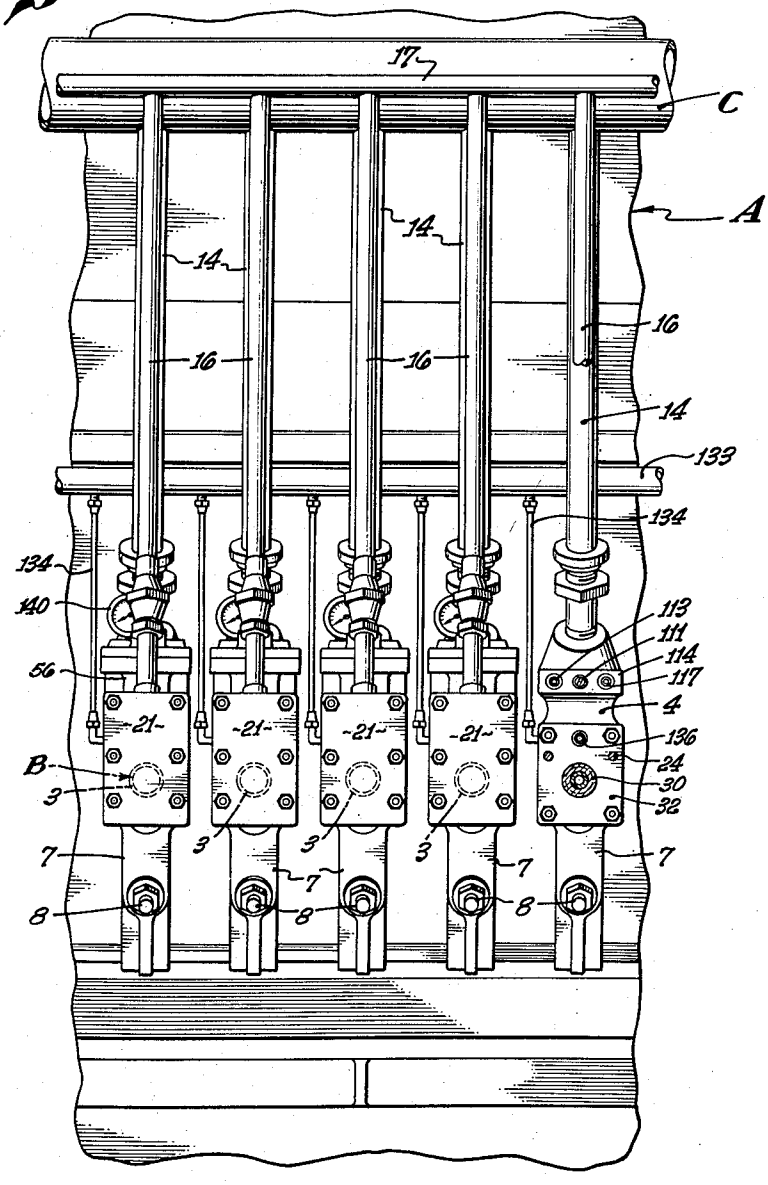
Dec. 14, 1954 B. T. BERGE 2,696,979

AUTOMATIC TUYERE PUNCHING APPARATUS

Filed April 16, 1951 7 Sheets-Sheet 1

Fig. 1.



BYRON T. BERGE,
INVENTOR.

BY
Knight & Rodgers
ATTORNEYS.

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AUTOMATIC TUYERE PUNCHING APPARATUS

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Fig. 2.

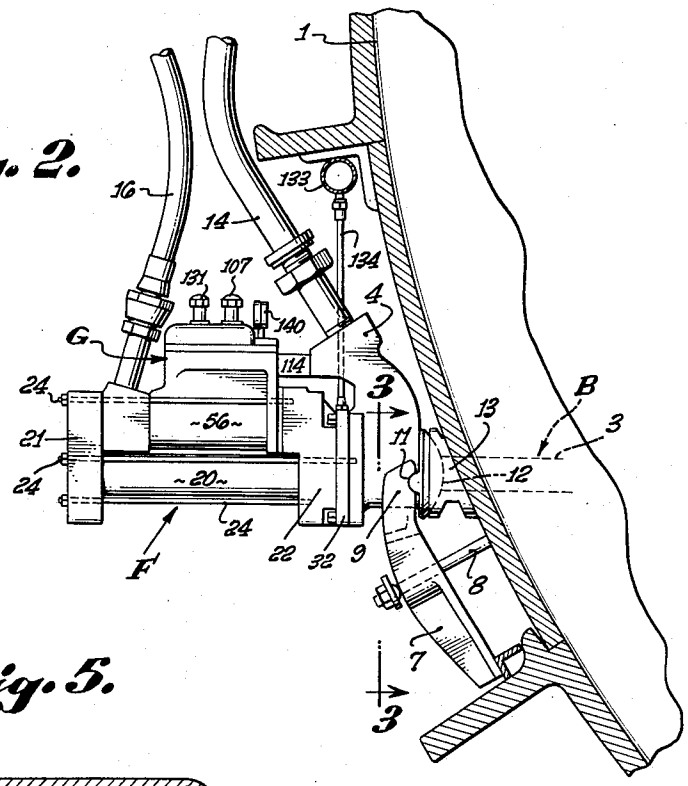


Fig. 5.

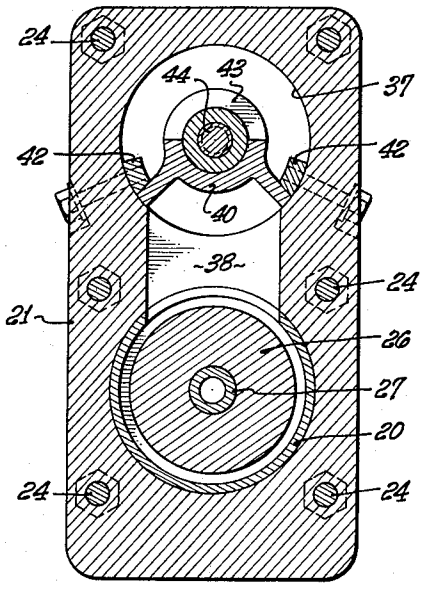
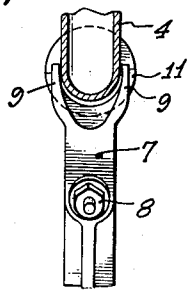


Fig. 3.



INVENTOR.
BYRON T. BERGE,
BY
Knight & Rodgers
ATTORNEYS.

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AUTOMATIC TUYERE PUNCHING APPARATUS

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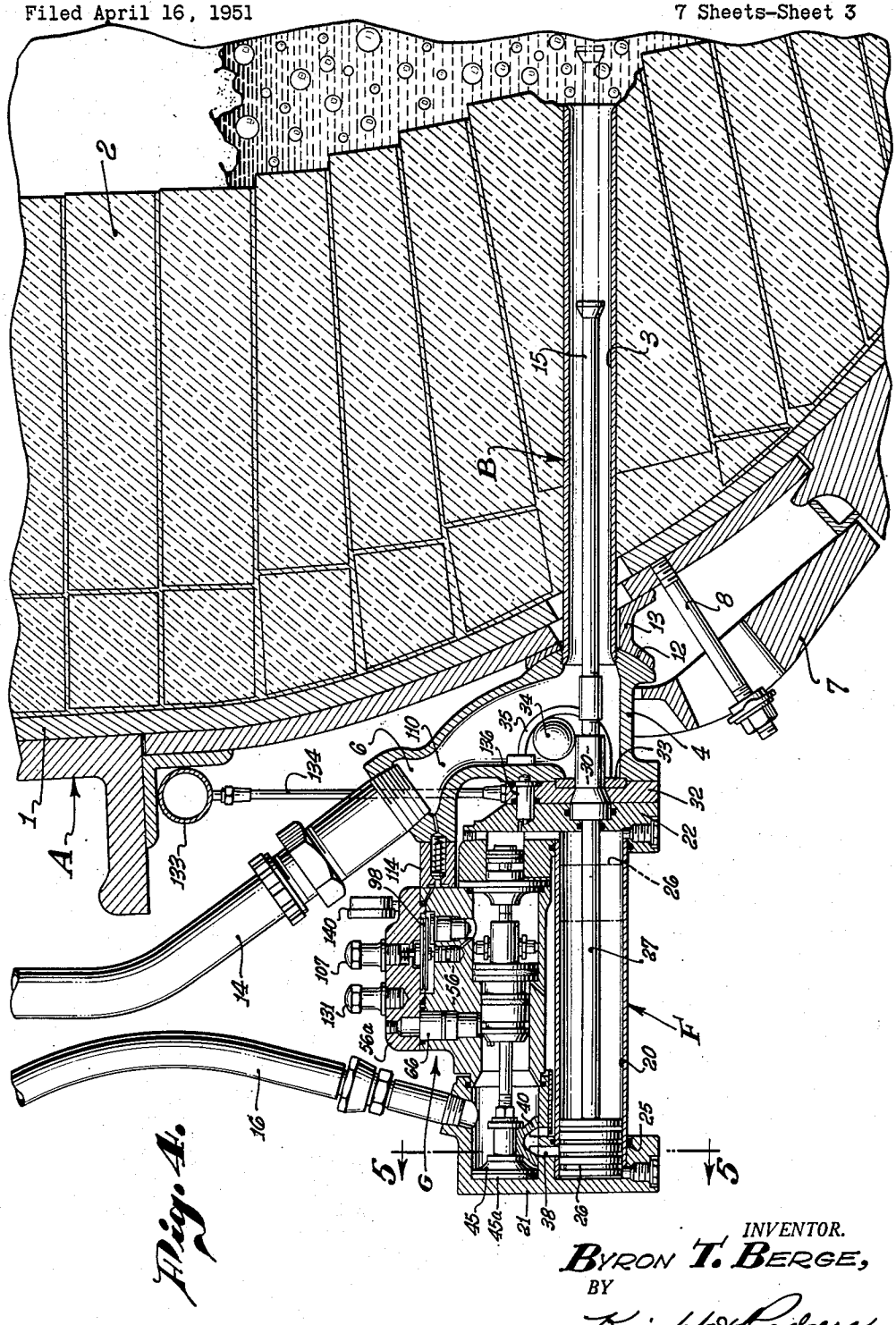

Fig. 4.

