Sept. 22, 1942. F. S. BLOOM 2,296,255

INDUSTRIAL FURNACE AND FIRING APPARATUS

Filed June 10, 1939 3 Sheets-Sheet 1

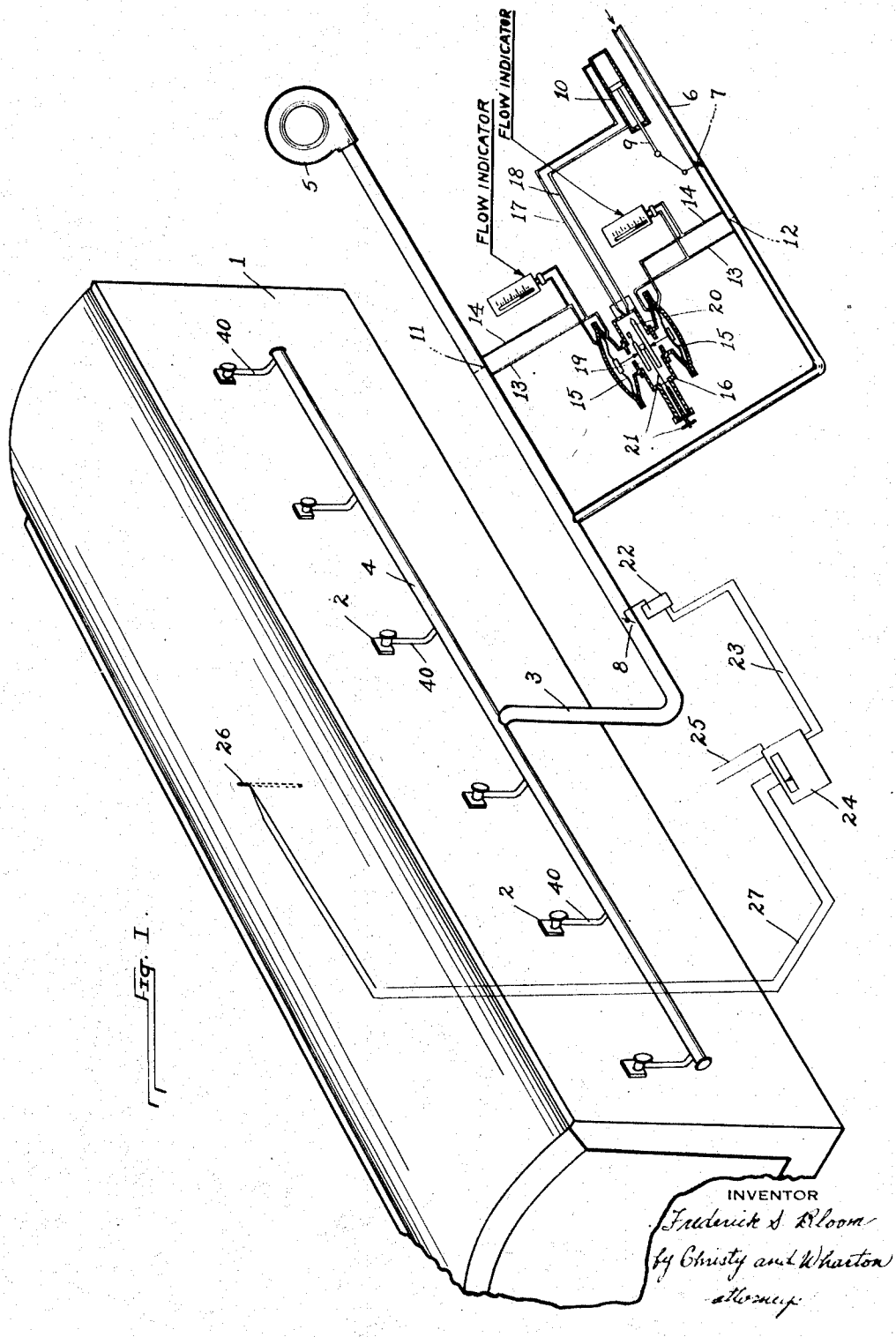


Fig. 1.

