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3,340,893

THROTTLE

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2 Sheets-Sheet 1

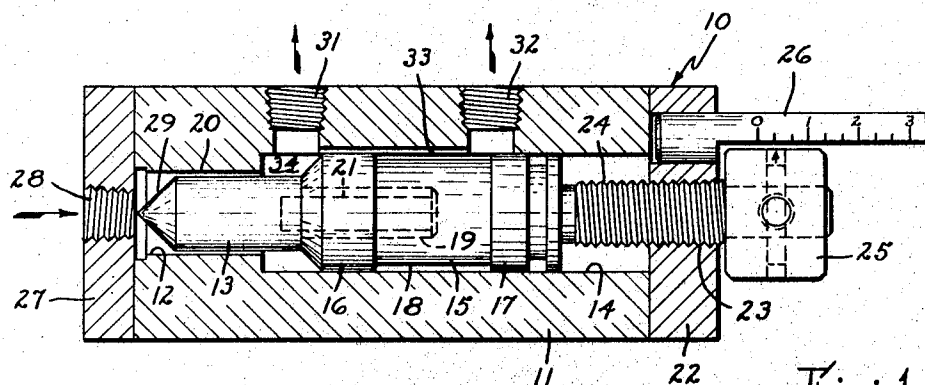
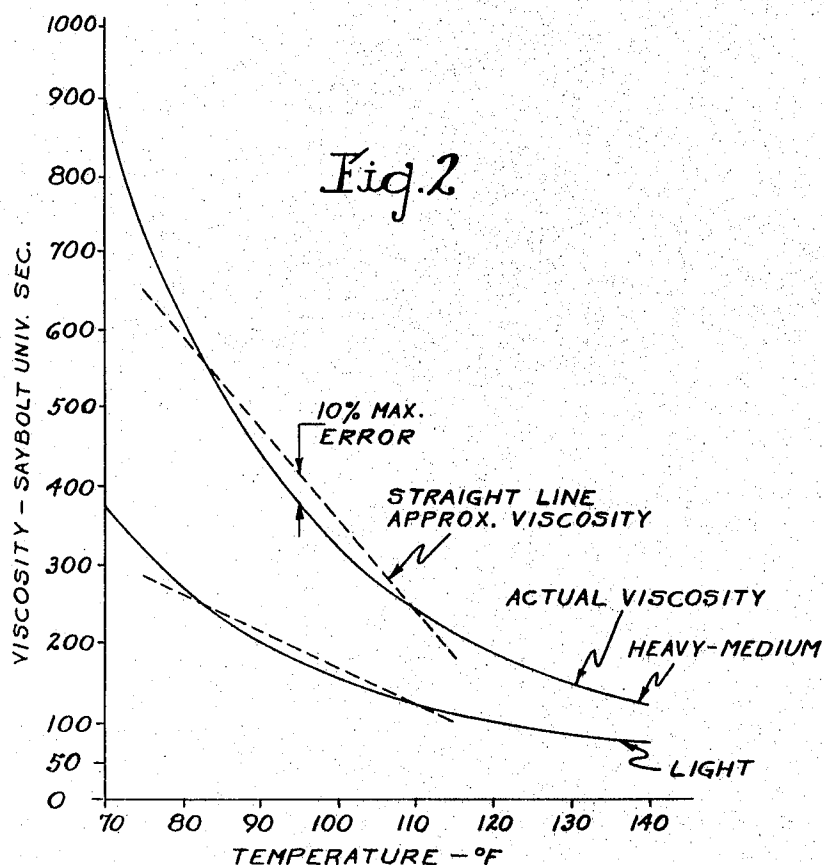