INVENTOR.
BYRON T. BERGE,
BY
Knight & Rodgers
ATTORNEYS.

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AUTOMATIC TUYERE PUNCHING APPARATUS

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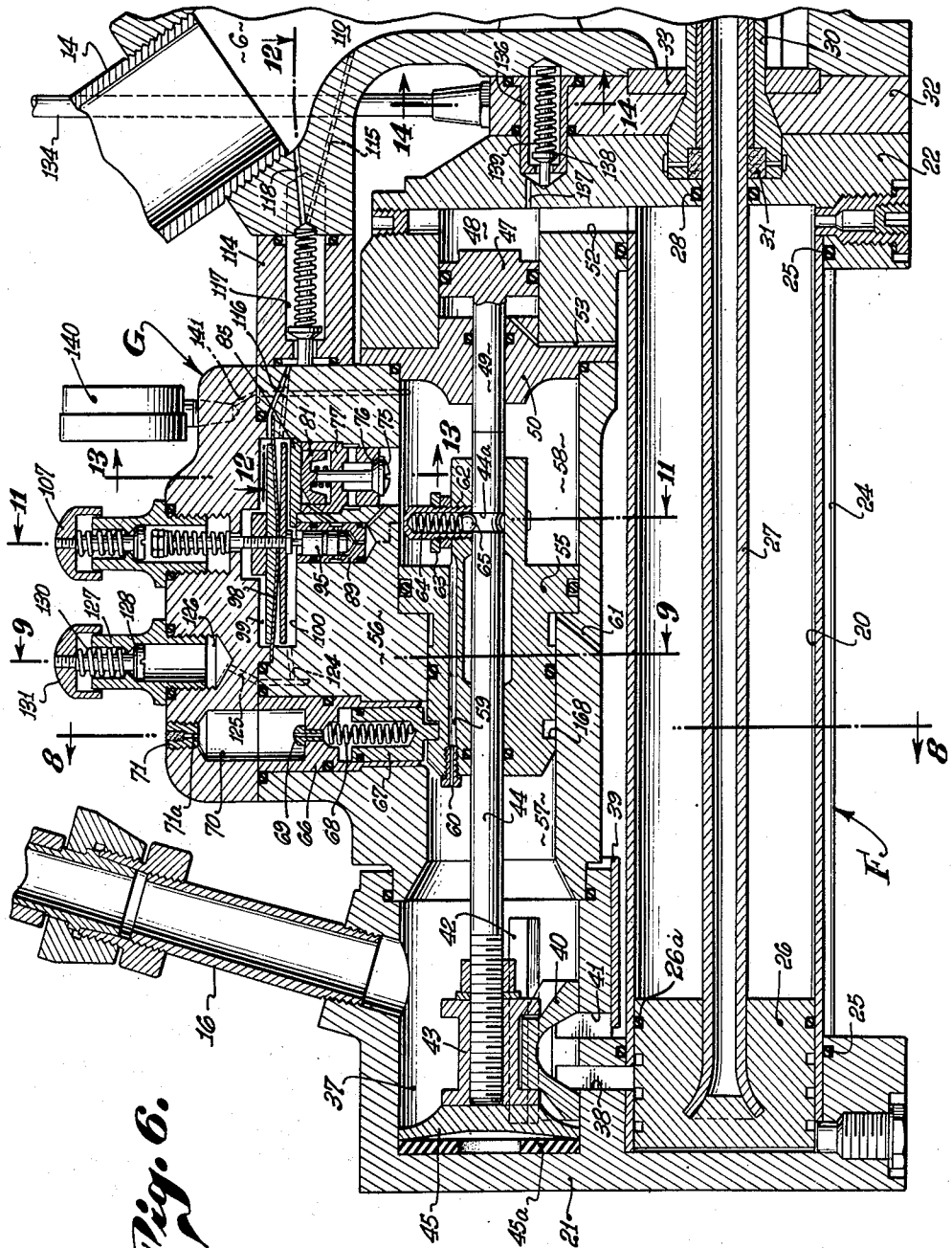

Fig. 6.

INVENTOR.
BYRON T. BERGE,
BY
Knight & Rodgers
ATTORNEYS.

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AUTOMATIC TUYERE PUNCHING APPARATUS

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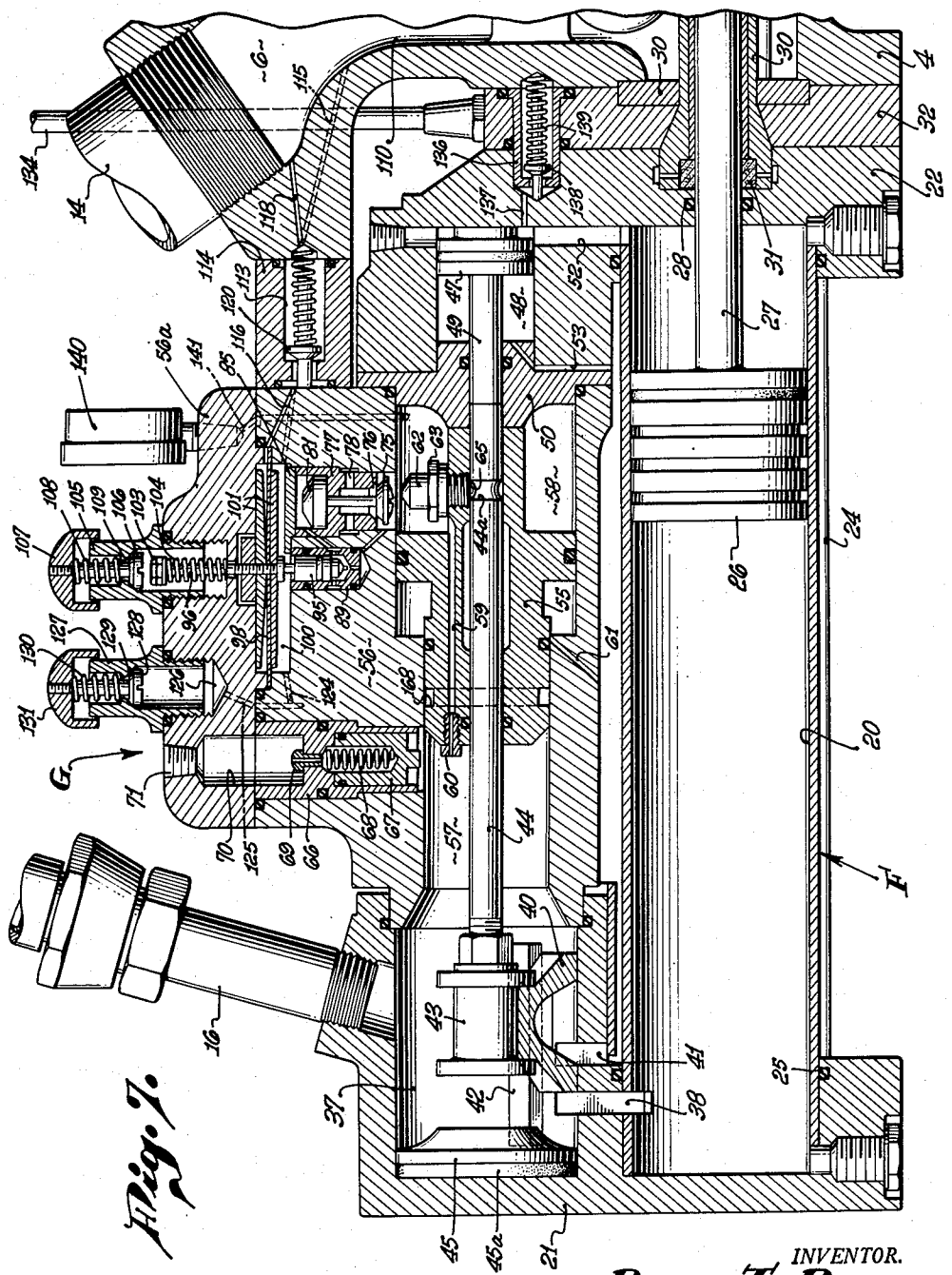

Fig. 7.

INVENTOR.
BYRON T. BERGE,
BY
Knight & Rodgers
ATTORNEY.

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AUTOMATIC TUYERE PUNCHING APPARATUS

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Fig. 8.

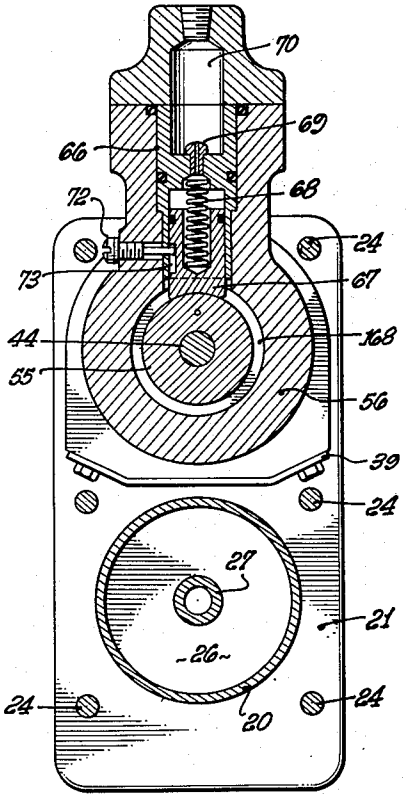


Fig. 9.

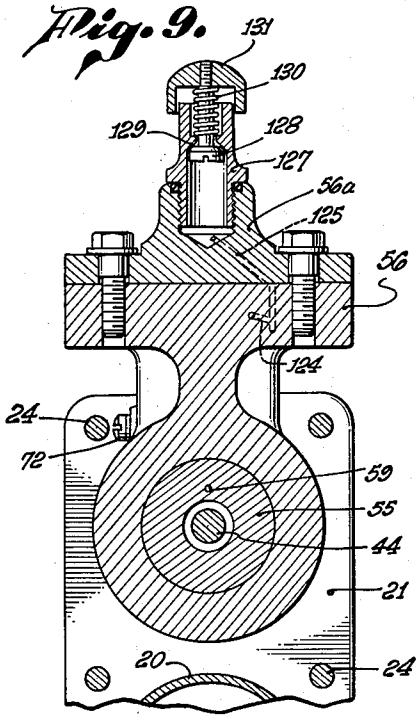


Fig. 10.

