April 21, 1936. E. W. NEUBAUER 2,037,994

APPARATUS FOR METERING FLUIDS

Filed July 9, 1932 4 Sheets-Sheet 1

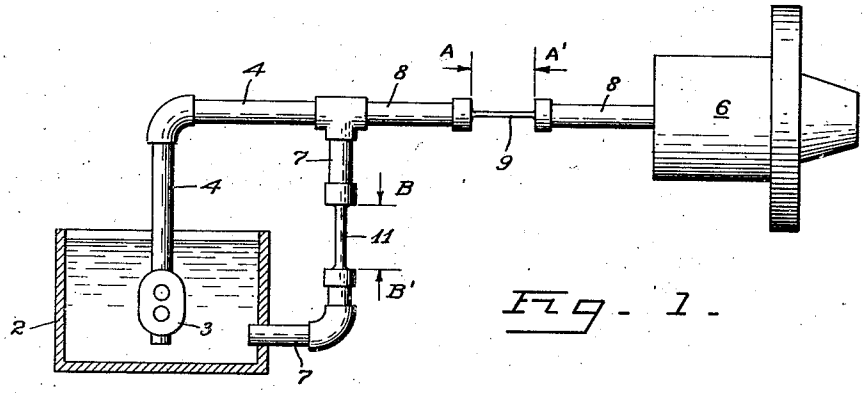


Fig. 1.

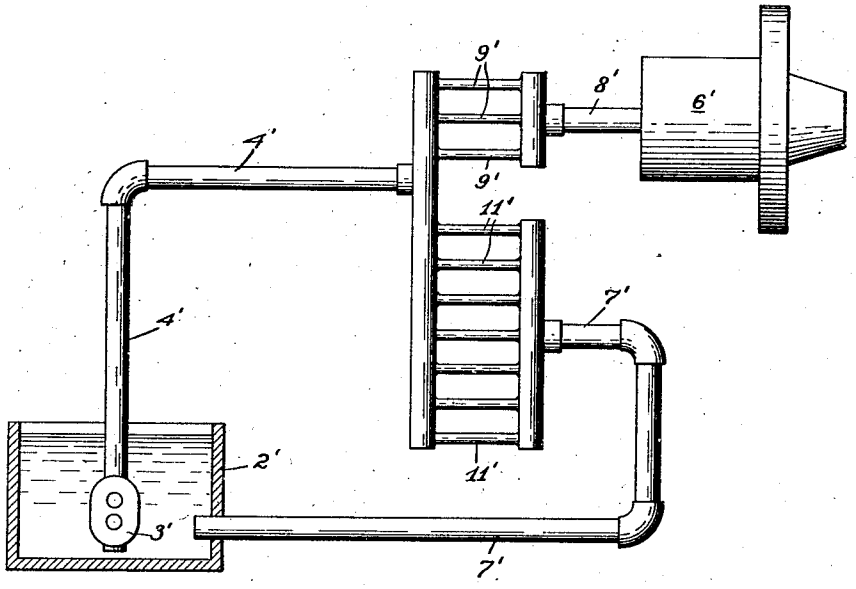


Fig. 2.

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APPARATUS FOR METERING FLUIDS

Filed July 9, 1932 4 Sheets-Sheet 2

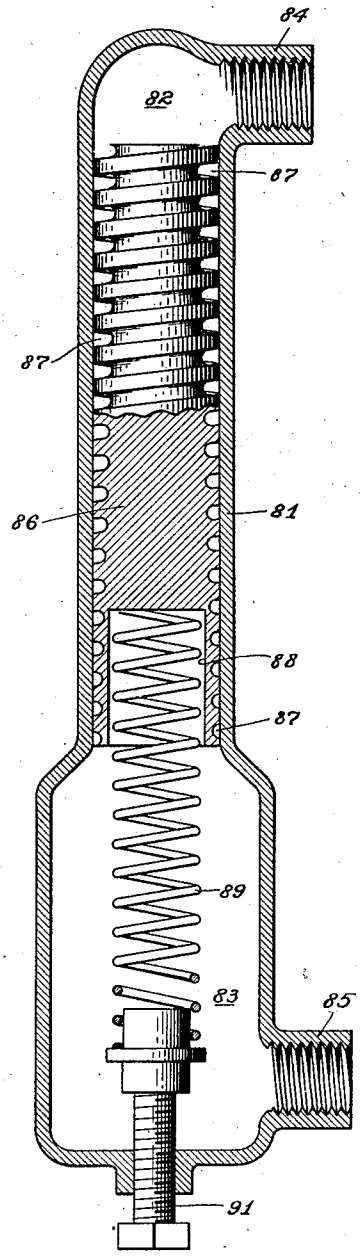


Fig. 5.

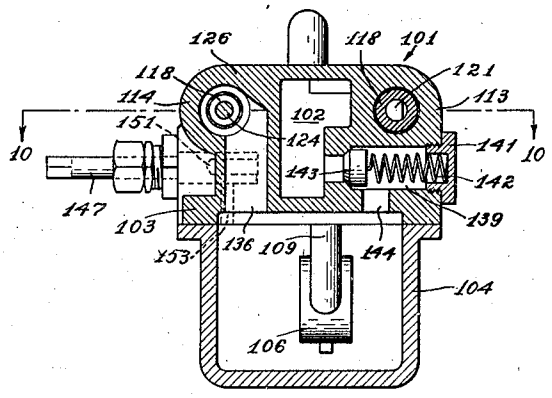


Fig. 8.

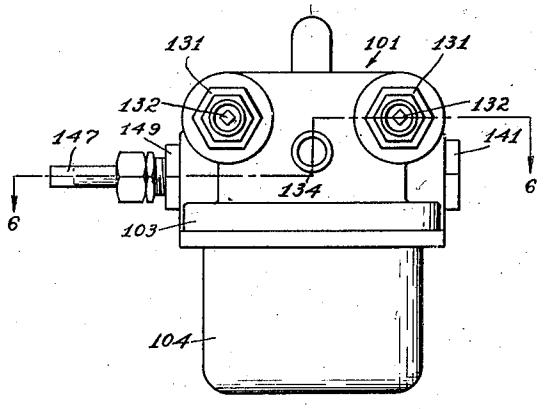


Fig. 9.

