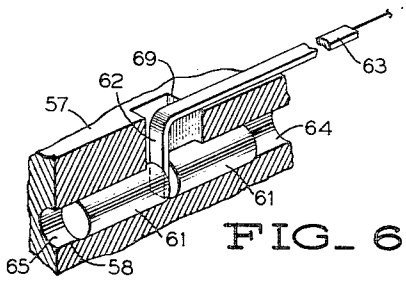


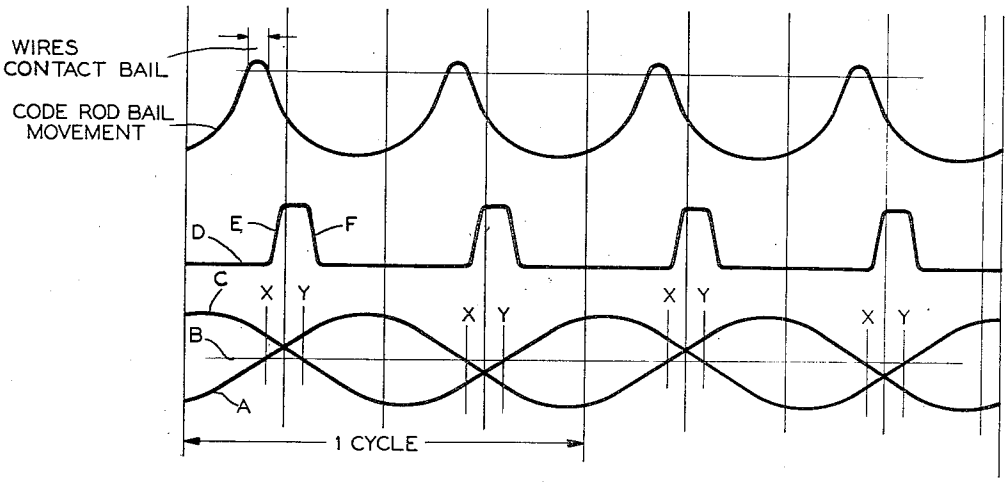
FIG_6_

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FIG_7_



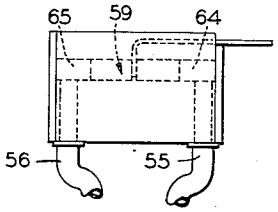
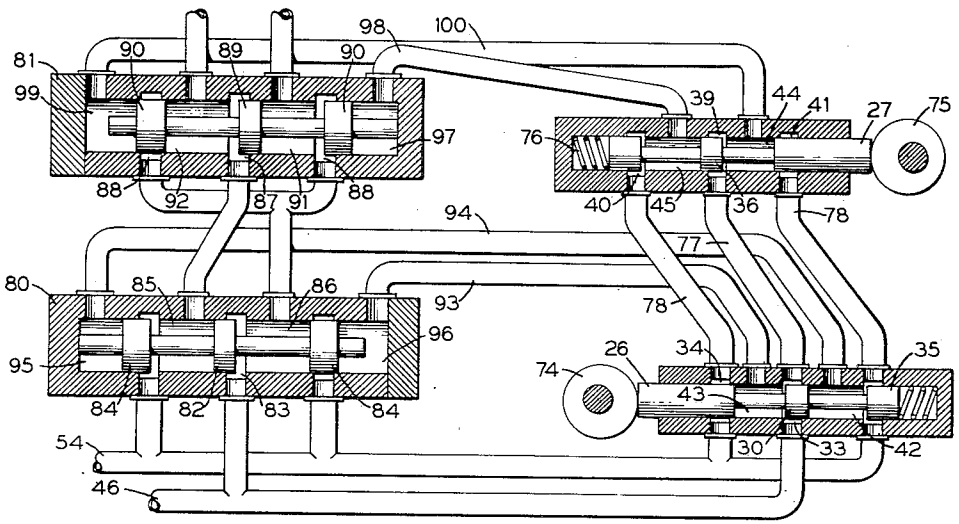


FIG_8_



United States Patent Office

2,800,885

Patented July 30, 1957

2,800,885

HYDRAULIC CONTROL APPARATUS

Hugo A. Panissidi, Binghamton, N. Y., assignor to International Business Machines Corporation, New York, N. Y., a corporation of New York

Application December 31, 1954, Serial No. 479,111

14 Claims. (Cl. 121—147)

The invention relates to hydraulic apparatus and more particularly to hydraulic apparatus capable of applying a rapid driving impulse to a driven member.

