April 25, 1933. C. M. TERRY 1,905,658

METHOD AND APPARATUS FOR CONTROLLING COMBUSTION

Filed May 6, 1929 3 Sheets-Sheet 1

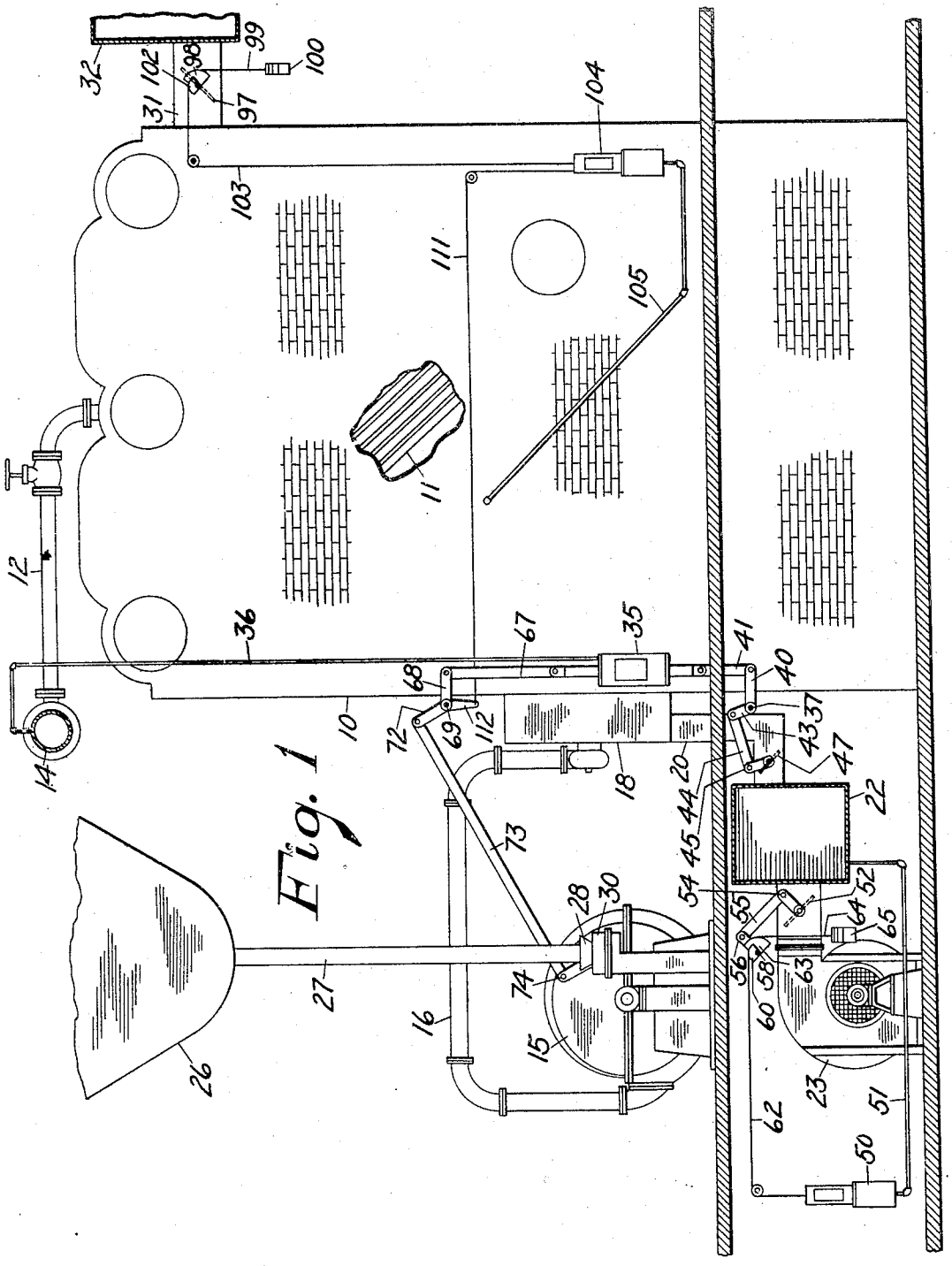



Fig. 1

WITNESS
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METHOD