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3,146,798

FLOW CONTROLLER

Filed Oct. 30, 1961

FIG. 1.

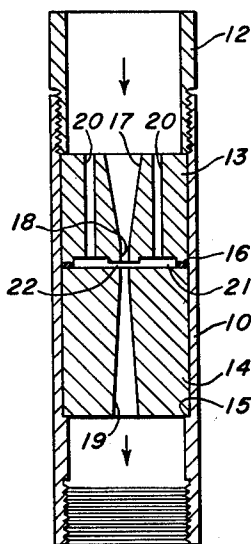


FIG. 2.

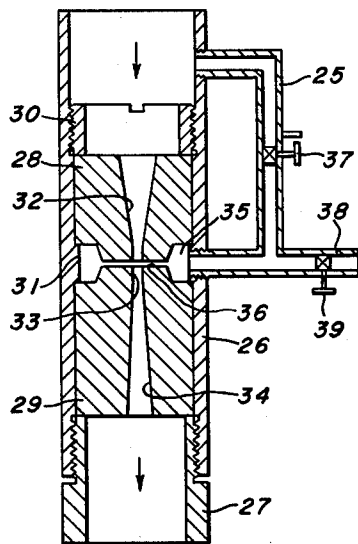


FIG. 3.

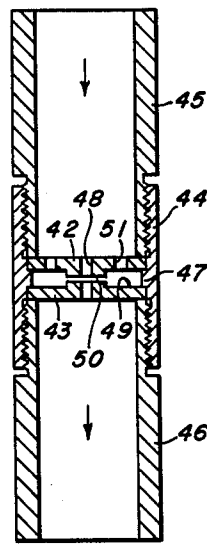


FIG. 4.

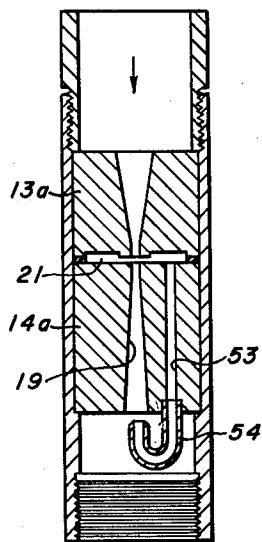
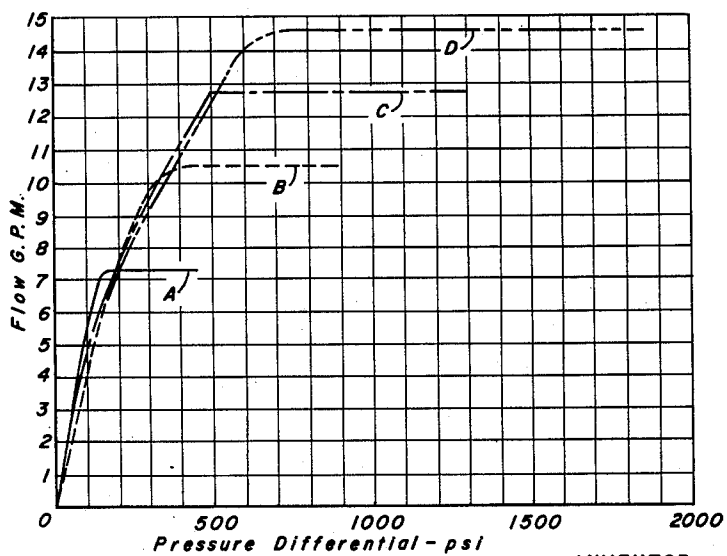


FIG. 5.



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3,146,798 FLOW CONTROLLER

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This invention relates to an improved controller for limiting the rate at which fluid can flow through a hydraulic or pneumatic system.

Although my invention is not thus limited, my controller is particularly useful as a governor applied to a hydraulically operated subsurface motor and pump combination used in an oil well. Conventionally such combinations include a hydraulic motor and a reciprocating pump located near the bottom of a well. A stream of power oil is pumped down the well tubing at a substantially constant pressure to drive the motor. Exhaust power oil from the motor subsequently returns to the surface, either blending with oil pumped from the well or via a separate return line. In practice the load on the pump may be removed quite suddenly, as when the well pumps off, or the load may be removed during part of a stroke because of free gas in the oil. When the pump is thus unloaded and loses resistance, the motor tends to run at a high speed which results in damage to the mechanism. Because of the compressibility of oil and elasticity of the tubing, a large amount of energy may be stored in the power oil. Hence any control means located at the surface is ineffective for preventing damage. Nevertheless my controller may have application elsewhere for overcoming analogous problems in a hydraulic or pneumatic system.