It is one of the objects of the invention to apply a rapid hydraulic impulse to a driven member which is of short duration during a portion of a cycle of operation.

It is another object of the invention to provide a hydraulic drive for a driven member which is cyclically operated within limits to provide a rapid forward and reverse stroke and a relatively long inactive retracted dwell.

It is still another object of the invention to provide a print head for a wire printer with a hydraulic drive means which is timed to produce a high pressure impulse of short duration to perform the printing operation.

One application for the improved hydraulic drive mechanism relates to wire printers. Heretofore, it has been customary to mechanically drive the print head for wire printers to perform the printing operation by the use of eccentric cams and the like. While these various printing head drive mechanisms operate reasonably satisfactorily at lower speeds, the problem of accurate cam operation and inertia forces becomes acute as higher and higher speed requirements are demanded.

In accordance with the invention, there is provided the usual print head to be cyclically driven in timed relation to the other operating parts of the printer. Directly connected to the print head is a drive or print piston having opposite sides exposed to oppositely disposed pressure chambers. The liquid in these pressure chambers is in turn under the control of a pair of reciprocatable spool or pilot print valves. The timing of these valves is such that two driving impulses are supplied to the print head for each complete cycle of valve movement. However, during the major portion of their movement, the drive piston is held retracted by liquid under pressure which is applied to one of the chambers. Only during a small portion of total valve movement is liquid under pressure supplied to the opposite chamber to drive the print piston forward to perform the printing operation, after which the print head is quickly retracted to its inactive position by the reversal of the application of liquid under pressure.

By operating the two pilot valves with a predetermined phase angle difference between eccentrics, the timing of the print head operation may be controlled within close limits and at the same time the duration of the driving impulse may be reduced to a relatively short time interval. By providing a hydraulic driving means of this type, the inertia forces in the operating mechanism are reduced.

It is, therefore, another object of the invention to provide a driving member with a pair of cyclically reciprocatable control valves operated at a predetermined phase angle difference which directs a short high pressure driving impulse to the driving member during a portion of the cycle of operation.

It is another object of the invention to provide driving means for a print head which is capable of high speed operation and adds relatively low inertia forces to the moving parts.

Other objects of the invention will be pointed out in the following description and claims and illustrated in the accompanying drawings, which disclose, by way of examples, the principle of the invention and the best mode, which has been contemplated, of applying that principle.

In the drawings:

Fig. 1 is a partial vertical sectional view of the improved control and driven means as applied to a wire printer and with the print head retracted.

Figs. 2 to 5, inclusive, are enlarged diagrammatic views of the various positions of the control valves during different phases of the cycle of operation.

Fig. 6 is an enlarged perspective view showing piston and rod structural features.

Fig. 7 is a timing diagram showing the control valve operation synchronized with the printer operation to provide the improved print head operation.

Fig. 8 is a modification of the improved control means.

Referring now to the drawings for a detailed description for one example of an application of the improved hydraulic control as applied to a printing mechanism, there is shown a suitable wire printer **10** having the improved hydraulic control mechanism **11** applied thereto. The wire printing mechanism may be of the type shown and described in Frank J. Furman et al. application, Serial No. 478,650, filed December 30, 1954, and the setup mechanism **12** for the code rods **13** may be of the type disclosed in the above application or that disclosed and claimed in Frank J. Furman and Hugo A. Panissidi application, Serial No. 479,112, filed December 31, 1954. In addition, a suitable electric control means **14**, the details of which are not shown, for the setup mechanism **12** may be of the type described and claimed in Henry A. Jurgens et al. application, Serial No. 479,107, filed December 31, 1954.

Since the means **14** for receiving the data to be printed, the setup mechanism **12** for the wire printer, the particular details of a print head **15**, its associated platen **16** and carriage structure **17** and the like form no part of this invention, only a general description thereof will be given.

Briefly, the data to be printed is received in any suitable manner and at the proper time in the machine cycle is transmitted, in the form of electrical pulses or the like to the setup mechanism **12** to position the code rod **13**. The code rod is then moved laterally by a bail **18** to physically shift certain related wires in the wire array **19** to set up the desired character to be printed by the print head **15**. The timing of the code rod setup mechanism **12** and operation of the print head **15** are such that, shortly after the desired wires have been set up, a forward impulse is applied to the print head to drive the same against a suitable paper form **21**, backed by the usual platen **16** to thereby print the desired character. As the character is printed, the hammer action of the print head **15** returns the projected wires to their original retracted positions. The print head **15** is then retracted and is ready to be again driven forward to print the next character set up by the code rod **13**.