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APPARATUS FOR METERING FLUIDS

Filed July 9, 1932 4 Sheets-Sheet 3

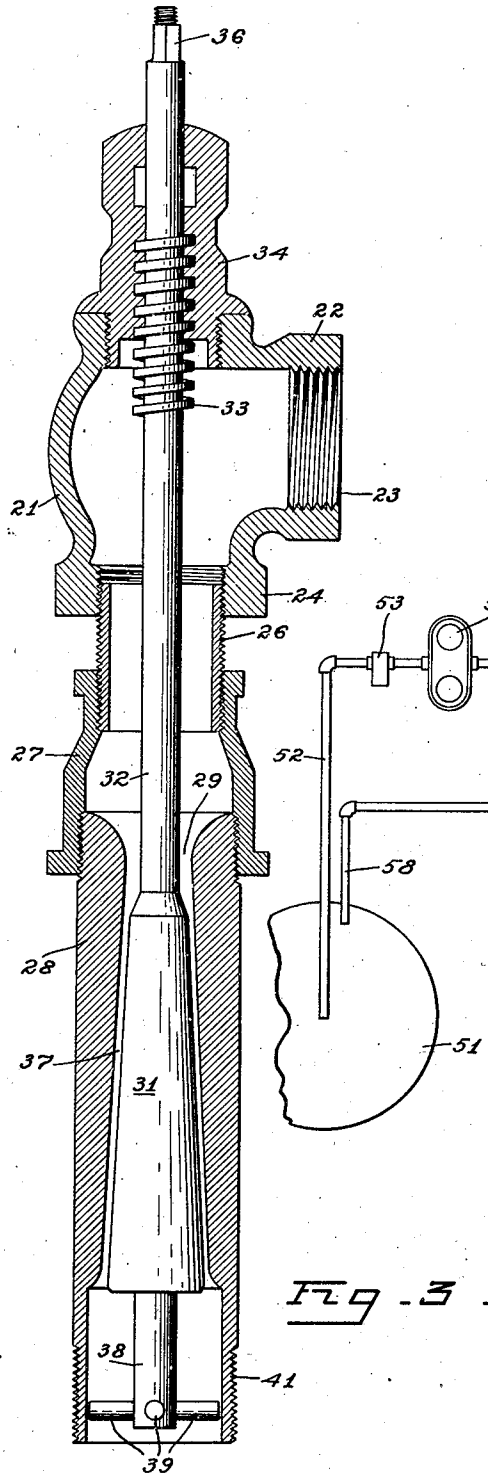


Fig. 3.

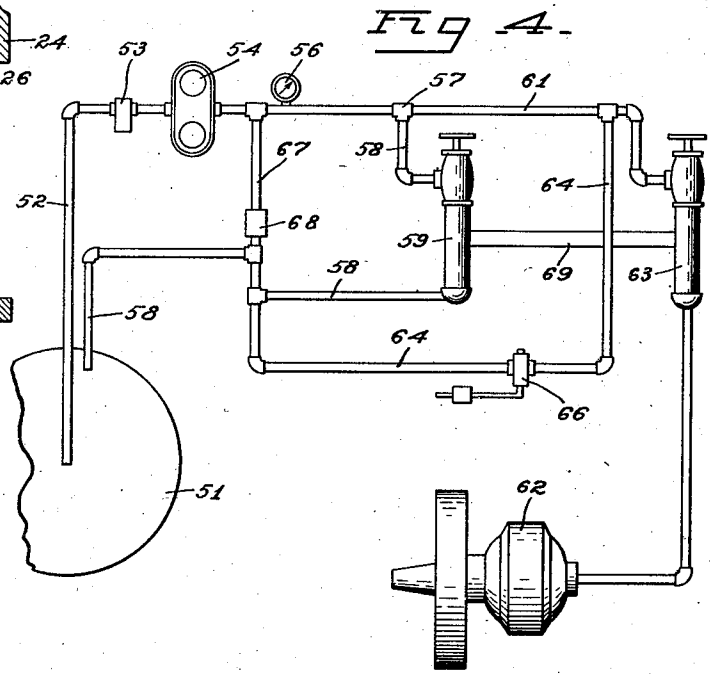


Fig. 4.

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APPARATUS FOR METERING FLUIDS

Filed July 9, 1932 4 Sheets-Sheet 4

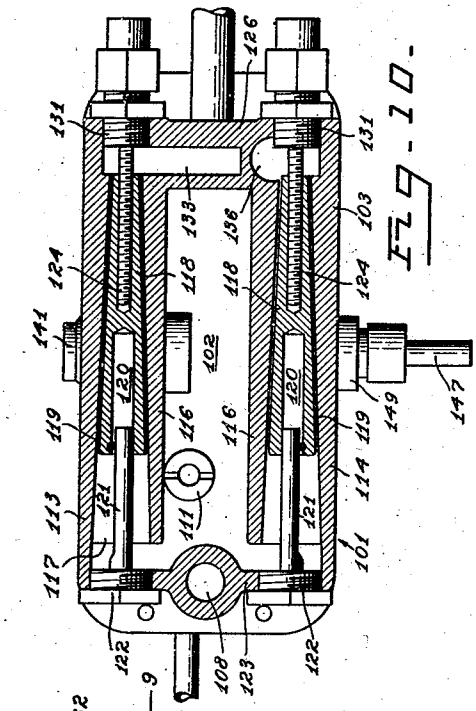


Fig. 10.

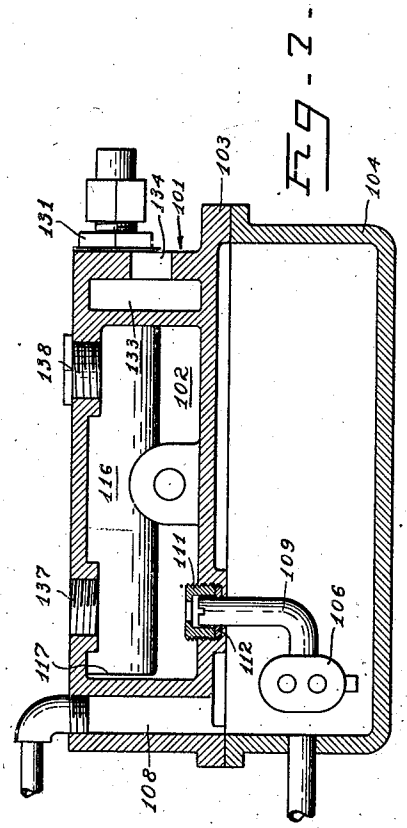


Fig. 7.

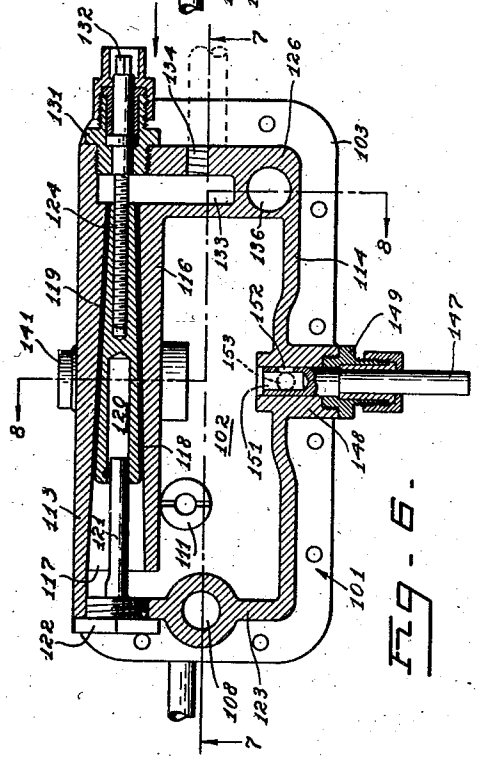


Fig. 9.