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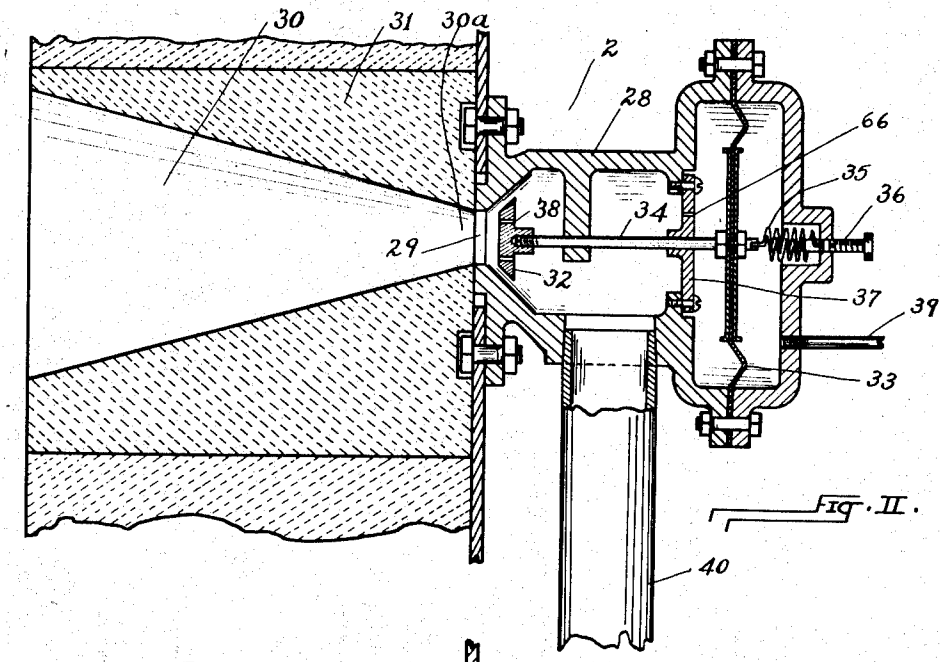


FIG. II.

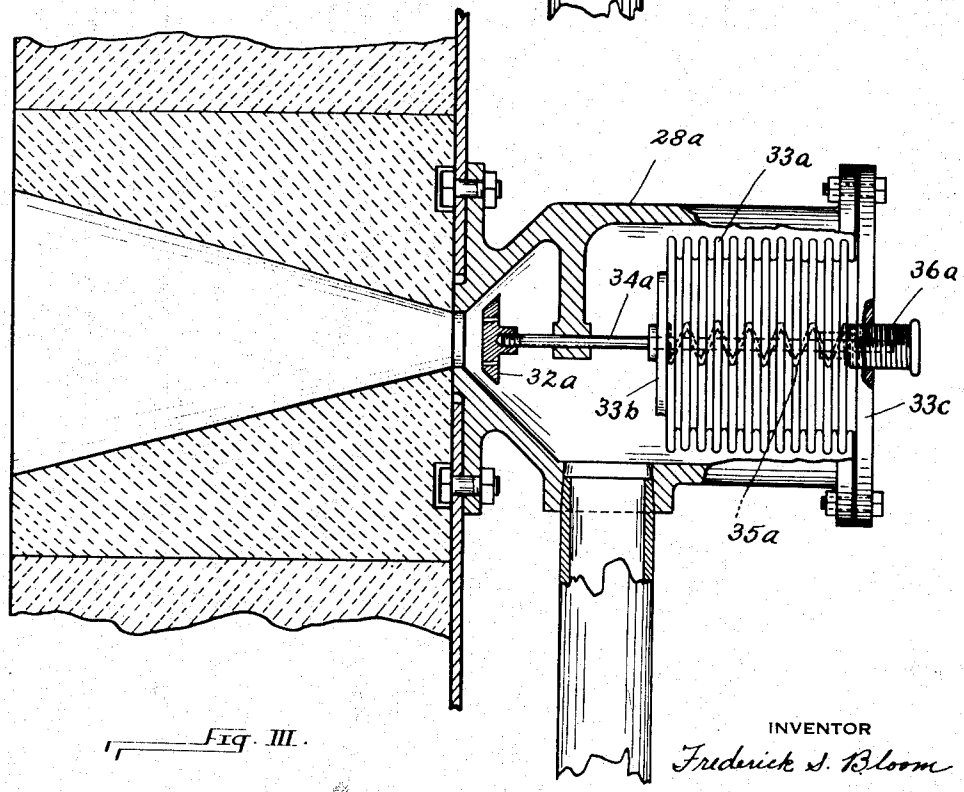


FIG. III.

