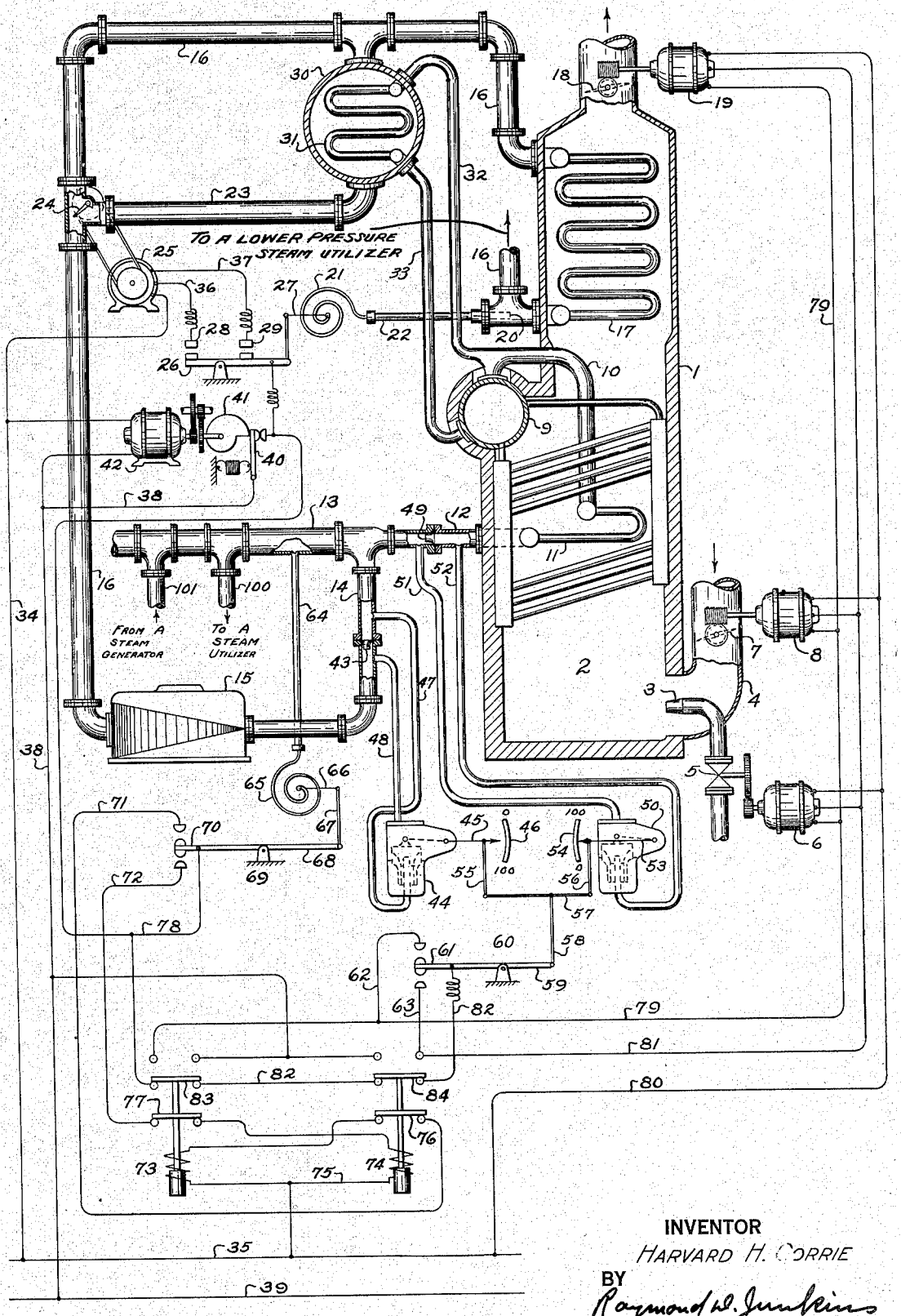
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CONTROL SYSTEM

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INVENTOR
HARVARD H. GORRIE
BY
Raymond W. Jenkins
ATTORNEY

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CONTROL SYSTEM

Harvard H. Gorrie, Cleveland Heights, Ohio, assignor to Bailey Meter Company, a corporation of Delaware

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My invention relates to control systems such as may be employed for the automatic control of certain variable factors or conditions in the operation of a power producing or using apparatus, and in particular it is concerned with the control of the feeding of the elements of combustion to a vapor generating or heating apparatus, as well as with the proportioning and heating of fluids in such an apparatus.