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Patented Apr. 21, 1936 2,037,994

UNITED STATES PATENT OFFICE

2,037,994

APPARATUS FOR METERING FLUIDS

Edwin W. Neubauer, Portland, Oreg., assignor to Ray Burner Company, San Francisco, Calif., a corporation of Delaware

Application July 9, 1932, Serial No. 621,677

4 Claims. (Cl. 158—36.3)

My invention relates to a method and apparatus for metering fluids in such manner as to prevent change in rate of flow of a fluid caused by change in viscosity thereof. More particularly, the method and apparatus of my invention are especially adapted in oil burner systems where it is extremely desirable to maintain a uniform flow of oil to the burner, unaffected by variations in viscosity of the oil. This application is a continuation in part of my copending application, Serial No. 533,169, filed April 27, 1931.

Introduction

In oil burner systems, the control of rate of flow of oil to the burner has heretofore been quite a problem, particularly in such systems which function automatically to shut off and turn on the oil. With a system set for a predetermined flow or rate of oil to the burner, changes in oil viscosity have heretofore affected the rate of flow, thus rendering unstable the size of the burner flame. In the automatic systems referred to, the oil decreases in viscosity after its flow to the burner is shut off, because the remainder of oil in the system warms, under actual boiler-room conditions, when the burner is off. Consequently, if the oil is turned on again, the burner flame size will be different from that prior to the shutting off of the oil. Also, when the system is first set in operation in the early morning after being shut off for the night, the oil is cold and is therefore quite viscous; as a result the feed is reduced to such an extent as to make ignition of the oil extremely difficulty. Upon burning of the oil in the burner the oil flowing in the system becomes heated and its viscosity decreases. Obviously, with the conventional type of system, the burner flame size will be affected by such changes in viscosity. If an attendant is constantly present to take care of an oil burner system, he can regulate the size of the burner flame to maintain it substantially constant, by opening or closing a manually operable valve for controlling the rate of flow. The added expense of an attendant makes his presence undesirable.

Objects of invention

Various systems have been heretofore employed in an effort to overcome the foregoing described difficulty. However, none of these systems has been able to maintain constant rate of flow regardless of changes in viscosity of the oil.

It is therefore one of the objects of my invention to provide an apparatus and method which will meter a fluid, such as oil to an oil burner, at a substantially fixed predetermined rate regardless of viscosity changes in the fluid.

Another object of the invention is the provision of an apparatus, of the character described, which can be economically manufactured.

An additional object of my invention is the provision of an apparatus, the mode of operation of which is simple and which, therefore, requires little or no attention.

A further object is the provision of a method and apparatus, of the character described, which will permit the utilization of heavier and cheaper oils than heretofore possible in previous automatic systems, thus materially reducing the cost of operation.

Other objects of my invention will become apparent from a perusal of the following description of my invention.

Although the apparatus and method of my invention are of general application and therefore can be employed for any purpose where it is desired to render ineffective change in viscosity of a liquid upon rate of flow thereof, the apparatus and method are particularly adapted for a fuel oil burner system, where the use of the system of my invention has solved the heretofore bothersome problem. I have therefore chosen for the purpose of illustrating the principle of my invention, the application thereof in an oil burner system.

General description

In general terms, the apparatus of my invention employed with an oil burner, comprises a conduit system for distributing oil from a given source. The system includes a plurality of conduits or fluid conducting means, through which the oil has a divided flow. One conduit or fluid conducting means is connected to the oil burner to provide for delivery of oil to the burner, while another forms a branch conduit or fluid conducting means connected with the delivery conduit to by-pass the surplus oil back to the given source. The oil is distributed through the system from the source, by a substantially constant volumetric pump (i. e., a pump which is capable of feeding an approximately fixed volume of oil per unit of time). In each of the plurality of conduits or fluid conducting means beyond the point of division of fluid flow, are formed restricted passageways of materially less cross-sectional area than that of the conduits connected to the ends of the passageways, so as to offer considerable resistance to the flow of oil and thereby convert the pressure head on the oil into

streamline viscous friction. Each restricted passageway is of such length and cross-sectional area as to create a substantial pressure drop across the passageway (i. e., difference in pressure between the pressure of the oil entering the passageway and its pressure leaving the passageway) greater than the back pressure created by the oil in the portion of the conduit branch beyond the discharge end of the passageway.

Passageways of the character described will cause flow of oil therethrough in compliance with Poiseuille's law, which is, briefly, that for tubes or passageways of properly selected diameter and length, the rate of flow of a fluid therethrough is directly proportional to the pressure and to the fourth power of the tube radius (the square of the cross-sectional area) and inversely proportional to the length of the tube and to the viscosity of the fluid. Tubes in which the flow of fluids obeys Poiseuille's law are called Poiseuille tubes; the restricted passageways in the system of my invention are, therefore, of the character of Poiseuille tubes.

Mathematically, Poiseuille's law may be expressed as follows:

$$\frac{V}{T}=\frac{\pi r^4 P}{8lu}$$

where,

V=volume of oil
T=time
r=tube radius
P=pressure of oil across tube
l=length of tube
u=absolute viscosity of oil

The ratio of volume to time is the same as oil rate which may be designated as O. For a given tube, π, r, 8 and l are constants. Therefore, for a given tube the formula may be expressed as follows:

$$\frac{V}{T} \text{ or } O=(k)\frac{P}{u}$$

or,

$$\text{Oil rate}=(\text{a constant})\ \frac{\text{Pressure}}{\text{Viscosity}}$$

Since in my system, employing a plurality of conduits or fluid conducting means having restricted passageways of the Poiseuille type, a substantially constant volumetric discharge pump is employed, it is apparent that the oil rate through the system as a whole will be substantially constant. Therefore, if the viscosity of the oil increases or decreases due to change in temperature, the pressure across these Poiseuille restricted passageways must increase or decrease proportionately. Thus, because of the Poiseuille fluid flow effect, changes in viscosity of the oil which might occur, are automatically compensated by a proportional change of a factor occurring in the Poiseuille formula; and the same quantity of oil will, consequently, flow from each restricted passageway regardless of changes in viscosity of the oil.

Description of figures

Reference is now made to the drawings for a more detailed description of my invention, in which—

Figure 1 illustrates diagrammatically the system of my invention employing two Poiseuille tubes.

Figure 2 illustrates schematically a system of my invention in which one number of Poiseuille tubes or restricted passageways is employed in one branch and a different number of tubes in another branch.

Figure 3 illustrates in vertical section a Poiseuille tube or passageway constructed in the form of a valve, to allow flexibility of adjustment in controlling the quantity of oil to the burner, and also to allow adjustment of pressure drop across the passageway.

Figure 4 is a diagrammatic view of a typical fuel burner installation, in which a high low flame control is utilized.

Figure 5 is a vertical sectional view of a type of valve different from that shown in Figure 3.