AND APPARATUS FOR CONTROLLING COMBUSTION

Filed May 6, 1929 3 Sheets-Sheet 2

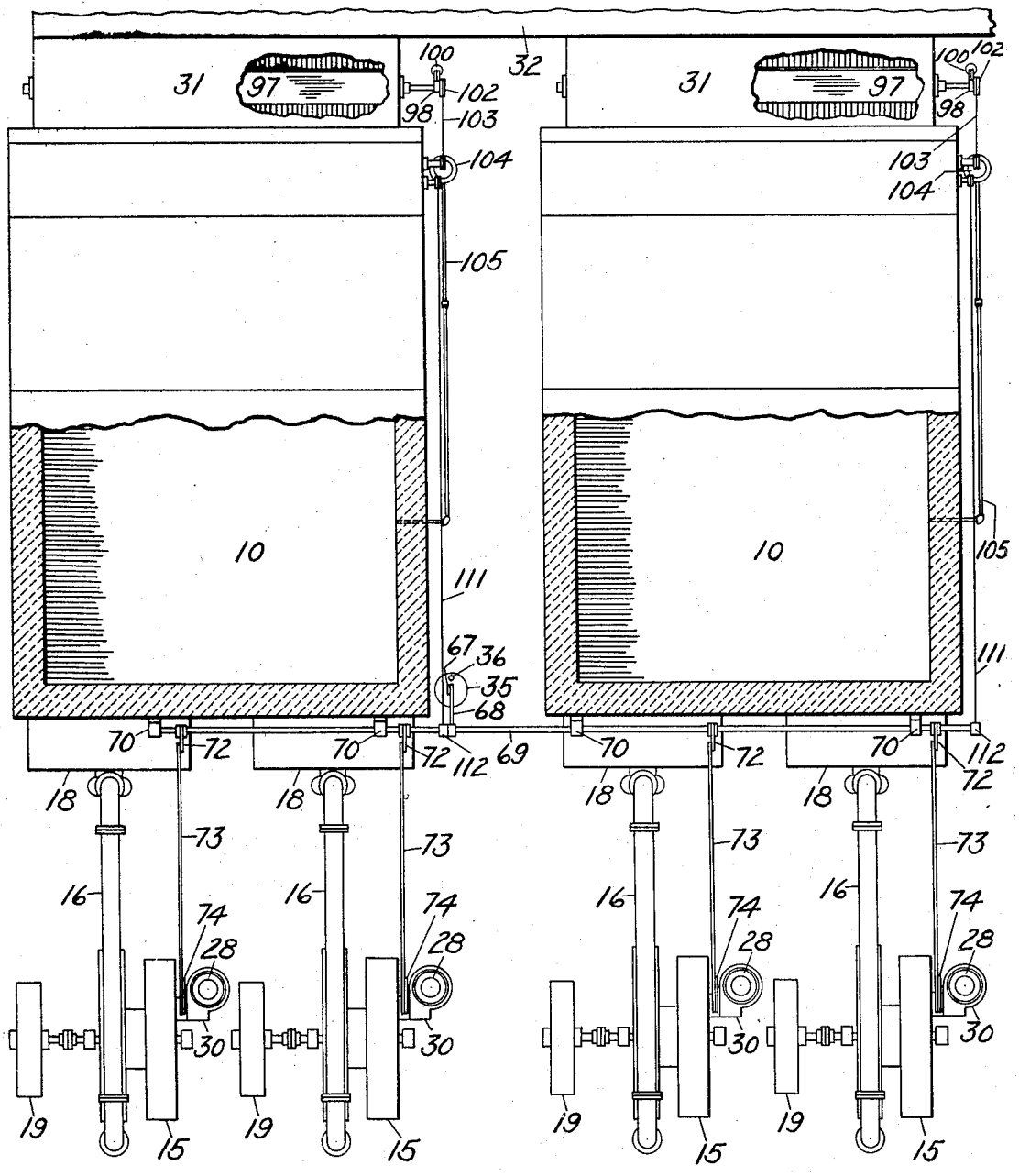



Fig. 2

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METHOD AND APPARATUS FOR CONTROLLING COMBUSTION