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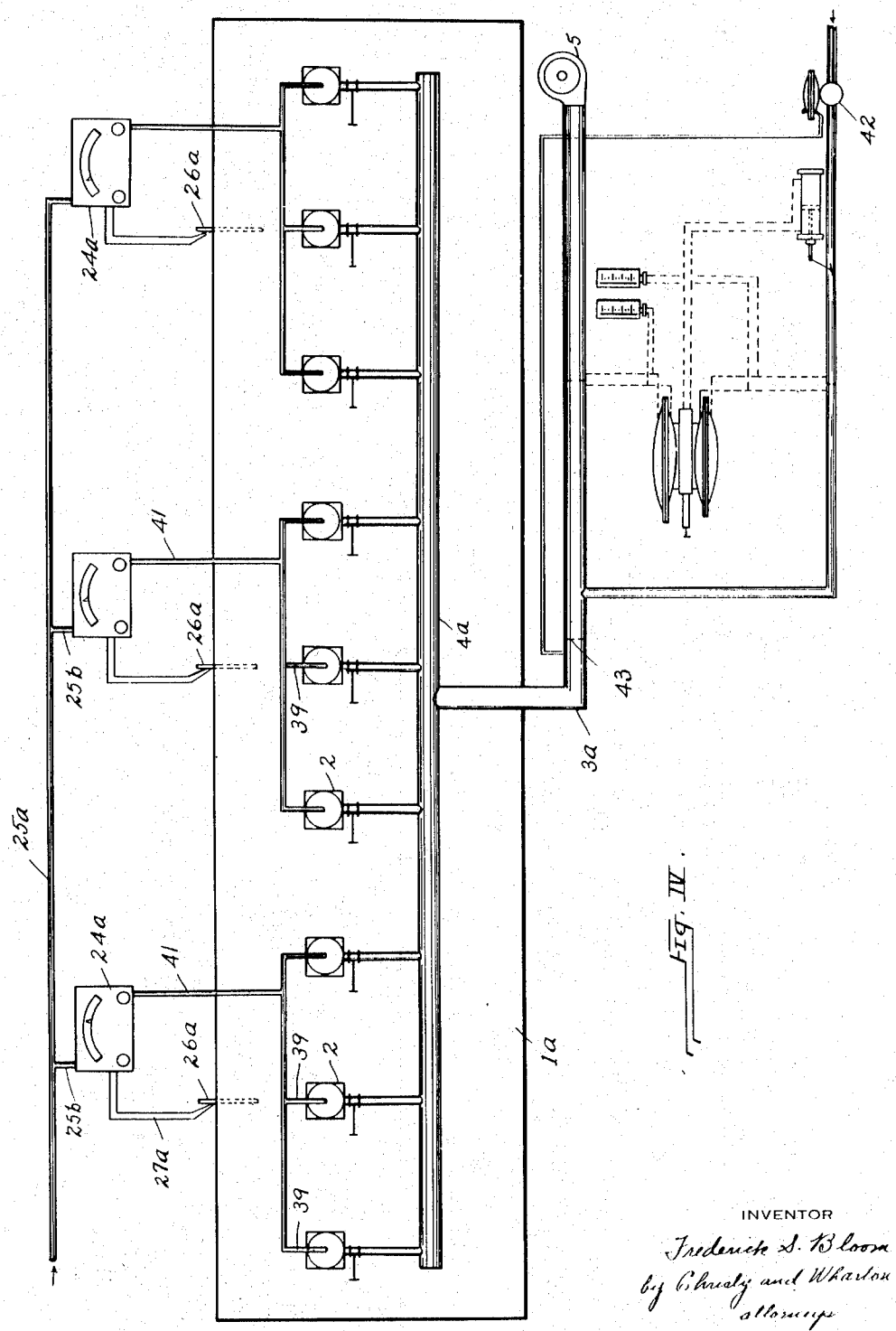


Fig. III.

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UNITED STATES PATENT OFFICE

2,296,255

INDUSTRIAL FURNACE AND FIRING APPARATUS

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Application June 10, 1939, Serial No. 278,520

8 Claims. (Cl. 236—15)

This invention relates to industrial furnaces, particularly to installations of one or more furnaces that are fired with pre-mixed gaseous fuel and air.

In the operation of such furnaces, the combustible mixture is delivered under pressure to the burners of the furnace. Ordinarily, valves are provided in the inlet pipes leading from the mixture supply line to the burners, and, while these valves may be manually adjusted, the essential regulation of the rate of combustion in the furnace is obtained by varying the pressure, with consequent variation in the quantity, of the combustible mixture delivered to the burners. It has been found in such furnace operation that the capacity of the burners is limited; that is, the range of combustion control is too narrow. If the pressure of the fuel and air mixture is reduced so far as is necessary to obtain the relatively low rate of combustion sometimes desired, there is danger of back-firing and explosion in the burners, and in the supply line. It is for this reason that the practice has been, hitherto, to provide means that will prevent the pressure of the combustible mixture from being decreased to the danger point. Thus, the range of operation of the burners is limited, and it is such objectionable limitations as this that have impeded the otherwise advantageous use of the premix method of firing.

