To all whom it may concern:

Be it known that I, John M. Hopwood, residing at Dormont, in the county of Allegheny and State of Pennsylvania, a citizen of the United States, have invented or discovered certain new and useful Improvements in Controlling Combustion by Flow and Pressure, of which improvements the following is a specification.

The invention described herein relates to a method of regulating the operations involved in the combustion of fuel for the purpose of generating steam or other gaseous products and consists generally stated in controlling the flow of products of combustion from the point of combustion of fuel, which may be of any desired kind, and regulating the feed of fuel to the point of combustion by and in accordance with variations in the static pressure or variations in dynamic pressures brought about by changes in the rate of flow of the steam or other gaseous products from the generator and regulating the flow of air to support combustion by and in accordance with the pressure of gases posterior to the point of combustion. This invention is of especial advantage in operating a plurality of boilers where all the steam generated in the several units flows into and through a common conduit from which it may pass to one or more points of use and where the stoking mechanisms are operated either individually or collectively, for the reason that there will be instant and simultaneous response by all the boilers discharging into the common conduit to the slightest variations in the demand for steam without waiting for changes in pressure brought about by the change in demand by regulating the supply of fuel in accordance with the demand, the supply of air being also regulated to maintain uniform furnace and fuel bed conditions at all rates of combustion so that if steam flow and pressure remain constant but changes occur in the fuel bed, the air supply and pressure will be regulated in accordance with the thickness and density of the fuel bed, the density being determined by the character of the fuel being employed, whereby a uniform rate of combustion will be maintained in all furnaces. The invention is hereinafter more fully described and claimed.

In the accompanying drawings forming a part of this specification, Figure 1 is a view partly in section and partly in elevation of a steam generating unit and apparatus for controlling combustion combined therewith, Fig. 2 is a similar view showing the controlling mechanism combined with a plurality of generating units. Fig. 3 is a view partly in section and partly in elevation of the preferred construction of regulating mechanism employed for carrying out the invention described herein, and Fig. 4 is a sectional plan view on a plane indicated by the line IV—IV, Fig. 3.

The mechanism employed for controlling the several operations hereinafter described is substantially similar to that shown and described in application Serial Number 254,975, filed September 20, 1918, and consists generally stated of two diaphragm motors, one adapted to be operated by and in accordance with variations in the differences between the static and dynamic pressures due to the flow of steam from the boiler A and the other by and in accordance with changes from a normal predetermined working pressure of the steam in the generator. The connections to the diaphragm motors from the outlet pipe C which may extend from a single unit as shown in Fig. 1 or be connected to a plurality of units as shown in Fig. 2 are formed by the pipes 11 and 12. In order to utilize the variations in the rate of flow and pressure of the steam of fluid for shifting the stack damper or dampers as herein described, it is preferred to employ an apparatus shown in Figs. 3 and 4, embodying two diaphragms, one shiftable by variations in the dynamic pressure of a flow of steam from one or more boilers and the other by variations of the static pressure only. Diaphragms are arranged intermediate a cap piece 2 preferably formed integral with the bed plate mechanism, and a shell 4, the diaphragms being spaced a suitable distance apart by an annulus 5. Each diaphragm preferably consists of two flexible members 7 and 8 spaced a suitable distance apart by a ring 6, a central transmitting block 9 which is arranged between the flexible members and a series of independently movable rings 10 arranged between the block and the spacing ring 6.

The chamber above the upper diaphragm is so connected by a pipe 11 to a pipe or conduit C connected to one or more boilers so that the upper side of the diaphragm will be subjected to static pressure modified by
the dynamic pressure of the steam flowing from the boiler or boilers while the chamber intermediate the diaphragms is so connected by a pipe 12 to the pipe or conduit that a pressure equal to and varying with the static pressure of the fluid in the pipe or conduit will be maintained therein. The underside of the lower diaphragm will be subjected to a constant pressure substantially equal to the normal working static pressure of the fluid in the pipe or conduit as desired in the boiler or boilers. This pressure is applied through a fluid cushion formed in the shell 4 in which is placed an inverted cup 13 and the shell filled with a suitable liquid. In charging the shell with liquid, air will be entrapped in the cup, thereby forming a resilient cushion operating on the underside of the lower diaphragm. In order that the desired working pressure may be established in the shell, the pipe 12 which is in communication, as shown in Fig. 1, with the outlet pipe of the boiler or boilers, is connected by a valved branch pipe 14 to the interior of the shell. As soon as the desired pressure has been established in the shell, the valve of the branch 14 is closed so that thereafter the underside of the under diaphragm will be subjected to a constant but yielding pressure substantially equal to the normal working pressure in the conduit or boiler. The blocks 9 of the diaphragms are operatively connected to the respective levers 15 and 16 by rods 15a and 16a, as shown and described in the patent above referred to and also shown in Fig. 4.