Filed May 6, 1929 3 Sheets-Sheet 3

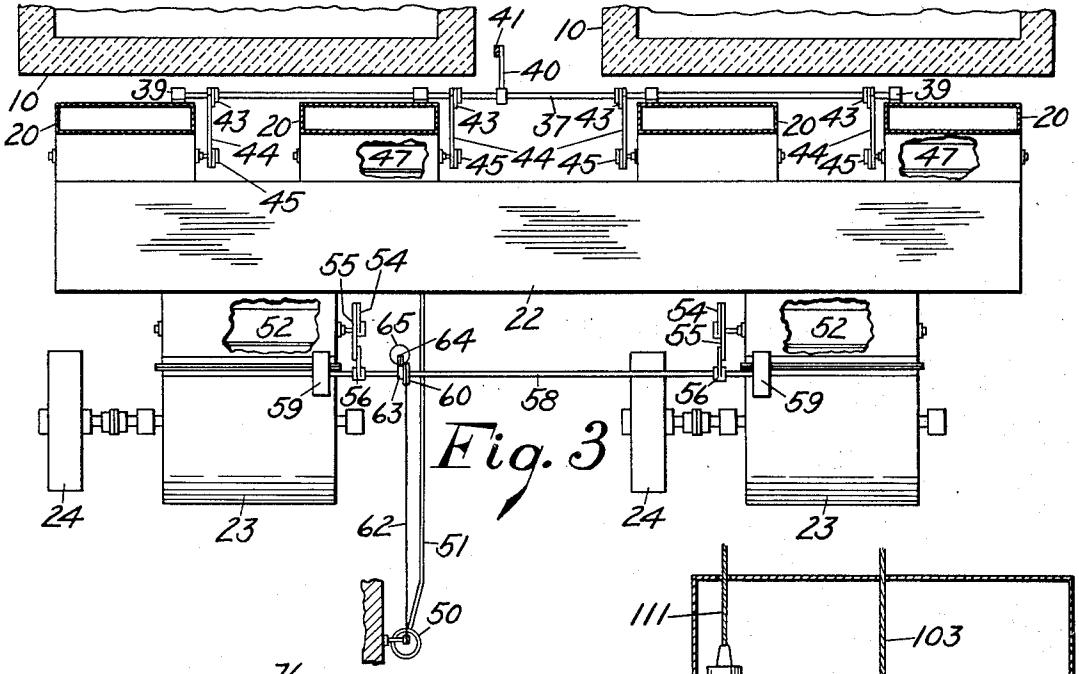



Fig. 3

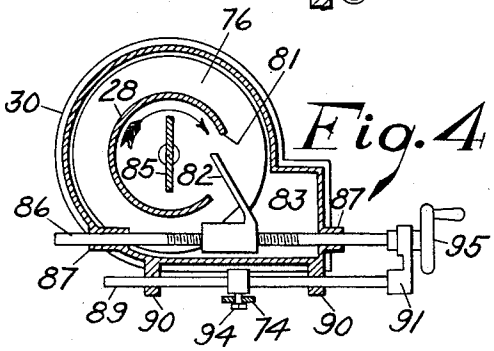



Fig. 4

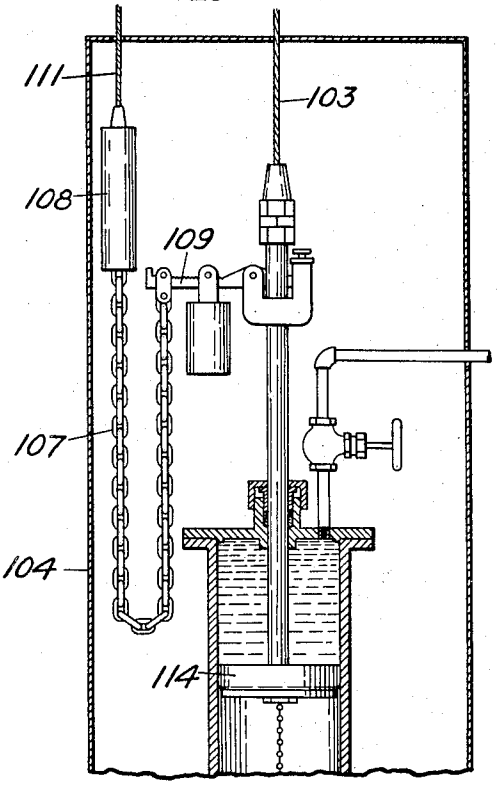
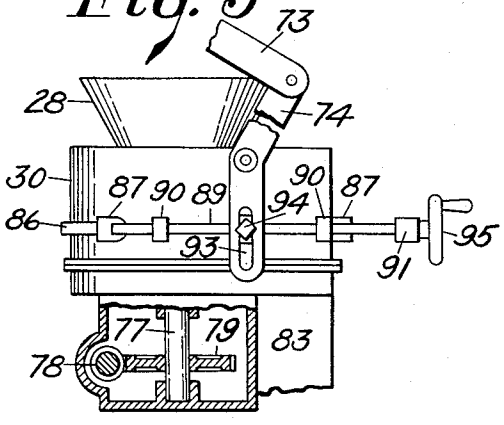