Fig. 1



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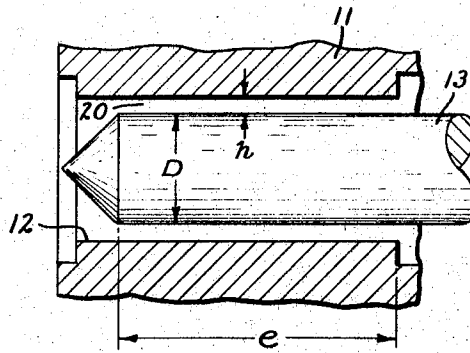
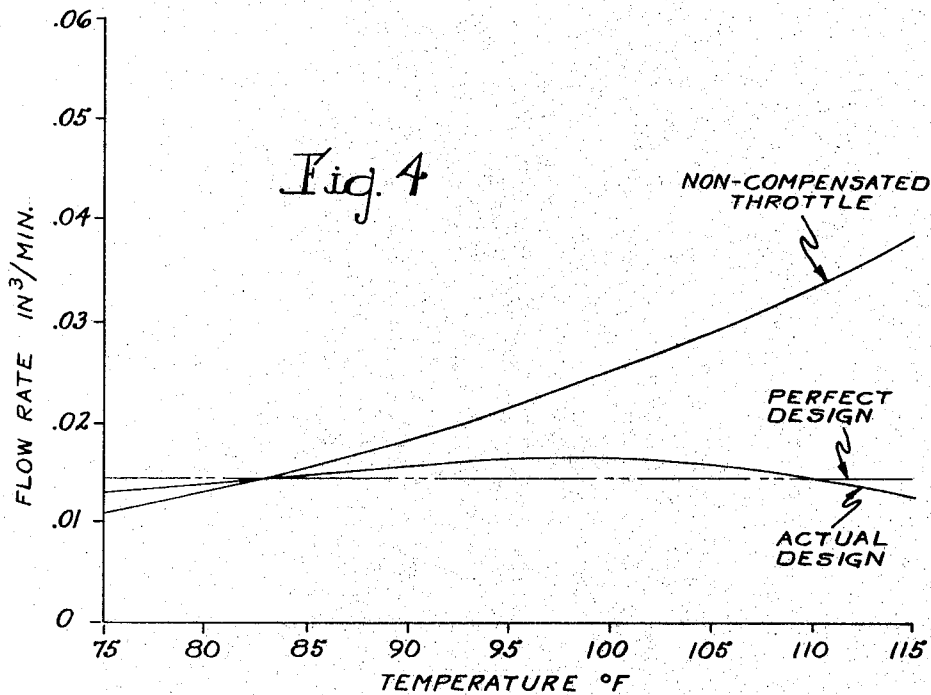
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Fig. 3



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THROTTLE

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ABSTRACT OF THE DISCLOSURE

The invention concerns itself with a throttle which presents a constant resistance to flow in a hydraulic system, irrespective of changes in temperature of the fluid in the system; this is accomplished by using materials of different thermal co-efficients of expansion.

The mechanical element known as a throttle finds frequent use in hydraulic systems for restricting the flow of fluid. Normally, it is a relatively simple element, since its only purpose is to introduce into the fluid system a passage which is smaller than other passages in the fluid system. When, however, one attempts to use such throttles in a situation where the fluid flow is to be at a very low rate, certain problems develop. When throttles constructed in accordance with the prior art are used with low fluid flow rates, it has been found that the resistance to flow of the passage varies a great deal with changes in temperature. Throttles which have been constructed to overcome this deficiency have, in the past, been very expensive and not entirely successful. These and other difficulties experienced with the prior art devices have been obviated in a novel manner by the present invention.

It is, therefore, an outstanding object of the invention to provide a throttle capable of presenting a fixed resistance to fluid flow, irrespective of changes in temperature.

Another object of this invention is the provision of a thermally-compensated throttle which is inexpensive to manufacture.

A further object of the present invention is the provision of a throttle adapted to regulate fluid flow at very low flow rate.

It is another object of the instant invention to provide a throttle having a special means for removing air and other gases from the fluid.

It is a further object of the invention to provide a throttle in which the amount of restriction is readily adjustable.

A still further object of this invention is the provision of a throttle which is simple in construction, which is inexpensive to manufacture, and which is capable of a long life of useful service with a minimum of maintenance.

With these and other objects in view, as will be apparent to those skilled in the art, the invention resides in the combination of parts set forth in the specification and covered by the claims appended hereto.

The character of the invention, however, may be best understood by reference to one of its structural forms as illustrated by the accompanying drawings in which:

FIG. 1 is a sectional view of a throttle embodying the principles of the present invention;

FIG. 2 is a graph showing a method of determining certain values relative to the viscosity of the fluid in the system;

FIG. 3 is a schematic view of the important portions of the invention; and

FIG. 4 is a graph showing test results using the present throttle.

