

Feb. 17, 1942.

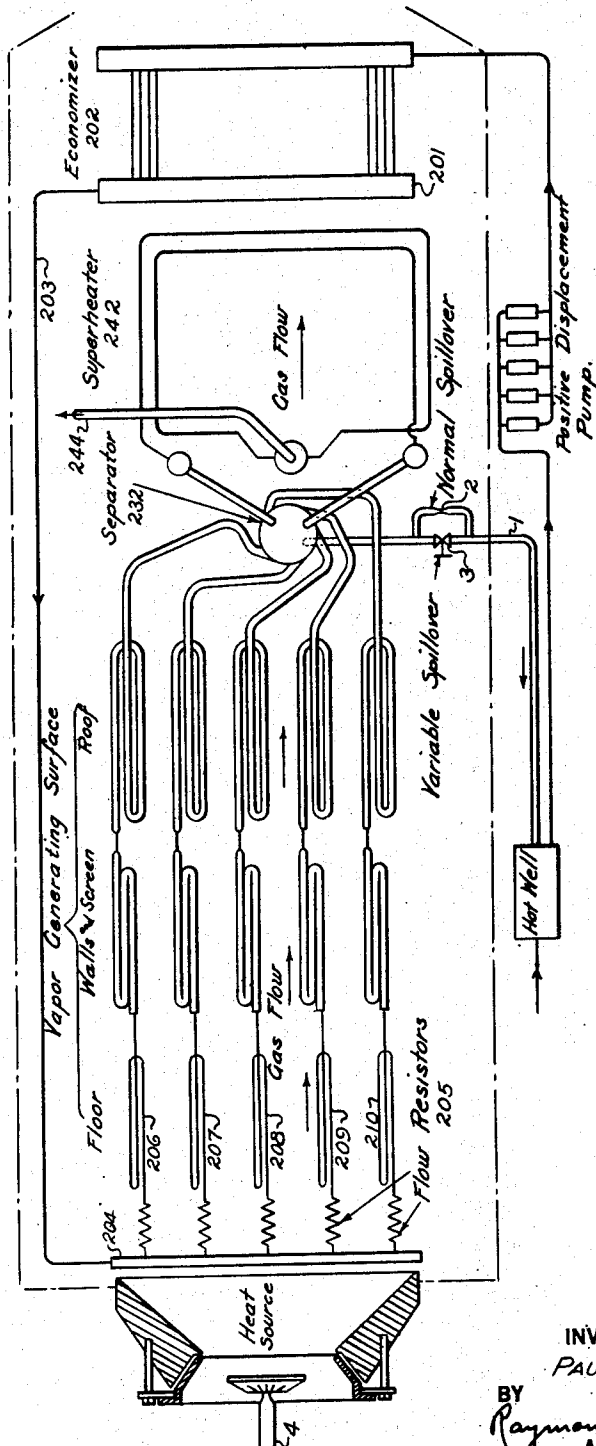
P. S. DICKEY

2,273,629

CONTROL SYSTEM

Original Filed Dec. 18, 1935

3 Sheets-Sheet 1



INVENTOR
PAUL S. DICKEY
BY
Raymond W. Jenkins
ATTORNEY

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