As in the construction described, the upper diaphragm is subjected on both sides to the same static pressure as in the pipe or conduit C. Any changes in such pressure will not have any effect thereon, but as the pressure on the upper side is the static pressure plus or minus the dynamic pressure dependent on the arrangement of the Pitot tube in the pipe C, any change in the rate of flow of the steam in the pipe C will cause an incremental movement of the diaphragm proportional to such change in flow. Hence by connecting the lever 15 by a rod 17 to a suitable indicating and recording mechanism 18, an efficient flow meter is formed.

The lever 15 is connected by a rod 19 to a frame 20 pivotally mounted at a and in the frame is mounted a shaft 21 provided with arms 22 and 23. The arm 22 extends toward the pivotal point of the frame and is connected to a stem 24 of the movable member of the valve mechanism 25, which is preferably of the construction shown in section to the right in Fig. 3. The arm 23 is connected at a point adjacent to its upper end to a swinging member 26 by a link 27, so that when the frame 20 is rocked the arm 22 will be moved with it, thereby shifting the valve to admit steam to the upper or lower end of a cylinder 28 to raise or lower the piston of such cylinder and with it the frame 29 at its opposite ends by cross bars to the piston rod 30. On the frame is secured a block 31 on which is adjustably mounted a bar 32 which can be shifted by suitable mechanism to any desired angle with the axis of the cylinder 30. On this rod is slidably mounted a shoe 33 pivotally connected to the upper end of the swinging member 26 which is pivotally mounted at its lower end. When, by the shifting of the movable member of the valve mechanism 25, the frame 29 is moved up or down, the rod 32 will be caused to slide along the shoe and thereby shift the upper end of the swinging member 26 an amount proportional to the angle of the rod or bar 32 to the axis of the cylinder. By this movement of the swinging member the arm 23 is shifted and by it the arm 22, in a direction opposite to that of the previous movement of the frame 20, thereby closing the valve without any movement of the frame. This operation is repeated, i.e., the valve 25 opened in one direction or the other by a movement of the upper diaphragm due to variations in the rate of flow and by a partial movement of the piston of cylinder 28 following such opening of the valve 25, the valve is again closed by the movement of the swinging member 26.

The changes in the rate of flow of products of combustion to the stack will produce a change in the pressure of the gases or products of combustion in the fire box 62 of the boiler. These variations of pressure are employed to operate a mechanism similar to that described and shown in the application above referred to to shift the pilot valve 47 controlling the flow of fluid pressure to a cylinder 50 which has its piston connected to a frame 48. This frame is connected by a cord 60 or other suitable means to the damper or valve 61 in the conduit 70 for conducting air under pressure to the underside of the bed of fuel in the furnace 62. Hence any changes of pressure of gases in the furnace will effect a change in the rate of flow of air to the furnace, such rate of flow being decreased as the pressure in the furnace rises and vice versa.

The mechanism operative by changes in furnace pressure embodies a lever 35 having secured to its ends inverted cups 36 and 37 which are immersed to a suitable extent in liquid contained in a tank 38, having a removable cover 39. A pipe or tube 40 leading from the fire box of the boiler is connected to a nozzle 41 projecting up into one of the cups, as 36, and as the lower end of the inverted cup is sealed by the liquid, any changes of pressure in the furnace will cause a corresponding shifting of the lever 35.
The cup 37 is employed more as a dash pot to prevent sudden movements of the lever and the latter is provided with weights 42 adjustably mounted on a rod 43. To the shaft of the lever 25 is secured an arm 44 having its outer end connected by a link 45 to the frame 46, similar in construction and operation to the frame 20 and adapted to shift a pilot valve 47 which in turn controls the admission of fluid pressure to a cylinder 50 having its piston rod 49 connected to a frame 48. In the construction shown to the right in Fig. 3 and employed as shown in Figs. 1 and 2 for controlling the shifting of the air feeding mechanism by and in accordance with furnace pressure, the swinging member 51 is mounted on a fixed pivot pin 52 at its lower end and is connected by a link 53 to an arm 54 of the rocking shaft 20 to which is also provided with an arm 56 connected to the stem of the pilot valve. On the frame 48 is secured a block 57 having a bar 58 so supported thereon as to be angularly adjustable with reference to the ends of the cylinder, and on said rod is slidably mounted a shoe 59 pivotally connected to the upper end of the swinging member 51. The operation of this mechanism is controlled by variations in furnace pressure and its movements are incremental and proportional to such changes of pressure.

