March 2, 1937. W. O. LUM 2,072,761

VISCOSITY COMPENSATED FLOW CONTROL

Filed May 1, 1935

Fig. 7.

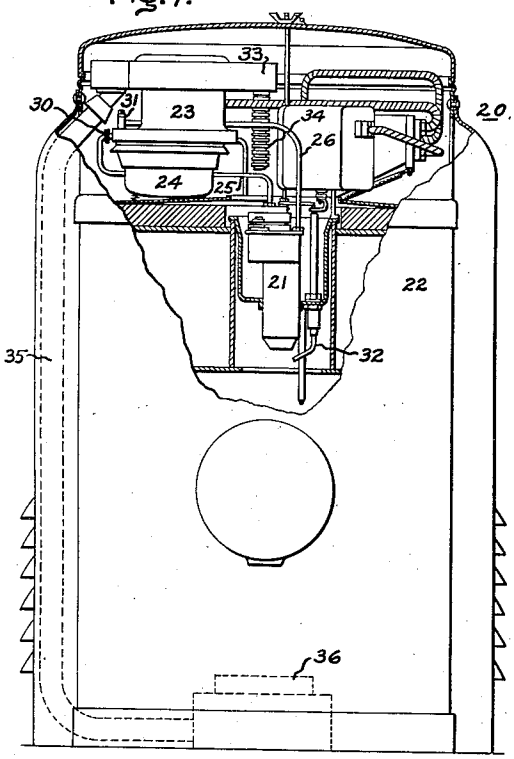


Fig. 1.

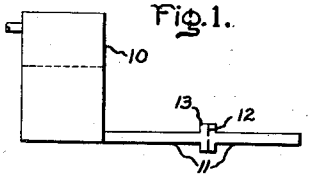


Fig. 2.

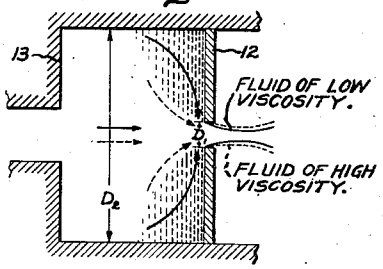


Fig. 3.

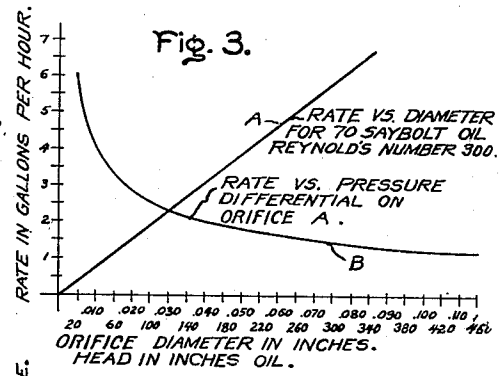


Fig. 4.

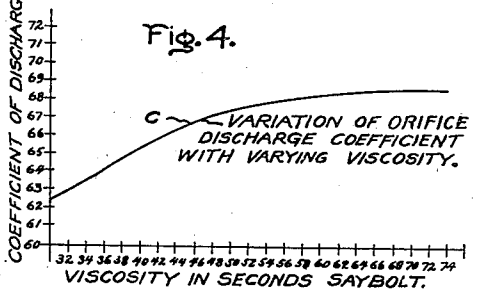


Fig. 5.

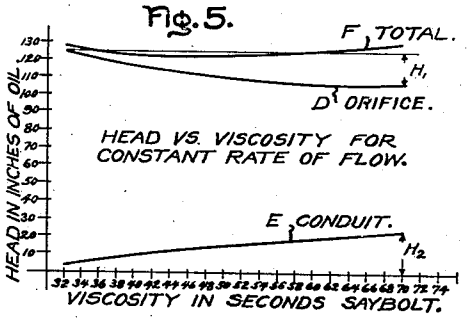
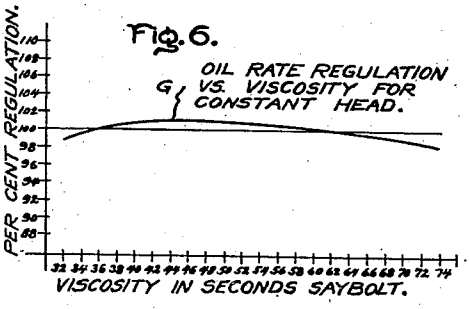


Fig. 6.



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His Attorney.