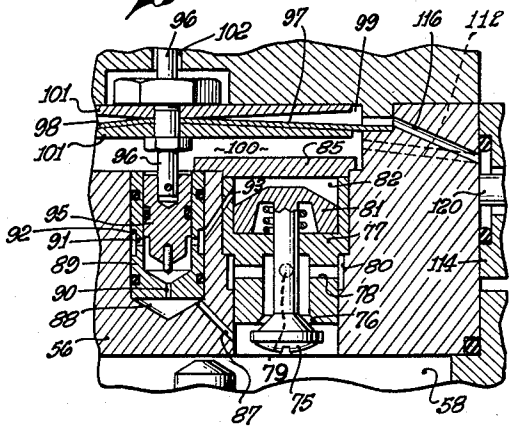
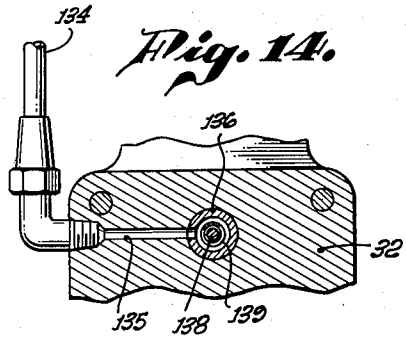


Fig. 14.



INVENTOR.
BYRON T. BERGE,
BY
Knight & Rodgers
ATTORNEYS.

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AUTOMATIC TUYERE PUNCHING APPARATUS

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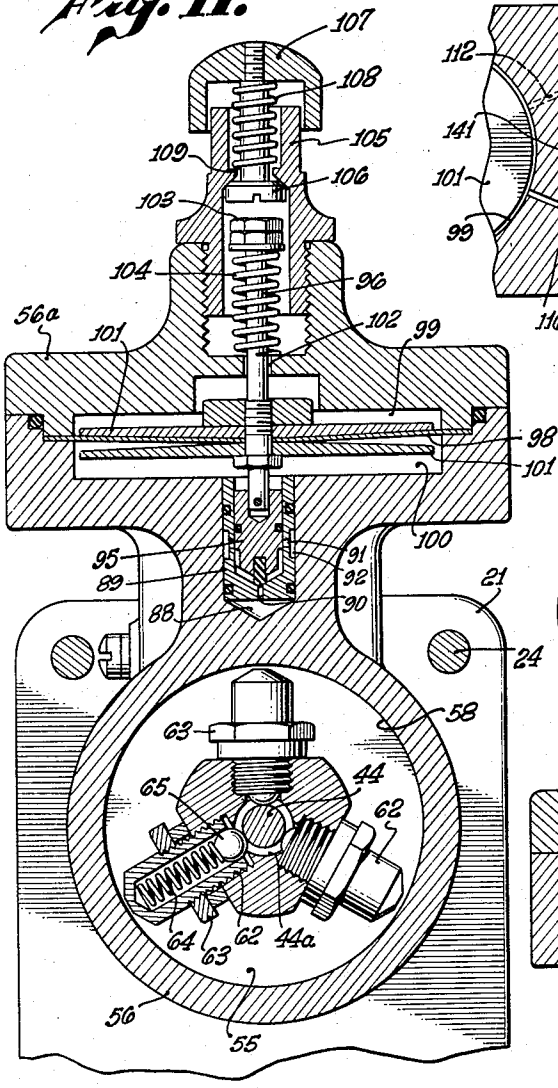
Fig. 11.



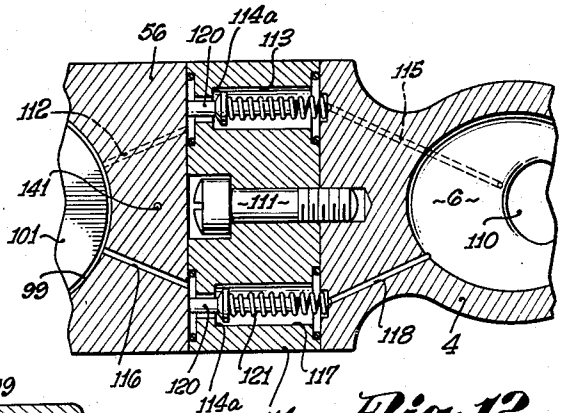
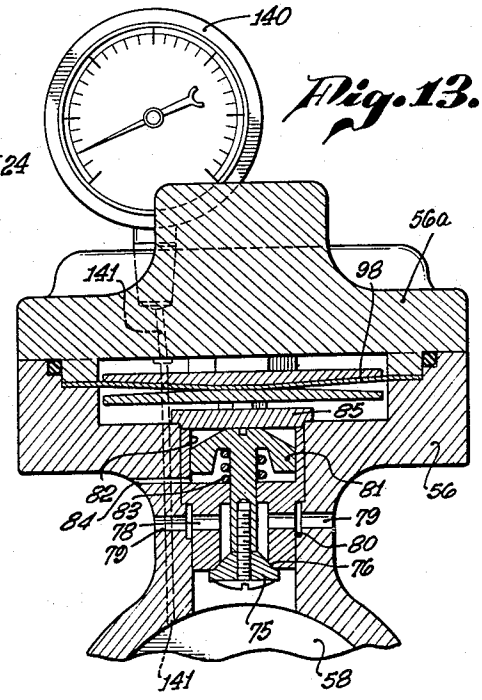


Fig. 12.

Fig. 13.



INVENTOR.
BYRON T. BERGE,
BY
Knight & Rodgers
ATTORNEYS.

United States Patent Office 2,696,979
Patented Dec. 14, 1954

2,696,979

AUTOMATIC TUYÈRE PUNCHING APPARATUS

Byron T. Berge, McGill, Nev., assignor to Kennecott Copper Corporation, New York, N. Y., a corporation of New York

Application April 16, 1951, Serial No. 221,253

11 Claims. (Cl. 266—42)

This invention relates to apparatus for mechanically punching the tuyères of converters, and more particularly to automatically controlled fluid pressure operated apparatus for cleaning such tuyères to remove encrustations or obstructions that are formed at the inner ends of the tuyères during blowing periods in which air is introduced through the tuyères into the molten material under treatment in the converter.

Examples of fluid operated mechanical tuyère punching apparatus are shown in Larson and Berge Patent No. 2,432,996, issued December 23, 1947, and reference is made thereto for a further description of the operation of converters such as those used in the production of blister copper, and the necessity for frequent punching of the tuyères to remove the obstructions and thereby maintain a satisfactory rate of introduction of blowing air. As brought out in said patent, it is advantageous to provide a separate complete punching unit mounted on the converter adjacent each tuyère and provided with motor means for effecting a rapid reciprocation of a punch rod within the tuyère, to move the tip of the punch rod rapidly inward past the zone of obstruction at the inner end of the tuyère and to then quickly reverse the movement and move the punch rod tip outwardly past the obstruction zone to a normal rest position within the tuyère.

Reference is also made to an application of Larson and Berge Ser. No. 109,084, filed August 8, 1949, now Patent No. 2,619,938, granted Dec. 2, 1952 which discloses a particularly advantageous type of fluid pressure operated motor for use in such a converter punching unit, in which an inward or forward stroke of the punch rod is effected by supply of motive fluid under pressure at the rearward side of a piston connected to the punch rod, and in which air is trapped and compressed forwardly of the piston during the forward stroke and is utilized to effect a rapid reversal and return stroke of the piston and punch rod.

In the forms of apparatus shown in the above mentioned patents, the operation of each punching unit to effect rapid reciprocatory movement of its punch rod is initiated by manual control means at such intervals as considered necessary in order to maintain a satisfactory rate of introduction of blowing air. The blowing air is normally supplied under suitable pressure through a manifold or bustle pipe having separate branch connections to the individual tuyères, so that any excessive obstruction formed at the inner end of one or more individual tuyères causes a material reduction in the rate of inflow of air through such tuyère or tuyères. For optimum operation, it is desirable to maintain a relatively uniform high rate of introduction of air through all the tuyères. More particularly, it is desirable to clean each individual tuyère promptly whenever it becomes so obstructed as to reduce the air flow therethrough below a certain minimum rate, and the principal object of this invention is to provide an automatically controlled apparatus for accomplishing this desirable result.

It accordingly becomes a particular object of this invention to provide a punching apparatus for a converter having a plurality of tuyères that automatically cleans a tuyère when the rate of flow of blowing air to that particular tuyère falls below a certain predetermined value, independently of conditions at other tuyères.

A further object of the invention is to provide an automatic tuyère punching unit having a reciprocably operated punch rod and a novel and advantageous control device

responsive to variations in rate of flow of air and operable to initiate operation of the punching unit to cause rapid reciprocation of punch rod.

It is another object of the invention to provide an advantageous design of an automatic control device for a fluid motor that initiates action of the fluid motor in response to a pressure differential created in an air supply line.

These and other objects of my invention have been attained in a converter having a plurality of tuyères and a plurality of separate branch air supply lines for blowing air, one branch line leading to each of the tuyères, by providing a plurality of separate and individual punching units which are mounted on the converter with one unit on and associated with each tuyère. Each punching unit has a punch rod which is connected to the motor for reciprocation of the rod within the tuyère. An automatic control device is mounted upon each of the punching units and includes means responsive to variations in the rate of flow of the blowing air in the branch supply line leading to the associated tuyère. When actuated by a change in the rate of air flow, the automatic control device initiates operation of the fluid motor attached to that particular tuyère.

The automatic control device is itself novel and is adapted to effect initial movement of the motor valve from an exhaust to an admission position. To do this, the control device is provided with a valve shifting member, which is typically and preferably a differential piston subjected at opposite sides to fluid pressure. At one side the fluid pressure is relatively constant and is preferably the fluid pressure of the working fluid for the motor. The pressure at the other side of the valve shifting member is varied in order to obtain movement of the valve shifting member. Such variation is obtained by opening an exhaust valve, thus connecting one side of the differential piston with the atmosphere and causing movement toward that one side. The exhaust valve is actuated by pressure responsive valve operating means which responds to a differential in pressure created in the air supply line to the tuyère by suitable flow metering means. Such flow metering means is typically a Venturi tube, but other suitable means may be employed. The reduced pressure at the Venturi throat as compared with the static pressure of the air at a point upstream from the Venturi throat establishes a differential pressure which bears a known relation to the rate of flow through the Venturi tube. When the quantity of air per unit time flowing through the tuyère drops below the quantity deemed satisfactory for converter operation, this pressure differential at the Venturi tube likewise drops below a value which can be predetermined; and this decreased pressure differential in turn acts upon the pressure responsive means for operating the exhaust valve.

