Jan. 4, 1938. R. COLSTON 2,104,221

CONTROL SYSTEM FOR FURNACES

Filed June 22, 1935

Fig. 3.

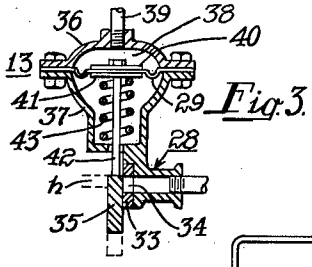
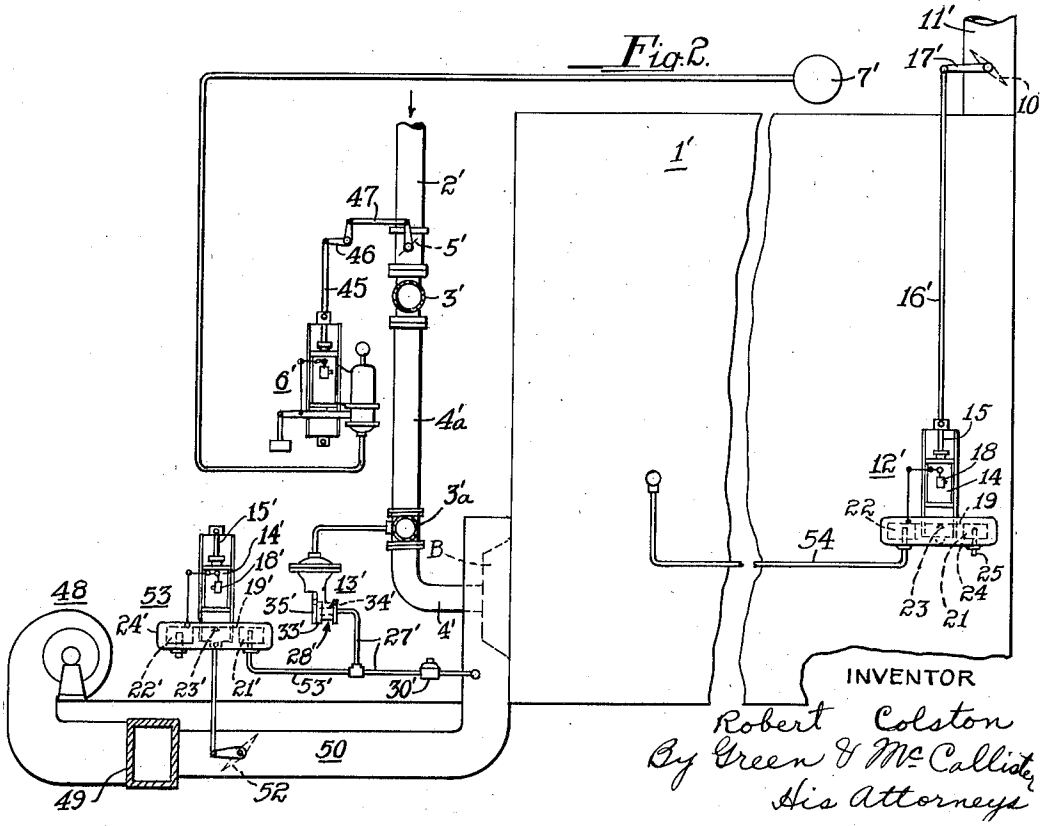


Fig. 1.

Fig. 2.



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CONTROL SYSTEM FOR FURNACES

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5 Claims. (Cl. 236—14)

This invention relates to furnaces of the gaseous or fluid fuel fired type and more particularly to control systems for automatically maintaining that relationship between the rates of delivery of air and fuel to the furnace which is required for a predetermined standard or efficiency of combustion.

An object of this invention is the provision of a control system for furnaces, of the type fired by gaseous, or fluid fuels that will continuously measure the rates of delivery of air and fuel and adjust each in relation to the other so that a predetermined standard of combustion efficiency will be maintained for all the values of rating or load at which the furnace may be operated.