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UNITED STATES PATENT OFFICE

2,072,761

VISCOSITY COMPENSATED FLOW CONTROL

Walter O. Lum, Schenectady, N. Y., assignor to General Electric Company, a corporation of New York

Application May 1, 1935, Serial No. 19,268

6 Claims. (Cl. 137—78)

This invention relates to the control of the flow of fluids of variable viscosity. The principal object is to provide a substantially constant fluid flow irrespective of variations in the viscosity of the fluids within predetermined limits.

Although the present invention is of general application, a special object is to maintain substantially constant the rate at which fuel oil of varying viscosity is supplied to an oil burner from a substantially constant low pressure source. Thus, while it will be understood by those skilled in the art that the invention may be used in other fluid flow control service, the principle of the invention and the best mode in which applicant has contemplated applying that principle will be explained in connection with an oil burner.

Viscosity compensated flow control is desirable in an oil burner due to the fact that it is and has been for many years practically impossible to expect any uniformity in the viscosity of fuel oils. Fuel oils even of the same commercial grade vary in viscosity due to the widely varying characteristics of the different crudes as well as the different mixes or blends.

Ordinarily variation in fuel oil viscosity will result in serious difficulties in the operation of oil burners, particularly of the domestic type, utilizing relatively low atomizing pressures. For example, the burner may be designed or adjusted to ignite and operate satisfactorily on certain commercial grades of fuel oil. However, when these burners are installed in homes in some other territory, it may be almost impossible to make these burners operate satisfactorily even on the same commercial grades of oil. Likewise in the same territory with fuel oil supplied by one dealer the burners may operate satisfactorily while with fuel oil of the same commercial grade supplied by another dealer the burners may fail to operate satisfactorily. Even with identically the same fuel oil the viscosity will always vary widely with variations in its temperature.

The difficulties outlined above are quite well known and many efforts have been made heretofore to maintain a substantially constant rate of feed of fuel oil of varying viscosity to an oil burner. Special metering types of oil pumps, complicated pressure regulating devices, steam and also electric oil heaters have been proposed for this purpose but have not proved entirely satisfactory.

By means of the present invention, a very simple and inexpensive viscosity compensated flow control is obtained which is capable of maintaining a practically constant oil rate in an oil burner irrespective of variations of the viscosity of the fuel oil within predetermined limits, these limits being sufficiently wide to include the various grades of fuel oil ordinarily used in oil burners of the domestic type.

Briefly, the viscosity compensated flow control of the present invention consists of a co-operating combination involving a specially proportioned thin walled, sharp-edged control orifice and a specially proportioned compensated fluid supply conduit connected with a source of fluid maintained under substantially constant. pressure. The control orifice is proportioned to determine the rate of fluid flow which may be any value desired. At the same time, the control orifice is proportioned so that it automatically increases its orifice discharge coefficient under a constant orifice pressure differential upon an increase in the viscosity of the fluid between the predetermined limits. Such control orifice, if acting alone, would automatically increase the rate of fluid flow as the viscosity of the fluid increases due to the increased orifice discharge coefficient thereof. However, the compensating fluid delivery conduit is proportioned so as to function automatically to regulate the pressure differential of the control orifice as the viscosity of the fluid increases and thereby maintain the rate of fluid flow substantially constant. To accomplish this result the compensating fluid delivery conduit is proportioned to provide a predetermined increased pressure drop upon the increase in viscosity of the fluid between the predetermined limits. This increased pressure drop of the conduit functions to reduce the pressure differential of the control orifice upon the increase in the viscosity of the fluid and thereby maintains a substantially constant rate of fluid flow through the orifice and conduit.

In the accompanying drawing, Fig. 1 is a schematic diagram showing the general combination of the control orifice and compensating fluid delivery conduit in the viscosity compensated flow control of the present invention; Fig. 2 is an enlarged sectional view of the control orifice indicating schematically the flow variation resulting with fluids of high and low viscosity; Fig. 3 is a chart showing in Diagram A the relation between the rate of fluid flow at the value of Reynold's number and viscosity indicated and the inner diameter of the control orifice of Fig. 2 required to provide such rate and showing in Diagram B the corresponding relation between the rates of fluid flow indicated in Diagram A and the orifice pressure differentials required to pro-