The above general description of the printing operation applies for any cycle of operation. Under actual operating conditions, this driving or cycling of the print head **15** occurs rapidly, that is, in the order of 1,600 characters per minute and under some conditions higher. Thus, it becomes necessary to provide a rapid driving and return

impulse to the print head 15 and at the same time maintain the inertia forces at a relatively low value. Therefore, the improved hydraulic print head drive means or mechanism 11 has been provided which not only provides a low inertia mass to the system, but at the same time is capable of operating over wide speed ranges well over that considered practical for mechanical drives.

As shown in Fig. 1, the print head 15 is in its retracted position and the hydraulic control mechanism 11 is at some point along the dwell portion of the print cycle. This hydraulic mechanism comprises a control section 22, including a cored housing 23 having a pair of first and second parallel cylindrical walls 24 and 25, in which is disposed reciprocatable first and second spool-type control of print valve means 26 and 27, respectively. The first spool valve 26 includes the usual central and spaced end lands 30, 31 and 32, respectively, which are adapted to overlap and control liquid flow through related recessed ports 33, 34 and 35, respectively, and the second spool valve 27 includes similar lands 36, 37 and 38 for controlling related recessed ports 39, 40 and 41. In addition, the lands on the first spool valve 26 cooperate with the first cylindrical wall 24 to provide right- and left-hand liquid conducting chambers 42 and 43, respectively, disposed on opposite sides of the central land 30. Likewise, the lands on the second spool valve 27 cooperate with its related wall to provide right- and left-hand liquid conducting chambers 44 and 45, respectively, disposed on opposite sides of the central land 36. As shown, the chamber 43 in the first passage 24 is in direct communication with the recessed port 39 in the second passage and the chamber 42 is in direct communication with the recessed ports 40 and 41 in the second passage by means of a divided channel. These valves provide openings and cutoff and direct liquid under pressure therethrough in series in a manner to be hereinafter described.

Liquid under pressure is supplied to the pressure port 33 of the first print valve 26 over a conductor or conduit system 46 which is connected to the discharge side of a positive displacement gear pump 47 whose inlet in turn is connected by means of a duct 48 to a suitable sump or reservoir 49. The conductor or conduit 46 is provided with the usual check valve 51 at the discharge of the gear pump, a pressure relief valve 52 and an accumulator 53 to provide substantially constant liquid pressure at the pressure port 33. The outer or discharge ports 34 and 35 of the first print control valve 26 are connected to the reservoir through suitable divided drain conduits 54.

Extending from the chambers 44 and 45 on opposite sides of the central land 39 of the second print valve 27 are a pair of liquid transfer ducts or conduits 55 and 56, respectively. These conduits are connected to a suitably cored stationary housing 57 having a bore 58 therein for guiding a reciprocatable driving member or print piston assembly 59. This print piston assembly includes a pair of identically shaped pistons 61 whose inner faces are disposed on opposite sides of an inturned extension 62 of an offset print piston drive wire or rod 63. The outer faces of these pistons are exposed to opposed pressure chambers 64 and 65 to which liquid under pressure is supplied through the conduits 55 and 56, respectively under the control of the print control valves 26 and 27. With this construction, the inner surfaces of the pistons are urged together and frictionally engage the offset print piston drive wire extension 62 by the pressure applied from the pressure chambers.

The print piston drive wires 63 includes a forward extension preferably mounted within a flexible cable 66 which has one end thereof suitably secured to a stationary support 67 forming a part of the frame of the machine, while the forward end is clamped to a laterally movable print head support 68. This cable acts to prevent flexing or buckling of the print wire during forward travel of the print piston while at the same time permitting lateral movement thereof.

At the central portion of the bore 58 is an elongated slot 69 projecting through the housing 57 which guides the downturned end 62 of the drive wire during reciprocation and a cap member 71 prevents lateral displacement of the guide wire 63 during operation. With an arrangement of this type, it is desirable to limit the stroke of the print piston assembly 59 in both directions of travel, therefore, a pair of adjustable stop members 72 carried in end closures 73 are provided at both ends of the bore 58. As shown in Fig. 1, the print piston is normally held against the rear stop 72 by the liquid pressure applied from the return or retraction chamber 64, and this indicates the normal position of the print head 15 during the time the code rod 12 is being manipulated to set up the desired character to be printed.