Separate means are provided for returning the motor valve from the admission to exhaust position, this valve return means being operated by fluid trapped ahead of the working piston. After return of the motor valve, the exhaust valve of the automatic control device is closed and pressure is again built up at both sides of the differential piston so that the unit is again restored to a condition in which it is ready for operation.

Other objects, not specifically mentioned, will be brought out hereinafter or will be apparent from the following description of a preferred embodiment of my invention, with reference to the accompanying drawings, in which:

Fig. 1 is a rear end elevation of a plurality of automatic punching units mounted on a converter adjacent a plurality of tuyères, showing a portion of the side of the converter;

Fig. 2 is a side elevation of one of the punching units mounted on the converter, showing means including an adapter housing for mounting the unit on the converter and the connections for supplying air under pressure to the tuyère and to the punching unit and its automatic control means;

Fig. 3 is a fragmentary combined elevation and sectional view on line 3—3 in Fig. 2, showing a clamp for securing the adapter housing to the converter;

Fig. 4 is a longitudinal median section of a punching unit including its automatic control means, and the adjacent tuyère and mounting means, with the punch rod in the retracted or rest position within the tuyère, and with certain parts shown in elevation;

Fig. 5 is an enlarged transverse vertical section on line 5—5 in Fig. 4;

Fig. 6 is an enlarged longitudinal median section of the punching unit, similar to Fig. 4, with most parts in the same positions as in Fig. 4;

Fig. 7 is a view similar to Fig. 6 but showing the parts in the positions occupied when the punch rod actuating piston is moved to a position near the forward end of its working stroke;

Figs. 8 and 9 are transverse vertical sectional views on lines 8—8 and 9—9 respectively in Fig. 6;

Fig. 10 is a fragmentary longitudinal median section showing the exhaust valve and related parts in the same positions as in Fig. 7, but on a still larger scale;

Fig. 11 is an enlarged transverse vertical section on line 11—11 in Fig. 6;

Fig. 12 is a fragmentary horizontal section on line 12—12 in Fig. 6;

Fig. 13 is an enlarged partial transverse section on line 13—13 in Fig. 6; and

Fig. 14 is a fragmentary vertical section on line 14—14 in Fig. 6.

Figs. 1, 2 and 4 show a portion of a copper converter A having a plurality of longitudinally spaced tuyères B arranged in a row along one side thereof. The converter comprises a cylindrical metal shell 1 and a refractory lining 2, and is constructed and mounted for rotation about its longitudinal axis in the conventional manner as shown and described more fully in Patent 2,432,996 mentioned above.

Each tuyère B comprises a pipe or tube 3 extending through aligned openings in the converter shell and the refractory lining into the interior of the converter. The tuyère is a means for introducing blowing air through the walls of the shell and the lining into the body of molten material within the converter.

At the outer end of each tuyère B there is an adapter 4 connected to the outer end of tuyère pipe 3 and secured in place on the converter shell by means of clamp 7 and bolt 8. (See Figs. 2 and 3.) Clamp 7 has a pair of upwardly extending arms 9 which at their upper ends are recessed to engage lugs 11 on the adapter housing, while the lower end of clamp 7 rests against a portion of shell 1. The ends of the clamp are held in engagement with their respective opposing members by tightening down the nut on bolt 8 which passes through the intermediate portion of clamp 7. Adjacent lugs 11 adapter 4 is provided with a convex spherically curved surface portion 12 which is held firmly against a similarly shaped concave seat member 13 by the thrust of clamp 7. The thrust of the adapter holds seat member 13 against the external face of the converter shell.

Adapter 4 has an internal chamber 6 which communicates with the outer end of pipe 3 and forms a part of the passage supplying blowing air to the tuyère pipe. Also connected to adapter 4 and communicating with internal passage 6 is a branch supply line 14 for blowing air. As may be seen from Fig. 1, there are a plurality of tuyères, each with its own punching unit and each provided with its own branch air supply line 14, all of lines 14 communicating at their upper ends with a common manifold or bustle pipe C which extends longitudinally of the converter.

As shown in Figs. 1 and 4, adapter 4 also serves as a means for mounting in place on a tuyère the punching unit provided for each individual tuyère. Each of these punching units consists generally of a fluid pressure actuated motor F attached to one end of punch rod 15 for effecting rapid reciprocation of the punch rod within pipe 3, as indicated particularly in Fig. 4. Each fluid motor F is provided with an automatic control device indicated generally at G, the control device being mounted directly upon the housing of fluid motor F of the punching unit with which the control device is associated. As will be explained later in greater detail, the automatic control device includes means responsive to variations in the rate of flow of blowing air to the tuyère and operates to initiate action by the associated fluid motor to cause the punch rod 15 within the tuyère to reciprocate and clean out any obstruction which causes air

to flow through the pipe at a rate below a predetermined value.

Compressed air, or other suitable elastic fluid, for operating the fluid motor is supplied individually to each automatic control device and punching unit through branch supply line 16; and as may be seen from Fig. 1 the individual branch lines 16 are connected at their upper ends to a common high pressure manifold 17 which extends longitudinally of the converter.

Referring particularly now to Figs. 4 and 6, it will be seen that fluid motor F comprises cylinder 20 suitably mounted in and between rear cylinder head casting 21 and front cylinder head casting 22. The terms "front" and "rear" or other directional terms are used with reference to the working stroke of piston 26 as being in a "forward" direction, such stroke being from left to right in Fig. 6. The two head castings 21 and 22 are drawn together by a plurality of tie bolts 24, shown in Fig. 2. A fluid tight connection between the walls of cylinder 20 and the surrounding walls of the cylinder-receiving sockets in the two head castings, is obtained by the use of packing means at 25, such as an O-ring type or other suitable type of packing, adapted to hold the relatively high pressures reached in operation of the fluid motor. Within cylinder 20 is working piston 26 which reciprocates within the cylinder and has attached to it piston rod 27 which projects out of the cylinder through an opening in front cylinder head 22. The front cylinder head is provided at 28 with suitable packing, such as an O-ring type seal, adapted to prevent the escape of working fluid under pressure around piston rod 27. At 25 and 28, as well as at numerous other locations, O-rings have been indicated as a preferred means but without necessary limitation to any particular means for holding fluid presures. Any suitable kind of fluid packing may be used at the indicated or other locations as may be required.

Piston rod 27 also extends through and is slidably received in sleeve or gland 30 which supports and guides the piston rod during its reciprocatory movement. Gland 30 is provided with lubrication means in the form of packing at 31 which is provided with a suitable lubricant for the piston rod. Additional lubricant may be supplied to 31 by a suitable conventional type of lubrication fitting, not shown in the drawing.

In order to receive fluid motor F and its automatic control device G for mounting upon the tuyère, adapter 4 is provided at its rear side with cover plate 32. Plate 32 has an opening through which gland 30 extends and also holds between it and the rear face of adapter 4 an apertured ball seat plate 33. Gland 30 extends through the opening in ball seat plate 33, as shown in Figs. 4 and 6. The forward end of piston rod 27 extends beyond gland 30 even when piston 26 is in the rear or rest position of Fig. 4. Thus the forward end of piston rod 27 passes through the internal air passage 6 of adapter 4 and is connected to punch rod 15, the piston rod and punch rod being coaxial of tuyère pipe 3.

In order to prevent the escape of blowing air through adapter cover plate 32 when the fluid motor and its piston rod are removed, adapter 4 is provided with ball check valve 34 which is located inside the adapter in chamber 6. When the piston rod and punch rod are removed from the tuyère, ball 34 falls down by gravity against the central opening in ball seat plate 33 and closes the opening therein to prevent the escape of air. When it is desired to mount the fluid motor in place, the punch rod is inserted in the opening in seat member 33 and when forced ahead moves the ball check out of the way. The movement of the valve ball is guided by a pair of curved guides 35 inside the adapter. In the drawings the ball valve is shown only in the raised position which it occupies when the fluid motor is in place and the punch rod is in the tuyère.

Within rear cylinder head casting 21 and at a position near the rear end of cylinder 20, there is located pressure chest or supply chamber 37. Working fluid under pressure is supplied to chamber 37 through supply line 16 which is connected to communicate directly with supply chamber 37. Near the rear end of cylinder 20, but preferably spaced a short distance therefrom, is port 38 which serves not only as a means for admitting working fluid to the rear end of the cylinder behind piston 26 but also as a means for exhausting fluid from that end of the cylinder. As may be seen particularly well from Fig. 7,

port 38 communicates between cylinder and supply chamber 37.

The flow of working fluid from the supply chamber to the cylinder through port 38 is regulated by means of a reciprocable valve assembly that includes slide valve 40 which is within the supply chamber and is movable between the admission position of Fig. 7 and the exhaust position of Fig. 6. When moved forward as shown in Fig. 7, valve 40 uncovers port 38 and allows direct flow of working fluid from the pressure chest into the working cylinder of the fluid motor F. When the valve is moved to the rear, port 38 is closed to chamber 37 and is placed in communication with port 41 which communicates with the atmosphere thus allowing working fluid in the cylinder to escape through port 38 and the space underneath valve 40 into port 41 and thence to the atmosphere. Adjustable baffle plate 39 is slidably mounted on rear cylinder head casting 21 in position to more or less restrict port 41 and regulate the rate at which fluid exhausts through it. Valve 40 is held against rotation within chamber 37, which is here shown as being circular in cross-section, by a pair of lateral guides 42, shown in Fig. 5.

Valve 40 is shifted between the two operating positions by means of spool 43 which engages the valve and is connected to valve shifting rod 44. Valve rod 44 extends parallel to piston rod 27. Rod 44 and spool 43, together with the valve member 40 are considered as constituting the valve assembly of the fluid motor for controlling admission of working fluid to the motor cylinder. The rear end of supply chamber 37 is provided with a buffer assembly 45 including a resilient member 45*a*. The buffer assembly limits the rearward travel of the valve assembly to properly locate valve member 40 in the exhaust position and also absorbs in member 45*a* the shock of stopping the valve assembly as it shifts to the rear.