vide such rates; Fig. 4 is a chart showing in Diagram C the variation of the discharge coefficient of the control orifice of Fig. 2 under a constant pressure differential upon variation of the viscosity of the fluid between predetermined limits; Fig. 5 is a chart showing in Diagram D the variation of the pressure differential upon the control orifice of Fig. 2 required to provide a constant rate of fluid flow with variation of the viscosity of the fluid between the limits shown in Diagram C and showing in Diagram E the variation of the pressure stop provided by the compensating fluid delivery conduit with variation of the viscosity of the fluid flowing therein between the predetermined limits; and showing in Diagram F the substantially constant combined total pressure required to produce a substantially constant rate of flow of fluid through the control orifice and compensating fluid delivery conduit irrespective of variations in the viscosity of the fluid; and Fig. 6 is a chart showing in Diagram G the substantially constant regulation of the rate of fluid flow which may be obtained by means of the viscosity compensated control of the present invention with variation of the viscosity of the fluid between the predetermined limits, this regulation being within one percent of the desired rate of flow; and Fig. 7 shows the application of the viscosity compensated control of the present invention to a preferred form of oil furnace.

Referring to the schematic diagram of Fig. 1, 10 represents a source from which fluid under substantially constant pressure is supplied to the fluid delivery conduit 11. The flow control orifice 12 is located in an enlarged portion 13 of the conduit 11 in co-operating relation with the conduit for both determining the rate of fluid flow therethrough and maintaining the flow substantially constant irrespective of variations in the viscosity of the fluid between predetermined limits. It will be understood that the particular location of the control orifice is not critical, as it may be located anywhere intermediate the ends of the fluid delivery conduit 11 or at either end thereof.

As more clearly shown in Fig. 2, the control orifice 12 is preferably of the thin walled, sharp-edged disc type having an inner diameter D_1 and and an outer diameter D_2. Such an orifice has the characteristic of automatically increasing the discharge coefficient thereof under a constant pressure differential upon an increase of the viscosity of the fluid therethrough between predetermined limits. This characteristic may be explained by the increased adherence of the molecules of the more viscous fluid to the face of the orifice 12 as indicated schematically in Fig. 2 by the dotted line. Thus, with fluids of high viscosity the radial component of flow to the orifice is reduced and the diameter of the vena contracta of the stream of fluid passing through the orifice is increased over that obtaining with a fluid of lower viscosity as shown by the dotted lines in Fig. 2. With fluids of lower viscosity the radial flow through the orifice is not impeded by adherence to the face of the orifice as indicated by the solid arrows adjacent the face of the orifice 12 in Fig. 2. As a result of this radial flow component, the stream of fluid of lower viscosity through the orifice has a vena contracta of less diameter than is the case with a fluid of high viscosity.

Due to the variation in diameter of the vena contracta outlined above, the discharge coefficient of the orifice 12 is dependent upon the viscosity of the fluid flowing therethrough, the discharge coefficient being greater for a fluid of high viscosity than for a fluid of low viscosity. To extend the variation in discharge coefficient of the orifice 12 over a wide viscosity range, it is desirable that the face of the orifice be relatively large with respect to the orifice opening, that is, that the ratio

$$\frac{D_1}{D_2}$$

be relatively small. For this reason, the diameter ratio of the orifice 12 when used in oil rate control for an oil burner preferably is such that the outer diameter D_2 is at least five times the inner diameter D_1, thereby providing for a sufficiently wide variation in viscosity to include the various grades of fuel oil ordinarily used in oil burners of the domestic type.

To obtain a desired oil rate for an oil burner, the inner diameter D_1 of control orifice 12 may be varied as indicated by the Diagram A in Fig. 3. This Diagram A results from plotting the equation

$$\frac{VD}{u}=300$$

wherein V is the flow velocity through the orifice, D the diameter of the orifice, u the kinematic viscosity and 300 is a Reynold's number pertaining to fluid flow and providing for a wide range of viscosity variation. This Reynold's number is not critical and may range from as low as 200 up to 400 or 500, although 300 is preferable. Upon simplifying and correlating this equation to the units of gallons per hour and inches as indicated in Fig. 3, it becomes $D_1=.013R$, wherein D_1 is the inner orifice diameter in inches and R is the rate of flow in gallons per hour for a viscosity of 70 Saybolt seconds, which latter may be assumed to be the maximum viscosity of any ordinary heavy domestic fuel oil.