In order to cyclically reciprocate the control valves 26 and 27 to selectively direct liquid under pressure to the forward and return chambers 65 and 64, a pair of shaft-driven rotatable eccentric cams 74 and 75, respectively, are provided, one for each print or control valve. These eccentrics engage their related control valves 26 and 27, respectively, and are effective to reciprocate, within limits, the control valves in a predetermined timed relation dependent upon shaft rotation. Disposed on the opposite side of each control valve is a suitable compression spring 76 to continuously urge the control valves against the related eccentric to follow the same. The cams 74 and 75 may be mechanically driven by any suitable means for synchronous rotation.

As shown in the timing chart, Fig. 7, the first print or control valve 26 is moved or laterally shifted by its related cam 74 to follow along the curve A in a cyclic manner with respect to a horizontal neutral or cutoff line B. As this control valve motion crosses the neutral line B, extends above the same and returns in a cyclic manner, the central land 30 of the first valve passes from one to the other side of the high pressure port 33. At each point where the first control valve 26 crosses the neutral line B indicated at X, the central land 30 moves to cut off the application of liquid under pressure to the one chamber and transfers the same to the other chamber on the opposite side of the central control land. Simultaneous with this action, of course, the latter chamber is cut off from its related exhaust port while the former is connected to exhaust.

The second print or control valve 27 likewise following its cam 75 is moved in the same timed relation with the first valve 26. However, the cam 75 is positioned with respect to the cam 74 to provide a valve movement which follows along the cyclic curve C, as clearly shown in Fig. 7. This valve motion is such that when its central control land 36 crosses the cutoff or neutral line B at a later time, at the point Y, it is moving in a direction opposite to the first control valve 26 and provides a cutoff or liquid reversing function with respect to the application of liquid to the related right- and left-hand chambers 45 and 44, respectively.

In order to control the duration of the application of liquid under pressure to the opposed pressure chambers 64 and 65, at the opposite sides of the print piston assembly 59, and more important the duration of the interval liquid is supplied to the forward driving chamber 65, the cams 75 and 76 are relatively adjusted to provide a phase angle difference therebetween, which, in this instance, has been established as 40°. With this 40° phase angle difference, assuming the first valve 26 is leading the second valve 27 over the neutral line B, it can be seen that as the cams are operated in synchronism and the first valve 26 is actuated to supply liquid to the forward chamber 65 at the point X, the second valve 27 moving in the opposite direction provides cutoff at the point Y. Thus, the duration of liquid under pressure supplied to the opposite sides of the print piston assembly 59 is not equally divided. In the example given, the directing of liquid under pressure to the forward drive chamber 65 is repre-

sented by the distance X—Y, Fig. 7, while the duration of liquid under pressure supplied to the retraction chamber 64 is represented by the distance Y—X for each one-half cycle of valve movement.

From the above, movement of the first control valve 26 to apply liquid pressure to the forward chamber 65 and cutoff by the second control valve 27 consumes approximately 8 milliseconds of the 36 total millisecond time for one-half cycle of valve movement. Thus, pressure is supplied to the forward chamber 65 for approximately 8 milliseconds and to the retraction chamber 64 for 28 milliseconds. This application of pressure to the chamber 65 is shown by the curve D in Fig. 7, wherein the pressure increases to a maximum along the curve E, after the first print valve 26 crosses the neutral line B. Eight milliseconds later the second control valve 27 crosses the neutral line B but moving in the opposite direction to return the application of pressure along the curve F. From this, it can be seen that print head 15 is rapidly driven forward to complete the printing operation and quickly retracted to permit the code rod to set up the next character during the 28 millisecond dwell. By shifting the phase angle difference between the cams 74 and 75, i. e., varying the spacing between X—Y, the duration of the driving pulse may be varied over a wide range. However, this mechanism is primarily intended to provide very rapid pressure pulses of short duration to hydraulic systems.