The object of my invention is to provide improvements and refinements in the structure of the burners and control instrumentalities of such furnaces, by virtue of which the range of combustion control is so far widened as to remove all practical limitations to the use of the premix method of firing, and to eliminate all dangers of back-firing and explosion. In one installation I may maintain the velocity of flow of the mixture at substantially constant value, while varying the quantity of the combustion-sustaining mixture delivered into the furnace. And in another installation I may vary the velocity of the mixture flowing into the furnace, with variation in the quantity of the mixture delivered into the furnace. But in either case all danger of backfiring and explosion is eliminated.

It is further my object to provide means to the end that the individual burners, or selected groups of burners, may be independently and automatically controlled in accordance with temperature conditions within the furnace.

An embodiment of the invention is illustrated in the accompanying drawings, in which

Fig. I is a fragmentary view in perspective of a typical furnace equipped with the burners and control apparatus of the invention: the control apparatus is illustrated diagrammatically, partly in elevation and partly in section.

Fig. II is a view of my burner structure in vertical section; the burner is shown in position of service, with the wall of the furnace and the inlet pipe shown fragmentarily.

Fig. III is a view comparable with Fig. II, illustrating partly in vertical section and partly in side elevation a burner of modified form.

And Fig. IV is a diagrammatic view, showing a furnace in side elevation, and certain modifications in the apparatus for controlling combustion within the furnace.

Referring to Fig. I of the drawings, the reference numeral 1 is applied to the furnace, which may be a batch furnace, or a continuous furnace, or a lehr, for heating or heat-treating articles formed of metal, glass, or other materials. A line of burners 2 is mounted on each of the opposite side walls of the furnace, and in service these burners are adapted to project burning columns of fuel into the furnace chamber. The combustible mixture of gaseous fuel and air is delivered by a supply line 3 into a manifold 4, and pipes 40 severally connect the burners with such manifold.

The apparatus employed for supplying the desired combustible mixture includes a fan 5 that delivers air under pressure into supply line 3, and a pipe 6 that delivers fuel gas under superatmospheric pressure to the said line 3.

The quantities of fuel and air delivered to the burners (and in consequence the rate of combustion and the temperature within the furnace) are controlled by means of a butterfly valve 8 arranged in the supply line 3, and in accordance with my invention, I not only provide means for maintaining the desired ratio of fuel to air in the supply line 3, but I provide, in cooperative organization with such means, instrumentalities for automatically adjusting the valve 8, to establish and maintain specified temperature conditions within the furnace. I shall first consider the matter of controlling the mixture of fuel and air—the fuel to air ratio.

It will be initially understood, of course, that in order to establish and maintain the desired efficiency of combustion in the furnace, it is essential that the ratio or proportion of fuel to air must be accurately controlled. To this end a butterfly valve 7 is provided in the fuel line 6. The valve 7 is automatically adjusted in accordance with the quantity of air flowing into line 3,

and in consequence of such adjustment of valve 7 the quantity of fuel admitted to the line 3 is regulated and the desired ratio of fuel to air is established and maintained, and this holds true even though there be fluctuation and variation in the flow of either the fuel or the air.

Means for so automatically controlling the mixture of fuel and air are, as has already been mentioned, known to the art, and in exemplary way I shall briefly describe a widely used piece of apparatus known as the Askania ratio regulator. Such regulator includes a plunger 9, in response to whose movement in a pneumatic cylinder 10, in one direction or the other, the valve 7 is opened or closed a greater or less degree, depending upon the magnitude of plunger movement. The movement of the plunger is determined and controlled by the pressure differential between the fuel and the air. Specifically, orifice plates 11 and 12 are arranged in the air and fuel lines, respectively. Tubes 13 and 14 lead from opposite sides of each orifice plate to the opposite sides of a flexible diaphragm 15, and, as shown, the two diaphragms 15 are arranged in opposing relation, each standing in open communication on one side—the side that communicates with the low pressure side of the orifice plate (11 or 12)—with a pressure chest 16, from which chest two tubes 17 and 18 extend, one to each of the opposite ends of the valve-operating cylinder 10. Within the chest 16 a counterpoised lever 19 and jet-pipe 20 are arranged to swing in response to the movement of the diaphragms, and in known way the delicately counterpoised jet-pipe sways into and stands in a position that is determined by the aggregate effect of the gas and air pressures upon the two diaphragms 15. The position of the distal end of the jet-pipe in known manner determines the relative pressures of fluid in the two tubes 17 and 18, and, as the pressure is augmented in one tube or the other, the plunger 9 in cylinder 10 is caused to move in one direction or the other. Thus, the valve 7 is swung towards open or closed position, according as the pressure of the air (that is, the quantity of air flowing through orifice plate 11) increases or decreases relatively to the pressure (quantity) of fuel gas flowing through orifice plate 12. The automatically adjusted valve 7 makes compensation in the rate of flow of the fuel for variations in the rate of flow of the air, and so the desired ratio of air to fuel is accurately maintained, irrespective of the quantity of the mixture of air and fuel that, under the control of valve 8, flows to the burners 2. Needless to say, the ratio regulator may be provided with the usual means (21) for varying the value of the ratio of air to fuel which is maintained, but this specification need not be concerned with such known matters of detail.