An object of my invention is to provide an improved controller which effectively limits the flow rate of fluid therethrough to a safe maximum despite loss of resistance to flow downstream of the controller.

A further object is to provide an improved controller which achieves the foregoing purpose, yet is of simple compact construction of dimensions to be installed near the bottom of a well and free of moving parts.

A more specific object is to provide an improved controller which has the foregoing characteristics and includes a housing, a restriction in the housing for increasing the velocity of a stream of fluid as it flows therethrough, and means for creating turbulence in the stream at the point of increased velocity.

In accomplishing these and other objects of the invention, I have provided improved details of structure, preferred forms of which are shown in the accompanying drawing, in which:

FIGURE 1 is a longitudinal sectional view of one form of controller constructed in accordance with my invention;

FIGURE 2 is a longitudinal sectional view showing a modification;

FIGURE 3 is a longitudinal sectional view showing another modification;

FIGURE 4 is a longitudinal sectional view showing still another modification; and

FIGURE 5 is a graph showing a set of curves to demonstrate how my controller limits the rate of flow therethrough to a definite maximum.

FIGURE 1 shows one form of my controller which comprises a housing 10, a connector 12 at the upstream end of the housing, and a two-part venturi device 13, 14. When I use this controller with a hydraulically operated subsurface motor and pump combination, I attach the downstream end of housing 10 to the inlet of the motor as close to the motor as possible, and I attach connector 12 either directly to the power oil tubing of an insert-type pump, or to a fishing neck and oil inlet nipple of a

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pump that may be inserted and removed hydraulically. Housing 10 has an internal shoulder 15 against which the downstream part 14 of the venturi device rests. I may place an annular gasket 16 on the other face of the downstream part 14 and place the upstream part 13 of the venturi device on this gasket. Optionally the gasket can be omitted and the upstream part 13 can bear directly against the downstream part 14. The connector 12 is threadedly engaged with the upstream end of housing 10 and bears against the face of the upstream part 13 to hold the venturi device in position.

The venturi device has walls which form a tapered inlet passage 17, a throat 18 and a flared outlet passage 19. The upstream part 13 has a plurality of intake passages 20 spaced in a circle around the inlet passages 17. The face of the upstream part 13 adjacent the downstream part 14 has an annular groove 21. The space within this groove forms a chamber which communicates with passages 20. The upstream part also is cut away adjacent throat 18 to form an annular connecting passage 22 which affords communication between the chamber and throat.

In operation, a stream of fluid enters the upstream end of housing 10, flows through passage 17, throat 18 and passage 19, and discharges through the downstream end. Normally this fluid is under substantially constant pressure upstream of the housing, but the pressure downstream may drop. Loss of downstream pressure of course increases the pressure difference between the two ends of the housing. As long as the pressure difference remains within a predetermined range, the rate at which the stream flows through the housing varies almost directly with the pressure difference. Whenever the loss of downstream pressure increases the pressure difference above a critical value, the rate of flow through the housing levels off, and thereafter remains substantially constant despite any further increase in the pressure difference. This result is attained by fluid flowing through passages 20, chamber 21 and passage 22 and impinging on the high-velocity stream at throat 18, where the stream has a greater velocity than it has through the remainder of the housing.

FIGURE 2 shows a modification in which a bypass 25 replaces the intake passages 20. I use this form of controller in accessible locations where compactness is less essential. The controller comprises a housing 26, a connector 27 threadedly engaged with the downstream end of the housing, a two-part venturi device 28, 29 and an annular plug 30 threadedly engaged with the housing upstream of the venturi device. The housing contains an internal flange 31. I fix the upstream part 28 of the venturi device between plug 30 and flange 31, and I fix the downstream part 29 between connector 27 and flange 31. The venturi device has a tapered inlet passage 32, a throat 33 and a flared outlet passage 34. The space between its two parts 28 and 29 forms an annular chamber 35 and an annular connecting passage 36, which affords communication between the chamber and throat, similar to corresponding parts in FIGURE 1. I connect one end of the bypass 25 into the housing upstream of the venturi device, and the other end to the housing opposite chamber 35. The bypass contains a valve 37, which I can adjust to regulate the value at which the flow rate levels off. Preferably I also connect an outside source 38 of fluid with the bypass as an alternate means for supplying fluid to the venturi throat. This source is equipped with a valve 39.