I have chosen to illustrate and will describe a preferred embodiment of my invention, in connection with a primary steam generating boiler adapted to utilize the waste products of combustion for heating the secondary steam exhausted from a primary steam utilizer and having provision for supplementing the heating of the secondary steam by means of primary steam.

One of the objects of the invention is to control the feeding of the elements of combustion to a vapor generating boiler, in proportion to the heat desired to be utilized from the waste products of combustion.

Another object is to utilize the heat contained in the waste products of combustion for reheating the vapor generated by the boiler after it has given up some of its heat content in a utilizing apparatus.

Still another object is to provide means for supplementing, by the heat of a part of the vapor generated, the waste heat of the products of combustion, where such waste heat is insufficient to reheat the vapor as desired.

A still further object is to control the feeding of the elements of combustion to a vapor generating boiler in accordance with a comparison between a measure of the flow of vapor from the vapor generator to a header, and a measure of the flow of vapor from the header to a utilizing apparatus.

With these and further objects in view, I will now describe the embodiment of my invention illustrated in the drawing, which is a somewhat diagrammatic representation of a steam generating boiler in sectional elevation, and to which the invention has been applied.

I have illustrated generally at 1 a steam generating boiler having a combustion chamber 2 supplied with fuel such as oil or gas, for example, through a burner 3, and with air for combustion through the conduit 4. The rate of admission of fuel to the furnace is controlled through the positioning of a valve 5 by a reversible means illustrated as a reversible electric motor 6. The rate of feed of air to the furnace as an element of combustion through the conduit 4 is controlled by the positioning of a damper 7 relatively across the conduit 4 by a reversible means illustrated as a reversible electric motor 8.

Heat liberated through combustion in the chamber 2, generates steam which collects in the drum 9, passes through the pipe 10 to a superheater 11, and is discharged through an outlet pipe 12 to a steam header 13. From the header 13 leads a branch 14 to a steam utilizing apparatus illustrated as a steam turbine 15. While in the practice of my invention it is not necessary that there be more than a single vapor generator and a single vapor utilizer. I have for the sake of clearness of understanding, shown a second branch 100 leading from the header 13 to a steam utilizer and a branch 101 joining the header 13 from a steam generator.

The steam exhausted from the turbine 15 is desirably reheated or supplied with additional heat after having passed through the turbine, so that it may be used in a second utilizing apparatus such as a lower pressure turbine (not shown), and passes to the second utilizing apparatus through a pipe 16, joining the turbine 15 at its exhaust end. In the pipe 16 is desirably placed a heater comprising a number of relatively smaller heating tubes 17, positioned at the outlet of the gas passage through the boiler 1 and subjected, in heat conducting relation, to the effect of the heat contained in the waste products of combustion leaving the boiler; the flow of the products of combustion being controlled by the positioning of a damper 18 by a reversible means illustrated as a reversible electric motor 19.

At the outlet of the heating tubes 17 and in the pipe 16, I preferably install a thermostatic bulb 20, forming a part of a gas-filled thermometer system of which 21 is a Bourdon tube, connected to the bulb 20 by a pipe 22; the bulb 20 sensitive to temperature of the reheated steam leaving the heater 17.

Between the turbine 15 and the heater 17 I have shown a bypass connection 23 to the pipe 16; the flow of steam through the bypass 23 being controlled by a valve means 24, positioned by a reversible means illustrated as a reversible electric motor 25. The motor 25 is under the control of fulcrumed contactor 26, positioned relative to contact points 28 and 29 through the departure from a predetermined temperature, of the indicator arm 27 attached to the Bourdon tube 21.

Inserted in the bypass line 23 is a heat exchanger 30 through which steam passes from the

pipe 16 and around the heating coils 31. The coils 31 are supplied with relatively higher temperature or primary steam from the boiler drum 9 through a pipe 32 and condensate from the heating coils 31 returns to the drum 9 through the pipe 33. There are no valves shown in the heating system comprising the pipe 32, the coils 31 and the pipe 33, so that flow therethrough is controlled entirely by the condensation of steam through heat transfer within the heater 31, the condensate returning through the pipe 33 to the boiler drum 9 through the gravity head of the difference in elevation between the heater 31 and the drum 9, the steam pressure being balanced between the two. It will be seen that primary steam for heating, is always available through the pipe 32 to the heating coils 31, and the amount of heat exchanged will depend upon the amount of lower heat content or secondary steam passed through the pipe 23 to the pipe 16, around the heating coils 31, which in its passage tends to cool the coils 31 and condense the steam within them.