It will be perceived that, if the butterfly valve 8 is moved towards closed position, the fan 5 will deliver less air, and that in consequence the flow of air through orifice 11 will decrease, whereupon the apparatus 11—21 will operate immediately to shift the valve 7 and decrease the flow of gas. Upon such movement of the master valve 8 towards closed position, the pressure of the gaseous mixture in the manifold 4 will drop, and, as presently will appear, certain valves in the burners 2 will automatically close a corresponding degree, whereby, although the pressure and volumetric rate of flow of the combustible mixture are decreased, the velocity of flow from the burners will be maintained at sufficiently high value to prevent back-firing.

In accordance with the invention, the firing of, or rate of combustion within, the furnace is caused to function automatically, under the influence of the temperature conditions within the furnace.

To this end, I organize an electric motor 22 with the valve 8; this motor is energized by a circuit 23, leading from an electric pyrometer 24; pyrometer 24 is connected, by leads 25, to a suitable source of electric energy (not shown); and the pyrometer is subject in its operation to a theremocouple 26 which, connected by a circuit 27 to said pyrometer, is exposed to the temperature within the furnace. Those skilled in the art are familiar with the construction and operation of each of these instrumentalities; they can obtain them on the open market; and inasmuch as my invention lies in the organization of such instrumentalities with apparatus of the sort above described, and with burners of the particular construction presently to be described, it will suffice to describe the operation of the devices 22, 24, 26 generally.

When the temperature in the furnace rises, the usual electro-thermal current flowing in circuit 27 increases in value; when the temperature rises through a certain increment the increased current becomes effective momentarily to close a relay in the pyrometer 24, and the closing of the relay effects the energizing of the circuit 23; under the influence of such momentary flow of current in circuit 23 the armature of motor 22 moves through a predetermined interval, and swings the valve 8 through a predetermined interval towards closed position. If, thereafter, the temperature in the furnace continues to rise, the apparatus repeats the operation, until the valve 8 is adjusted in the position at which the rate of fuel delivery and the rate of combustion are reduced to the point at which the rise in temperature is arrested. If the temperature in the furnace falls below critical value, the thermo-electric current decreases in value and such decrease in current in circuit 27 effects the closing of a different relay in the pyrometer 24, with the consequence and effect that an energizing current flows in reverse direction in circuit 23, and causes the motor 22 to step the valve 8 into more widely opened position. In this way the quantity of the combustible mixture supplied to the furnace is increased, and the furnace temperature elevated. Thus, the valve 8 operates automatically (in conjunction with the ratio-regulating apparatus already described) to regulate the rate or intensity of combustion, in such manner that the desired temperature conditions are established and maintained in the furnace. And it will be manifest that by proper selection and adjustment of the thermocouple and pyrometer, the temperature at which the furnace is maintained may be varied to suit the work.

Turning to Fig. II, the construction of my improved burners will be considered. Each burner consists in a metal housing 28 adapted to be mounted, as shown, on the furnace wall, with the outlet orifice 29 of the burner in registry with the mouth of a conical passage 30 in the refractory port-block 31 which, as usual, is embodied in the furnace side wall. The combustible mixture of fuel and air enters the housing by way of pipe 40, and within the housing a valve 32 is arranged to control the flow through orifice 29.

It will be understood that in service the com-

bustion of the mixture streaming through orifice 29 and port-block 31 into the furnace is initiated in the conical passage 30 in the port-block, and that so long as the velocity of the streaming gases is above a certain critical value, there is no danger of the flame burning back through the orifice 29 and causing premature combustion and explosion in the burner body 28 or in the supply pipe 40. With this in mind, it is to be understood that my burner structure includes, advantageously, means for adjusting the valve 32, in accordance with variations in the pressure of the combustible mixture supplied to the burner, so that, regardless of the pressure at which the combustible mixture enters the burner, the velocity of flow through the orifice 29 will either be held above critical value, or the valve 32 will close.