Figure 6 is a horizontal sectional view of a preferred Poiseuille valve unit employed in the system of my invention. The section is taken in planes indicated by line 6—6 in Figure 9.

Figure 7 is a longitudinal sectional view taken in a plane indicated by line 7—7 in Figure 6.

Figure 8 is a transverse sectional view taken in planes indicated by line 8—8 in Figure 6.

Figure 9 is an end elevation of the unit, looking in the direction of arrow 9 in Figure 6.

Figure 10 is a horizontal sectional elevation taken in a plane indicated by line 10—10 in Figure 8.

Description of Figure 1 modification

With reference to Figure 1, which is for the purpose of illustrating the principle of the invention, the system in its simplest form may comprise a tank or reservoir 2 for holding the oil, in which is located a constant volumetric discharge pump 3 of any suitable construction. A main supply line 4, connected to the discharge end of pump 3, leads to the burner 6; and a branch line 7 by-passes oil from the main supply line back to tank 2. It is to be observed that the conduit portion 8 of the main supply line between branch 7 and burner 6 provides for delivery of oil to the burner, and that the oil has a divided flow through conduit portions 8 and 7. A Poiseuille tube 9 is interposed in burner delivery line 8 and another Poiseuille tube 11 of larger size is connected in by-pass branch 7.

The division of flow of oil through the two conduits or fluid conducting means 7 and 8 will be proportional to the size of tubes 11 and 9, respectively. For example, if the constant volumetric discharge pump 3 has a displacement of 20 gallons of oil per hour and the two tubes are of the same size, 10 gallons of oil will flow through each of the conduits in an hour's time. Should it be desired to feed, for example, only five gallons of oil per hour to the burner 6, the size of tube 9 may be so selected with respect to the size of tube 11 as to cause three times as much oil to flow through the by-pass branch 7 as through the delivery conduit 8. Because of the character of the restricted passageways formed by Poiseuille tubes 9 and 11, the flow of oil to the burner will be substantially constant regardless of changes in viscosity of the oil. The latter would not be the case if ordinary valves or tubes were employed in place of the Poiseuille restricted passageways, it being a phenomenon in the flow of liquids that for a given branch system the quantities of fluid flowing through the various branches will ordinarily change upon change in viscosity of the fluid.

From a purely academic point of view, the phenomenon of the peculiar action of the Poiseuille tubes may be explained as follows. Due to the restricted passageways which the tubes provide, a damming effect obtains at the points A and B,

where the oil enters the tubes 9 and 11. Therefore, should the division of flow of oil through the branches tend to vary so as to cause more than the proportionate share of oil to flow through, for example, branch 7, the damming effect at B will hold the oil back and allow only the proportionate share of oil to flow through tube 11. This same effect obtains at A in case more oil tends to flow through branch 8. The mutual damming effects at both A and B, therefore, compel a constant distribution of oil through the branches. Because Poiseuille tubes 9 and 11 are of such character and of such dimensions that the internal friction developed therein during the flow of oil therethrough produces a pressure drop or difference in pressure between the ends of each tube greater than the back pressure (at A^1 and B^1) developed in the system beyond the discharge ends of the tubes, the tubes render negligible the unbalancing effect of such back pressure upon flow of oil through the tubes. This, coupled with the proportionate damming effect, results in a constant division of flow in the two branches for all viscosities of the oil. In actual practice, it is preferable to select the length and diameter of each tube, so that the pressure drop or difference in pressure between the ends of the tube is from 10 to 15 times the back pressure.

As long as the restricted passageways or tubes 9 and 11 form Poiseuille tubes or substantially Poiseuille tubes (i. e., passageways which will have the precedingly pointed out characteristics and in which the flow of fluids will obey Poiseuille's law), change in viscosity of the oil will have no material effect on distribution of flow. By selecting the size of burner branch tube 9 with respect to the size of by-pass branch tube 11, the quantity of oil to the burner may be fixedly predetermined in accordance with the capacity of pump 3, the quantities of oil flowing through the two branches being proportional to the sizes of the tubes, as previously explained. For any particular metering system, the actual dimensions of a set of tubes when properly selected may vary within wide limits, depending upon the normal viscosity variation of the fuel oil at the temperature employed, the capacity of the constant volumetric discharge pump, and the practical pressure range which can be safely developed in the system and still effect feeding of oil through the system.

With respect to the practical pressure, it has been previously explained that, for a given tube,

$$\text{Oil rate} = (\text{a constant}) \frac{\text{Pressure}}{\text{Viscosity}}.$$

Therefore, since the oil rate is fixed by the constant volumetric discharge pump employed, the pressure must increase or decrease with increase or decrease of viscosity, respectively. In view of this, the size of the tubes should be so chosen as to preclude unsafe pressures developing in the system for relatively high viscosity of the oil, to preclude bursting of the system. The actual dimensions of the tubes, to form Poiseuille tubes, may be readily calculated from Poiseuille's formula, by those skilled in the art pertaining to the flow of liquids. In making such calculations, the known factors are: the oil rate (determined by the constant volumetric discharge pump); P (the practical pressure range; 8; u (the viscosity range of the oil being employed); and, finally, the division of flow desired in the two branches namely, the delivery and by-pass fluid conducting means or conduits. The length for a preselected cross-sectional area of each tube, or vice versa, may therefore be calculated from the formula,

$$\frac{V}{T} \text{ or } O = \frac{\pi r^4 P}{8lu}$$

The following examples will illustrate some of the many wide ranges which the various factors in the system of my invention (employing two Poiseuille tubes through which the fluid has divided flow) may have, depending upon operating conditions desired, and for systems in which the friction developed outside the Poiseuille tubes is negligible compared to that in tubes.

Example I

Constant volumetric discharge pump capacity.	40 gals. per hr.
Desired feed to the burner	10 gals. per hr.
By-pass feed	30 gals. per hr.
Viscosity range of oil to be burned.	600–2400 seconds Saybolt furol
Pressure developed	17¾ lbs.–71 lbs. per sq. in.
Poiseuille tube 9 to burner may be.	6 ins. long and .19 in. diameter
Poiseuille tube 11 in by-pass branch may be.	6 ins. long and .25 in. diameter

Example II

Constant volumetric discharge pump capacity.	40 gals. per hr.
Desired feed to the burner	5 gals. per hr.
By-pass feed	35 gals. per hr.
Viscosity range of oil to be burned.	1120–2800 seconds Saybolt furol
Pressure developed	49 lbs.–123 lbs. per sq. in.
Poiseuille tube 9 to burner may be.	10 ins. long and .167 in. diameter
Poiseuille tube 11 in by-pass branch may be.	10 ins. long and .270 in. diameter

Example III

Constant volumetric discharge pump capacity.	40 gals. per hr.
Desired feed to the burner	15 gals. per hr.
By-pass feed	25 gals. per hr.
Viscosity range of oil to be burned.	2014–5350 seconds Saybolt furol
Pressure developed	25⅓ lbs.–67½ lbs. per sq. in.
Poiseuille tube 9 to burner may be.	10 ins. long and .3 in. diameter
Poiseuille tube 11 in by-pass branch may be.	10 ins. long and .34 in. diameter