The reasons for a sudden reversal and a rapid retraction of the punch rod after a forward punching stroke are set forth in greater detail in Patent 2,432,996 referred to above. In order to accomplish this motion, it is desirable that pressure actuated valve return means be provided for automatically and positively shifting the valve to exhaust position at a predetermined point in the forward stroke of punch rod 15. This valve return means comprises auxiliary piston 47 mounted for reciprocation in cylindrical bore 48 which is located in the upper portion of front cylinder head 22. The rear end of piston 47 has attached to it piston rod 49 which is guided in retainer plate 50 that closes the rear end of cylinder 48 and the forward end of cylinder 58. Piston rod 49 is mounted coaxially with valve rod 44 and the opposed ends of these two rods are adapted to engage each other, as shown in Fig. 6.

The front end of cylinder 48 ahead of piston 47 is in free communication with the front end of cylinder 20 ahead of piston 26 through passageway 52 so that air trapped in the working cylinder ahead of the piston is utilized to actuate auxiliary piston 47, as will be later described more fully. At the rear side of piston 47, cylinder 48 is placed in communication with the atmosphere by means of passage 53, thus preventing fluid pressure from building up on the back side of piston 47. Piston 47 is provided with an O-ring or other suitable sealing means in order to effect a fluid-tight seal between the piston and the cylinder walls, and the same is also provided for piston rod 49 in retainer plate 50. It will be noted that the forward end of piston 47 is provided with a forwardly extending projection so that when the piston is in engagement with the forward end wall of the cylinder, passage 52 is not completely closed off by the piston (see Fig. 7).

Except for certain novel features of construction of adapter 4, the apparaus thus far described is generally old and is disclosed in the aforementioned Patent No. 2,619,938. I have combined with this fluid motor, apparatus of novel design for automatically initiating action of the fluid motor of any individual tuyère when the rate of flow of blowing air through the tuyère falls below a predetermined value as measured by the rate of flow in the supply line for that tuyère.

One element of the automatic control device is a valve shifting member adapted to effect automatically the movement of valve 40 to the admission position. This shifting member is here shown in the form of differential piston 55 which is mounted to reciprocate within a differential bore in cylinder block 56. The differential bore is in two parts of different diameters. One part is cylinder 57 of relatively smaller diameter which opens at one end to supply chamber 37; the other part is cylinder 58 of relatively larger diameter which is closed at its forward end by retainer plate 50. The walls of the differential bore constrain differential piston 55 to linear movement parallel to valve rod 44, which extends through the differential piston, and parallel to the movement of valve 40. It will be seen that with this arrangement the end of piston 55 of smaller diameter is subjected to the substantially constant fluid pressure existing in supply chamber 37 while the other or opposite side of the piston is subjected to the variable fluid pressure existing in cylinder 58. Cylinders 57 and 58 are in communication with each other through passage 59 which extends longitudinally of the differential piston, the rate of flow of fluid through the passage being closely regulated by means of orifice screw 60 screwed into the front end of passage 59. Passage 59 is not necessarily in piston 55 but may be located at any other suitable position.

A vent 61 is provided in the wall of the differential cylinder at the junction of the sections of large and small diameters. This prevents air from being trapped in the cylinder underneath the larger diameter portion of piston 55.

Differential piston 55 can slide upon the valve rod 44 in order to permit relative movement between these two members under certain conditions; and disengageable connecting means are provided to connect the piston to valve rod 44 so that under certain other circumstances the two parts move together as a unit. For this purpose, on a forwardly projecting portion of the differential piston there is mounted a plurality of housings 62 which are threaded into the projection of the piston, these housings 62 each being held in place by a locknut 63, as shown particularly in Fig. 11. Within each housing is a compression spring 64 which presses a ball 65 against valve rod 44. The valve rod is provided with a circumferential groove 44*a* and when balls 65 are pressed into this groove the piston and valve rod are connected together to move as a unit. It will be realized that other types of releasable clutch means may be utilized for connecting the valve to the shifting member.

Time delay detent means are provided to engage and hold the differential piston against premature movement when the piston is in the rearward or rest position shown in Fig. 6. This detent means is an apparatus of the dashpot type contained in an insert 66 in a vertically extending bore in block 56. In the bottom portion of the insert is plunger 67 which is provided at its lower end with a projection engageable with annular groove 168 around the circumference of the differential piston. When the plunger engages this groove as shown in Fig. 6, piston 55 is held against forward movement. Plunger 67 is normally biased towards the downward position of engagement with the differential piston by spring 68 contained within a bore inside the plunger. One end of spring 68 presses against the plunger while the other seats against a shoulder in insert 66. Just above this shoulder, is an orifice screw 69 having a longitudinally extending metering orifice. The space below the orifice screw and above plunger 67 is filled with oil which can be forced through the orifice in screw 69 into reservoir space 70 above. Access to reservoir 70 for replenishing or changing the liquid or for other purposes is afforded by removing screw plug 71. Plug 71 has a vent 71*a* through which any excess pressure in reservoir 70 can bleed off to the atmosphere to prevent accumulation of super-atmospheric pressure in the reservoir that would affect the operation of plunger 67. The upper end of passage 71*a* is preferably covered by a porous filter to exclude foreign matter.

The lower end of plunger 67 is always exposed to the pressure of working fluid in cylinder 57; and this fluid pressure exerts a force on the plunger which raises the plunger in opposition to spring 68. The upward force is greater than the downward force on the plunger when the fluid pressure in cylinder 57 reaches a predetermined value. After this pressure has been reached, plunger 67 rises; but its movement is delayed since the oil below screw 69 must be forced upwardly through the orifice therein into reservoir 70 before the plunger rises sufficiently to disengage the differential piston.

In order to prevent plunger 67 from being forced too far down by the action of biasing spring 68 when the

differential piston is not in position to limit downward movement of the plunger, limiting pin **72** is provided as shown in Fig. 8. Pin **72** is threaded into the side of cylinder block **56** and has a portion which projects into a short vertically extending slot **73** in the side of the plunger. At the upper end of this slot is a shoulder which engages pin **72** in order to limit downward range of travel of the plunger.

The release of fluid pressure in chamber **58** ahead of the differential piston is through exhaust passage means at the forward side of the differential piston; and fluid flow through the passage means is controlled by an exhaust valve assembly which includes a poppet-type valve **75** which closes against a conical seat at **76** on insert **77** contained in a bore in block **56**. The details of this construction are shown particularly in Figs. 10 and 13, the valve being shown in the open position in the first of these figures. In the lower part of insert **77**, the stem of valve **75** passes through a bore of substantially larger diameter so that when the valve is spaced from its seat fluid in cylinder **58** can enter into this bore and then into laterally extending passages **78** in the insert. These passages communicate with openings **79** in the cylinder block which lead to the surrounding atmosphere. To eliminate the need for exact alignment of passages **78** and **79**, the block is counterbored at **80** to provide an annular manifold passage between the valve insert and the cylinder block which connects all of passages **78** with the terminal passages **79**.

The stem of valve **75** extends upwardly through a horizontal wall insert **77** and at its upper end is provided with piston **81** movable within cylinder **82** formed in the upper end of insert **77**. Between the bottom wall of the cylinder and the under side of piston **81** is spring **83** which normally urges the valve upwardly to the raised or closed position of Fig. 13. When closed the valve is also held in that position by pressure of the fluid in cylinder **58** against the head of the valve. In order to open valve **75** against this fluid pressure, piston **81** has a greater area than the area on valve **75** exposed to pressure within cylinder **58**. Also, the space under piston **81** is in free communication with the atmosphere through passage **84** (see Fig. 13) which relieves pressure underneath the piston that would interfere with downward movement of piston **81** to open position. The upper end of cylinder **82** is closed by plate **85** to retain fluid pressure within the cylinder. Thus valve **75** and its piston **81** constitute a differential piston which can be moved to a position in which the valve is open by applying fluid pressure to the larger piston end of the valve, as will now be explained.

Fluid under pressure is admitted into cylinder **82** from cylinder **58** through a devious combination of passages. From cylinder **58**, passage **87** leads into the bottom of bore **88** in the valve block. In bore **88** is valve insert **89** which has a centrally located passage **90** through which fluid goes into the interior of the valve insert and then outwardly through radial passages **91** into annular passage **92**. This last passage is connected by inclined passage **93** with cylinder **82**.

The flow of fluid under pressure from cylinder **58** into cylinder **82** through the system of passages just described is controlled by pilot valve **95** which is mounted for vertical reciprocation in a bore inside insert **89**. When in the raised position of Fig. 10, fluid flow through these passages is permitted since passage **90** and radial passages **91** are uncovered by valve **95**. When the valve is lowered as in Figs. 6 and 11, the valve closes central passage **90** and covers the inner ends of the radial passages **91** thus preventing any flow of fluid out of cylinder **58**. This pilot type of valve structure **95** is selected because passage **90** is of such small diameter that but very little force is required to be exerted upon the valve by the diaphragm to keep it seated against the upper end of passage **90** in opposition to air pressure of the magnitude encountered in cylinder **58**, whereas forces of considerable magnitude may be required at times to open or close exhaust valve **75**. This way the exhaust valve is opened by the application of air pressure rather than by a direct mechanical connection to the pressure responsive means, now to be described, for operating the exhaust valve, the application of the air pressure being controlled by pilot valve **95** and the pressure sensitive elements.

In order to raise and lower pilot valve **95**, it is connected to the lower end of rod **96** which passes through and is connected to flexible diaphragm **98**. As will be explained more fully, this diaphragm is movable in response to fluid pressures applied to it; and a piston or other type of movable member could be used instead, but a diaphragm is preferred for practical reasons as it can be made more sensitive to pressure differentials of small magnitude. Diaphragm **98** is confined around its periphery by having its marginal portions clamped between opposing shoulders on the two halves of cylinder block **56**. Thus the diaphragm subdivides an internal chamber into an upper chamber **99** and a lower chamber **100**. Diaphragm **98** is preferably mounted between a pair of reinforcing members **101** which are relatively rigid. The upper member **101** engages the cylinder block at the top of chamber **99** to limit the upward travel of the diaphragm.