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Referring first to FIG. 1, which best shows the general features of the invention, the throttle, indicated generally by the reference numeral 10, is shown as consisting of an elongated main body 11, having a passage or bore 12 in which resides a regulating member 13. In the preferred embodiment, the main body 11 is made of Invar, a metallic alloy having substantially no coefficient of thermal expansion, while the regulating member 13 is formed of aluminum having a coefficient of thermal expansion of 12×10^{-6} inches per inch per degree Fahrenheit. Generally speaking, however, the metals of which the main body 11 and the regulating member 13 are made must have substantially different coefficients of thermal expansion, as will be explained more fully hereinafter. The diameter of the regulating member 13 is less than the diameter of the bore 12 by an amount in the order of .0006 inch, thus leaving an annular passage 20 therebetween for the flow of fluid.

Extending through the main body 11 coaxially of the bore 12 is a counterbore 14 in which a cylindrical support member 15 is mounted. The support member is provided with two cylindrical portions 16 and 17 which fit tightly in the bore 14 and guide it. Between these portions extends an elongated reduced portion 18. The regulating member 13 is provided with a threaded extension 19 which is mounted in a similarly threaded bore in the end of the support member 15 facing the regulating member. A bore 21 extends into the end of the extension 19 to prevent damage due to the differences in thermal co-efficient of expansion.

The end of the main body 11 on which the counterbore 14 opens is closed by a head 22 provided with a threaded bore 23 which is co-axial of the bore 14. Threaded in the bore 23 is a threaded extension 24 of the support member 15. Mounted on the extreme end of the extension 24 is an indicator block 25 having an arrow which points toward a scale 26, extending longitudinally away from the head 22 and carrying indicia indicative of flow settings of the throttle.

The other end of the main body 11 is provided with a head 27 having an inlet port 28 opening into the passage or bore 12. The regulating member 13 is provided with a conical surface 29 on its extreme end. An outlet port 31 extends laterally into the main body 11 and opens into the counterbore 14 immediately adjacent its junction with the bore 12. A bleed port 32 extends laterally into the body 11 at a point substantially spaced from the outlet port 31 intermediate of the length of the counterbore 14. The outlet port 31 is normally located to the left of the cylindrical portion 16 of the support member 15, while the bleed port 32 normally has access to the reduced portion 18 of the support member, i.e., between the cylindrical portions 16 and 17.

The surface of the counterbore 14 between the outlet port 31 and the bleed port 32 is provided with a shallow relief groove 33 which, in the preferred embodiment, may be a few thousandths of an inch deep.

The operation of the apparatus will now be readily understood in view of the above description. The present throttle is intended for regulating the flow of small quantities of fluid per unit time. It may, for instance, be used in the exhaust line of a hydraulic cylinder where it is desired to cause the piston to move through the cylinder at a very slow rate. The pressure line is connected to the inlet port 28 and oil under pressure flows through the port into the bore 12 around the conical surface of the regulating member 13. The oil then passes through the passage 20 between the bore 12 and the surface of the regulating member 13. Since this passage has a thickness in the order of .0003 inch, the flow is very small, despite the fact that the pressure in the fluid may be quite high. The oil

emerges from the other end of the passage into a vestibule 34 formed by the end of the counterbore 14 adjacent the bore 12 and the cylindrical portion 16 of the support member 15. The oil passes from this vestibule into the outlet port 31 and from there to the sump of the fluid system. Normally, the throttle 10 would be mounted in the machinery with the end carrying the head 22 being higher than the end carrying the head 27, so that the axis of the bore 12 and the counterbore 14 resides at about 15° to the horizontal. This means that any air contained in the fluid will flow in the vestibule 34 toward the support member 15. From there it will enter the relief groove 33 and pass through that relief groove around the cylindrical portion 16 of the support member ending, eventually, in the area around the reduced portion 15 from which it passes into the bleed port 32 and is disposed of. Since the flow of fluid is very small, a given body of fluid stays in the vestibule 34 for a considerable length of time giving air bubbles an ample opportunity to drift toward the relief groove. When it is desired to adjust the flow of fluid, it is only necessary to rotate the support member 15 and, because of its threaded connection with the head 22, the support member (carrying the regulating member 13) will move longitudinally, thus making the length of the annular passage 20 shorter or longer, as is desired. Naturally, when the passage is longer, the throttle will present greater resistance to flow while, if it is shorter, the flow will take place more easily and will, therefore, increase.

It is interesting to note the methods by which the sizes of the elements in the present invention are calculated and the formulas defining the method by which it operates. Referring to FIG. 3, in the discussion which follows the letters are used to indicate the quantities indicated below:

D=Basic diameter of the regulating member 15 at the minimum design temperature. This is approximately the same as the mean annular diameter of the passage 20, since the clearance between the bore 12 and the regulating member 13 is very small compared to its diameter

h =Radial clearance in inches

l =The effective length in inches which, of course, is variable for throttle adjustment

μ_g =Viscosity of fluid in reyns

P =Pressure drop across the throttle in p.s.i.