Such means may, as shown in Fig. II, consist in a flexible diaphragm 33, to which the stem 34 of valve 32 is secured. A spring 35, whose effective force may be adjusted by means of a screw 36, bears upon one side of the diaphragm and tends to shift the rod 34 in right-to-left direction and to move the valve 32 towards closed position, while the pressure of the combustible mixture, transmitted through a passage 66 in partition 37, is effective on the opposite side of the diaphragm, and, opposing the force of spring 35, tends to move the valve into more widely opened position. As in service the pressure of the combustible mixture supplied to the burner rises or falls, under the automatic combustion-controlling regulation of valve 8 (Fig. I), the valve 32 is shifted to the right or to the left, and accordingly increases or decreases the effective area of the orifice 29, with the consequence that the velocity of the gases flowing through the port-block 31 is maintained above critical value—above the value at which the flame can work back through the orifice 29 and cause premature combustion in the burner body 28.

If the pressure of the combustible mixture should drop to a value at which a safe velocity through orifice 29 cannot be maintained, the valve 32, under the urging of spring 35, moves into fully closed position, and in such position it is effective, obviously, to prevent backfiring. Manifestly, it is merely a matter of properly adjusting the effective force of spring 35 to insure that the valve shall close before the danger point is reached. The body of the valve, it is to be noted, includes one or more small passages 38, which, when the valve is in closed position, permit the flow of a slight but sufficient quantity of the combustible mixture into the throat (30) of the port-block, to sustain a pilot flame.

It is important to note that the valve 32 is arranged to control the flow of the combustible mixture, not at some point in the line of flow removed a substantial interval from the inlet end of the passage 29, 30, but immediately at the inlet end of such passage, and preferably immediately at the inlet end 30a of the conical throat of the port-block 31. As will be perceived in Fig. II, when the valve 32 is seated in explosion-preventing position, all communication (with the exception of the communication afforded by the vents 38) is blanked between the combustion chamber of the furnace and the interior of the burner. This is a feature of construction that will prove valuable in burners that are manually controlled, or are controlled by means other than those illustrated and described herein.

In refinement of the structure described, I connect a line 39 to the diaphragm chest in the burner, as shown. This line constitutes in the burner structure an auxiliary inlet for fluid under pressure, and provides means whereby a regulatory pressure may be established in the burner, and used in the control of burner operation. In this case compressed air is supplied through the line 39 to the diaphragm chest, and the pressure of such air is caused to supplement the pressure of the spring 35 on the diaphragm 33. By increasing or decreasing the pressure of the air in line 39, the total effect of the pressures on the righ-hand side of the diaphragm may be increased or decreased, and the valve 32 controlled at will. The pressure in line 39 may be regulated at a station more or less remote from the furnace. In some cases, the springs 35 may be dispensed with, and the operation of the burners made subject to pneumatic pressures alone. All of the burners of the furnace, or various groups of burners, may by the use of a manually operated air valve be made entirely responsive to the will of the attendant, or they may be caused to operate automatically, as first described. And additionally it is to be noted that the pressure of air supplied by pipe 39 may be governed and held to a value that will provide (either with or without a spring 35) such pressure on the right-hand side of the diaphragm 33 as will effect the desired automatic operation of the valve 32. The pneumatic lines 39 of the several burners may be subject to a single control valve, so that the operation of all burners may be simultaneously regulated or varied.

In Fig. III, I illustrate a modification in the means that control the burner valve. Specifically, I show a Sylphon or metal bellows 33a, whose inner head 33b is secured and sealed to the valve-stem 34a, and whose outer head 33c includes a threaded plug 36a, the counterpart of the screw 36 of the first-described burner, which is adapted to adjust the force of a compression spring 35a arranged within the Sylphon and bearing against the inner face of the Sylphon head 33b. In known way the Sylphon expands and contracts with variations in the pressure of the gaseous mixture to which it is exposed within the burner body 28a, and in consequence the valve 32a operates in the same general manner as the valve 32.

In Fig. IV, I show that the master control valve 8 (Fig. I) may be eliminated in certain installations, and that the valves (32, Fig. II) of the several burners may serve not only as the backfire-preventing instrumentalities but as the combustion control means as well. More specifically, the pneumatic control leads 39 of the burners may be connected to a pyrometer that controls pneumatic pressure (rather than an electric current) for regulation of the rate of combustion in the furnace.