Rod **96** extends upwardly from the diaphragm and passes loosely through a guide bore at **102** in a web of the cylinder block. A pair of lock nuts **103** on the upper end of rod **96** provides a shoulder against which compression spring **104** bears, the spring surrounding rod **96** and bearing against the block around bore **102**.

The upper ends of valve rod **96** and spring **104** are housed in sleeve **105** threaded into the upper portion **56***a* of the cylinder block. Sleeve **105** has an internal bore which extends the full length of the sleeve and which is closed by a manually operable valve assembly consisting of valve member **106** connected to cap **107** and compression spring **108** held between cap **107** and the top side of valve seat **109**. Valve **106** engages the underside of seat **109** to provide a fluid-tight seal and prevent the escape to the atmosphere of any fluid under pressure in chamber **99** and is biased toward this closed position by spring **108**. However, when pressure is manually applied to cap **107**, spring **108** is compressed and valve **106** is lowered to open position in which fluid in chamber **99** can escape through bore **102** and around valve **106** to the atmosphere. For this reason, the internal bore of cap **107** is larger than the external diameter of the upper end of sleeve **105**. Upon release of manual pressure, the valve is closed by spring **108**.

Diaphragm **98** is a pressure sensitive element whose position is determined at any time by the relative fluid pressures existing in upper and lower chambers **99** and **100** respectively. It is desired that the position of the diaphragm be made to respond to fluid pressures existing at some location outside of the automatic control device, in this instance the location being in the air supply line to the tuyère with which the automatic control device is associated. For this purpose, the means for supplying blowing air to the tuyère is provided with a flow meter of the type creating a differential pressure having a known relation to the velocity of air flow within the air supply line. A simple and convenient construction is to form a section of the air supply means in the shape or with the characteristics of a Venturi tube. Equivalent means such as a Pitot tube or orifice meter may be used instead. Obviously this Venturi tube section may be located at another convenient position, but it has been found convenient to form it within adapter **4** as a part of internal cavity **6**. Hence adapter **4** is designed so that the blowing air after entering from conduit **14** passes through the constricted throat **110** of the Venturi tube and then into the enlarged portion of chamber **6** before entering tuyère pipe **3**.

The spaces above and below diaphragm **98** are placed in communication with the air stream at the Venturi tube by means of two separate sets of passages. These are shown in Figs. 6 and 12. From lower chamber **100** passage **112** extends forwardly through valve block **56** to a larger passage **113** in valve block **114**. Valve block **114** is fastened to adapter **4** by bolt **111**. The forward end of passage **113** is connected to throat **110** of the venturi by way of passage **115** in adapter **4**.

By a similar arrangement passage **116** extends from upper space **99** forwardly to passage **117** in valve block **114**. From passage **117** communication is through passage **118** to a point within the adapter upstream from the Venturi throat where the cross section of the air supply passage is approximately the same as the cross section within conduit **14**. Thus the static pressure existing in the stream of blowing air at any time is communicated to space **99** above diaphragm **98**. At the same time the lower fluid pressure existing in Venturi throat **110** by virtue of the increased stream velocity brought about by

the decreased cross section of the air passage at the throat, is communicated to chamber **100** beneath diaphragm **98**. Hence, the position of the diaphragm is determined by the differential of fluid pressure existing at these two points in the air supply line.

As will be further apparent from later discussion, the diaphragm, the pilot valve, and the exhaust valve constitute pressure responsive means for regulating air flow out of the forward cylinder **58** through the exhaust passages closed by valve **75**. Because of the types of valves used and the magnitudes of the pressures regulated as well as the regulating pressures on the diaphragm it is preferred to control the exhaust valve indirectly, as through a pilot valve or other actuating means.

In each of bores **113** and **117** there is a valve **120** which is normally urged by compression spring **121** toward a position in which the valve seats against an internal shoulder **114***a* in valve block **114** to close the associated passage against the escape of air from the air supply line. When the fluid motor F and its control device G are mounted in place on the tuyère, cylinder block **56** engages the ends of valves **120** and presses them inwardly to the position shown in Fig. 12 in which the valves open passages **113** and **117**. As long as the control device is in place these valves remain open and the communication between the control device and the air supply line is maintained; and when the control device is removed from the tuyère, bores **113** and **117** are automatically closed to prevent escape of blowing air from the system.

Manually operable means is also provided to release fluid pressure in chamber **100** at the underside of diaphragm **98** similar to valve **106** and pushbutton **107** already described. Extending laterally from chamber **100** is passage **124** in cylinder block **56**. Passage **124** intersects an upwardly extending passage **125** which terminates at its upper end at the bottom of bore **126** in the upper half **56***a* of the cylinder block. Into bore **126** is screwed sleeve **127** having an internal bore within which valve **128** is mounted. The lower end of valve **128** engages the underside of annular seat **129** in sleeve **127** and the valve is biased toward this closed position by spring **130** mounted on the valve stem and bearing at its lower end against the shoulder on the upper side of valve seat **129**. On the upper end of the stem of valve **128** is mounted cap **131** and the upper end of spring **130** bears against the under side of the cap to force the valve upwardly. By manually applied downward pressure on cap **131**, spring **130** may be compressed and valve **128** moved downwardly away from the valve seat to permit the flow of fluid out around the valve in the open upper end of sleeve **127**. For this reason, clearance is provided between the depending rim of cap **131** and the upper end of sleeve **127**.

It is also preferred to incorporate in this structure another feature disclosed in the Patent No. 2,619,938 referred to above. This is the provision of a third air supply system generally designated as back pressure. It consists of an air line **134** connected to some relatively fixed part of each individual installation, as adapter cover plate **32**, all lines **134** receiving air from manifold pipe **133** as shown in Figs. 1 and 2. Air from line **134** goes through passage **135** in adapter plate **32** into valve housing **136** (see Fig. 14) and thence out through the front end of the valve housing and passage **137** into cylinder **48**. Within housing **136** is valve **138** normally urged by spring **139** to a closed position. When front cylinder head **22** engages the projecting end of valve **138** as the fluid motor is mounted on the tuyère, the valve is moved to the open position shown in Fig. 6 and air may flow through the passages into cylinder **48**. However, when the fluid motor is removed, valve **138** is moved to a closed position by its spring and automatically shuts off the back pressure air supply so that air does not escape to the atmosphere from line **134**. This additional air supply is furnished in order to maintain the body of fluid which is trapped in front of working piston **26** at proper volume and pressure in order to insure full movement of the piston on its return stroke, as will be more fully described. Also, make-up air is furnished to allow for any loss through seepage past either piston **26** or **47**. The air or other compressible fluid supplied through line **134** is at a relatively low pressure, say 5 lbs. to 7 lbs. per square inch above atmospheric. This is adequate to insure the necessary body of compressible fluid at all times in cylinder **20** ahead of working piston **26**.

Another optional feature which is preferably provided in order to check the performance of the automatic control device, is pressure gauge **140**. The pressure gauge is connected by means of an upwardly extending passage **141** with the cylinder space **58** ahead of the differential piston and by indicating the fluid pressure existing in this cylinder the pressure gauge readings are evidence of general operating conditions, as will be explained more fully.

Having described the construction of my invention, I shall now set forth in greater detail the operation of my improved form of automatic control device and how it initiates operation of the fluid motor for reciprocating the punch rod. When the fluid motor F and the control device G are assembled on the tuyère and before operating fluid is applied to the motor, the various parts may be assumed to be in the positions shown in Fig. 6 which are referred to as the normal or rest positions of the several operating parts. Working piston **26** is fully retracted to the rear end of its cylinder. Differential piston **55** is connected to valve rod **44** and both are at the rear of their strokes. The differential piston is held in place by plunger **67**. When the assembled fluid motor and its automatic control device are mounted on adapter **4**, connections are automatically made with passages **113** and **117** and the bore in housing **136** as the valves at these locations are automatically opened. Operating fluid, such as compressed air or other elastic fluid, is supplied to the motor and to the control device through conduit **16** which is now connected to supply chamber **37**. As typical of the pressures used, but not necessarily limitative thereof, operating fluid is supplied at a pressure in the neighborhood of 75 lbs. to 100 lbs. per square inch with the latter pressure preferred. Compressed air under this high pressure fills supply chamber **37** and cylinder **57**, the latter being an extension of the former, and exerts a forward pressure on the end of differential piston **55**. Since initially there is no opposing pressure on the other end of the piston in cylinder **58**, the piston would move forward if it were not locked in place by detent plunger **67**.

High pressure air in rear cylinder **57** flows through passage **59** into forward cylinder **58** at a rate which is determined by the size of the orifice in screw **60**; and after the lapse of sufficient time the forward cylinder is completely filled with air at a pressure which is equal to the operating pressure in the rear cylinder and supply chamber **37**. When this condition exists the pressure rearwardly on the differential piston is greater than the forward pressure because of the larger area exposed to the air pressure in cylinder **58**. During this time the lower end of plunger **67** has been exposed to the high pressure in cylinder **57** and the force on the plunger exerted by the compressed air moves the plunger upwardly, compressing spring **68** and forcing liquid out of the space immediately above the plunger through the orifice in screw **69** into reservoir **70**. The orifice in screw **69** is of a selected size to meter the flow of liquid to a desired rate. In this way the time required to lift detent plunger **67** to disengage groove **168** in the differential piston is sufficient that the air pressure in the forward cylinder **58** builds up to a pressure adequate to prevent forward movement of the piston.

Since the detent **67** is responsive to the pressure existing at one side of the differential piston, its operation is automatic. Being of a dash-pot construction it has a delayed action that prevents premature release of piston **55**. Forward motion of the piston is thus delayed until the normal desired fluid pressure is built up in the forward cylinder so that the forward end of the piston is subjected to fluid pressure adequate to hold it in the rest position without the operation of detent plunger **67**. This action is of value when the assembly consisting of a fluid motor and its control device is first mounted on the tuyère as when a unit is being replaced that has been removed for servicing. Furthermore, by controlling the strength of spring **68** the detent can be prevented from disengaging the differential piston when the operating air pressure in the supply chamber falls below a predetermined minimum value, as for example 75 lbs. per square inch.