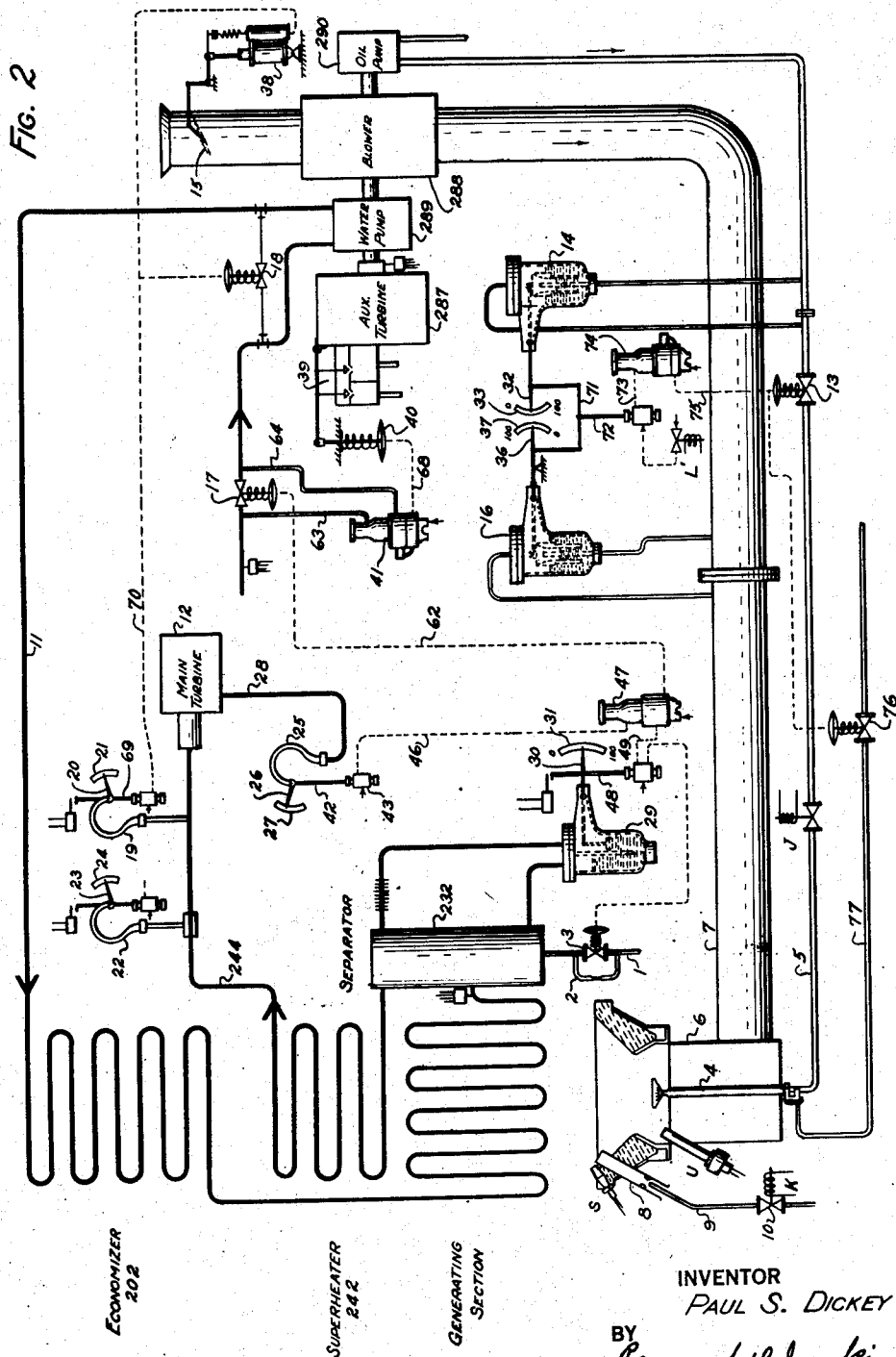
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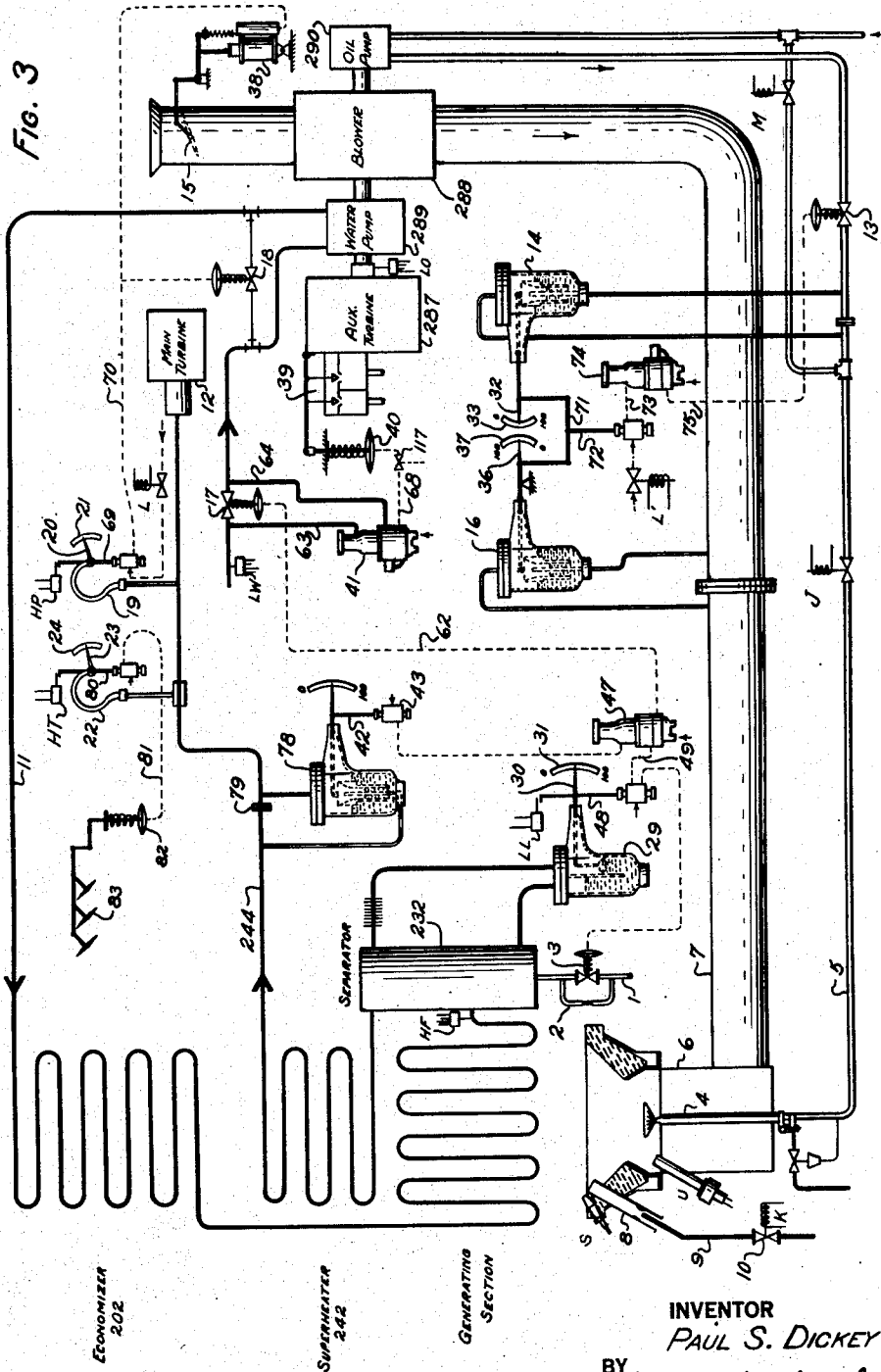
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INVENTOR
PAUL S. DICKEY
BY *Raymond W. Jenkins*
ATTORNEY