For a better understanding of the print piston operation, Figs. 2 to 5 show the various extreme positions of the control valves 26 and 27 during certain portions of their cyclic operation. As shown in Figs. 1 and 2, the second control valve 27, following its cam 75, is to the right to position the central control land 36 and end lands 37 and 38, connecting the forward drive pressure chamber 65 in the print piston housing 57 to drain by means of the chamber 45, the open central port 39 which leads to the chamber 43 in the first control valve 26 and the drain port 34. With the second control valve 27 in the above-described position, the first valve cam 74 has permitted the first control valve 26 to shift to the position shown wherein its central land 30 is to the left. Under these conditions, the pressure port 33 directs liquid under pressure to the right through the chamber 42 and channel leading to the now open right-hand port 41 of the second control valve 27, which in turn directs the liquid through the associated chamber 44 and conduit 55 to the retraction drive chamber 64 of the print piston. Thus, it can be seen that during the conditions above-described, the print piston assembly 59 and thus the print head 15 are maintained in their retracted positions by the liquid under pressure and that the forward drive conduit 56 is directly connected to drain through the open exhaust port 34. The above positions of the valves 26 and 27 represents the dwell time interval indicated from Y—X in the timing chart during the first and second half cycles of cam rotation.

As the eccentric cams rotate in synchronism, with the second cam 75 lagging the first cam 74 at a phase angle difference of 40°, the point is reached wherein the first cam 74 shifts the following first control valve 26 to the right, as shown in Fig. 3. As its shifting central control land 30 reaches the neutral point X, Fig. 7, the liquid under pressure is transferred or redirected at the pressure port 33 to the left-hand chamber 43 which communicates with the central control port 39 of the second valve 27. Since this latter valve has not changed its over-all liquid directing position, the liquid passes through the chamber 45 and over the conduit 56 to the forward driving chamber 65. This is effective to drive the print piston rapidly forward, or to the right, following the curve at E to perform the printing operation at the platen 16. Of course, as the first control valve 26 shifts to the right, the right-hand exhaust port 35 opens to direct the displaced liquid in the retraction chamber 64 to drain, as shown by the arrows in Fig. 3.

Approximately 8 milliseconds after the first control valve shifts to the right and passes over its cutoff or neutral position, represented as the distance X—Y on the timing chart, the cam 75 shifts the second control valve 27 to the left or in the opposite direction so that the central land 36 cuts off the supply of liquid to the forward chamber 65 at the point X, shown in the timing chart. Further travel to the left redirects the liquid under pressure supplied to the port 39 through the chamber 44 and the retraction conduit 55 to the retraction chamber 64. This quickly returns the print piston 59 against its stop in the retracted position. The position of the valves is represented in Fig. 4 and the return motion of the print piston follows the curve F, Fig. 7. The shifting action of the second control valve, of course, cuts off the right-hand port 41 to prevent discharge to drain and at the same time connects the forward piston chamber 65 to the left-hand port 40 which is now connected to drain through the passage leading to the right-hand exhaust port 35 of the first control valve 26, as shown by the arrows. With the pistons as shown in Fig. 4, it is obvious the print head will be held retracted as in Fig. 2, but the control lands of both valves have been transferred to the opposite sides of their pressure ports. This represents the completion of a half cycle of cam and valve movement.

As the cams continue their rotation, the second control valve 27 is maintained with the right-hand side of the port 39 open, however, the first control valve 26 now shifts to the left, as shown in Fig. 5. After its cutoff position is reached at the point X, continued travel opens the right-hand side of the pressure port 33. Thus, liquid under pressure is redirected to the right chamber 42, passes through the channel leading to the now open left-hand port 40 of the second control valve 27, continues through the chamber 45 and conduit 56 and is applied at the forward chamber 65 to again drive the print head 15 forward. Upon print piston movement to the right, the liquid in the retraction chamber 64 is displaced, passes through the central port 39 of the second valve 27, the channel leading to the chamber 43 in the first valve 26 and the left-hand exhaust port 34 to drain, as clearly shown by the arrows.

As the print head performs the printing operation, the second control valve 27, lagging the first valve 26, now shifts to the right and at the point Y, its central land 36 acts to cut off the supply of high pressure liquid at the left-hand port 40. This action connects the forward chamber 65 to drain through the central port 39 which in turn is connected to the left-hand exhaust port 34 in the first control valve 26. As this occurs, of course, the right-hand port 41 of the second control valve is opened which immediately applies liquid under pressure to the retraction chamber 64, as indicated by the arrows in Fig. 2, to return the print piston to its dwell position. Thus, the valves have now completed a full cycle as indicated on the timing diagram, Fig. 7. This latter position is the same as the control valves positions shown in Fig. 2 and further control valve operation from this point would be repeated in a cyclical manner.