Example IV

Constant volumetric discharge pump capacity.	40 gals. per hr.
Desired feed to the burner	8 gals. per hr.
By-pass feed	32 gals. per hr.
Viscosity range of oil to be burned.	116–580 seconds Saybolt furol
Pressure developed	18 lbs.–90 lbs. per sq. in.
Poiseuille tube 9 to burner may be.	12 ins. long and .143 in. diameter
Poiseuille tube 11 in by-pass branch may be.	12 ins. long and .203 in. diameter

Example V

Constant volumetric discharge pump capacity.	25 gals. per hr.
Desired feed to the burner	10 gals. per hr.
By-pass feed	15 gals. per hr.
Viscosity range of oil to be burned.	583–2330 seconds Saybolt furol
Pressure developed	20 lbs.–80 lbs. per sq. in.
Poiseuille tube 9 to burner may be.	6 ins. long and .186 in. diameter
Poiseuille tube 11 in by-pass branch may be.	6 ins. long and .206 in. diameter

Example VI

Constant volumetric discharge pump capacity.	25 gals. per hr.
Desired feed to the burner	5 gals. per hr.
By-pass feed	20 gals. per hr.
Viscosity range of oil to be burned.	1110–2775 seconds Saybolt furol
Pressure developed	40 lbs.–100 lbs. per sq. in.
Poiseuille tube 9 to burner may be.	10 ins. long and .176 in. diameter
Poiseuille tube 11 in by-pass branch may be.	10 ins. long and .249 in. diameter

Example VII

Constant volumetric discharge pump capacity.	55 gals. per hr.
Desired feed to the burner	10 gals. per hr.
By-pass feed	45 gals. per hr.
Viscosity range of oil to be burned.	566–2265 seconds Saybolt furol
Pressure developed	20 lbs.–80 lbs. per sq. in.
Poiseuille tube 9 to burner may be.	6 ins. long and .185 in. diameter
Poiseuille tube 11 in by-pass branch may be.	6 ins. long and .269 in. diameter

Example VIII

Constant volumetric discharge pump capacity.	55 gals. per hr.
Desired feed to the burner	5 gals. per hr.
By-pass feed	50 gals. per hr.
Viscosity range of oil to be burned.	1120–2800 seconds Saybolt furol
Pressure developed	40 lbs.–100 lbs. per sq. in.
Poiseuille tube 9 to burner may be.	10 ins. long and .176 in. diameter
Poiseuille tube 11 in by-pass branch may be.	10 ins. long and .313 in. diameter

In the examples set forth, either one or both of the tubes 9 and 11 may be made longer or shorter, by correspondingly increasing or decreasing, respectively, the diameter or cross-sectional area, provided that no values are selected that will introduce errors in the Poiseuille equation.

Description of Figure 2 modification

Instead of employing two single Poiseuille tubes of different size, with one connected in the delivery conduit and the other in the by-pass conduit, to effect the predetermined division in flow of fluid through the two conduits or branches, I may employ all tubes of the same size with a given number in the by-pass branch and a different number in the burner or delivery branch line. The quantities of oil which will flow through the two branches per unit of time will be directly proportional to the number of Poiseuille tubes in each branch.

Figure 2 illustrates diagrammatically a system in which Poiseuille tubes, all of the same size, are employed with different numbers in each branch or conduit. The oil is pumped from tank or reservoir 2' by constant volumetric discharge pump 3', through main supply line 4', connected to the burner 6'; and a branch line 7' by-passes oil back to tank 2'. The portion of main supply line 4' connected to the burner forms a branch 8' the oil having a division of flow between this branch and branch 7'. Three Poiseuille tubes 9', all of the same size, may be interposed in burner branch 8' and seven Poiseuille tubes 11', of the same size as tubes 9', may be interposed in by-pass branch 7'. With such connection, the division of flow in burner branch 8' with respect to by-pass branch 7' will be as 3 is to 7.

For example, assuming that the capacity of constant volumetric discharge pump 3' is 10 gallons per hour; in an hour's time 3 gallons will flow to the burner and 7 gallons will be by-passed. Thus, as with respect to the Figure 1 embodiment, the provision of the means for producing the effect of a Poiseuille type of fluid flow in each of the fluid conducting means beyond the point of division of fluid flow, enables the rate of flow to be unaffected by viscosity changes. The following examples illustrate some of the many ranges possible for a 10-gallon-per-hour constant volumetric discharge pump and with tubes connected as in Figure 2.

Example IX

With tubes each 6 inches long and .1 inch in diameter, the system will meter oils ranging in viscosity from 90 seconds Saybolt universal to 5000 seconds Saybolt furol, with a pressure range of .34 pounds to 204 pounds per square inch.

Example X

If the tubes of Figure 2 are each twenty inches long and .08 inch in diameter, the system will meter the same range of oil viscosity as in Example IX, but with a pressure range of .28 pounds to 1688 pounds per square inch.

Example XI

Tubes, each 4 inches long and .12 inch in diameter will also meter the same range of oil viscosity as in Example IX, but with a pressure range of .011 pound to 66 pounds per square inch.

Adjustable valve (Fig. 3)

The preferred type of system is, due to its simplicity, that illustrated in Figure 1, where only two Poiseuille tubes are employed. However, in such system where the tubes are fixed in size, variable flow to the burner cannot be obtained. For fixed sizes of the tubes, only a constant quantity of oil will be fed to the burner per unit of time. In order that this quantity may be variably controlled, I have devised an adjustable valve which has a restricted passageway, forming a Poiseuille tube the effective cross-sectional area of which may be changed to vary the size of the passageway. Figure 3 illustrates one form of valve, which may be substituted for either one of the tubes in Figure 1, or two of the valves may be employed in place of both of the tubes. By varying the ratio of the Poiseuille restricted passageway sizes, it is apparent that different quantities of oil per unit of time may be caused to flow to the burner. Hence, the size of the burner flame may be regulated when desired.

With reference to Figure 3, the valve comprises an elbow 21, having a hub 22, adapted to be connected to a conduit in the system by threads 23, and also having a hub 24 threaded onto sleeve 26. Sleeve 26 is threaded in connecting member 27, in turn threaded onto the tube 28 which is formed with a frusto-conical or tapered passageway 29. In the passageway is mounted for movement a complementary tapered valve element or plug 31 having a stem 32 provided with threads 33, threaded in plug 34 sealing elbow 21. The end of stem 32 projects beyond plug 34 and is provided with flats 36, whereby the stem 32 may be gripped by a suitable tool to effect turning thereof and consequent movement of plug 31 longitudinally of passageway 29. It is to be noted that the circumferential space 37 between the inner surface of tube 28 and the surface of plug 31 is restricted, thus providing a restricted passageway having the characteristics of a Poiseuille tube. Movement of plug 31 will vary the effective diameter or cross-sectional area of the passageway 37. To center plug 31 in its movement, the end thereof is provided with a pin 38 connected to radially projecting pins 39 adapted to contact with the lower enlarged cylindrical portion of tube 28. This portion is threaded at 41 to provide means for connection of the discharge end of the tube.