Following initial assembly, air also enters through passage **137** from the back pressure line **134** which supplies air at a comparatively low pressure of approximately 5 to 7 lbs. per square inch. This air fills cylinder **48** and working cylinder **20** ahead of pistons **47** and **26** respec-

tively with compressed air at this low pressure, though the invention is not limited thereto.

When the various cylinders within the fluid motor and its attached control device have become charged with fluid under pressure and pressures are stabilized throughout, the device may be said to be "cocked" since it is now ready for normal operation. All parts are still in the same position as in Fig. 6, except that detent plunger **67** is raised clear of the cylinder as shown in Fig. 7. The device will now operate automatically in response to pressure conditions existing at the Venturi tube through which blowing air is supplied to the tuyère pipe. Blowing air is normally supplied through conduit **14** to pipe **3** at a pressure of approximately 12 to 15 lbs. per square inch, although this pressure is in no way limitative upon the present invention. When the tuyère is unobstructed blowing air flows through it and Venturi throat **110** at a known rate depending on the supply pressure; and as a result there is a known differential between the pressures existing in Venturi throat **110** and at a selected point upstream from the throat where the air passage has its full normal cross-sectional area.

It will be understood without detailed explanation that as accretions forms at the forward end of the tuyère the tuyère becomes artificially constricted with the result that air flows through it at a lower rate than normal. In consequence there is a decrease in the rate of air flow through the Venturi section and a new and lesser differential is established between the air pressures existing in the Venturi throat and at the same selected point upstream therefrom. The two points at which these measurements are taken are of course fixed and are the locations at which passages **115** and **118** open into the Venturi tube. The control device is designed to operate the fluid motor when the differential in pressures existing between these two points drops to or below a predetermined value.

By means of passages **112**, **113** and **115** the fluid pressure existing at the Venturi throat is also maintained in space **100** beneath the diaphragm **98**; while by means of passages **116**, **117** and **118** the higher pressure existing upstream from the Venturi throat is applied to space **99** above the diaphragm. Under normal flow conditions the differential in pressure is sufficient and in a direction to deflect diaphragm **98** downwardly until valve **95** closes ports **90** and **91**, thus preventing escape of fluid under pressure from cylinder **58** ahead of the differential piston. Downward movement of diaphragm **98** compresses spring **104**. When the rate of fluid flow through the Venturi throat drops below the minimum established for satisfactory converter operation, the differential fluid pressure on diaphragm **98** is reduced to a predetermined value. At or below this predetermined value, the upward force of spring **104** overcomes the net downward force on the diaphragm as a result of the fluid pressures applied thereto and spring **104** lifts the diaphragm upwardly, carrying valve **95** upwardly to the position of Fig. 10 in which air passages **90** and **91** are open.

With these latter passages open, compressed air can escape from cylinder **58** through passages **87**, **90**, **91**, **92** and **93** into cylinder **82**. In this cylinder the fluid pressure builds up rapidly until piston **81** is driven downwardly, as shown in Fig. 10, compressing spring **83** and moving exhaust valve **75** to the open position. The quantity of air escaping from cylinder **58** through these passages into the cylinder **82** is relatively small, since the volume of cylinder **82** is small compared with the volume of cylinder **58**. As a result there is no appreciable reduction in the value of the air pressure in cylinder **58** and cylinder **82** fills very rapidly. With the opening of exhaust valve **75** an escape passage to atmosphere of comparatively large size is made available through passages **78**, **80** and **79** to cause a sudden and substantial drop in pressure in cylinder **58**.

This drop in pressure permits differential piston **55** to move forwardly under the force applied to it by the operating air pressure at the rear of the piston. As the piston moves forward it gains in velocity and the forward cylinder continues to exhaust through open valve **75** so that the forward motion of the piston is not hindered.

As the differential piston moves forward it carries with it rod **44** by virtue of its connection thereto through balls **65** engaging circumferential groove **44***a* of the rod. This moves valve **40** from the exhaust position of Fig. 6 to the admission position of Fig. 7 in which inlet port is uncovered by the valve. This establishes free communication between supply chamber **37** and cylinder **20**. Forward movement of valve rod **44** also moves piston **47** and piston rod **49** by virtue of engagement of the latter with valve rod **44**. This forward movement continues until piston **47** hits the front end wall of cylinder **48** as in Fig. 7, thus stopping forward movement of rods **44** and **49**. The parts are preferably proportioned so that the differential cylinder also engages retainer **50**.

The back pressure on the forward side of piston **26** is sufficient to keep the working piston normally in a fully retracted position (as in Fig. 6) in which the piston covers inlet port **38**. However, this does not prevent admission of working fluid into the cylinder since the piston has small but adequate clearance between it and the cylinder walls to allow high pressure fluid to pass from inlet port **38** around the piston to reach the rear face of the piston and drive it forward. For this reason, packing as shown at **26***a* to effect a fluid-tight connection betwen the piston and cylinder walls is limited to the forward end of the piston at a position which is always forward of inlet port **38**. Two advantages are secured by keeping the piston when at rest at the extreme rear end of the cylinder. In the first place, the piston always makes a full and uniform stroke since it is definitely positioned at the beginning of each working stroke. In the second place, the partial constriction of port **38** causes fluid pressure behind the piston to build up more slowly than if the space were at once fully opened to the port with the result that piston **26** accelerates more gradually and more smoothly.

After slide valve **40** has been advanced to uncover at least a part of port **38**, the operation of the fluid motor F is initiated and its operation is then substantially as described in greater detail in the Patent No. 2,619,938 referred to above. Briefly stated, the piston starts to move with a fluid pressure of relatively nominal value, perhaps 5 to 7 lbs. per square inch, ahead of it and a relatively high working pressure reaching perhaps 90 to 100 lbs. per square inch behind it. This relatively greater force causes the piston to accelerate rapidly, reaching a maximum velocity at about midpoint of the forward stroke. For about the last 15% of the stroke, the piston decelerates rapidly because of the absorption of its kinetic energy by air trapped between the piston and the forward end wall of the cylinder. The body of fluid ahead of the piston eventually absorbs all of its energy remaining after the punch rod removes accretions in the tuyère and brings the piston to a stop at the dotted position of Fig. 4, and then by expanding returns the piston rapidly to the rear end of the cylinder. The energy of forward movement is sufficient to raise the pressure ahead of the piston to several hundred pounds per square inch, which pressure insures full return of the piston.

This return action is permitted by virtue of the valve return means which shifts the slide valve **40** to exhaust position at some point late in the forward stroke of the working piston, which is about the position of the piston in Fig. 7. As the pressure of the fluid ahead of the working piston builds up the same pressure is transmitted through passage **52** to piston **47**, and a point is reached at which the pressure acting upon piston **47** becomes sufficient to force that piston rearwardly in cylinder **48**. Because of engagement of piston rod **49** with valve rod **44** the rearward movement of the piston shifts the valve rearward to the exhaust position of Fig. 6. In so doing, rod **44** is disconnected from differential piston **55** since the differential piston is held in its forward position by the continued high operating pressure on its rear side. Thus the slide valve is returned alone to its initial position in which port **38** is connected through the valve with exhaust port **41**.

As piston **26** starts its return or rearward stroke under the relatively higher fluid pressure existing on its front face, working fluid is exhausted through port **41** at a rate which can be controlled by positioning slide **39** so as to restrict more or less the net opening of port **41**, to the atmosphere. This rate of exhaust has an effect upon the piston movement. The more the exhaust outlet is restricted, the greater the resistance to the piston during its return movement; and this may be utilized to slow down its rearward velocity. As the leading face of the piston passes port **38**, a small amount of fluid is trapped between it and the rear cylinder head to provide a cushion pressure that rapidly decelerates the piston. However, in actual operation the piston may strike the end

wall and this, combined with the elastic nature of the trapped air, causes the piston to rebound silghtly beyond port **38**. The piston thus may bounce or oscillate before it comes to rest. The final rest position is at the end of the cylinder (as in Fig. 6) since the pressure between the piston and the rear end of the cylinder is reduced to zero while at the forward face of the piston there is always the residual back pressure which pushes the piston rearwardly in its cylinder.

Assuming that the punching stroke of rod **15** is sufficient to clean out the accretions in the tuyère, normal flow conditions are reestablished which in turn causes reestablishment of the normal pressure differential across diaphragm **98**. As a result the diaphragm is again deflected downwardly by air pressures acting on it, valve **95** cuts off escape of fluid under pressure from cylinder **58** through passage **87** and consequently pressure can now build up in cylinder **58**. Air under pressure continually flows through passage **59** into cylinder **58** but during this time has not built up any pressure in the chamber as long as exhaust valve **75** remains open In practice, the reduction of pressure in cylinder **58** to substantially atmospheric allows the air under high pressure to escape from cylinder **82**, which air has caused exhaust valve **75** to open. In this way cylinder **82** is drained of air, permitting the exhaust valve to close and again retain pressure within cylinder **58** in front of the differential piston.

With the restoration of high pressure in cylinder **58**, the force on the forward face of piston **55** is greater than on the rear face and the piston is again driven back to its rearward position shown in Fig. 6 when balls **65** snap into groove **44***a* and again connect the piston to the valve. The fluid motor and its control device are again "cocked" and ready for another stroke.

The sizes of the various air passages are such that it may require several seconds to ready the apparatus for another stroke. A normal operating condition is indicated by a pressure gauge reading of 100 pounds, or whatever the line pressure is in conduit **16**, within an interval of 10 to 15 seconds depending on the size of the orifice in screw **60**, following the forward stroke of the piston. If a much lower gauge reading is indicated, it is a warning to the operator that for some reason the device is not operating properly.

It is characteristic of this fluid motor that piston **26** moves through a single complete reciprocation forward and back for each opening of motor valve **40**, which is promptly closed and cannot again be opened for at least several seconds even when everything is working properly. Several features contribute to this, such as the small size of the orifice in screw **60**, the disconnectable nature of the connection of piston **55** to valve rod **44**, and others. For this reason, the fluid motor is termed a single-cycle motor to distinguish from one adapted to repeated cycles or to continuous application of operating pressures to piston **26**.