Q =Flow rate in cubic inches per second

C_1 =Coefficient of thermal expansion of the material used for the regulating member 13 in inches per inch per degree Fahrenheit

C_0 =Coefficient of thermal expansion of material used for the body 11 in inches per inch per degree Fahrenheit

T =Temperature range of design in degrees Fahrenheit

R =Ratio of the low temperature viscosity to the high temperature viscosity, i.e., $\mu_{\min}/\mu_{\max}$.

$h_{\min}$ =Clearance at minimum temperature

$h_{\max}$ =Clearance at maximum temperature

As design considerations, C_1 must be greater than C_0 . Basically, the design involves the construction of a coaxial cylindrical throttle for laminar flow control of viscous fluids, which throttle is automatically compensated for changes in viscosity due to changes in fluid temperature. In the discussion which follows, the admission and discharge coefficients have been ignored on the premise that the restrictor is long. Naturally, the design must be made for a specific fluid and one should be selected whose viscosity index can be assumed to be constant for the design temperature range, i.e., the change in viscosity to be linear with temperature. Basically, this temperature-viscosity insensitive throttle is intended for very low flow rates which are not practical to control by orifice control, and a variable throttle has been provided which is insensitive to the changes in fluid viscosity resulting from changes in temperature.

From the basic flow equations for this type of flow passage:

$$Q = \frac{h^3 \pi D P}{12 \mu l}$$

It can be seen that the flow rate is proportional to h^3 and inversely proportional to μ ; it is clear that for perfect thermal compensation of flow the expression h^3/μ must be constant (the other factors in the equation having been arbitrarily selected. In other words:

$$\frac{h_{\min}^3}{\mu_{\min}} = \frac{h_{\max}^3}{\mu_{\max}}$$

or

$$\frac{\mu_{\max}}{\mu_{\min}} = \frac{h_{\max}^3}{h_{\min}^3} = R$$

or

$$(1) \quad h_{\max}^3 = R h_{\min}^3$$

From the basic physics of the invention:

$$(2) \quad h_{\max} = h_{\min} + \frac{DC_1 T}{2} - \frac{DC_0 T}{2}$$

From Equation 1:

$$(3) \quad h_{\max} = h_{\min} \sqrt[3]{R}$$

Substituting Equation 3 in Equation 2:

$$(4) \quad h_{\min} \sqrt[3]{R} = h_{\min} + \frac{DC_1 T}{2} - \frac{DC_0 T}{2}$$

or

$$h_{\min} \sqrt[3]{R} - h_{\min} = D \left(\frac{C_1 T - C_0 T}{2} \right)$$

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$$h_{\min} = D \left[\frac{C_1 T - C_0 T}{2(\sqrt[3]{R} - 1)} \right]$$

This gives $h_{\min}$, the radial clearance or thickness of the passage 20 at high temperature. Similarly, substituting Equation 2 in Equation 3:

$$h_{\max} = \left[\frac{C_1 T - C_0 T}{2(\sqrt[3]{R} - 1)} \right] \sqrt[3]{R}$$

45 This gives the radial clearance at low temperature.

In a specific application of the invention, using the above equations, the body 11 was made of Invar with a thermal expansion of zero and the regulating member was formed of aluminum with a thermal expansion of 12×10^{-6} in./in./° F. The actual viscosity of the fluid (heavy-medium oil) is shown on the chart in FIG. 2. A straight line is used to approximate the curve in the temperature range selected (70° F.-115° F.) and from this line the R is equal to 4. Therefore, using Equation 1:

$$(a) \quad (h_{70})^3 = (4) (h_{115})^3$$

Now, the diameter, d , of the regulating member 13 at 115° F. is:

$$(b) \quad d_{115} = d_{70} + 12(10^{-6})(45)d_{70}$$

Now:

$$\frac{d_{115} - d_{70}}{2} = h_{70} - h_{115}$$

or

$$(c) \quad h_{115} = h_{70} - \left(\frac{d_{115} - d_{70}}{2} \right)$$

Combining Equations (b) and (c):

$$(5) \quad h_{115} = h_{70} - \left[\frac{d_{70} + 12(10^{-6})(45)d_{70} - d_{70}}{2} \right] = h_{70} - \left[\frac{12(10^{-6})(45)d_{70}}{2} \right]$$