Fig. 6

Fig. 5




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Patented Apr. 25, 1933 1,905,658

# UNITED STATES PATENT OFFICE

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## METHOD AND APPARATUS FOR CONTROLLING COMBUSTION

Application filed May 6, 1929. Serial No. 360,978.

This invention relates to the automatic control of combustion, and more particularly to a method and apparatus for controlling the combustion of finely divided fuel fed to the furnace burners of steam generating boilers.

In the practical use of a furnace burning finely divided fuels, such as pulverized coal, fed as a stream to the furnace burner and burned in suspension, a serious problem is presented in that the load on the boiler is seldom uniform, and the demand for steam is constantly changing from one moment to the next. This necessitates frequent adjustments of the combustion rate in accordance with the changes in demand, in order to prevent the steam pressure from deviating considerably from the pressure desired. Because of the high velocity with which the fuel passes through the furnace, and the consequent short period of time within which a given particle of fuel must be completely burned, it is essential that the fuel and air be delivered to the furnace in the correct proportions at all times. Any change in the rate of fuel feed must always be accompanied by a simultaneous and corresponding change in the rate of air flow. If there is a momentary deficiency in the air supply, incomplete combustion of fuel will occur. If the air supply is at any time greater than necessary, heat is wasted in raising the temperature of the excess air to that of the flue gases. Changes in the combustion rate tend to cause changes in the gas pressure within the combustion chamber of the furnace, and it is desirable to regulate this pressure so as to prevent too high pressures which cause the burning gas to permeate the crevices in the furnace walls and so be detrimental to the furnace refractories, or too low pressure which cause excessive air infiltration into the furnace.

Pulverized fuel is ordinarily fed to the furnace by means of a transporting current of primary air, on which it is carried as a cloud of dust. The pulverized fuel may be fed at a desired rate from a storage bin or the coarse fuel may be fed in a regulated amount to a unit pulverized and there pulverized and transported directly to the burner. In either case, it is preferable to employ such proportions of fuel and primary air and to feed them at such a rate that an explosion cannot take place and the flame cannot strike back into the fuel feed pipe. Consequently, only enough air is supplied as primary air to suffice for transporting the fuel dust, and the remaining air, known as secondary air required for burning the fuel completely, is fed to the fuel at the furnace, and preferably through the burner. The primary air may be forced through the system at a substantially uniform rate and pressure irrespective of the amount of fuel carried thereby, and in that case it is necessary, to get the proper amount of air for combustion, merely to regulate the rate of flow of the secondary air. If, however, more than one burner is supplied from a single secondary air duct, then a change in the number of burners in operation, as well as various other changes in the operating conditions, will affect the pressure in the air supply pipe and the damper regulation of the air will be affected. Likewise, in a single burner system, any change in pressure resulting perhaps from irregularity in fan speed or for other reasons independent of boiler rating will affect the regulation of air flow, ordinarily controlled simply by a damper. That is, for a given boiler rating, the air controlling damper will always stand in a certain position, hence any variation in the air pressure in advance of the damper will affect the rate of flow through the dampered orifice. It is, therefore, desirable, for many fuel burning installations, that the secondary air be supplied under a uniform pressure, or at least it is desirable that the secondary air be varied, as the fuel supply is varied, to furnish the correct proportion of air for the fuel, and that for a given boiler rating there be a definite air flow.

A further condition, besides the pressure in the main duct and the position of the secondary air damper, which has an effect on the rate of air flow is the pressure in the furnace chamber into which the air is dis-

charged. Since it is important for efficient regulation that the air flow for a given boiler rating be always the same, it is desirable to control the furnace pressure in such a way that it will always have a definite value for a given boiler rating, and that the outflow of the products of combustion will be regulated, as the inflow of air and other furnace conditions are varied, to give the desired furnace condition of either a uniform furnace pressure or one which varies in a predetermined manner.