Thus the heat which is added to the steam flowing through the pipe 16, prior to its reaching the heater 17, will depend upon the amount of said steam bypassed through the pipe 23 and thus upon the positioning of the valve 24. The positioning of the valve 24 has been shown to depend upon the temperature effective upon the bulb 20 of the thermostatically operated contactor 26, and the bulb 20 is sensitive to a temperature of the steam after it has passed the heater 17. Thus the steam passing through the heater 17 absorbs heat from the waste gaseous products of combustion passing from the boiler 1, and if the heat so transferred from the products of combustion is not sufficient to raise the temperature at the bulb 20 to a predetermined desirable point, then the variation of said temperature from a predetermined value will effect a positioning of the contactor arm 26 and correspondingly of the valve 24, to bypass a part of the steam through the pipe 23 and the heater 31.

I have illustrated the motor 25 as connected by a conductor 34 to the power line 35, and by a conductor 36 to the contact 28, and by a conductor 37 to the contact 29. The contact bar 26 is connected through a conductor 38 to the other power line 39. From the contact arm 26 I lead the conductor 38 through an interrupting finger 40, through whose agency the conductor 38 is periodically disconnected from the contact arm 26 by means of a cam 41 driven at desirable speed of rotation by a continuously operating motor 42 connected directly across the power lines 35 and 39 through the conductors 34, 38. Thus I have provided that the movement of the valve 24 will occur by intermittent operation of the motor 25 rather than a continuous operation of the same, to prevent overtravel and hunting.

In the embodiment here illustrated, all of the steam exhausted from the turbine 15 passes through the waste gas heater 17, and I desirably control the rate of combustion in the furnace 2, such that the heat available in the waste products of combustion will be in proportion to the rate of flow of the steam through the heater 17. With a constant rate of steam passing through the heater 17, if I allowed the combustion rate within the furnace 2 to decrease, then the steam passing through the heater would not be heated to the desired temperature; or if I allow the combustion rate within the furnace 2 to increase relative to the quantity of steam passing through the heater, then the steam will be heated to a higher temperature than desired.

The steam passing through the heater 17 from the pipe 16 is directly related to the load on the turbine 15, and is the same steam admitted to the turbine through the pipe 14, so that I may take as an indication of the steam passing through the heater 17, either an indication of the load on the turbine 15 or a measure of the steam flowing through the turbine, and have in the present illustration shown the invention as utilizing a measure of the steam passing to the turbine through the pipe 14. Inserted in the pipe 14 is shown a flow nozzle 43 as a means of causing a temporary increase in velocity of the steam, for producing a pressure differential bearing a known relation to the rate of flow of the steam through the pipe, and said pressure differential is made effective upon a steam flow measuring meter 44 to position a pointer 45 relative to an index 46. I lead to the flow meter 44 a pressure from the inlet side of the flow nozzle 43 through a pipe 47, and from the outlet side of the flow nozzle 43 through a pipe 48. The flow meter 44 is of a type well known in the art, having a liquid sealed bell adapted to be positioned vertically responsive to variations in a pressure transmitted through the pipe 47 and a pressure through the pipe 48 effective within and without the bell respectively, such vertical positioning producing angular movement of an indicating arm 45 relative to an index 46 in a clockwise direction of rotation for an increase in the rate of flow, the wall of the bell being so shaped as to translate the non-linear relation between rate of flow and differential pressure to a linear relation.

As an indication of the rate of operation or output of the boiler 1, I take a measure of the steam generated by the boiler and passed through the pipe 12 to the header 13. Inserted in the pipe 12 is shown a flow nozzle 49 for creating a pressure differential bearing a known relation to the rate of flow of steam therethrough, and said pressure differential is effective upon a flow meter 50 through the pressure pipes 51 and 52 for positioning an indicator 53 relative to an index 54. The flow meter 50 is similar to the flow meter 44 and is arranged in a manner such that an increase in rate of flow of steam through the pipe 12 causes the pointer 53 to move in a clockwise direction over the index 54.