In this particular embodiment, the eccentrics or cams 74 and 75 are actually rotated at half the speed of the code rod setup mechanism 12 because the pressure impulses directed from the control valves to the print piston occur twice for each complete revolution of the control valve cams. This timing is exactly in agreement with the rate of code rod operation. This is shown in the timing chart wherein the print head movement is timed to occur immediately after the code rod bail 18 has been retracted to a position out of contact with the setup wires, as shown in Fig. 7. Of course, if the code rod is set up at a higher or lower rate, the rate of operation for the eccentric cams would be varied accordingly.

Any suitable gear reduction arrangement (not shown)

may be provided to positively drive the print control valve cams 74 and 75 in synchronism with the code rod bail 18 and other required elements which are operated in predetermined machine cycle point relationships.

While briefly described previously, another feature of this mechanism relates to the simplified driving piston construction. Figs. 1 and 6 show an inexpensive and simple driving piston assembly 59 which eliminates the necessity of shaft packings or the like and, at the same time, insures equal pressure areas at both sides of the driving piston without the use of special compensating piston diameters to provide equal pressure areas. With a construction of this type, the pair of simple symmetrical pistons 61 may be manufactured from bar stock and require no special or costly machining or handling operations. These pistons may be formed on any standard form of machining equipment, such as a centerless grinder or the like, and cut to length.

The print head drive wire or shaft 63 is offset from the axis of the pistons 61 and a simple right angle bend provides the projecting portion or end 62 which extends through the elongated opening 69 in the print piston housing 57. The end 62 of the drive wire is disposed between the inner surfaces of the pistons and is frictionally held by means of the oppositely acting fluid pressures acting on the outer surfaces of the pistons. Thus, it can be readily seen that as pressure is applied to the outer surface of either the right or left-hand piston, the drive wire 63 must of necessity follow the piston movement. A construction of this type is extremely economical because no sealing problems are presented.

Referring now to Fig. 8, there is shown a modified form of the hydraulic control mechanism which is adapted to applications where a larger quantity of liquid is required to drive the piston or member 59. As shown, the first and second control valves 26 and 27 are identical in construction to the first modification and are operated in an identical manner. Therefore, with like parts given like reference characters, further detail description of these valves and their operation is not deemed necessary. The only changes relate to the manner of interconnecting the two valves. In this instance, liquid under pressure is supplied to both central ports 33 and 39 in parallel by means of the conduit 46 and connector 77. Also, the ports 40 and 41 are parallel connected with the exhaust ports 34 and 35 by means of conductors 78.

As shown, conductors leading from the chambers in both control valves are selectively connected to the opposite sides of a pair of first and second slave or power control valves 80 and 81, respectively. These valves are hydraulically connected in a manner identical to the first modification. The first slave valve 80 includes a central land 82, covering the pressure port 83 and two spaced end lands 84 for controlling the application of liquid to and from the pressure and exhaust lines 46 and 54, respectively. The opposite chambers 85 and 86 on either side of the central land 82 are connected to the central control port 87 of the second slave valve 81 and to the spaced ports 88, respectively. The slave valve 81 includes a central land 89 and end lands 90. Right and left-hand chambers 91 and 92 in this valve are suitably connected to the conduits 55 and 56 which lead to the right and left-hand pressure chambers 64 and 65, respectively.

In this particular modification, a conductor 93 extends from the left-hand pressure chamber 43 in the valve 26 to the right-hand side of the first slave valve 80 and the chamber 42 is connected by means of a conductor 94 to the left-hand side of the same valve. Thus, the first slave valve 80 is provided with outer valve displacing control chambers 95 and 96 and the valve motion is under the direct control of the first control valve 26. Likewise, the chamber 45 in the second control valve 27 communicates with the right-hand control chamber 97 in the second slave valve 81, through a conductor 98, and the chamber 44 communicates with the left-hand control chamber 99 through a conductor 100.

As shown in the drawing, the control valves 26 and 27 are in the position whereby high pressure liquid is directed through the chambers 43 and 44 to hold the first slave valve 80 to the left and the second slave valve 81 to the right. Under these conditions, it can be seen that high pressure liquid is conducted from the pressure port 83 through the right-hand chamber 86, the right-hand port 88 and chamber 91 of the second slave valve 81, and the conduit 55 leading to the retraction piston chamber 64. At this time the conductor 56 is connected to drain through the central port 87 in the second slave valve 81 and the left-hand exhaust port of the first slave valve 80. This represents the piston in its retracted position.