FIGURE 3 shows a modification in which upstream and downstream orifice plates 42 and 43 replace the venturi device. This form comprises a housing 44 and upstream and downstream connectors 45 and 46 threadedly engaged with opposite ends of the housing. The housing contains an internal flange 47. I fix the upstream

orifice plate 42 between connector 45 and flange 47 and I fix the downstream orifice plate 43 between connector 46 and flange 47. The orifice plates provide a restricted orifice 48 for increasing the fluid velocity. The space between the orifice plates forms an annular chamber 49 and an annular connecting passage 50 which affords communication between the chamber and orifice. The upstream orifice plate 42 contains a plurality of intake passages 51 which afford communication between the upstream face and chamber 49. The operation is similar to that already described for the form shown in FIGURE 1, although the venturi has an advantage that it offers less increase in pressure drop with increases in velocity.

FIGURE 4 shows a modification in which the fluid which reaches the chamber is taken from the downstream end of the restriction. The housing, connector and venturi parts are constructed similarly to those already described in FIGURE 1, except that the upstream venturi part 13a has no intake passages, but instead the downstream venturi part 14a has a single intake passage 53 communicating with chamber 21. I fix a Pitot tube 54 to the downstream face of the venturi part 14a communicating with passage 53. I position the inlet end of the Pitot tube adjacent the downstream end of the restriction where it receives a portion of the fluid discharging from the flared outlet passage 19. This fluid flows back through the Pitot tube and passage into chamber 21, where its action is similar to that already described for FIGURE 1.

FIGURE 5 shows a series of curves which demonstrate the results of tests I conducted with my controller constructed as shown in FIGURE 1. The abscissae of these curves represent pressure differentials in pounds per square inch at opposite ends of the controller, and the ordinates the resulting flow in gallons per minute. The inlet passage 17 of this controller had an included angle of 14°, the throat 18 a length of $\frac{3}{4}$ inch and a diameter of $\frac{1}{8}$ inch, and the outlet passage 19 an included angle of 8°. The fluid was a relatively light hydraulic oil. Curve "A" shows results I obtained by holding the upstream pressure constant at about 500 p.s.i. and varying the downstream pressure with a throttle valve. This curve shows that the flow rate increased rapidly with increases in pressure difference until the differential reached about 150 p.s.i. with a flow rate of about 7.25 gallons per minute, whereafter greater pressure differences produced no further increase in the flow rate. The velocity at the venturi throat with the limiting flow rate was about 189 f.p.s. Similarly curves "B," "C" and "D" show results I obtained with the same controller and fluid, but with the upstream pressure held constant at 1000 p.s.i., 1500 p.s.i. and 2000 p.s.i. respectively. In each instance the flow rate reached a definite limiting value which was maintained regardless of further increases in the pressure differential.

As fluid from the chamber impinges on the stream at the restriction, it creates turbulence in the stream. I believe this turbulence is responsible for limiting the flow rate, but I am unable to explain the action further. The static pressure of the stream at the restriction of course decreases as the velocity increases, in accordance with Bernoulli's well-known principle. Thus the static pressure might drop sufficiently to approach the vapor pressure, with the result that a liquid would vaporize. The velocity of the vapor would automatically be limited to the speed at which sound travels therethrough. However, my observation is that the velocity does not reach sufficient values to explain the action in this manner. I obtained the curves of FIGURE 5 with oil of low vapor pressure, but I have obtained similar curves with water of much higher vapor pressure. I also find the action is independent of the viscosity of the fluid, at least within the limits of about 1 to 40 centipoises. As long as the fluid is a liquid, the limiting flow rate is proportional to the square root of the absolute upstream pressure, and the critical value of the pressure difference is about one-third the absolute

upstream pressure. The limiting flow rate also is directly proportional to the cross sectional area of the restriction. If the fluid is a gas, the limiting flow rate of the gas reduced to standard condition is directly proportional to the absolute upstream pressure.