Another object of the invention is the provision of a control system of the character referred to above that may be utilized with furnaces operating either on natural or forced draft.

A further object of the invention is the provision of a control system that shall be adaptable to a single furnace or to a bank or plurality of furnaces and require but one master regulator for controlling the delivery of fuel to all the furnaces, the control of the air supply to the individual furnaces being accomplished by local regulators of similar design and in accordance with the rate of delivery of fuel to each individual furnace.

Other objects of the invention will, in part, be apparent, and will, in part, be obvious from the following description taken in conjunction with the accompanying drawing, in which:

Figure 1 is a more or less diagrammatic view of a control system embodying one form of the invention as applied to a boiler furnace supplied with a natural draft;

Fig. 2 is a more or less diagrammatic view of a control system embodying the invention as modified for use with furnaces having a forced draft air supply; and

Fig. 3 is a view in section taken on line III—III of Figs. 1 and 2, of a device embodied in the control system shown therein.

Throughout the drawing and the specification like reference characters indicate like parts.

In Fig. 1 of the drawing a boiler furnace 1 is shown of the natural draft type and which is fired with fuel gas supplied from a supply pipe 2 connected to a furnace bank header 3, i. e., a header which supplies a bank of furnaces and from which the burners of one or more furnaces may be supplied. Furnace 1 may have one or more burners, each connected by a pipe 4 to furnace header 3a, i. e., a header which supplies only the burners of an individual furnace. Each furnace header 3a is connected by a pipe 4a to bank header 3. The pressure of the gas delivered to the furnace headers and the burners connected thereto is controlled by a butterfly valve 5 in the main supply pipe which is actuated by a regulator 6 in accordance with the load demand on the furnace.

The boiler furnace or furnaces deliver steam to a header 7. Regulator 6 responds to the pressure of the steam in this header and operates the butterfly valve to adjust the pressure of the fuel gas and therefore the rate of delivery of fuel gas to the furnaces in accordance with the load, or the demand for steam. Variations in load on the furnace or furnaces is reflected in variations in steam pressure in the steam header 7. If the steam pressure is rising, this indicates that the load demand is decreasing, while a decreasing steam pressure indicates that the load demand is increasing. If the load demand is decreasing, regulator 6 operates to shift butterfly valve 5 towards closed position so as to reduce the supply of fuel gas to the furnace burners, and if the load is increasing, regulator 6 responds to a decrease in steam pressure in the main header 7 and opens butterfly valve 5 in accordance with the demand. When the steam pressure remains fixed at the desired value, regulator 6 does not move and holds valve 5 in a fixed position. Regulator 6 is shown as being of the type disclosed in United States Letters Patent No. 1,371,243 granted to John M. Hopwood on the 15th day of March, 1921, although any load responsive regulator suitable for the purpose intended may be employed.

The burner shown in Fig. 1 is of the aspirating type, that is, the air for combustion is admitted to the furnace through a ported member 9 disposed around the burner pipe 4, by the combined effect of the furnace suction and the aspirating action of the gas delivered to the furnace through the burner pipe. The furnace is provided with a damper 10 in the outlet or uptake 11 which is under the control of a regulator 12. This regulator, for any required rate of delivery of gas to the furnace, adjusts damper 10 to maintain the furnace suction at a given value but when the rate of delivery of fuel gas changes because of a change in load, regulator 12 is unbalanced by a device 13 which responds to the pressure of the gas in burner header 3a, causing regulator 12 to shift the outlet damper 10 to a different position. When the damper has been shifted to that position which results in the draft required for the new rate of fuel delivery, the

regulator 12 will be in balance again, comes to rest, and will not be operated as aforesaid until the rate of fuel delivery is changed. In this manner a predetermined standard of combustion efficiency is maintained.