By comparing the rate of flow of the steam from the boiler 1 with the rate of flow of steam to the turbine 15, I have a comparison of the operation of the boiler with the demand for such operation or demand for heat at the heater 17. I therefore desirably compare the position of the flow meter arm 45 with the flow meter arm 53 and upon a departure from desired relationship between the two, I cause to be effected a change in the rate of operation of the boiler. This is accomplished through the positioning of a contactor effective in varying the rate of supply of fuel and air to the combustion chamber 2, and the rate of discharge of the products of combustion from the boiler. From the pointer 45 is suspended a freely hanging link 55, and from the pointer 53 is suspended a freely hanging link 56. The links 55 and 56 at their lower ends are joined by a freely floating bar 57 from which is suspended, intermediate its ends, a rod 58 in a manner such that when the flow meters 44 and 50 indicate the same or desired proportional rate of flow, regardless of quantity, within the limits of their capacity, the rod 58 will not

be moved from its vertical position. If, however, the indications of the flow meters 44 and 50 vary from the desired proportionality, then the rod 58 will be positioned vertically either upward or downward, and in amount depending upon the deviation between the two flow meter readings. Such vertical positioning of the rod 58 serves to move in a clockwise or counter-clockwise rotation an arm 59 forming a part of a contactor device 60.

In the contactor device 60, the arm 59 has an extension 61 at the opposite side of a fulcrum, and when the arm 59 is moved from a predetermined position, the extension 61 may close circuit with a contact terminal of the conductor 62 or of the conductor 63.

While I have provided a control system tending to maintain the rate of operation of the boiler 1 proportional to the rate of operation of the turbine 15, I find it desirable that the pressure of the steam going to the turbine be of a predetermined value. To insure this, I have provided a further control of the elements of combustion to the boiler, sensitive to variations in pressure of the steam.

Connected to the header 13 is shown a pressure pipe 64 for transmitting pressure from within the pipe 13 to a Bourdon tube 65 which tends to unwind and move an arm 66 in a clockwise rotation for an increase in pressure, or in a counterclockwise rotation for a decrease in pressure. The arm 66 positions vertically a freely suspended link 67, resulting in an angular positioning of an arm 68 connected at its free end to the lower end of the link 67, and at its pivoted end effective to position an extension 70 of a contactor indicated generally at 69, of similar type to that illustrated at 60, to close circuit with either the contact terminal of the conductor 71 or of the conductor 72, depending upon the direction of departure of steam pressure within the pipe 13 from a predetermined value.

Closure of circuit at either of the contactors 60, 69 tends to cause a rotation of the motors 6, 8 and 19 for a varying of the rate of feed of fuel and air to the furnace 2, or of a throttling of the flow of products of combustion leaving the boiler. Positioned between the contactors and the motors mentioned I have shown two magnetic switches illustrated generally at 73 and 74, which serve the purpose of allowing precedence of one of the contactors over the other, at the same time preventing the possibility of energizing the motors simultaneously in opposite directions, or simultaneously from the two contactors.

The solenoid coils of the magnetic switches 73 and 74 have a neutral wire 75 joined to the power line 35. The switch 73 may be energized upon a closing of circuit between the contact arm 70 and the conductor 71, interlocked through switch points 76 of the switch 74. Similarly, the switch 74 may be energized upon closing of circuit by the contact arm 70 with the conductor 72, interlocked through the switch 73 at the switch points 77, the contact arm 70 being connected by conductors 78 and 38 to the other power line 39.

The conductor 78 joins the conductor 38 through the interrupting finger 40 previously described as periodically open circuited through rotation of the continuously driven cam 41. Thus any energization of the magnetic switches 73 or 74 through a closing of circuit by the contactor arm 70 with the conductor 71 or with the conductor 72 would be intermittent, depending upon the interrupting finger 40.

Upon energization of the switch 73, circuit is closed between the conductor 38 and a conductor 79 joining the three motors. A return conductor 80 leads from the three motors to the power line 35. Upon the energization of the switch 74, the conductor 38 is joined to a conductor 81, joining the three motors for an energization of same in the opposite rotation.

Contact of the arm 61 with the contact terminal of the conductor 62 closes circuit between the conductor 79 and a conductor 82 to the conductors 78, 38, and the power line 39. Contact of the arm 61 with the contact terminal of the conductor 63 closes circuit for the motors by the conductors 81, 63, contact arm 61, conductors 82, 78, 38 and the power line 39, the return from the motors being the conductor 80.

Positioned in the conductor 82 are the switch points 83 of the switch 73 and the switch points 84 of the switch 74, in a manner such that energization of either of the switches 73 or 74 will break the circuit of the wire 82 and prevent the energization or actuation of the motors through a positioning of the contactor arm 61.