The main objects of my invention are, therefore, to provide a method of regulating the combustion of finely divided fuel transported through a burner pipe to the furnace of a steam generating boiler, whereby the combustion rate will always be in proportion to the steam demand and the air supply will always be maintained in the proper ratio to the fuel supply, and, where desired, to combine such a fuel and air regulation with the regulation of the furnace gas pressure so as to prevent any variation in the air flow or either air infiltration or refractory burnouts.

A further object is to provide a method of regulating the combustion of fuel in suspension in a steam boiler furnace, in which the fuel is fed in a finely divided condition to the furnace and there mixed with a variable quantity of air, so that any variations in external conditions tending to affect the pressure of the air independently of the boiler rating will be automatically compensated for and the air flow may therefore be predetermined for each boiler rating in spite of such variations.

A further object is to regulate the fuel feed and the air supply to each of a group of furnaces burning finely divided fuel which receive air from a common air duct so that the fuel and air supply to each furnace may be regulated in accordance with the demand for steam from the group and each furnace will receive the correct amount of air for the fuel, as the fuel supply varies.

It is a further object of my invention to provide a simple and inexpensive arrangement of apparatus to carry out efficiently the methods set forth in the above-mentioned objects.

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

In accordance with my invention, I regulate the supply of finely divided fuel to the furnace in accordance with the demand on the boiler. I prefer to utilize the pressure in the boiler, or in the main header where there are a plurality of boilers, as an indication of the demand. When the unit pulverizer system is used to provide pulverized fuel, one feasible way of controlling the fuel supply is to regulate the rate at which the coarse fuel is delivered to the pulverizers. I control the air supply to the furnace in accordance with the load requirements and in exact synchronism with the fuel supply. For example, the air supply may be regulated by means of a damper located in a branch duct leading from a main air duct, and a constant pressure of air may be maintained in the main duct in advance of the damper so that a given damper position will always result in a definite rate of air flow to the furnace. The main duct pressure may be kept constant by regulating a damper at the outlet of the fan supplying air to the duct, or by varying the speed of the fan. I preferably regulate the discharge of the products of combustion from the furnace in accordance with the pressure in the furnace, so as to insure the desired furnace pressure. In plants intended for operation at extremely high rates of combustion, I prefer to decrease the furnace pressure with an increase in the rating, thereby avoiding the possibility of damage to the furnace walls.

Referring to the drawings illustrating one embodiment of my invention and in which like reference numerals indicate like parts,

Fig. 1 is a side elevation of a regulating system as applied to a steam boiler plant, the fuel being supplied to the furnaces by pulverizers of the unit type;

Fig. 2 is a plan view partly in section showing the arrangement of the pulverizers and burners above the boiler room floor;

Fig. 3 is a plan view partly in section showing the arrangement of the forced draft fans and air ducts in the basement;

Fig. 4 is a detail in section showing one of the fuel feeding devices, the section being taken on the line 4—4 of Fig. 5;

Fig. 5 is an elevation of the fuel feeding device, with parts broken away for clearness of illustration; and

Fig. 6 is a vertical section showing in detail the construction of the variable draft connection to the furnace pressure regulator.

In the embodiment of the invention illustrated in the drawings, I have shown a pair of steam generating furnaces arranged to burn pulverized coal, each comprising a combustion chamber 10 and a boiler 11, and each boiler being connected by a pipe 12 to a main steam header 14 (Fig. 1), which may lead to a steam turbine or other apparatus arranged to use the steam. In order to supply pulverized fuel for combustion in the furnaces, I have shown four unit type pulverizers 15, each connected by a pipe 16 with a suitable burner 18 mounted on the furnace wall. The pulverizers may be of any construction which will pulverize the fuel to a sufficient degree of fineness and deliver it on a current of air to the furnace. One such

construction is disclosed in the patent to Andrews No. 1,646,720. Each pulverizer may be driven by a direct connected constant speed motor or turbine 19 (Fig. 2). The burners 18 may be of various constructions within the scope of my invention, but I prefer to utilize burners of the type which deliver the entire secondary air supply to the furnace together with the pulverized fuel and primary air, one suitable construction being disclosed in the patent to Couch No. 1,532,041.