When the orifice diameter D_1 and the desired rate of flow are once determined for the maximum viscosity flow, the differential pressure of the orifice becomes fixed at a corresponding value. The relation between the orifice pressure differential and the rate is indicated in Diagram B of Fig. 3, the value of the pressure differentials being expressed as head in inches of oil. Diagram B is to be considered in connection with Diagram A. These diagrams show that when the orifice diameter is relatively small so as to provide a relatively low rate of fluid flow, the pressure differential on the orifice is correspondingly low. When the size of the orifice is increased as indicated by Diagram A to provide any desired increased rate of fluid flow, the pressure differential on the orifice then must be correspondingly increased to the value indicated by Diagram B to obtain the desired rate of fluid flow. Thus for example, in case a rate of flow of 2.5 gallons per hour of oil of 70 Saybolt seconds viscosity should be desired, then an inner orifice diameter of .0325 inch and a pressure differential head of 103 inches of oil will be required to provide the desired rate of flow. Diagram B results from plotting the equation

$$h=\frac{637}{R^2}$$

wherein h is the orifice pressure differential head in inches of oil and R is the rate in gallons per hour. This equation results from simplifying and

correlating the proper units in the general equation

$$h=\frac{U^2}{2_g}$$

With the inner diameter D_1 and pressure differential of the control orifice 12 determined for the desired oil rate with the maximum viscosity oil as outlined above, Diagram C in Fig. 4 indicates the variation of the discharge coefficient of orifice 12 obtaining upon progressive decrease in the viscosity of the oil flowing therethrough under a constant pressure differential. This variation in the orifice discharge coefficient is a phenomenon resulting from the reduction in the diameter of the vena contracta as the viscosity of the oil is decreased as previously explained in connection with Fig. 2. To maintain a constant oil rate through the orifice 12 when the discharge coefficient thereof decreases due to the progressive decrease in viscosity of the oil as shown in Fig. 4, the pressure differential head on the orifice must be increased correspondingly. Diagram D in Fig. 5 indicates the progressive increase in the orifice pressure differential required to maintain a constant rate of flow through the orifice 12 under these conditions.

In order automatically to vary the pressure differential head of orifice 12 in the manner indicated in Diagram D upon variation in viscosity of the oil flowing therethrough, the compensating oil delivery conduit 11 is proportioned to provide a pressure drop therein which varies substantially inversely with the required variation of the differential pressure head of orifice 12. This variable pressure drop in the compensating oil delivery conduit 11 is indicated by Diagram E in Fig. 5. To obtain this result, the length and diameter of conduit 11 are proportioned in accordance with the equation

$$\frac{L}{D^4}=7960\,\frac{1.1H_1}{Ru}$$

wherein L is the length of the conduit expressed in feet; D is the inside diameter of the conduit expressed in inches; H_1 is the variation in the orifice pressure differential head; R is the rate of fluid flow expressed in gallons per hour and u is the kinematic viscosity in centistokes. In this equation, the value $1.1H_1$ corresponds to the value H_2 shown in Fig. 5 as the pressure drop in the conduit with fluid of maximum viscosity flowing through the conduit and expressed in head in inches of fluid occurring between the maximum and minimum viscosity values as shown in Diagram D. Diagram F in Fig. 5 shows the combined total pressure head of the orifice and conduit expressed in inches of oil under which the source 10 shown in Fig. 1 must be maintained in order to obtain a substantially constant rate of flow therefrom through the compensating fluid delivery conduit 11 and the orifice 12. It will be observed that the total pressure head indicated by Diagram F is substantially constant throughout the entire range of viscosity control. Hence after the conduit 11 and orifice 12 are once properly proportioned and connected in co-operating relation with the source 10, all that is required to maintain the liquid flow from the source 10 substantially constant irrespective of variations in the viscosity of the liquid is to maintain the source 10 at the substantially constant pressure value indicated by Diagram F. This may be readily accomplished by any constant pressure regulating means well known to those skilled in the art.

In Fig. 7, the oil furnace 20 is shown of the type described in the copending application of Aldo Macchi, Serial No. 505,867, filed December 31, 1930, and assigned to the assignee of the present application although the invention may be applied to any ordinary type of pressure feed oil burner. In the type of furnace shown the oil atomizing nozzle 21 extends into the top of the combustion chamber of the steam or hot water boiler 22 and is supplied with oil, atomizing air and combustion air from the electric motor driven blower compressor unit 23. The atomizing nozzle 21 is shown as of the type described and claimed in the copending application of John Eaton and W. O. Lum, Serial No. 691,320, filed September 28, 1933, and assigned to the assignee of the present invention. The motor driven blower compressor unit 23 is shown as of the improved type described and claimed in my copending application, Serial No. 553,119, filed July 25, 1931. In this unit the fuel oil and atomizing air therefor are maintained under pressure in the sump tank 24 upon operation of the electric motor driven blower and pumping mechanism. The fuel oil is conducted from the sump chamber 24 to the nozzle 21 through the pipe 25 and the atomizing air is conducted from the sump 24 through nozzle 21 through the air line 26.