I have also obtained interesting results by connecting two of my controllers in series and measuring pressure at the upstream end of the upstream controller, between the two controllers, and at the downstream end of the downstream controller. Two controllers lowered the limiting flow rate only slightly as compared with a single controller. However, the resistance before the limiting flow rate was reached approximately doubled, as I would expect. Before the limiting flow rate was reached, the pressure drop was divided evenly between the two controllers. After this flow rate was reached, the pressure drop across the upstream controller remained constant, and all additional pressure drop took place across the downstream controller. I actually observed a small but measurable decrease in flow rate with increasing pressure differentials above the critical value.

From the foregoing description it is seen that my invention affords a controller of especially simple construction for effectively limiting the rate at which fluid can flow therethrough. My controller is compact, as required for use in an oil well, and it is entirely free of moving parts likely to need maintenance. It is apparent also that I can use the bypass of FIGURE 2 or the Pitot tube of FIGURE 4 with the orifice construction of FIGURE 3.

While I have shown and described certain preferred embodiments of my invention, it is apparent that other modification may arise. Therefore, I do not wish to be limited to the disclosure set forth but only by the scope of the appended claims.

I claim:

1. A flow controller comprising a housing having upstream and downstream ends for receiving and discharging a stream of fluid, a first member fixed in said housing and having an opening which extends therethrough and tapers toward said downstream end, a second member fixed in said housing between said first member and said downstream end and having an opening which extends therethrough and is aligned with said first-named opening and flares toward said downstream end, said openings jointly defining a venturi throat through which the stream flows at a higher velocity than through the remainder of the housing, said members having surfaces which face each other adjacent their outer peripheries and are spaced apart to define an annular chamber, said members also having surfaces which face each other between said chamber and said throat and are spaced apart a shorter distance than said first-named surfaces to define an annular passage which furnishes communication between said chamber and said throat throughout the circumference of the latter, and intake means furnishing communication between said chamber and said upstream end for introducing fluid to said chamber and thence through said passage into said throat to impinge on the stream in said throat, thereby creating turbulence in the stream which limits the flow rate through said housing to a predetermined maximum as long as the pressure on said upstream end remains constant despite loss of pressure on said downstream end.

2. A controller as defined in claim 1 in which said intake means is in the form of passages which extend through said first member.

3. A controller as defined in claim 1 in which said intake means is in the form of a bypass extending outside said housing, and said controller includes an adjustable valve in said bypass.

4. The combination, with a source of fluid adapted to be maintained at substantially constant pressure and means connected to said source to which a stream of fluid is delivered therefrom, said means being subject to loss of resistance which increases the pressure difference between said source and said means, of a controller com-

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prising a housing having upstream and downstream ends connected respectively to said source and to said means to receive and discharge the fluid stream, a first member fixed in said housing and having an opening which extends therethrough and tapers toward said downstream end, a second member fixed in said housing between said first member and said downstream end and having an opening which extends therethrough and is aligned with said first-named opening and flares toward said downstream end, said openings jointly defining a venturi throat through which the stream flows at a higher velocity than through the remainder of the housing, said members having surfaces which face each other adjacent their outer peripheries and are spaced apart to define an annular chamber, said members also having surfaces which face each other between said chamber and said throat and are spaced apart a shorter distance than said first-named surfaces to define an annular passage which furnishes communication between said chamber and said throat throughout the circumference of the latter, and intake means furnishing communication between said chamber and said upstream end for introducing fluid to said chamber

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and thence through said passage into said throat to impinge on the stream in said throat, thereby creating turbulence in the stream which limits the flow rate through said housing to a predetermined maximum as long as the pressure at said source remains constant despite loss of resistance at said first-named means.

5. A combination as defined in claim 4 in which the fluid is a liquid, the maximum flow rate is proportional approximately to the square root of the absolute pressure at said source, and the maximum flow rate is reached when the difference in pressure between said source and said first-named means is approximately one-third the absolute pressure at said source.

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