Device 13, as will be shown later herein, when used in the system above mentioned, causes regulator 12 to maintain automatically the proper stack draft regardless of whether variations in stack draft are caused by atmospheric changes or because the products of combustion of other furnaces are discharged into the same outlet breeching.

Regulator 12 is shown as being of the balanced float type such as disclosed in United States Letters Patent Re. 18,479 dated May 24, 1932, and comprises a reciprocating motor which includes a cylinder 14 having a reciprocating piston therein (not shown) to which is connected a piston rod 15 coupled by a link 16 to crank arm 17 of the outlet damper 10. Motive fluid for moving the piston up or down is admitted either to the upper or lower end of the cylinder through a pilot valve 18 which is operated through a system of levers and linkages, by a float beam 19. A regulator of this type as shown in the patent referred to, includes a cut-off mechanism which operates to return the pilot valve 18 to off position whenever the piston has moved a predetermined distance in either direction for a given amount of opening of the pilot valve. Thus step-by-step movement of the piston is accomplished in either direction with the resulting step-by-step adjustment of the outlet damper. The mechanism which operates pilot valve 18 to its "on" position in response to furnace draft comprises inverted bells 21 and 22 carried at the opposite ends of float beam 19 which is fulcrumed on a knife edge 23. The open ends of the floats or bells extend into a liquid such as oil contained in a tank or casing 24. Float or bell 21 communicates with the atmosphere through a pipe 25 which extends upwardly through the bottom of the tank and into the interior of the bell to a point above the level of the oil. The interior of float 22 is connected by a pipe 26 to a metering pipe 27 one end of which is connected to the combustion chamber of the furnace and the other end of which is connected to the atmosphere through an adjustable valve or orifice 28 forming part of device 13 and which is operated by a pressure sensitive diaphragm 29 in accordance with the pressure of the gas delivered to the furnace burners. A fixed orifice 30 is connected in pipe 27 between its point of connection to the interior of the furnace combustion chamber and the point to which float 22 is connected to pipe 27. Regulator 12 is adjusted to be in equilibrium for a predetermined value of suction existing in that portion of pipe 27 which is between the adjustable valve 28 and the orifice 30. If the suction or pressure at this point changes either because of a change in pressure in the furnace combustion chamber or because of a change in the extent of opening of valve or orifice 28 as effected by a change of pressure of the fuel gas delivered to the furnace burners, the float mechanisms 21, 22, 19 will become unbalanced and operate pilot valve 18 in the required manner. The outlet damper 10 will then be shifted in such a direction and to such a position that the suction in pipe 27 between valve 28 and orifice 30 will be restored to the value for which the float mechanism is balanced. Regulator 12 comes to rest when the suction is restored to this value but moves again when the suction acting on float 22 departs from this value and unbalances the float mechanism.

Device 13, pipe 27, and orifice 30 may be considered as a metering mechanism, in that the rate of fuel delivery to the furnace is measured and the draft adjusted accordingly to maintain a rate of air supply to the furnace which bears substantially a linear relationship to the fuel supply rate.

This metering mechanism is capable of such adjustment that when the boiler is operating at high rating, the rate of air supply may be gradually increased with respect to the rate of fuel supply to obtain a gradual increase of excess air, while at the lower ratings, the linear relationship of fuel to air will be maintained. The adjustment just mentioned applies to the systems herein illustrated in Figs. 1 and 2, and makes possible the maintenance of any desired relationship between the rates of fuel and air supply at any rating.

Device 13 is shown in detail in Fig. 3 and comprises valve or orifice 28 the outlet of which is connected to pipe 27. One end of the valve is provided with a removable plate 33 in which an inlet opening 34 is formed.