The feed of fuel is controlled by and in accordance with variations in the rate of flow of steam through a pipe or conduit and variations from the normal working or static pressure of the steam. While the construction and arrangement of stoking mechanism and stoking regulating mechanism herein shown will be generally preferred, it will be apparent to those skilled in the art that other forms and constructions of stoking and regulating mechanisms known in the art can be readily adapted for use in the practice of the method claimed herein.

In the shown construction, the feed of fuel to the furnace is controlled by a roto-reciprocating valve mechanism 67 shown and described in the application above referred to and also in Letters Patent to F. H. Brown, No. 1,094,116, dated April 21st, 1914. The movable member of this valve mechanism is shifted longitudinally by a lever 66 or other suitable means operative by the frame 29. In the mechanism shown, this lever is connected to a cord 69 extending from the frame and passing around suitable guide pulleys. The movements of the roto-reciprocating valve are synchronous with the shifting of the valve or damper in the outlet to the stack and by the movements of this valve mechanism the flow of fluid pressure through the pipe 65 to the motors of the stoking mechanism is controlled.

It is also characteristic of the method carried out by the automatic operation of the mechanism shown in Fig. 1 that the rate of flow of products of combustion from the stack and the feed of fuel to the furnace are incrementally increased or decreased by and in accordance with variations in the differences between the static and dynamic pressures of the flow of steam from the boiler and also by changes from the normal working pressure of steam in the boiler and that the flow of air to the furnace for supporting combustion is automatically increased or decreased incrementally by and in accordance with changes of pressure in the furnace of the boiler, such changes being controlled as before stated by the valve or damper in the outlet to the stack. And it is further characteristic of the improvement that supply and pressure of the air for combustion is automatically varied in accordance with changes in the thickness and density of the bed of fuel.

It is also characteristic of the invention described herein that the mechanisms controlling combustion such as the stack damper, stoking mechanism, and devices controlling the feed of air, will be adjusted directly or indirectly to increase combustion both by an increase in the rate of flow and by a drop in static pressure, while an increase of static pressure and a decrease in the rate of flow each of them bring about a reduction of combustion.

In Fig. 2 the method shown in Fig. 1 and hereinbefore described is shown as applied to a plurality of boiler units. The frame 29 is connected by a cord 57 or other suitable means to the valves or dampers 58—58a in the outlets for the products of combustion and roto-reciprocating valve 67 which is also operative as hereinbefore described by the frame 29 and has two connections one to the motor of the stoking mechanism of one of the furnaces 62 and the other to the motor of the stoking mechanism of the other furnace 62a so that both the flow of products of combustion through the outlet pipes to the stack and also the feed of fuel to the several furnaces is controlled by the flow of steam through the conduit C which is connected to the boilers of both units, the pipes 11 and 12 leading to the diaphragm motors controlling the pilot valve mechanism of the cylinder 28 being connected to this common conduit. Variations of pressure in the respective fire boxes are communicated, as hereinbefore described, to pilot valve mechanisms 47 (see Fig. 1) of independent controlling apparatus, and the frames 48 48a carried by the pistons in the cylinders 50 50a of such apparatus are connected respectively to valves or dampers 61—61a in the conduits 70—70a for conducting air to the undersides of the beds of fuel in the respective furnaces. It will be observed that in applying the method to a
plurality of units that the stack dampers and the stoking mechanisms of all the units composing a group are controlled or operated by and in accordance with changes in the differences between the static and the dynamic pressures in a steam of steam flowing through a conduit connected to all the units and by variations from the normal working pressure in the boiler but that the flow of air to the furnaces of the several units is controlled by the pressure of gases in the furnace of each of such units.

By regulating combustion by and in accordance with changes in flow, supplemented by changes in pressure, a very advantageous operating condition is brought about. With steam pressure normal, fuel and air will be fed to the furnace in proportion to the demand on the generator, and the products of combustion liberated from the furnace in like proportion.

Should the rate of combustion be such as to raise the steam pressure, this rate will be decreased, but sufficient coal and air will be fed to maintain the rate of flow constant. Should the demand on the boiler be increased, it will not be necessary to wait for a drop in the static pressure in order to feed the required amount of fuel and air, as the flow section of the regulator will immediately respond to the increased demand. A change in pressure either up or down, will however modify the regulation that the flow produces. Fluctuations in steam pressure are very undesirable especially in present day plants embodying large turbines, because a decrease in steam pressure causes a disproportionate increase in the quantity of steam required.