A number of different reasons may cause malfunction of the control device. For example, dirt my clog one of the small air passages or settle on a valve seat, and prevent the valve from properly closing. Under such conditions air pressure in cylinder **58** may not build up to the minimum operating pressure, herein assumed to be 75 pounds per square inch. It sometimes happens that the punch rod does not sufficiently clean out a tuyère. This may be a result of excessive accretions in the tuyère but is more likely a result of mechanical failure because the tip of the punch rod is worn or broken or may perhaps have been melted off. Under these circumstances, the normal rate of air flow through the tuyère is not reestablished as a result of a punching stroke and consequently the normal differential pressure across diaphragm **98** is not reestablished. Lack of this full pressure differential prevents the diaphragm from closing pilot valve **95** and air entering cylinder **58** continues to escape. Failure of pressure gauge **140** to indicate substantially the operating line pressure within a short time, perhaps 15 to 20 seconds, following a forward stroke of piston **26**, is a warning to the operator that for one of the reasons enumerated, or some other reason, the punching unit is not operating properly. If the difficulty is in the failure of the punch rod to enlarge the tuyère sufficiently, this may be ascertained quickly by cocking and subsequently actuating the punching unit by means of the manual control buttons.

The motor and control mechanism may be chocked manually by depressing button **131** which opens valve **128** and places the under side of diaphragm **98** in communication with the atmosphere. As a result the pressure underneath the diaphragm is lowered and the air pressure above the diaphragm forces valve **95** downwardly to a closed position. If the button is held down until gauge **140** shows a pressure equal to the pressure of line **16**, then the operator knows that the differential piston has again been connected to the valve rod and the device is cocked ready to operate. Action of fluid motor F may now be initiated by releasing button **131** since upon release the diaphragm is raised by spring **104** in the absence of air pressure above the diaphragm sufficient to hold it down in position to close valve **95**.

The control device may be manually operated to initiate a stroke of the working piston at any time under normal operating conditions by manually depressing button **107**. When button **107** is depressed sufficiently to unseat valve **106**, the space above diaphragm **98** is vented to the atmosphere and the higher pressure beneath the diaphragm raises pilot valve **95**, initiating action of the fluid motor in the manner described above.

During such periods as the blowing air may be shut off so that there is no pressure above atmospheric in conduit **14** or adapter **4**, the device may still be operated manually by depressing button **107** as far as possible. When no differential air pressure is applied to the diaphragm it is raised by spring **104** to the upper position of Fig. 10 in which pilot valve **95** is open. As valve **106** moves down, it first engages the upper end of valve rod **96**, and further downward movement of the button causes valve **95** to move downwardly to a seated or closed position. The valve is held in this position by maintaining manual pressure on button **107** until line pressure, as indicated by gauge **140**, has been built up in cylinder **58** ahead of the differential piston. When button **107** is now released, spring **104** raises the diaphragm and valve **95** with the result that action of the fluid motor is initiated in the manner previously described.

From the foregoing description it will be seen that various changes in details and arrangement of parts will occur to persons skilled in the art without departing from the spirit and scope of my invention. In the course of the description, various departures from the preferred design have been mentioned but it will be realized that these are not the only changes that may be made; and it is to be understood that I am not necessarily limited to the exact details of the disclosure already made. Consequently, it is to be understood that the foregoing disclosure is considered as being illustrative of, rather than limitative upon, the appended claims.

I claim:

1. The combination with a converter tuyère subject to accumulation of obstructions during normal converter operation, a punch rod reciprocable within the tuyère for periodically removing such obstructions, and an air supply line connected to the tuyère for supplying blowing air that flows past the zone of obstructions into the converter, of apparatus for automatically reciprocating the punch rod when obstructions reduce air flow through the tuyère below a predetermined value, comprising: a single cycle fluid motor operatively connected to the punch rod to reciprocate the rod upon supply of operating fluid to said motor and having a valve movable from a normal rest position shutting off supply of operating fluid to the motor to a second position admitting operating fluid to the motor; a movable valve shifting member; means for subjecting opposite sides of said valve shifting member to fluid pressure; exhaust passage means at one side of the valve shifting member opening to the atmosphere for relieving fluid pressure at said one side to produce movement of the valve shifting member; means connecting the valve to the valve shifting member to move the valve to said second position in response to said movement of the valve shifting member; exhaust valve means normally closing said exhaust passage; fluid pressure responsive means for opening said exhaust valve; and passage means placing the pressure responsive means in communication with the blowing air supply line to actuate said pressure responsive means when the rate of flow in the tuyère past the obstructions drops below a predetermined value.

2. The combination as in claim 1 in which the apparatus for reciprocating the punch rod also comprises a second fluid supply line supplying operating fluid to the motor and directly to the valve shifting member at the side of the shifting member away from the exhaust passage means; and constricted passage means communicating with the spaces at each of the two sides of the valve shifting member conducting operating fluid to said one side of the shifting member adjacent the exhaust means at a relatively slow rate.

3. The combination as in claim 1 in which the fluid pressure responsive means for opening the exhaust valve includes means biasing the exhaust valve toward a normally closed position; a piston connected to the valve; fluid passage means leading from said one side of the valve shifting member to one side of said valve piston to apply fluid pressure to the piston in a direction to open the exhaust valve; a pilot valve controlling fluid flow through the last named fluid passage means; and a movable pressure sensitive element connected to the pilot valve and sensitive to fluid pressure in the blowing air supply line to hold the pilot valve normally in closed position and to move the pilot valve to open position when the flow of blowing air drops below a predetermined value.

4. The combination as in claim 3 that also includes manually operated means for moving the pilot valve to closed position.

5. The combination as in claim 3 that also includes fluid passage means communicating between one side of the pressure sensitive element and the atmosphere, and a valve normally closing the last mentioned fluid passage and movable to open the passage to release fluid pressure acting on one side of the pressure sensitive element.

6. In combination with a converter tuyère and a blowing air supply line leading to the tuyère, an apparatus for automatically punching said tuyère comprising: a punch rod mounted for reciprocatory movement in the tuyère; a fluid motor for effecting a single, rapid reciprocation of the punch rod upon supply of operating fluid to said motor; a valve normally held in a rest position shutting off supply of operating fluid to said motor and movable to a second position to supply operating fluid to said motor; a cylinder; a differential piston reciprocable in said cylinder; means for subjecting the piston at the side of smaller area to a relatively constant operating fluid pressure; means for supplying fluid under pressure to the opposite side of said piston to hold the piston in a normal rest position; exhaust passage means leading from said cylinder at said opposite side of the piston for releasing fluid from said cylinder to reduce the pressure at said opposite side; means operatively connecting the piston to said valve to shift the valve from said rest position to said second position in response to such decrease in pressure at said opposite side of the differential piston; exhaust valve means normally closing said exhaust passage; and means communicating with said air supply line and responsive to variations in flow of fluid in said air supply line, operable to open said exhaust valve when the rate of flow of fluid in said air supply line decreases below a predetermined value.

7. The combination as in claim 6 in which the apparatus for punching the tuyère also comprises: detent means biased toward a position of engagement with the differential piston when in normal rest position, said detent means being subjected to the relatively constant pressure at the smaller side of the differential piston to be held out of engagement with the piston when said pressure exceeds a predetermined value; a constricted passage through the piston conducting working fluid from the side of smaller area to the other side of a relatively slow rate; and time delay means associated with the detent means to delay disengagement from the piston until fluid pressures at both sides of the differential piston are substantially equal.

8. In an automatic control device of the character described for controlling actuation of a single-cycle fluid motor having a reciprocable valve shiftable between a normal rest position shutting off supply of operating fluid to the motor and a second position admitting operating fluid to the motor, the combination comprising: a cylinder; a differential piston reciprocable in said cylinder; means for subjecting the piston at the side of smaller area to a relatively constant working fluid pressure; a constricted passage for supplying fluid under pressure at a relatively slow rate to the opposite side of said piston to hold the piston in a normal rest position; detent means biased toward a position of engagement with the differential piston when in said normal rest position, said detent means being subjected to the relatively constant fluid pressure at the smaller side of the differential piston to be held out of engagement with the piston when said constant pressure exceeds a predetermined value; exhaust passage means leading from said cylinder at said opposite side of the piston for releasing fluid from said cylinder to reduce the pressure at said opposite side; means operatively connecting the piston to said valve to shift the valve from said rest position to said second position in response to such decrease in pressure at said opposite side of the piston; an exhaust valve normally closing said exhaust passage; and pressure responsive means connected to an air supply line outside the control device and responsive to variations in flow of fluid in said line, operable to open said exhaust valve when the rate of flow of fluid in said air supply line decreases below a predetermined value.

9. An automatic control device as in claim 8 that also includes time-delay means associated with the detent means to delay disengagement from the piston for sufficient time that fluid pressures at both sides of the differential piston are substantially equal.

10. In an automatic control device of the character described for controlling actuation of a fluid motor having a valve shiftable between exhaust and admission positions, the combination comprising: a movable valve shifting member operatively connected to the motor valve; means for subjecting opposite sides of the valve shifting member to fluid pressure; exhaust passage means at one side of the valve shifting member for relieving fluid pressure at said one side; exhaust valve means regulating fluid flow in the exhaust passage; a Venturi tube through which a stream of air flows; pressure responsive valve operating means opening said exhaust valve means in response to fluid pressure existing at said Venturi tube and comprising a second movable member, means for subjecting one side of the second movable member to the fluid pressure existing in the throat of the Venturi tube, and means for subjecting the opposite side of the second movable member to the fluid pressure existing at a point upstream from the Venturi throat; and valve means normally biased to a closed position and manually operable to move to an open position to release fluid pressure acting on one of the two opposite sides of the second movable member.

11. In an automatic control device of the character described for controlling actuation of a fluid motor having a valve shiftable between exhaust and admission positions, the combination comprising: a movable valve shifting member operatively connected to the motor valve; means for subjecting opposite sides of the valve shifting member to fluid pressure; exhaust passage means at one side of the valve shifting member for relieving fluid pressure at said one side; exhaust valve means regulating fluid flow in the exhaust passage; pressure responsive valve operating means opening said exhaust valve means in response to fluid pressure existing at a location outside the control device, and valve means normally biased toward a closed position and manually operable to move to an open position to release fluid pressure acting upon said pressure responsive valve operating means independently of pressures existing at said location outside the control device.

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