The flow area through opening 34 is controlled by a valve slide 35 which is operated by diaphragm 29. The marginal edge of diaphragm 29 is clamped between housing members 36 and 37 thereby forming a chamber 38 to which the pressure of the gas in pipe 4a is communicated by a pipe 39. The diaphragm is reinforced by backing plates 40 and 41, and plate 41 is connected to valve slide 35 by a plunger 42. The valve slide is urged towards closed position by a compression spring 43 disposed about plunger 40 and within housing member 37. When the fuel gas pressure is at the minimum desired value, valve slide 35 will be urged by spring 43 to its uppermost position, in which position the flow area through opening 34 is a minimum, or completely closed if required, and this corresponds to a condition of no load or minimum load and minimum draft, i. e., damper 10 would be closed or nearly closed; and when the gas pressure is at its maximum, valve slide 35 would be in a position to completely uncover or nearly uncover opening 34 and this would correspond to a condition of maximum load and therefore a condition of maximum draft.

The variation in draft in the combustion chamber of the furnace from minimum to maximum load conditions may include a range for example of 0.1 inch to 0.6 inch, or more of water. While this variation occurs within the furnace, the suction which is maintained between valve 28 and orifice 30 will be maintained at the minimum value, say 0.1 inch of water, or whatever value for which regulator 12 is adjusted to be in equilibrium. In practice, the system is adjusted by reducing the gas pressure to a value corresponding to minimum load conditions, in which case valve slide 35 closes opening 34 or is adjusted to close it. Regulator 12 is then adjusted until it shifts damper 10 to a position in which the suction in the furnace is of the proper value for minimum load. With valve slide 35 in position to close opening 34, the suction between valve 28 and orifice 30 will be equal to the suction in the furnace. As the pressure of the gas delivered to the burners increases, in which case the rate of supply of fuel to the furnace increases, valve slide 35 is shifted to

uncover opening 34, thereby changing the suction between valve 28 and orifice 30 and unbalancing regulator 12. Damper 10 will then be shifted to increase the furnace draft and the suction in the furnace until the flow through valve 28 has increased to a point where the suction between it and orifice 30 has been restored to the equilibrium value, i. e., 0.1 inch of water for the range above mentioned. This action takes place throughout the entire operating range of the furnace, i. e., the range from no load or minimum load to maximum load. Throughout this range the pressure drop across valve 28 remains constant, although the drop across orifice 30 will vary over a relatively wide range.

In certain cases it may be found necessary to so shape opening 34 that the area of opening will vary at a rate which does not bear a linear relationship to travel of slide 35. When a rectangular opening is employed the area will vary linearly with the travel of the slide from either closed or wide open position and linearly with the pressure of the fuel gas in pipe 4a. In other words, the area of the uncovered portion of opening 34, if it is rectangular, would be expressed by the equation $A=Kh$, when K is a constant and h is the distance from the upper edge of opening 34 to the upper edge of slide 35, and therefore the area "A" should be equal to K'.P. where K' is a constant and P the fuel gas pressure in pipe 4a. If the flow of fuel through pipe 4a and the burners were directly proportional to the pressure in pipe 4a in front of the burners, the shape of opening 34 could be rectangular and the flow through meter pipe 27 would be directly proportional to the pressure of the fuel gas in, and the flow through, pipe 4a. The flow through a burner is similar to the flow through an orifice, and the flow is proportional to the square root of the difference of the squares of the pressures on each side of the orifice, i. e., the flow

$$=\sqrt{KP_1^2-P_2^2}$$

where K is a constant and P_1 and P_2 are the pressures on the high and low pressure sides respectively of the orifice. The area of the opening 34 should therefore be such that for each value of pressure in pipe 4a and impressed on diaphragm 29, the flow through meter pipe 27 would vary by and in accordance with the flow through pipe 4a.