Now as the cam 74 permits the valve 26 to shift to the left, high pressure liquid passes through the chamber 42 to the left-hand control chamber 95 of the first slave valve 80 and connects the right-hand control chamber 86 to drain. Thus, the first slave valve is quickly shifted to the right. As this valve shifts, with the second slave valve 81 in the position shown, high pressure liquid is directed through the left-hand chambers 85 and 92 of both valves to conductor 56 leading to the forward drive chamber 65 to perform the forward driving operation. Further rotation of the cams 74 and 75 results in shifting of the second valve 27 to the right, and such action directs fluid under pressure to the right-hand control chamber 97 of the slave valve 81 and connects the left-hand control chamber 99 to drain through the chamber 44 and port 41. Thus, the second slave valve 81 is rapidly shifted to the left to redirect the liquid under pressure from the central port 87 to the conductor 55 to drive the piston 59 in the opposite or retraction direction.

Continued operation of the cams 74 and 75 results in the in-phase following motion of the slave valves 80 and 81. As in the first modification, the relationship between the forward and reverse strokes and dwell periods of the drive piston 59 is determined by the phase difference between the cams. The foregoing valve arrangement is particularly adapted to apparatus which requires a relatively large volume of liquid to transmit driving pulses to a driven member. While in this construction the slave valves are moved from full "off" to full "on" position, their operation is substantially identical to the first modification.

From the foregoing it can be seen that a hydraulic control mechanism has been provided for operating the print head of a wire printer which can be made extremely fast in operation and at the same time maintain inertia forces to a minimum. For example, by properly positioning the phase angle differences between the print control valves operating cams, a print head operating speed of 4 milliseconds or less may be realized. Another important feature of the invention is that very rapid pressure pulses may be provided which would be beyond the physical capacity of a single control valve because it would require valve movement at the desired speed of the pulses. Thus, by utilizing two control valves as described, only relatively slow valve operation is necessary to provide a rapid driving pulse of extremely short duration.

While the above-described hydraulic control and drive mechanism has been described as applied to a wire printer, as a specific example, it is to be clearly understood this control mechanism may have many other applications. In fact, it would have possible application wherever it is desired to reciprocate or oscillate a driven member within certain predetermined limits to provide a rapid forward and reverse stroke and, if desired, to provide a relatively long dwell. It should also be borne in mind that the particular type of code rod setup mechanism and the details of the print head and the like have no bearing on the invention as set forth.

While there have been shown and described and pointed out the fundamental novel features of the invention as ap-

plied to a preferred embodiment, it will be understood that various omissions and substitutions and changes in the form and details of the device illustrated and in its operation may be made by those skilled in the art, without departing from the spirit of the invention. It is the intention, therefore, to be limited only as indicated by the scope of the following claims.

What is claimed is:

1. A control for a fluid operated drive piston, comprising a first valve having fluid conducting passages communicating with fluid under pressure, a second valve having fluid passages, means for connecting said fluid passages to said first valve and to opposite sides of said drive piston, and means for selectively operating said valves in timed sequence to control the duration of the application of fluid under pressure to opposite sides of said drive piston.

2. A control for a fluid operated drive piston, comprising first and second valves connected for series conduction to fluid under pressure, means providing communication between said second valve and opposite sides of said drive piston whereby fluid under pressure is directed to one side thereof to maintain said piston in a retracted position, means for operating said first valve to transfer the application of fluid under pressure through said second valve in its initial position to the opposite side of said piston to advance the same, and means for operating said second valve after said first valve has transferred to redirect the fluid under pressure back to said one side to return said piston.

3. A control for a fluid operated drive piston for operating a print head with a rapid forward and reverse stroke and provide a relatively long retracted dwell, comprising first and second valves connected for series conduction of fluid under pressure, means providing communication between said second valve and opposite sides of said drive piston whereby fluid under pressure is directed to one side thereof to maintain said piston in a retracted position, means for operating said first valve to transfer the application of fluid under pressure through said second valve in its initial position to the opposite side of said piston to advance the same, and means for operating said second valve after said first valve has transferred to redirect the fluid under pressure back to said one side of said piston to return the same, said first and second valve operation being synchronized to provide an operating phase difference therebetween whereby a rapid forward and reverse impulse is applied to said drive piston.

4. A control for a hydraulically operated piston, comprising a ported first valve communicating with liquid under pressure and to control the flow of liquid therethrough, a second valve having ports connected in series to the ports of said first valve, means for hydraulically connecting said second valve to opposite sides of said piston, and means for operating said first and second valves in timed sequence to control the duration of the application of pressure to the opposite sides of said drive piston.