In order to maintain the rate of oil flow through nozzle 21 substantially constant irrespective of variations in the viscosity of the oil, in accordance with the present invention a control orifice 30 is connected in the oil supply pipe 25. It will be understood that this orifice 30 is proportioned as to diameter, size and ratio to provide the oil rate desired in the manner previously described. Likewise the pipe 25 is proportioned in length and diameter to co-operate with the control orifice 30 so as to maintain the desired oil rate substantially constant irrespective of variations in viscosity in the same manner as described in connection with the compensating fluid supply conduit 11 of Fig. 1.

A substantially constant oil level is maintained in the sump 24 by means of a float operated by-pass valve, not shown. The oil in sump 24 is maintained under a substantially constant pressure by means of the automatic air pressure regulating valve 31 which controls a by-pass from the atomizing air supply line 26 to the air inlet of the pump mechanism. Under these conditions, the rate at which oil is supplied from the sump 24 to the nozzle 21 is maintained substantially constant irrespective of variations in viscosity of the oil throughout a range sufficiently wide to include the ordinary commercial grades of fuel oil.

In operation, the oil supplied to nozzle 21 is atomized and ignited by the electric spark from the electrode 32, low pressure combustion air is supplied from the blower 33 through the flexible air pipe 34 to nozzle 21 and through the air conduit 35 to the air box 36 which extends into bottom of the combustion chamber of the furnace.

In accordance with the provisions of the patent statutes, I have explained the principles of operation of my invention and described the apparatus which I now consider represents the best embodiment thereof but I desire to have it understood that the apparatus shown is only illustrative and that the invention can be carried out by other means. It also should be understood that the invention may be carried out with a plurality of

control orifices and conduits of the character described connected either in series to provide a desired rate of fluid flow under high pressure or in multiple to provide an increased rate of flow under low pressures.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. A compensated flow control for fluids of varying viscosity comprising a thin wall sharp edge control orifice proportioned to increase the discharge coefficient thereof under a constant pressure differential head upon an increase of the viscosity of the fluid between predetermined limits, and a fluid delivery conduit connected with said orifice and proportioned to decrease the pressure differential head of said control orifice upon said increase of the viscosity of the fluid to maintain the fluid flow through said orifice substantially constant.

2. A compensated flow control for fluids of varying viscosity under substantially constant initial pressure comprising a delivery conduit having the pressure drop therein increasing as a function of the increase in viscosity of the fluid, and a thin wall sharp edge orifice connected with the delivery conduit and proportioned to increase the discharge coefficient thereof upon said increase of the viscosity of the fluid between predetermined limits to maintain the fluid flow through said conduit substantially constant.

3. Means for feeding fluids of varying viscosity at a substantially constant rate comprising a reservoir for the fluids, means for maintaining a substantially constant pressure in the reservoir, a thin wall sharp edge orifice for determining the rate of fluid flow from the reservoir and proportioned to increase the discharge coefficient thereof under a constant pressure differential head upon an increase of the viscosity of the fluid between predetermined limits, and a fluid delivery conduit connected with the orifice and proportioned to decrease the pressure differential head of said orifice upon said increase of the viscosity of the fluid to maintain a substantially constant rate of fluid flow through said orifice.

4. An oil burner having a thin wall sharp edge orifice for determining the oil rate thereof and proportioned to increase the oil discharge coefficient upon increase of the oil viscosity between predetermined limits, and an oil delivery conduit proportioned to decrease the pressure differential head of said orifice upon said increase of oil viscosity to maintain the oil rate substantially constant.

5. An oil burner having means for supplying oil under pressure for combustion including an oil delivery conduit having the pressure drop therein increasing as a function of the increase in viscosity of the oil, and a thin wall sharp edge orifice for determining the rate of oil flow through the conduit and proportioned to increase the discharge coefficient thereof upon said increase of the viscosity of the oil between predetermined limits to maintain the oil flow through said conduit substantially constant.

6. An oil burner having an oil reservoir, means for maintaining a substantially constant pressure in said reservoir, a thin wall sharp edge orifice for determining the rate of oil flow from said reservoir and proportioned to increase the oil discharge coefficient thereof under a constant pressure differential head upon an increase of the viscosity of the oil between predetermined limits, and an oil delivery conduit proportioned to provide a pressure drop between said reservoir and said orifice increasing with said increase of the oil viscosity to maintain a substantially constant rate of oil flow from said reservoir.

WALTER O. LUM.