In the arrangement shown in Fig. 1 the pressure at the inlets and the outlets of the burners vary with fuel gas pressure and furnace draft, but the aspirating effect of the fuel gas through the burners combined with the effect of the draft as regulated by the outlet damper 10, causes air to be delivered to the furnace at the proper rate and at a rate which is substantially directly proportional to the pressure to the fuel gas in pipe 4, and to the rate of supply of fuel to the furnace. For this reason the shape of opening 34 may be substantially rectangular. At any event the shape of opening 34 should have such a characteristic that as slide 35 moves with changes in pressure on diaphragm 29 it should so affect the operation of regulator 12 and the adjustment of damper 10 that the rate of air supply to the furnace will be caused to bear a linear relationship to the rate of supply of fuel. If an aspirating type of burner is not used, opening 34 should have such a shape that the area would vary in accordance with the expression $A=K(P_1^2-P_2^2)^{1/n}$ where n is greater than unity.

In Fig. 2 the metering device of Fig. 1 is employed, the parts therefore being designated by reference characters 13', 27', 28', and 30', and this device is utilized to so regulate the forced draft air supply that the rate of supply of air will bear a linear relationship to the rate of supply of fuel. As shown in Fig. 2, a furnace 1' is supplied with fuel, such as gas, from a supply pipe 2' which is connected to a furnace bank header 3'. Header 3' is connected to the furnace burner header 3'a of each furnace by a pipe 4'a to which the burners B of one or more furnaces are connected each by pipes 4'. The rate of supply of fuel is regulated by a butterfly valve 5' which is operated by a regulator 6', the regulator being connected to the valve crank arm by means of a link 45, the bell-crank 46, and link 47. Regulator 6' responds to variations in boiler load as reflected by variations in steam pressure in steam header 7'. Thus the rate of supply of fuel to the furnace burners as well as the pressure of the fuel in pipes 4'a which serve these burners, is regulated by and in accordance with the load, as in Fig. 1.

A variable source of supply of air for supporting combustion may be provided, as for example, by a motor driven forced draft fan or blower 48 which delivers the air to a header 49 from which one or more furnaces may be supplied, each furnace being served by a conduit 50 connected to the header. The rate of supply of air to each furnace is controlled by a regulator 53. Where only one blower is employed for a bank of furnaces, a damper 52 (one in each conduit 50 where more than one furnace is involved) may be utilized to regulate the air supply to each furnace, and each damper is operated by a regulator 53, for example, of the balanced float type such as regulator 12, and to similar parts of which similar reference characters are applied. The outlet draft of furnace 1' is controlled by a regulator 12' which is connected by a pipe 54 to the combustion chamber of the furnace. This regulator is adjusted to so operate damper 10' that the pressure or draft in the furnace combustion chamber is maintained at a constant value, say atmospheric. Regulator 12' operates to shift damper 10' towards open position, as the rate of air supply is increased, and towards closed position as the air supply rate is decreased, these adjustments being at all times of such extent as to maintain the combustion chamber pressure constant.

Device 13' responds to the pressure of the fuel in the burner supply pipe 4'a and its valve slide 35' is operated in the manner described in connection with Figs. 1 and 3. Valve 28' is connected to one end of meter pipe 27' and the other end of this pipe is connected to conduit 50 at a point in front of the burners. Since the pressure of the air in conduit 50 is above atmospheric, air flows from this conduit through orifice 30' in pipe 27' and discharges through valve 28' to the atmosphere. In Fig. 1, the flow through meter pipe 27 is in the opposite direction since the pressure in the combustion chamber is below atmospheric. Regulator 53 responds to the pressure in that portion of pipe 27' located between valve 28' and orifice 30' and so controls the position of damper 52 that such a pressure will be maintained in conduit 50 as will cause the pressure between orifice 30' and valve 28' to remain

constant at the value for which regulator 53 is balanced, for all positions of valve slide 35'.