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Substituting in Equation (a):

$$(h_{70})^3 = 4 \left\{ h_{70} - \left[\frac{12(10^{-6})(45)d_{70}}{2} \right] \right\}^3$$

or:

$$h_{70} = \sqrt[3]{4 \left\{ h_{70} - \left[\frac{12(10^{-6})(45)d_{70}}{2} \right] \right\}}$$

Therefore:

$$= 1.588h_{70} - 429(10^{-6})d_{70}$$

$$.588h_{70} = 429(10^{-6})d_{70}$$

$$h_{70} = 730(10^{-6})d_{70}$$

In the example, the diameter, d , of the regulating member 15 at 70° F. was selected as 1.00", so that:

$$h_{70} = 730(10^{-6})(1.0000) = .000730''$$

Using this value, the diameter of the bore 20 was b equal to $1.0000 + 2 \times .000730 = 1.00146''$.

The flow with the example throttle is obtained by using the general flow equation. The fluid had a μ of $17.5(10^{-6})$, the length, l , of the passage 20 was 1.00" and the pressure drop through the throttle was 100 p.s.i.

$$Q = \frac{h^3 \pi DP}{12 \mu l} =$$

$$\frac{[730(10^{-6})]^3 \times 3.14 \times 1.00 \times 100}{12 \times 17.5 \times 10^{-6} \times 1.00} =$$

$$5.85 \times 10^{-4} \text{ in.}^3/\text{sec.}$$

The throttle was tested and the results are shown in FIG. 4. The flow rate varies from a perfect condition by a small amount due, principally, to the assumption of straight-line variation of the viscosity of the fluid with temperature. It is interesting to note that the greatest test variation from the ideal design occurs where this assumption is greatest in error, i.e., in the center of the temperature range.

It can be seen, then, that the present invention produces a throttle capable of substantially compensating for the change in viscosity of the fluid throughout a wide range of temperatures. The throttle is relatively simple in construction and should be relatively inexpensive to manufacture. There are no complicated parts to become inoperative and a relatively simple means has been developed for removing air bubbles from the flow of fluid. The continuing presence of air in the fluid would result (at the low flow rates involved) in erratic motion of the actuator or hydraulic cylinder being controlled.

It is obvious that minor changes may be made in the form and construction of the invention without departing from the material spirit thereof. It is not, however, desired to confine the invention to the exact form herein

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shown and described, but it is desired to include all such as properly come within the scope claimed.

The invention having been thus described, what is claimed as new and desired to secure by Letters Patent

5 is:

1. A throttle, comprising

(a) a main body having a passage,

(b) a regulating member in the passage defining a flow space between the surface of the passage and the surface of the regulating member,

the main body and the regulating member being formed of materials having substantially different co-efficients of thermal expansion, such that the change in cross-sectional area of the said space with a given change of temperature of the fluid is sufficient to compensate for the change in viscosity of the fluid due to the said change in temperature, which viscosity change would otherwise result in change in flow of the fluid, the main body being provided with a vestibule at the discharge end of the flow space, a relatively large exit port opening into the vestibule for the removal of the fluid and a relatively small passage opening into the vestibule for the bleeding of air.

2. A throttle as recited in claim 1, wherein the main body is made of Invar and the regulating member is formed of aluminum.

3. A throttle as recited in claim 1, wherein the passage is cylindrical and the regulating member is also cylindrical and is mounted co-axially of the passage to define a tubular flow space.

4. A throttle as recited in claim 3, wherein the body is provided with a bore which extends co-axially of the regulating member and wherein a cylindrical support member is mounted in the bore and is connected to the regulating member to support it centrally of the passage.

5. A throttle as recited in claim 4, wherein the support member is formed of the same material as the body.

6. A throttle as recited in claim 5, wherein the regulating member is formed with a recess located in the area of its attachment to the support member to prevent damage due to their different co-efficients of thermal expansion.

References Cited

UNITED STATES PATENTS

1,871,287	8/1932	Whittaker	138—46
2,283,311	5/1942	Bevins	137—468 X
2,610,300	9/1952	Walton	137—468 X
2,881,869	4/1959	Yarrick	
2,966,170	12/1960	Raulins	236—93 X

55 EDWARD J. MICHAEL, *Primary Examiner*.