The methods and apparatus described herein have been designed to meet this present day practice. Wide and rapid fluctuations of steam pressure such as must take place when regulation from pressure is employed, are very detrimental to the efficiency of a plant, and the operation of the forced draft equipment, etc.

When installing mechanisms for the practice of the invention described herein, the position which the stack damper should occupy under normal working conditions is determined and the regulating mechanism is so adjusted that the predetermined or normal static pressure in the boiler will, operating through the regulating mechanism, hold the damper in such position. After such adjustment, variations in flow will cause a fluctuation of the piston of cylinder 28 from its normal position, the range of the fluctuation being proportional to the changes in the rate of flow of steam from the boiler. In case of a change in static pressure, the piston will assume another position and changes of flow will produce fluctuations of the piston relative to its new position. In other words, the field of movement of the piston due to changes of flow will be largely determined by the static pressure of the steam. In other words, when there are fluctuations in the rate of flow of vapor from the generator and also fluctuations in the static pressure of the vapor in the generator, the position of a part or element controlling one of the operations affecting combustion, as for example the stack damper, is regulated in accordance with variations in an effect due to dynamic or flow pressure and static pressure, and variable with changes in the dynamic or flow pressure and with changes in static pressure occurring in sequence or simultaneously.

When the rate of flow is constant, then changes in the position of a controlling part or element will follow changes in the static pressure and on the other hand when the static pressure is constant changes in the rate of flow will result in a shifting of said controlling part or element.

As is well known, the pressure of the steam and the rate of flow of steam from a boiler are the factors which determine the horse power developed by a boiler and hence it is characteristic of the invention described herein that regulation of combustion is effected in accordance with the horse power developed.

While the invention has been described and shown in connection with apparatus for the generation of steam, it will be apparent that the improvements can be used for controlling combustion with vapor generators generally.

I claim herein as my invention:

1. The method herein described for regulating combustion in the furnace of a generator of vapor which consists in controlling the discharge of products of combustion from the furnace and the feed of fuel to the furnace by and in accordance with changes in the rate of flow of vapor from the generator and changes in the normal static pressure of the steam and regulating the supply of air for combustion by and in accordance with changes of pressure of gases in the furnace.

2. The method herein described for regulating combustion in the furnace of a generator of vapor which consists in controlling the discharge of products of combustion from the furnace and the feed of fuel to the furnace by and in accordance with changes in the rate of flow of vapor from the generator and changes from the normal static pressure of the vapor and regulating the supply of air for combustion by and in accordance with the changes of pressure of gases in the furnace resulting from changes in the static and dynamic pressures of the vapor flowing from the boiler.

3. The method herein described which
consists in controlling the discharge of products of combustion from the furnaces of a plurality of generators of vapor and the feed of fuel to the said furnaces by and in accordance with the rate of flow of vapor from all the generators and in accordance with changes from the normal static pressure of such vapor and regulating the flow of air to each of said furnaces by and in accordance with the pressure of gases in the respective furnaces.

4. The method herein described for regulating combustion in furnaces of a plurality of vapor generators which consists in controlling the discharge of products of combustion from all of the furnaces and the feed of fuel to the same by and in accordance with the rate of flow of vapor from all the generators and in accordance with the changes from the normal static pressure of such vapor.

5. The combination of a generator for vapor having a furnace, a damper controlling the discharge of gases from the furnace of said generator, means for feeding fuel to the said furnace, mechanism operative by and in accordance with the dynamic and static pressures of vapor flowing from the generator for operating said damper and fuel feeding means, means for feeding air for combustion to said furnaces and means operative by and in accordance with the pressure of gases in the furnace for regulating the supply of air to the fuel proportional to changes in the dynamic and static pressures of steam flowing from the boiler.

6. The combination of a plurality of generators for vapor furnaces for said generators, dampers controlling the discharge of products of combustion from the several furnaces of said generators, means for feeding fuel to the several furnaces, means operative by and in accordance with the dynamic and static pressures of vapor flowing from all the generators for controlling the fuel feeding means, and means for feeding air to each furnace and means operative by and in accordance with the pressure of gases in the respective furnaces for regulating the air feeding means.

7. The method herein described for regulating combustion in the furnace of a generator of vapor which consists in utilizing the rate of flow of steam from the generator to control the feed of fuel to the furnace, and the discharge of the products of combustion from the furnace, and utilizing the changes in furnace pressure brought about by such control to admit air in quantities sufficient for combustion and at pressures necessary to penetrate the existing fuel bed.