Secondary air may be supplied to the burners 18 through branch ducts 20 leading from a main duct 22, which is shown as located in the basement below the boiler room floor. One or more forced draft fans 23 (two being shown) are arranged to discharge into the main duct. The fans may be driven by direct connected motors or turbines 24, preferably of the constant speed type.

Coarse fuel, such as bituminous coal, is supplied from an overhead bunker 26 through downspouts 27 leading to the hoppers 28 of the pulverizer feeders 30. The coal is then pulverized and delivered to the furnaces 10, together with a supply of secondary air furnished by the fans 23. Combustion is completed in the furnaces, and the products of combustion pass through the boilers 11, thereby generating steam, and are discharged through uptakes 31 into a breeching 32 which leads to a stack (not shown).

In order to maintain the steam pressure substantially uniform, I control the rate of fuel and air flow into the furnace in accordance with the demand for steam. As an indication of the demand I prefer to use the pressure in the main header 14, and I permit a slight variation in the pressure for purposes of regulation. For example, I may provide for a pressure of 400 pounds per square inch at the lowest rating, and allow this pressure to drop to 390 pounds at the highest rating, thereby establishing an operating range of 10 pounds. In order to make use of this pressure change for regulation, I provide a suitable regulating device 35, which is connected by a small pipe 36 to the header 14 and which is preferably of the compensating type having a hydraulic piston arranged to move in accordance with the steam pressure variations. In the example mentioned, the regulator would be adjusted to make a full stroke throughout the 10 pound operating range, taking one extreme position at 400 pounds, the other extreme position at 390 pounds, and a corresponding intermediate position for any intermediate pressure. With such a construction the regulator floats with the pressure. A slight increase in the demand is accompanied by a correspondingly slight increase in the rate of combustion, and sudden extreme fluctuations in fuel feed with the resulting inefficiency are avoided. It is not considered necessary to illustrate the detailed construction of the regulator 35, since a number of suitable devices are in commercial use, and one satisfactory regulator is disclosed in my prior Patent No. 1,653,324.

For the purpose of controlling the air supply to the burners by means of the steam pressure regulator 35, I provide a shaft 37 rotatably mounted in bearings 39 and having an arm 40 which is connected by a link 41 to the piston rod of the regulator. The shaft 37 carries four arms 43, each connected by a link 44 to the arm 45 of a damper 47 in each branch duct 20. With this construction the dampers 47 assume a definite position for each steam pressure within the operating range. However, a definite damper position does not necessarily provide a definite air flow, since the air flow is dependent upon the main duct pressure as well as the damper position. Hence, in order to obtain the results desired I maintain a constant air pressure in the duct 22 which is high enough to supply all the burners with the necessary air at the maximum combustion rate. The pressure maintained will depend upon the design of the particular burner used.

The pressure in duct 22 may be maintained at the desired point by means of a regulator 50 connected to the duct by a pipe 51. This regulator is preferably of the non-compensating type utilizing a hydraulic piston, one suitable construction being disclosed in my prior Patent No. 1,596,031. However, any suitable regulator which is sufficiently sensitive may be used. The regulator 50 may be arranged to control the duct pressure by means of chronometer valves or rheostats which vary the speed of the turbines or motors driving the fans 23. However, this method of regulation has disadvantages in that the fans ordinarily will not change their speed quickly enough for the best results. In the preferred embodiment illustrated, I operate the fans at a constant speed and control the duct pressure by means of dampers 52 located at the fan outlets. Each of these dampers has an arm 54 connected by a link 55 to an arm 56. The arms 56 are carried on a shaft 58 which is rotatably mounted in bearings 59, and which is provided with a quadrant 60 connected by means of a cable 62 to the regulator 50. The shaft 58 also carries a second quadrant 63, connected by a cable 64 to a weight 65, which tends to rotate the shaft in a clockwise direction in Fig. 1, and this maintains the cable 62 under tension at all times.

For satisfactory operation it is necessary to maintain the rate of fuel feed at all times in exact accord with the rate of air flow. For this purpose I connect the piston rod of

the steam pressure regulator 35 by means of a link 67 to an arm 68 on a shaft 69 rotatably mounted in bearings 70. The shaft 69 carries four arms 72, each connected by means of a link 73 to an arm 74 on one of the pulverizer feeders 30. With this arrangement, all of the fuel feeders 30 and all of the secondary air dampers 47 are controlled by the same regulator, and therefore always move together in exact synchronism.