5. In hydraulic control apparatus, the combination of a driving member, a pair of control valves, means for directing liquid under pressure to one of said control valves, means dependent upon movement of said one of said control valves for selectively directing liquid under pressure through the other of said control valves to drive said member in one direction, means dependent upon movement of the other of said control valves for transferring the application of liquid under pressure to drive said member in the opposite direction, and means for operating said control valves with a phase angle difference therebetween.

6. In hydraulic drive control apparatus, the combination of a drive piston having forward and normally retracted positions, a ported first control valve to which liquid is supplied under pressure, a ported second control valve, means for interconnecting said ports to provide for series liquid flow therethrough, means for hydraulically connecting said second control valve to said drive piston, and means for reciprocating said valves with a lagging time differential therebetween, whereby when said first valve is moved in one direction it transfers the application of liquid through said second pilot valve from one side of said drive piston to the other to operate the same in a forward direction and at the predetermined lagging time interval said second piston is moved to transfer the liquid under pressure to reapply the same to said one side to return said piston to its retracted position.

7. Control apparatus for hydraulically operating a drive piston having forward and retracted positions, comprising a first control valve including a pressure port for liquid under pressure and a spool having a land covering said port for directing the application of liquid under pressure from one or the other side thereof, a second control valve including ports and a spool having lands covering said ports for directing the application of liquid under pressure supplied thereto from said first control valve to opposite sides of said drive piston, a first eccentric for reciprocating said first control valve in timed relation to alternately supply liquid from said port to opposite sides of said land to direct liquid under pressure through said second valve to drive said piston forward, and a second eccentric for reciprocating said second control valve to transfer the applied liquid under pressure to the opposite side of said drive piston to retract the same, said eccentrics being disposed with a phase angle difference to limit the application of liquid under pressure to the forward driving side of said piston to a relatively short time interval.

8. Control apparatus for hydraulically operating a drive piston in forward and retractive directions, comprising a first ported control valve to which liquid is supplied under pressure, a ported and chambered second control valve, means for interconnecting said ports to provide series liquid flow therethrough, means for connecting the chambers of said second control valve to the forward and reverse sides of said piston, said piston being normally held in its retracted position by the liquid under pressure acting through series connected passages extending through said control valves, and means for reciprocating said control valves with said second control valve lagging said first control valve by a predetermined phase angle difference, whereby said first valve transfers to apply liquid under pressure through said second valve to drive said piston in the forward direction and said second valve operates to transfer the liquid under pressure to the retraction side of said piston to return the same.

9. The combination as claimed in claim 8 wherein said reciprocating means for said control valves operates in a cyclic manner to provide two complete cycles of piston operation for each complete cycle of control valve operation.

10. The combination as claimed in claim 9 wherein said means for reciprocating said valves includes independent cams synchronized with a predetermined phase angle difference therebetween.

11. The combination as claimed in claim 10 wherein the phase angle difference between said control valve operation is such as to provide liquid under pressure to the forward driving side of said piston for a relatively short time interval with respect to the application of liquid under pressure to the retraction side of said driving piston.

12. In hydraulic control apparatus, the combination of a drive piston hydraulically driven in forward and retraction directions, a first ported control valve to which liquid is supplied under pressure, a cored and chambered second control valve, said control valves each including spaced lands for covering said ports and with liquid chambers therebetween, means for interconnecting the chambers and ports of said first and second valves to provide series flow of liquid therethrough, means for reciprocating said control valves in a cyclic manner, said reciprocating means being timed to provide a phase angle difference therebetween, and means for connecting the chambers of said second valve to opposite sides of said drive piston,

said second control valve having its lands disposed to normally supply liquid under pressure to the retraction side of said piston, means for moving said first control valve to transfer the application of liquid under pressure through said second valve from the retraction side of said piston to the forward side to drive said piston in a forward direction, said second valve being moved at a predetermined time interval later to transfer the supply of liquid under pressure back to the retraction side of said piston to restore the same to its retracted position.

13. The combination as claimed in claim 12 including rotatable cam means for reciprocating said control valves, said cams being provided with a slight phase angle difference therebetween to provide a relatively short time interval for the application of liquid during the forward

driving portions of said cycle and a relatively long dwell between forward strokes.

14. The combination as claimed in claim 13 wherein said cams are lobed to provide two complete forward and reverse driving cycles for each complete cycle of control valve operation.

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