From Figure 3 it can be seen that the portion of the conduit system outside of restricted passageway 37 is of large bore, so as to offer negligible resistance to the flow of fluid through such portion, thereby eliminating outside turbulence which might otherwise affect the flow of fluid through restricted passageway 37. Also, it is to be observed that the length of passageway 37 is not materially increased or decreased by movement of plug 31, compared to change in cross-sectional area of said passageway 37 caused by such movement. As the valve element or plug 31 is moved upwardly, the cross-sectional area of passageway 37 is diminished and the flow of fluid is consequently retarded. Downward movement of the plug 31 increases the cross-sectional area of the restricted passageway to produce increased flow. The variations in cross-sectional area of passageway 37, to form various sized restricted passageways having the characteristics of Poiseuille tubes, may be readily predetermined from the factors entering Poiseuille's formula as previously pointed out.

System employing adjustable valve (Fig. 4)

In Figure 4 is illustrated a system employing two of the described Poiseuille valves of Figure 3, which are connected in the fluid conducting means through which the fluid has divided flow. The system has a high-low flame control. A supply of oil is held in tank or reservoir 51 to which is connected a main supply line 52, having connected therein a strainer 53 at the intake side of a constant volumetric displacement pump 54. Pressure gauge 56, preferably located adjacent the discharge side of the pump 54, gives a visual indication of the pressure built up in the system. The supply line branches at 57, one portion, preferably the major portion, of the oil being returned to the tank 51 through by-pass branch 58. In the by-pass branch 58, I provide a valve 59 of the construction disclosed in Figure 3. In another branch 61, leading to the burner 62, a similar valve 63 is provided. A third branch 64 is preferably provided with a high-low fire valve 66 which is adjustable to open or close branch 64. Another branch 67 of the system includes a standard safety valve 68, which safety valve is set to open at a predetermined pressure, i. e., the maximum pressure that can be safely developed in the system without causing rupturing thereof.

In operation, oil normally flows through the by-pass branch 58 and through the burner branch 61. Thus, the oil passing through line 52 diverges at the point 57, portions being fed through the branches 58 and 61. The proportionate flow between such branches depends entirely upon the adjustment of the valves 59 and 63 relative to each other; and the rate of feed to the burner may be varied at will by adjusting either of valves 59 or 63 to change the ratio between the cross-sectional areas of restricted passageways 37 in the valves. With one style of apparatus the pump 54, which is preferably a rotary gear constant volumetric displacement pump, discharges sixty gallons of oil per hour uniformly and constantly into the main supply line 52. Depending upon operating conditions, the burner 62 utilizes from five to ten gallons of oil per hour, and the valves may be so adjusted that the remaining fifty to fifty-five gallons is fed back through the return or by-pass line 58 to the intake side of the pump or to the tank.

To maintain valves 59 and 63 at substantially the same temperature so that the viscosity of the oil in both valves may be substantially the same, I preferably connect the bodies of valves 59 and 63 by a heat-conducting strip 69 of metal or any other suitable heat-conducting material. With this arrangement, accurate metering of the oil to the burner, which might not otherwise occur if the oil viscosity were different in the two valves, is insured.

It may sometimes be desirable to diminish the flame size of burner 62 without relatively adjusting valves 59 and 63. This can be done by opening high-low flame valve 66. Valve 66 may be any suitable manually-operable valve, such as a ball valve or a gate valve. In normal operation of the system, valve 66 is closed, but when it is desired to produce a low flame the valve may be opened any predetermined amount depending upon the flame size desired. Upon opening of valve 66 a relatively large portion of the oil will be subtracted from the burner branch line 61, and the oil supplied to the burner will be correspondingly diminished to produce low fire conditions. It is unnecessary to have a valve similar to valves 59 and 63 in branch line 64, because generally, when valve 66 is operated, the oil in the system is at a viscosity equilibrium (that is, the system has been operating a substantial period and consequently all the oil is at substantially the same temperature and viscosity). Regardless of whether valve 66 is open or closed, valves 59 and 63 will meter the oil to the burner at a constant rate for any fixed position of the high-low flame valve.

It is to be observed with respect to the high-low flame valve 66, that the flame size of the burner diminishes upon opening of the valve. Thus, clogging of the system by foreign matter which might pass through strainer 53 is precluded. With respect to burner valves heretofore employed for diminishing the flame size and which depend upon closing of the valve to effect such diminishment, clogging is quite apt to occur.

As previously explained, only one valve, 59 or 63, having a Poiseuille restricted passageway, need be employed in the system of Figure 4; the other

Poiseuille restricted passageway may be formed by an ordinary fixed Poiseuille tube of the character disclosed in Figure 1. It is desirable, however, to employ the two valves 59 and 63 because then, if the pressure in the system builds up to dangerous limits because of the oil being of high viscosity, both valves may be adjusted together to increase the cross-sectional areas of both restricted passageways 87 therein, and thereby decrease the pressure developed in the system to within safe limits. The adjustment of both valves for this purpose may be made so that after final adjustment thereof the ratio between the cross-sectional areas of the restricted passageways therein is the same as the ratio before adjustment. Thus, the quantity of oil fed to the burner will be the same after such adjustment as that prior to the adjustment to maintain the flame size constant. Pressures developed in the system may be readily noted by reading pressure gauge 56.

Modified form of valve (Fig. 5)

In Figure 5 is illustrated a type of valve having a Poiseuille restricted passageway, which valve is automatically adjustable to maintain substantially constant the pressure in the system. A pair of such valves may be substituted for valves 59 and 63 in Figure 4.

The valve comprises a cylindrical tube 81 having an enlarged chamber 82 at one end and a second enlarged chamber 83 at the opposite end. Nipples 84 and 85 are connected to the chambers 82 and 83, to provide means for attachment of the valve in the conduit system. A plug 86 is movably mounted in the cylindrical portion of tube 81, the plug 86 being provided with a helical passageway 87. One end of passageway 87 communicates with chamber 82 and the other end of passageway 87 communicates with chamber 83. The sides of passageway 87 are preferably curved so that the passageway is, in section, a portion of a circle; and the passageway 87 is gradually tapered from the chamber 82, through which oil enters the valve, to the chamber 83, which is the discharge chamber for the valve. It is to be observed that passageway 87 forms with the inner surface of tube 81 a restricted passageway. The size of such restricted passageway may be predetermined from Poiseuille's formula, by those skilled in the art, in the manner previously pointed out.