Various types of fuel feeders may be used to deliver the coarse fuel to the pulverizers at regulatable rates, one suitable construction being shown somewhat diagrammatically in Figs. 4 and 5. As illustrated, the hopper 28 of each feeder is mounted above a horizontal disc shaped table 76 which is rotated about a vertical axis by means of a shaft 77 driven by a worm 78 and worm gear 79. The worm 78 may be rotated at a constant speed in any suitable manner, and preferably from the shaft of the pulverizer. The hopper 28 has an opening 81 in its lower portion, and an adjustable knife or scraper 82 is arranged adjacent to this opening and close to the surface of the table to sweep coal therefrom into a chute 83 leading to the pulverizing chamber. An agitator 85 is mounted within the hopper and arranged to rotate with the table, in order to prevent bridging of the coal in the hopper.

In order to permit adjustment of the feeding rate, the knife 82 is threaded to a rod 86 which is rotatably and slidably mounted in bearings 87 in the feeder housing. A second rod 89 is slidably mounted parallel to the rod 86 in bearings 90, and is connected to the other rod by a yoke 91 so constructed that rod 86 is free to rotate therein but cannot slide relative thereto. The lever arm 74 is pivotally mounted on the feeder housing, and is provided in its lower portion with a slot 93, the sides of which engage a screw or pin 94 mounted on the rod 89. As the lever 74 is moved about its pivot by the steam pressure regulator 35, the two rods slide lengthwise in their bearings, and the fuel feeding knife 82 is adjusted accordingly. By means of a handwheel 95 mounted on the rod 86, this rod may be rotated manually, thus sliding the knife relative to the rods, and permitting a convenient adjustment of the fuel to air ratio. Once this adjustment is correctly made it need not be changed so long as the fuel remains uniform.

In addition to the fuel and air control, I preferably control the pressure in each combustion chamber by regulating the discharge of the products of combustion therefrom. This is ordinarily accomplished by providing a damper 97 in each uptake 31. Each damper shaft carries a quadrant 98 connected by means of a cable 99 to a weight 100, and a second quadrant 102 connected by means of a cable 103 to a regulator 104. A pipe 105 leads from the interior of each combustion chamber to the corresponding regulator. The regulators may be of any suitable type, one such construction being disclosed in my prior Patent No. 1,596,031. If desired the regulators 104 may be the same as regulator 50, except that the furnace pressure regulators should be adjusted to maintain a pressure slightly below atmospheric instead of the positive pressure required in the main duct 22, and in many installations the maintenance of a constant furnace pressure in this manner will prove entirely satisfactory.

However, in cases where it is frequently necessary to attain extremely high rates of combustion, I prefer to alter slightly the construction shown in my prior patent to provide a furnace pressure which will vary inversely with the demands on the boiler and decrease as the combustion rate increases, thereby protecting the refractory walls of the furnace from damage. For this purpose I may automatically change the adjustment of the regulator in accordance with variations in demand in the manner shown in Fig. 6. As illustrated, the chain 107, which corresponds to the chain 43 in my prior patent, is connected at one end to a vertically movable weight 108, instead of being connected to the stationary cylinder of the regulator as in the patented construction. The other end of the chain is supported by the lever 109, this and all other parts being the same as in the patent.

Each weight 108 is connected by a cable 111 to an arm 112 on the shaft 69. As the shaft is turned about its axis by the regulator 35 in response to load variations, the cable 111 moves the weight 108 up or down as the case may be. This raises or lowers that end of the chain 107 which is attached to the weight, and thereby varies the proportion of the chain which is supported by the lever 109. As a result, the adjustment of the regulator is changed, the same as would be the case if weight 38 in my prior patent were moved along the lever, and the regulator piston 114 will, therefore, move the damper 97 until the furnace pressure has reached the desired value. These parts are so arranged that upon a decrease in steam pressure, the weight 108 will be lowered, causing more of the chain to be supported by the lever 109. This will move the regulator valve, and the piston 114 will then travel upwardly, thereby opening the damper 97 slightly and lowering the furnace pressure to a desired point. The regulator will maintain this new furnace pressure so long as the rating remains constant. As an example of furnace pressures which I have found suitable in certain instances, I may so adjust the various pieces of apparatus as to maintain the draft at .05 of an inch of

water at the minimum rating, and gradually increase this draft to .15 of an inch at the maximum rating.