When the pressure of the fuel gas in pipe 4'a is at a minimum value corresponding to minimum load, valve slide 35' will be in a position to close opening 34' and as a consequence regulator 53 will be subjected to the pressure existing in conduit 50. Regulator 53 is adjusted to be balanced at this value of pressure. As the load increases and valve 5' is opened wider and wider, the pressure of the fuel in pipe 4'a increases. This increasing pressure, since it acts on the diaphragm of device 13', moves slide 35' downwardly in steps proportional to the fuel pressure. As slide 35' moves downwardly air discharges through opening 34' to the atmosphere whereby the pressure between valve 28' and orifice 30' is reduced and regulator 53 unbalanced. This unbalance calls for a higher rate of air supply; consequently the regulator shifts damper 52 toward open position thereby increasing both the pressure of the air in duct 50 and the rate of supply of air to the furnace. This increased pressure causes an increase in flow through meter pipe 27' and an increase in the pressure between valve 28' and orifice 30' which acts on regulator 53. Regulator 53 will continue to open damper 52 until the pressure in the valve and orifice has increased to the value for which it is balanced, i. e., the value of pressure which exists in conduit 50 at minimum load conditions. With further increases in load this action continues until valve slide 35' is in its lowermost position and opening 34' is wide open. This condition corresponds to maximum load conditions calling for the maximum rates of air and fuel supply.

In the system shown in Fig. 2, it will be apparent that the fuel and air supplied to the furnace combustion chamber are delivered against a constant back pressure because regulator 12' in its operation of damper 10' maintains a constant pressure in the combustion chamber. However, the pressure of the fuel and the air as delivered to the burners and the furnace varies with variations in load. Also, the aspirating effect of the burners tends to accentuate the rate of air flow into the furnace. If the flow of fuel into the furnace and the flow of air thereto were directly proportional to the pressure of the fuel and the air in front of the burners, the variation in the area of opening 34' as it is uncovered by slide 35', could be a direct and linear function of the pressure of the fuel in front of the burners. However, since the flow of a liquid or gas through an orifice does not vary directly with the pressure drop across it, it follows that the shape of opening 34' should be such that its area characteristic as it is uncovered by slide 35', will allow the flow of air from conduit 50 through meter pipe 27', to vary linearly with the flow of fuel to the burners while the slide 35' is shifted in a linear relationship to the pressure on the fuel as acting on the diaphragm in device 13' which operates the slide. In other words, the shape of opening 34' should be such that the flow of air through the meter pipe 27' will bear a linear relationship to the flow of fuel to the burners via pipes 4'a although such relationship may not be a linear one with respect to the pressure of the fuel. This will be apparent to those skilled in the art dealing with the relation of pressure drops across an orifice to the flow therethrough.

Regulator 53 is connected to meter pipe 27' by a pipe 53'. This pipe extends upwardly through the bottom of tank 24' into the interior of float 21' instead of float 22 as in Fig. 1. Upward movement of float 21' in response to an increase in pressure above that for which the regulator is balanced, causes piston rod 15' to move in the same direction as piston rod 15 moves when float 22 of regulator 12 moves downwardly in response to an increase in suction over that for which regulator 12 is balanced—this direction of movement is downward—while decreased pressure in float 21' causes downward movement thereof and decreased suction in float 22 causes upward movement thereof, in which case piston rods 15' and 15 move upwardly. In both cases, the piston rods will be at rest when the float mechanisms of regulators 12 or 12' and 53 are in balance with the pressure or suction acting thereon.

Previously herein, it was stated that the regulating systems of Figs. 1 and 2 were each applicable to a single furnace or to a bank of furnaces, each bank comprising two or more furnaces. Where two or more furnaces are controlled by the system of Fig. 1, the burners of each furnace are supplied with fuel through a pipe 4a each connected to header 3 and the supply is controlled by one master regulator 6. Each furnace of a bank would be provided with a regulator 12 for operating its outlet damper 10 and each furnace would be provided with a metering device comprising a device 13, pipe 27, and orifice 30, and the metering device and regulator 12 for each furnace would operate in the manner described in connection with Fig. 1.