The under side of plug 86 is recessed at 88 to provide a seat for spring 89 which is connected to adjustable screw 91, threaded in the bottom of chamber 83, to provide means for placing a predetermined tension on spring 89, thus normally maintaining plug 86 co-extensive with tube 81. As the pressure in the system tends to increase or decrease, plug 86, because of its floating mounting on spring 89, will move downwardly or upwardly, respectively, to vary the effective length of passageway 87 in tube 81. During such movement the effective cross-sectional area of the passageway 87 is not materially changed compared to the change in length. Consequently, with increase or decrease in length of passageway 87, the resistance which is developed in the passageway is respectively increased or decreased to maintain substantially constant pressure. For example, if plug 86 is in a fixed position and the pressure rises due to increase in oil viscosity, the plug or valve element will move downwardly against the action of spring 89. Such movement shortens the length of restricted passageway 87 to decrease the resistance to flow. With such decrease in resistance to flow, the pressure will drop. It is thus seen that with the valve of Figure 5—instead of variations in viscosity being automatically compensated by changes in pressure as with respect to the previous described modifications—increase or decrease in viscosity which would normally alter rate of flow, is automatically compensated by a proportional decrease or increase, respectively, of the length of restricted passage 87. In this connection, it will be recalled from the Poiseuille formula previously discussed, that rate of flow is directly proportional to the pressure and to the square of the cross sectional area, and inversely proportional to the length of the passage and to the viscosity of the fluid. As a result, if the pressure and area are maintained substantially constant as in the Figure 5 valve, and since the rate of flow is maintained substantially constant, the length of passage 87 will vary inversely with changes in viscosity. Consequently, because of the Poiseuille fluid flow effect, the Figure 5 modification compensates automatically for changes in viscosity of the fluid, by inverse changes of the length (*l*) factor occurring in the Poiseuille formula, instead of the pressure (P) factor. By the use of the valve of Figure 5, the necessity of a safety valve in the system is obviated, and substantially constant pressure conditions will obtain regardless of change in oil viscosity.

Preferred construction (Figs. 6 through 10)

The valve system of my invention is especially adapted for use with oil burners in all places where it is desirable to burn cheap, thick oils, by means of a system the functioning of which is automatic to preclude the expense of an attendant. For example, the system finds particular applicability in apartment houses, hotels, and small industrial jobs.

For such uses the practical range of fuel rate to the burner is 1 gallon per hour to 34 gallons per hour, or 3 horse-power to 100 horse-power burner capacity. This calls for an oil pumping capacity of not less than 35 gallons per hour. The fuel oils available on the market for such heating purposes range in viscosity, at normal temperature, from 40 seconds Saybolt universal to 3200 seconds Saybolt furol. I have, therefore, constructed a unit containing two valves, connected so that the oil has divided flow therethrough and capable of forming Poiseuille restricted passageways, to meet the practical requirements in the uses pointed out. Such unit is shown in Figures 6 through 10.

The unit comprises a casing 101 having an interior chamber 102, and provided with a flanged bottom 103 adapted to be secured over a reservoir or tank 104 in which is located a constant volumetric discharge pump 106. To meet the requirements of the practical system, a constant volumetric discharge pump of 35 gallons per hour capacity will suffice. Preferably a slow, constant speed, medium pressure, tight, induction motor actuated, and rotary gear pump is employed. Tank 104 is not the main supply tank, which latter tank is generally located outside of the burner room. Casing 101 is therefore formed with a passageway 108, in a vertical end wall thereof, communicating with tank 104 and into which oil may be fed from a main supply tank (not shown). Pump 106 is connected to conduit 109, communicating with chamber 102 which is kept full of oil fed by the pump. The conduit 109 is secured to the bottom of casing 101 by

means of apertured cap 111, threaded into the bottom wall and against packing ring 112 surrounding conduit 109.

Adjacent the side walls 113 and 114 of casing 101 and at the top thereof are formed a pair of tapered tubes 116, one end 117 of each of which communicates with the chamber 102. The shape and arrangement of each of tubes 116 are the same; therefore only one will be described. In each of tubes 116 is mounted for movement a complementary tapered valve element or plug 118 adapted to form with the inner surface of the tube a restricted Poiseuille passageway 119. The large end of plug 118 is recessed at 120 to allow sliding over guide stem 121 integral with plug 122, threaded into casing wall 123. Into the small end of valve plug 118 is threaded a stem 124, extending through wall 126 of the casing and journaled in any suitable gland and seal structure 131. By turning outer end 132 of stem 124 with any suitable tool or key, longitudinal movement of valve element 118 is effected to vary the cross-sectional area of restricted passageway 119. Due to the fact that tube 116 is considerably longer than valve element 118, the effective length of restricted passageway 119 is not changed by such movement of the valve element.

Wall 126 of the casing is formed with an enlarged discharge passageway 133, communicating with aperture 134 in which may be connected a conduit leading to the burner. Passageway 133 also communicates with the restricted passageway 119 in one of the valves formed by tube 116 and plug 118. The discharge end of the other valve (by-pass valve) communicates with vertical passageway 136, open at the bottom and leading to tank 104. One of the core holes 137 in the top of casing 101 is threaded to receive a pressure gauge, while the other core hole 138 is plugged.

It is thus seen that fluid from the fluid source or feeding means divides, after leaving conduit member 109, and flows through the two Poiseuille passages 119. One of such passages 119 forms part of the delivery line to the burner together with passageway 133 and aperture 134; and the other forms part of a branch together with vertical passageway 136, for by-passing the fluid back to the source. Therefore, as with respect to the previously described systems, there are provided both a delivery conduit or fluid conducting means to the burner, and a branch conduit or fluid conducting means connected or communicating with the delivery conduit; and in each of such conduits is provided, beyond the point of division of fluid flow, the Poiseuille fluid flow effectuating means.

In the side wall (Figure 8) 113 of the casing and below the valve adjacent said wall is formed a passage 139, the inner end of which communicates with chamber 102. The outer end of passage 139 is closed by a cap 141, threaded into the casing and in which is seated one end of spring 142. Spring 142 bears against valve member 143 which normally closes the inner end of passage 139. Should the pressure in the system exceed a safe amount, valve member 143 will yield against the compression of spring 142; and the oil will pass through passage 139 and through aperture 144 communicating with the passage. Aperture 144 is formed in the bottom of the casing and the oil will therefore lead back into tank 104. Thus a safety valve is provided for the system, it being apparent that the size of spring 142 may be so selected as to cause the spring to yield only when the maximum safe pressure in the system obtains.

I preferably employ a high-low flame control valve in the unit of the preferred construction. Such valve (Figure 6) comprises a stem 147 journaled in the boss 148, formed in side wall 114 of the casing 101 and below the valve adjacent said wall. The stem 147 is also journaled in a suitable gland and seal structure 149 secured to boss 148. Inner end of stem 147 is provided with a recess 151 which communicates with the chamber 102; and the wall of the stem adjacent the recess is formed with an aperture 152 adapted to communicate with a passage 153, communicating with the bore of boss 148 and leading to tank 104. Normally, stem 147 is in such position that aperture 152 is not in communication with passage 153; therefore no oil will flow therethrough. When it is desired to reduce the size of the burner flame, stem 147 may be turned to effect registry of aperture 152 with passage 153; the oil will thus by-pass from chamber 102 into tank 104 and will be subtracted from the system to reduce the size of the burner flame.