8. The method herein described for regulating combustion in the furnace of a generator of vapor which consists in utilizing the rate of flow of vapor from and the pressure of steam in the generator to control the feed of fuel to the furnace and the discharge of products of combustion from the furnace and utilizing the changes in furnace pressure brought about by such control to admit the air in quantities sufficient for combustion and at pressures necessary to penetrate the existing fuel bed.

9. The method herein described for regulating combustion in the furnace of a vapor generator which consists in controlling a plurality of operations affecting combustion, such as flow of products of combustion from the furnace and the feed of fuel to the furnace and regulating the controlling means in the same direction by and in accordance with changes in the rate of flow of vapor from the generator and also by and in accordance with changes in the static pressure of vapor in the generator whereby a variation in the rate of flow of said vapor in one direction (up or down) will effect a similar regulation as a variation of static pressure in the opposite direction (down or up).

10. The method herein described for regulating combustion in the furnace of a vapor generator which consists in regulating the flow of products of combustion from the furnace of the generator and feed of fuel to the furnace of the generator in the same direction both by and in accordance with changes in the rate of flow of vapor from the generator and with changes in the static pressure of the vapor, whereby a variation in the rate of flow of vapor in one direction (up or down) will effect similar regulation as a variation of static pressure of the vapor in the opposite direction (down or up).

11. The combination of a vapor generator having a furnace with means for regulating a plurality of operations affecting combustion in the furnace and means operative to regulate the combustion controlling means in the same direction by and in accordance with changes in the rate of flow of vapor from the generator and with changes in the static pressure of the vapor, whereby a variation in the rate of flow of vapor in one direction (up or down) will effect similar regulation as a variation of static pressure in the opposite direction (down or up).

12. The method herein described for regulating combustion in a furnace of a vapor generator which consists in adjusting an operation involved in the generation of vapor by and in accordance with the static pressure of the vapor and varying such adjusted operation by and in accordance with the rate of flow of vapor from the boiler.

13. In a system comprising a furnace, a vapor generator, means for controlling the discharge of products of combustion from the furnace, a motor for shifting such means, and motor controlling means, the method of controlling the furnace op-
eration which consists in regulating the said motor controlling means by and in accordance with variations of an effect which results from the independent exerted action of variations in static pressure and variations of vapor flow from the generator.

14. The method of controlling a regulating mechanism of the furnace of a vapor generator comprising means for controlling the discharge of products of combustion from the furnace, a motor for shifting such means and a motor controlling means, which consists in regulating the operation of the motor controlling means by and in accordance with an effect resulting from the independent action of the static and dynamic pressures of vapor flowing from the generator.

15. The method of controlling a regulating mechanism of the furnace of a vapor generator comprising means for controlling the discharge of products of combustion from the furnace, a motor for shifting such means and a motor controlling means, which consists in regulating the operation of the motor controlling means by and in accordance with an effect resulting from the action of independent variations of the static and dynamic pressures of vapor flowing from the generator.

16. The method of controlling a regulating mechanism of the furnace of a vapor generator comprising means for controlling the discharge of products of combustion from the furnace, a motor for shifting such means, means for supplying air to the furnace and motor controlling means, which consists in regulating the variations of the motor controlling means by and in accordance with an effect resulting from the independent action of the static and dynamic pressures of vapor flowing from the generator and regulating the means for supplying air for combustion by and in accordance with changes of pressure of gases in the furnace.

17. In a system comprising a furnace, a vapor generator, means for controlling the discharge of products of combustion from the furnace, means for feeding fuel to the furnace, mechanisms for shifting such means and means for controlling such mechanism, the method of controlling the furnace operations which consists in regulating the means for controlling the mechanism by and in accordance with variations of an effect resulting from the independently exerted action of variations in the static pressure and variations in the rate of flow of the vapor flowing from the generator.

18. In a system comprising a furnace, a vapor generator, means for feeding fuel to the furnace, means for controlling the discharge of products of combustion from the furnace, means for feeding air to the furnace, mechanisms for shifting such several means, means controlling the mechanisms for regulating the discharge of products of combustion and the feed of fuel, the method of controlling the feed of fuel and discharge of products of combustion and the feed of fuel by and in accordance with variations of an effect which results from the independently exerted action of variations in static pressure and variations of the vapor flow from the generator and regulating the air feeding mechanisms by and in accordance with changes of pressure of gases in the furnace.

19. The method herein described of regulating the generation of heat in vapor generators which consists in operating the means employed for controlling the flow of products of combustion from the furnace of the generator by and in accordance with changes in the dynamic and static pressures of steam flowing from the generators.

In testimony whereof, I have hereunto set my hand.

JOHN M. HOPWOOD