The operation of the regulating system will now be apparent from the above disclosure. The regulator 35 serves to adjust the fuel feeders 30 and the secondary air dampers 47 in exact accordance with the steam pressure within the operating range, increasing the fuel and air slightly with a slight increase in demand, and decreasing the fuel and air slightly whenever the load is slightly reduced. The regulator 50 operates dampers 52 to maintain a constant and predetermined air pressure in the main duct 22 regardless of the rating, and this insures a constant and predetermined air flow to the burners for every setting of the dampers 47. The rates of fuel and air flow are thus controlled in exact synchronism, and efficient combustion is always obtained. The regulators 104 operate the dampers 97 to maintain a desired and predetermined furnace pressure for each rating, and this pressure decreases as the rating increases, thus preventing both over-heating of the furnace walls and infiltration of excess air.

It will be understood that the present invention can be used not only with steam generating boilers but also with boilers arranged to produce various other vapors, and the word "steam" in the claims is to be given an interpretation consistent with this statement. It will also be understood that it is possible to make use of the rate of steam flow as an indication of the demand on the boiler, as well as using the steam pressure for this purpose.

Having thus described my invention, what I claim as new and desire to secure by Letters Patents is:—

1. In combination with a plurality of steam boiler furnaces, means including regulatable feeding devices to deliver a controlled amount of pulverized fuel on a current of primary air to each furnace for combustion, a main air duct for secondary air, branch ducts leading from the main duct to each furnace, a movable damper in each branch duct, a plurality of fans arranged to discharge air into the main duct, a damper at the outlet of each fan, a compensating type regulator actuated by steam pressure and arranged to regulate simultaneously all of the feeding devices and all of the branch duct dampers in accordance with the demand on the boilers, and a non-compensating type regulator actuated by the pressure in the main duct and arranged to regulate all the fan outlet dampers and maintain this duct pressure constant.

2. In combination with a plurality of steam boiler furnaces, means including regulatable feeding devices to deliver a controlled amount of pulverized fuel on a current of primary air to each furnace for combustion, a main air duct for secondary air, branch ducts leading from the main duct to each furnace, a movable damper in each branch duct, a plurality of fans arranged to discharge air into the main duct, a damper at the outlet of each fan, a compensating type regulator actuated by steam pressure and arranged to regulate simultaneously all of the feeding devices and all of the branch duct dampers in accordance with the demand on the boilers, a non-compensating type regulator actuated by the pressure in the main duct and arranged to regulate all the fan outlet dampers and maintain this main duct pressure constant, a damper located at the outlet of each furnace to control the discharge of the products of combustion therefrom, and a non-compensating type regulator actuated by the pressure in each furnace and arranged to regulate each furnace outlet damper.

3. The method of operating a steam boiler furnace fired with pulverized fuel and air comprising the steps of maintaining a substantially uniform supply of primary air for transporting the fuel to the furnace, regulating the amount of fuel fed to and transported by the primary air in accordance with the demand on the boiler but without varying the supply of primary air and automatically regulating a supply of secondary air to the furnace so as to furnish the correct proportion of air for combustion as the fuel feed is varied.

4. The method of operating a steam boiler furnace fired with finely divided fuel comprising the steps of transporting the fuel to a burner on a current of primary air, regulating the supply of fuel carried by the primary air in accordance with the demand on the boiler, maintaining a supply of air in a secondary air duct, automatically regulating its pressure so that it will be substantially uniform irrespective of the amount withdrawn, and feeding secondary air from the duct to the furnace in accordance with the demand on the boiler, so as to vary the secondary air with the fuel supply and maintain a correct proportion of air and fuel at all times,

5. The method of operating a combustion system having a steam boiler furnace fired with pulverized fuel fed with primary air from a pulverizer to a burner, comprising the steps of regulating the rate of feed of fuel to the pulverizer in accordance with the demand on the boiler, maintaining a sufficient flow of primary air to transport the fuel from the pulverizer to the burner, maintaining a supply of secondary air in a damper controlled conduit leading to the furnace, automatically regulating the supply thereof so as to provide a substantially

constant pressure in the conduit in advance of the damper irrespective of the rate of withdrawal, and regulating the damper position in accordance with the demand on the boiler.

Signed at Decatur, Illinois, this first day of May 1929.

CHARLES M. TERRY.