Thus it will be seen that whenever the contact arm 70 of the contactor 69 contacts with the conductors 71 or 72 for an energizing of the switches 73 or 74, the circuit is broken to the contactor 60, making it ineffective and giving precedence to the contactor 69.

In operation, assume a constant load on the steam turbine, and consequently a constant rate of flow of steam through the pipe 14 as indicated by the flow meter 44, and that the rate of flow of steam through the pipe 12 to the header 13 is less than the amount taken by the turbine, so that a part of the steam passing to the turbine is supplied from the header 13. The waste products of combustion leaving the boiler 1 and available at the heater 17 will have a heating ability in proportion to the output of the boiler, and will be lower in proportion to the steam from the turbine flowing through the heater than necessary to raise the temperature of the steam to the predetermined value. Therefore it is desired that the rate of combustion at the boiler 1 be increased, and that the temperature of the steam leaving the heater 17 be brought up to the predetermined value. Two regulations are effected; namely, a bypassing of some of the steam flowing through the pipe 16, through the heater 30, and an increasing of the rate of combustion at the boiler.

Diverting a part of the exhaust steam through the heater 30 condenses some of the steam generated by the boiler 1, and the output through the pipe 12 is further reduced. The flow meter 50 indicates by a counterclockwise movement of the arm 53 a decrease in rate of flow through the flow nozzle 49, while the arm 45 of the flow meter 44 remains steady. The result is a downward positioning of the rod 58 and a closing of circuit by the contact arm 61 with the contact terminal of the conductor 62, to the end that upon the periodic rotation of the cam 41 an intermittent movement will be effected of the fuel supply valve 5, the air supply damper 7 and the exit damper 18 through intermittent energization of the corresponding motors 6, 8 and 19.

The lack of heating ability in the waste products of combustion at the heater 17 resulting in a temperature of the steam leaving the heater below the predetermined value, is effective upon the bulb 20 to produce a positioning of the contactor 26 for an operation of the motor 25 and

a positioning of the valve 24 in a direction to open for flow through the bypass 23 from the pipe 16 and divert more of the exhaust steam through the heater 30.

During the operation above described, whereby more or less of the exhaust steam is diverted through the heater 30 and whereby entirely independently the rate of combustion at the boiler 1 is increased or decreased, if at the same time the steam pressure within the header 13 increases or decreases relative to a predetermined value, the result is a positioning of the contactor 69 to effect a regulation of the motors 6, 8 and 19, taking precedence over the contactor 60.

In the event that all of the primary steam generated by the boiler 1 goes to the turbine 15 and no other steam from the header 13 goes to the turbine, the reading of flow by flow meters 44, 50 will be the same, and the contactor 60 will be open-circuited. If now the load on turbine 15 increases, calling for more steam, the pressure contactor 69 will cause an increase in rate of supply of the elements of combustion, whereby the steam flow through pipes 12 and 14 will increase and in the same amount.

It will be seen that I have a control system which, while illustrated and described in connection with a steam generating and heating apparatus, may be equally as well adapted to other similar apparatus, and I desire it to be distinctly understood that while I have illustrated and described a preferred embodiment of my invention, I do not intend to be limited thereby, other than as claimed in view of prior art.

The present application is a division of my copending application Serial No. 535,999, filed May 8, 1931, entitled Control systems.

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

1. In combination, a vapor generating boiler, means for supplying elements of combustion to the boiler, regulating means for said means, a header connected to the boiler and to which the generated vapor flows, a vapor utilizing apparatus connected to the header for utilizing vapor therefrom, a rate of flow meter for the vapor leaving the boiler, a second meter for the vapor going to the utilizing apparatus, flow ratio determining means adapted to be positioned by said meters, and control means for said regulating means responsive to a departure of said flow ratio determining means from a position indicative of predetermined ratio.

2. In combination, a vapor generating boiler, means for supplying elements of combustion to the boiler, regulating means for said means, a header connected to the boiler and to which the generated vapor flows, a vapor utilizing apparatus connected to the header for utilizing vapor therefrom, a rate of flow meter for the vapor leaving the boiler, a second meter for the vapor going to the utilizing apparatus, flow ratio determining means adapted to be positioned by said meters, control means for said regulating means responsive to a departure of said flow ratio determining means from a position indicative of predetermined ratio, and vapor pressure responsive means also effective upon said regulating means

3. In combination, a vapor generating boiler, means for supplying elements of combustion to the boiler, regulating means for said means, a header connected to the boiler and to which the generated vapor flows, a vapor utilizing apparatus connected to the header for utilizing vapor therefrom, a rate of flow meter for the vapor leaving the boiler, a second meter for the vapor going to the utilizing apparatus, flow ratio determining means adapted to be positioned by said meters, control means for said regulating means responsive to a departure of said flow ratio determining means from a position indicative of predetermined ratio, vapor pressure responsive means also effective upon said regulating means, and means for allowing said last named means to take precedence over said control means.