Where two or more furnaces are controlled by a system such as shown in Fig. 2, the burners of each furnace would be connected by pipes 4'a to header 3' and the supply of fuel would be controlled by one master regulator 6'. The combustion air for each furnace would be supplied by individual conduits 50 each connected to header 49. Each furnace would be provided with a regulator 53 for operating a damper 52 to control the rate of air supply to it in accordance with the rate of supply of fuel thereto. Also, each furnace would be provided with a metering device 13', 27', and 30' for operating its regulator 53 and a draft regulator 12' for so regulating its outlet damper 10' that a constant pressure is maintained in the combustion chamber.

While gas has been mentioned as the fuel supply which is controlled by the systems herein disclosed, it will be understood that these systems may be employed where the fuel is of liquid form. It will, therefore, be appreciated by those skilled in this art that modifications and changes may be made without departing either from the spirit or scope of the invention.

What I claim as new and desire to secure by Letters Patent is:

1. In a control system for furnaces provided with a supply of fluid fuel and means for supplying air thereto for combustion of the fuel, a metering device including spaced orifices, one fixed and one adjustable, connected to pass one of the fluids—air or fuel—essential to combustion at a rate that varies with the rate of supply of the other of them, means responsive to the pressure between said orifices for regulating the rate of flow of the one of said elements to the furnace in accordance with the rate of flow of the other thereto, and means for varying the rate of flow through the metering device in accordance with the rate of supply of the other of said elements to change the pressure between said orifices.

2. In a control system for furnaces provided

with a regulatable supply of fuel, a metering device connected to convey fluid at a rate proportional to the draft, said metering device having an adjustable orifice and a fixed orifice, a regulator for adjusting the draft, said regulator having a pressure responsive element connected between said orifices and arranged to respond to changes in pressure therebetween to cause said regulator to so adjust the draft that the pressure between said orifices is maintained substantially constant, and fuel supply responsive means for adjusting the adjustable orifice in accordance with the rate of supply of fuel.

3. In a control system for furnaces provided with a source of supply of fluid fuel and air, a meter pipe arranged to pass a fluid therethrough in accordance with the rate of supply of air, said meter pipe having an adjustable orifice and a fixed orifice therein, means responsive to the pressure of the fuel delivered to the furnace for adjusting the adjustable orifice to a degree of opening which will allow the flow through the meter pipe to bear a predetermined relationship to the rate of supply of fuel, and means responsive to the pressure between said orifices for so regulating the supply of air to the furnace that the pressure between said orifices is maintained substantially constant.

4. In a control system for furnaces provided with a source of supply of fluid fuel and a regulator for controlling the draft at the outlet of the furnace, a meter pipe having one end connected to the furnace combustion chamber and one end in communication with the atmosphere, an adjustable orifice and a fixed orifice in said meter pipe, means responsive to the pressure of the fuel as delivered to the furnace for adjusting said adjustable orifice, said adjustable orifice having such a flow characteristic that the flow through the meter pipe will bear a linear relationship to the rate of supply of fuel, and means responsive to the pressure between the orifices for so controlling the outlet draft regulator that the pressure between said orifices is maintained substantially constant.

5. In a control system for furnaces provided with a source of supply of fluid fuel and a source of supply of forced draft air, means for regulating the outlet draft of the furnace to maintain a substantially constant pressure in the combustion chamber of the furnace, a regulator for adjusting the rate of air supply, a meter pipe having one end connected to the forced draft supply and the other end open to the atmosphere, said pipe having a fixed orifice and an adjustable orifice therein, means responsive to the pressure between said orifices for causing the air supply regulator to maintain the air supply at such a pressure that the flow through the meter pipe will result in a substantially constant pressure being maintained between said orifices, and means responsive to the pressure of the fuel delivered to the furnace for so adjusting the area of opening of said adjustable orifice that the flow through the meter pipe will bear a substantially fixed relationship to the rate of supply of fuel to the furnace and cause the air supply regulator to establish a rate of air supply to the furnace that bears a fixed relation to the rate of fuel supply.

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