The mode of operation of the unit described is the same as that explained in connection with Figure 4. However, with the unit of the preferred construction it is not necessary to employ the heat conducting strip connected to the valves, because all the valves are part of the same integral casting, in which the oil will necessarily be of the same temperature and viscosity.

I shall now give the actual dimensions of the valve elements in the preferred unit device of my invention, which makes the device suitable for the range of fuel oil feed to the burner and for the oil viscosity range usually encountered in the previously described systems where the unit finds general applicability. Valve element or plug 118 is preferably 4⅞ inches long, is circular in cross-section and tapers uniformly and gradually from the large end, which is ⅞ of an inch in diameter, to the small end which is ½ inch in diameter. The taper of tube 116 is of the same degree or complemental to the taper of plug 118. With such dimensions the restricted passageways 119 will provide Poiseuille tubes in the described systems.

The relative clearance between said passageways and the clearances of each of said passageways may be fixed so as to cause feeding of the desired quantity of oil to the burner at the desired pressure range. When the valve elements 118 have been once fixed to obtain the desired clearance relationship, the functioning of the unit device is entirely automatic (i. e., a constant rate of discharge will be fed to the burner unaffected by change in viscosity of the oil).

Example XII

If the unit is installed for operation with an automatic "Ray fuel oil burner, Type AR130", and if a 35-gallon per hour constant volumetric discharge pump is employed, with a clearance of .075 inch in the by-pass valve and a clearance of .045 inch in the burner feed valve, the system will meter oils from 100 seconds Saybolt furol to 2600 seconds Saybolt furol. The rate will be 4.35 gallons per hour to the burner and 30.65 gallons per hour to the return or by-pass branch. The pressure will range from 6½ pounds to 170 pounds per square inch, depending upon the viscosity range of the oil.

Example XIII

With a clearance of .030 inch in the by-pass valve and .024 inch in the burner valve, the feed rate to the burner will be 10.4 gallons per hour with a by-pass rate of 24.6 gallons per hour, for oils ranging from 23 seconds Saybolt furol to 240 seconds Saybolt furol. The pressure will range from 12 pounds to 124 pounds per square inch, depending upon the oil viscosity range.

Example XIV

If the clearance is .045 inch in the by-pass valve and .024 inch in the burner valve, the feed rate to the burner will be 5.17 gallons per hour, with a by-pass rate of 29.83 gallons per hour, for oils ranging from 30 seconds Saybolt furol to 600 seconds Saybolt furol in viscosity. The pressure will range from 8 pounds to 165 pounds per square inch.

In the operation of the preferred unit device when connected to piping, back pressure is developed on both the burner valve and the by-pass valve. Therefore care should be taken in setting the system for operation with any given oil rate to the burner and with any given oil viscosity, that the back pressure is not great enough to unbalance the system. The pressure drop across the valves should consequently be made many times the back pressure, as has been previously explained. To further minimize the effect of back pressure I prefer to employ one-half inch piping connected to the burner valve and ⅜ inch piping as the burner tailpiece. Such piping is sufficiently large to offer negligible resistance to the flow of oil in the burner branch compared to the high viscous resistance developed in the restricted passageways of the valves.

It is to be understood that the preferred unit and dimensions thereof are given for the purpose of describing a device which will be satisfactory for most practical purposes. Such dimensions may be varied in a manner which will be apparent to those skilled in the art, from the teachings of my invention. Also, although a constant volumetric pump and true Poiseuille restricted passageways or tubes are preferred to obtain the best results, the system of my invention will operate and still give far superior results than systems heretofore employed, even if there is slight slippage of the pump and even if the restricted passageways do not form true Poiseuille tubes but approximate the characteristics of such tubes or passageways.

Conclusion

Although I have chosen for the purpose of illustrating my invention the application thereof in an oil burner system where my invention finds great applicability, the principle of my invention may be utilized in the metering of any fluids, particularly liquids, where it is desired to maintain a constant rate of flow unaffected by change in viscosity of such fluids.

From the preceding description it is seen that I have provided a system and a device of simple construction, which are therefore economical to build. Since the apparatus compels accurate metering of oil to the burner, regardless of change in viscosity of the oil, it makes possible the use of cheaper and heavier grades of oil, the employment of which have been heretofore precluded because such oils fluctuate widely in viscosity.

I claim:

1. A system for delivering liquid at a constant rate irrespective of changes in viscosity of the liquid, comprising a source, means for feeding liquid from said source at a substantially constant volume rate, a delivery conduit extending from said feeding means, a branch conduit connected to said delivery conduit, whereby the liquid flow from said feeding means will divide and flow through said delivery and branch conduits, and means in said branch conduit and in said delivery conduit beyond the point of connection of said branch conduit effectuating flow in each of said conduits substantially in compliance with Poiseuille's law.

2. The combination with a fuel oil burner and a source of fuel oil, of means for delivering fuel oil from said source to said burner and for maintaining the rate of volume delivery to said burner substantially constant irrespective of changes in the viscosity of the oil, comprising means for feeding oil from said source at a substantially constant volume rate, a delivery conduit extending from said feeding means to said burner, a branch conduit connected to said delivery conduit between said feeding means and said burner, whereby the fluid flow from said feeding means will divide and flow through said delivery and branch conduits, and means in said branch conduit and in said delivery conduit intermediate said burner and said branch conduit effectuating flow in each of said conduits substantially in compliance with Poiseuille's law.

3. The combination with a liquid fuel burner or the like; of a liquid feeding system for feeding and metering liquid to said burner comprising means for supplying to said system a substantially constant volume of liquid per unit of time, liquid conducting means communicating with said liquid supplying means and connected to said burner, and branch liquid conducting means communicating with said first mentioned conducting means whereby the liquid from said liquid supplying means will divide and flow through said first mentioned liquid conducting means and said branch liquid conducting means; and means for preventing changes in viscosity of the liquid from altering rate of flow of said liquid through said liquid-conducting means comprising liquid flow control means in each of said conducting means located beyond the point of division of liquid flow, each of said liquid control means being of such character as to produce the effect of a Poiseuille type of liquid flow.

4. In a system for delivering liquid to an oil burner or the like at a substantially constant rate irrespective of changes in viscosity of the liquid; a plurality of liquid-conducting means through which the liquid has a divided flow; means connected with said liquid conducting means for supplying to said system a substantially constant volume of liquid per unit of time; and means for preventing changes in viscosity of the liquid from altering rate of flow of said liquid through said liquid-conducting means comprising liquid flow control means in each of said liquid-conducting means located beyond the point of division of liquid flow, each of said liquid control means being of such character as to cause changes in viscosity of the liquid to be compensated for by proportionally changing a factor in the Poiseuille liquid flow formula.

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