4. In combination, a vapor generating boiler, fuel and air supply means connected to said boiler for maintaining combustion, regulating means for said supplying means adapted to vary the rate of supply, a header connected to the boiler and to which the generated vapor flows, a vaper utilizing apparatus connected to the header for utilizing vapor therefrom, means positioned responsive to variations in the magnitude of the steam demand on the boiler, means positioned responsive to variations in the magnitude of the steam demand at the utilizing apparatus, and control means jointly positioned by said last two named means and adapted upon being positioned away from a predetermined position to effect an actuation of said regulating means.

5. In combination, a vapor generating boiler, fuel and air supplying means connected to said boiler for maintaining combustion, regulating means for said supplying means adapted to vary the rate of supply, a header connected to the boiler and to which the generated vapor flows, a vapor utilizing apparatus connected to the header for utilizing vapor therefrom, means positioned responsive to variations in the magnitude of the steam demand on the boiler, means positioned responsive to variations in the magnitude of the steam demand at the utilizing apparatus, control means jointly positioned by said last two named means and adapted upon being positioned away from a predetermined position to effect an actuation of said regulating means, and vapor pressure responsive means also adapted to effect an actuation of said regulating means.

6. In combination, a vapor generating boiler, fuel and air supplying means connected to said boiler for maintaining combustion, regulating means for said supplying means adapted to vary the rate of supply, a header connected to the boiler and to which the generated vapor flows, a vapor utilizing apparatus connected to the header for utilizing vapor therefrom, means positioned responsive to variations in the magnitude of the steam demand on the boiler, means positioned responsive to variations in the magnitude of the steam demand at the utilizing apparatus, control means jointly positioned by said last two named means and adapted upon being positioned away from a predetermined position to effect an actuation of said regulating means, vapor pressure responsive means also adapted to effect an actuation of said regulating means, and means for allowing said last named means to take precedence over said control means.

7. The method of controlling the supply of elements of combustion to a vapor generator supplying vapor to a plurailty of vapor utilizers through individual branch conduits connected to a common header comprising supplying elements of combustion to said generator in an amount sufficient to generate vapor at a rate to meet the full demands of all of said utilizers operating together, and varying the quantity of the elements of combustion supplied to the generator in accordance with the variations in the ratio between

the quantity of vapor flowing to the header from the generator and the quantity of vapor flowing in one of said branches existing, when all utilizers are operated under normal load.

8. In a control for a supply of elements of combustion for a burner, a vapor generating chamber, a header receiving vapor from the generator, a plurality of vapor utilizers, branches connecting the header with the utilizers and receiving vapor therefrom in sufficient quantity to meet the full demands of all of said utilizers, whereby a ratio is established between the vapor flowing to the header from the generator and the vapor flowing through one of said branches and means for varying the quantity of the elements of combustion supplied to the burner in accordance with the variations from the ratio between the quantity of vapor flowing to the header from the generator and the quantity of vapor flowing in one of said branches when the utilizers are operating under normal load.

9. In combination, a vapor generating boiler, means for supplying elements of combustion to the boiler, regulating means for said means, a header connected to the boiler into which the generated vapor flows, a vapor utilizing apparatus connected to the header for utilizing vapor therefrom, a rate of flow meter for the vapor leaving the boiler, a second meter for the vapor going to the utilizing apparatus, flow ratio determining means adapted to be positioned by said meters, and control means for said regulating means responsive to said flow ratio determining means.

10. In combination, a vapor generating boiler, means for supplying elements of combustion to the boiler, regulating means for said means, a header connected to the boiler into which the generated vapor flows, a vapor utilizing apparatus connected to the header for utilizing vapor therefrom, a rate of flow meter for the vapor leaving the boiler, a second meter for the vapor going to the utilizing apparatus, flow ratio determining means adapted to be positioned by said meters, control means for said regulating means responsive to said ratio determining means, and vapor pressure responsive means also effective upon said regulating means.

HARVARD H. GORRIE.