Sometimes it is desirable to provide different rates of combustion at different points in the extent of the furnace, and, if such be the case, the burners 2 will be arranged in a plurality of groups that are severally responsive in operation to a plurality of pyrometers. The burners 2 of the furnace 1a in Fig. IV are shown to be arranged in three groups of three burners each, and the pneumatic control leads 39 of the burners in each group are connected in common to the control pipe 41 of a pneumatic pyrometer 24a. A thermocouple 26a is by a thermo-electric circuit 27a connected to each pyrometer, and the several pyrometers are, by leads 25b and a line 25a, con-

nected to a source of compressed air or other gas or fluid. The pyrometers include valves (not shown) that open and close in response to the increase and decrease of the thermo-electric currents in circuits **27***a*, and, as such valves in the pyrometers open and close, the fluid pressure in pipes **41** leading to the burner-controlling diaphragms (**33**, Fig. II) correspondingly rises and falls; that is to say, as the temperatures rise or fall (in the regions of the furnace into which thermocouples **26***a* extend) the pressures on the burner diaphragms increase or decrease, and in consequence shift the burner valves either towards closed positions or into more widely opened positions, and thus regulate the quantity of the fuel and air mixture delivered into the furnace. In organizing the burners in groups severally controlled by pyrometers that are individually responsive to thermocouples arranged at successive points longitudinally of the furnace, the temperatures at such points or regions of the furnace may be accurately maintained; that is, the desired temperature gradient in the furnace or lehr may be established and maintained.

The apparatus admits of great versatility in the matter of temperature regulation. The grouping of the burners may be quickly altered to provide the desired temperature gradient from one end of the furnace to the other; one burner on each side of the furnace may be connected to one pyrometer and five burners on each side may be connected to another, and so on; indeed, all burners may be connected to a single pyrometer, if the conditions should require a single control. This interchangeability of burner grouping is made practical and economical, due to the ease with which the small tubing **39** and **41** may be taken apart and re-connected in such way as to provide the desired burner grouping.

As illustrated diagrammatically in Fig. IV, the apparatus for supplying the fuel and air in proper proportion may be the same apparatus as that described in Fig. I. There is, however, an additional safety feature to be specifically considered, and this feature is applicable to either of the furnace installations described. It consists in an automatic valve **42** (Fig. IV) arranged in the fuel supply line. If for any reason the pressure of the air, or of the combustible mixture, should fall to the danger point the valve **42** closes and completely shuts off the supply of fuel. The fan **5** will continue in operation, and in such case will tend to scavenge the lines **3***a* and **4***a* of the combustible mixture therein. Accordingly, if one or more of the burner valves should fail to close when the pressure of the mixture falls below critical value, the valve **42** closes and provides a safeguard against explosion. I have shown the valve **42** as a know type of pneumatically operated valve, adapted in known way to close the fuel line when the pressure of the gases in pipe **3***a* falls below critical value.

In the foregoing specification, I have described in exemplary way apparatus which embody the invention, and it will be understood that the diaphragm **33** and Sylphon **33***a* are exemplary of the pneumatic (or hydraulic devices, or the movable members of such devices, that may be used in the automatic control of the valve **32** of each burner. The pyrometers **24** and **24***a* will be understood to be instrumentalities which, connected to a source of energy (c. f. **25** or **25***a*), are responsive to the thermo-electric currents of the thermocouples **26**, **26***a* for regulating, either through valve **8** (Fig. I) or pressure lines **39** (Fig. IV), the pressures which are effective in the control of the burner valves **32**.

Many advantages in addition to those mentioned are enjoyed in the structure of my invention; advantages in the matters of safety, control of combustion, range of furnace temperature control, uniformity of jet velocity (if desired), uniformity in distribution of heat in the furnace, and variation in jet velocity (if desired). And it is to be understood that within the terms and intent of the appended claims, many modifications and refinements are permissible.

Notice is hereby given of my copending application Serial No. 377,282, filed February 4, 1941.

I claim as my invention:

1. A pre-mix firing system for industrial furnaces including a plurality of burners provided severally with outlets in communication with the combustion chamber of the furnace, a duct with which said burners communicate, means for maintaining a mixture of air and fuel in said duct, a master valve arranged to control the flow of the mixture from the duct to said burners, means responsive to temperature conditions within the furnace for adjusting the position of said valve and regulating the pressure of the mixture flowing from the duct to said burners, means for maintaining at substantially predetermined value the ratio of air to fuel in said mixture while the position of said valve is so adjusted in accordance with temperature conditions within the furnace, and means in each burner responsive to variations in the pressure of the mixture delivered to the burners for regulating the flow of the mixture through the outlets of the burners.

2. A pre-mix firing system for industrial furnaces including a plurality of burners provided severally with outlets in communication with the combustion chamber of the furnace, a duct with which said burners communicate, means for maintaining a mixture of air and fuel in said duct, a master valve arranged to control the flow of the mixture from the duct to said burners, means responsive to temperature conditions within the furnace for adjusting the position of said valve and regulating the pressure of the mixture flowing from the duct to said burners, means for maintaining at substantially predetermined value the ratio of air to fuel in said mixture while the pressure of the mixture flowing to said burners is so regulated, and means for the prevention of explosive back-firing in the system, said means being organized with said burners severally and responsive to a drop in the pressure of said mixture to critical value.

3. A pre-mix firing system for an industrial furnace including a burner having an outlet in communication with the combustion chamber of said furnace, a duct communicating with the burner, means for maintaining a mixture of air and fluid fuel in said duct, a valve arranged to control the flow of the mixture from said duct to said burner, means responsive to temperature conditions within the furnace for adjusting the position of said valve and regulating the pressure of the mixture flowing from the duct to the burner, means for maintaining at substantially constant value the ratio of air to fuel in said mixture while the pressure of the mixture flowing to said burner is so regulated, and means responsive to variations in the pressure of the mixture delivered to said burner for regulating

the quantity of the mixture flowing through said burner outlet.

4. A pre-mix firing system for an industrial furnace including a burner having an outlet in communication with the combustion chamber of said furnace, a duct communicating with the burner, means for maintaining a mixture of air and fluid fuel in said duct, a valve arranged to control the flow of the mixture from said duct to said burner, means responsive to temperature conditions within the furnace for adjusting the position of said valve and regulating the pressure of the mixture flowing from the duct to the burner, means for maintaining at substantially constant value the ratio of air to fuel in said mixture while the pressure of the mixture flowing to said burner is so regulated, and means organized with said burner for safeguarding the burner and the system from explosive back-firing of the mixture.

5. A pre-mix firing system for industrial furnaces including a plurality of burners provided severally with outlets, a duct with which said burners communicate, means for supplying a mixture of air and fuel to said duct, flow-controlling means arranged to regulate the flow of the mixture from the duct to said burners, means responsive to temperature conditions within the furnace for adjusting said flow-controlling means and regulating the pressure of the mixture flowing from the duct to said burners, means for maintaining at substantially predetermined value the ratio of air to fuel in said mixture while said flow-controlling means are so adjusted in accordance with the temperature conditions within the furnace, and means in each burner responsive to variations in the pressure of the mixture delivered to the burners for regulating the flow of the mixture through the outlets of the burners.

6. A pre-mix firing system for industrial furnaces including a plurality of burners provided severally with outlets, a duct with which said burners communicate, means for supplying a mixture of air and fuel to said duct, flow-controlling means arranged to regulate the flow of the mixture from the duct to said burners, means responsive to temperature conditions within the furnace for adjusting said flow-controlling means and regulating the pressure of the mixture flowing from the duct to said burners, means for maintaining at substantially predetermined value the ratio of air to fuel in said mixture while said flow-controlling means are so adjusted in accordance with the temperature conditions within the furnace, and means for the prevention of explosive back-firing in the system, said means being organized with said burners severally and responsive to a drop in the pressure of said mixture to critical value.

7. A pre-mix firing system for an industrial furnace including a burner having an outlet in communication with the combustion chamber of said furnace, a duct communicating with the burner, means for maintaining a mixture of air and fluid fuel in said duct, flow-controlling means arranged to regulate the flow of the mixture from said duct to said burner, means responsive to temperature conditions within the furnace for adjusting the flow-controlling means and regulating the pressure of the mixture flowing from the duct to the burner, means for maintaining at substantially constant value the ratio of air to fuel in said mixture while the pressure of the mixture flowing to said burner is so regulated, and means responsive to variations in the pressure of the mixture delivered to said burner for regulating the quantity of the mixture flowing through said burner outlet.

8. A pre-mix firing system for an industrial furnace including a burner having an outlet in communication with the combustion chamber of said furnace, a duct communicating with the burner, means for maintaining a mixture of air and fluid fuel in said duct, flow-controlling means arranged to regulate the flow of the mixture from said duct to said burner, means responsive to temperature conditions within the furnace for adjusting the flow-controlling means and regulating the pressure of the mixture flowing from the duct to the burner, means for maintaining at substantially constant value the ratio of air to fuel in said mixture while the pressure of the mixture flowing to said burner is so regulated, and means organized with said burner for safeguarding the burner and the system from explosive back-firing of the mixture.

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