UNITED STATES PATENT OFFICE

2,273,629

CONTROL SYSTEM

Paul S. Dickey, Cleveland, Ohio, assignor to
Bailey Meter Company, a corporation of Delaware

Original application December 18, 1935, Serial
No. 55,023. Divided and this application April
16, 1938, Serial No. 202,381

1 Claim. (Cl. 122-448)

This invention relates to means for operating and controlling the operation of vapor generators; particularly vapor generators of the drumless, forced flow type, having a fluid flow path including one or more long small-bore tubes, in which the flow in the path is initiated by the entrance of liquid under pressure at one end, and the exit of vapor only at the other end; characterized by an inflow of liquid normally greater than the outflow of vapor, the difference being diverted from the path intermediate the ends thereof.

Such a vapor generator having small liquid storage and operated with wide range combustion devices forms a combination rendering practical extremely high heat release rates with the consequent ability to economically handle practically instantaneous load changes from minimum to maximum, and vice versa, without heavy standby expense, and is particularly suitable for operating conditions such as locomotive service, where load variations are of a wide range and are required to be met substantially instantaneously.

The generator has a minimum liquid storage capacity with a maximum heat absorbing surface so disposed and arranged as to be substantially instantaneously responsive to rapid changes and wide diversities in heat release rate in the furnace. The heat absorbing surface is arranged in relation to the path of the products of combustion and radiant heating so that the entering liquid is received at the cooler end of the path. Further, the vapor generator insofar as the passage of combustion gases is concerned has a continuously increasing resistance to gas flow throughout the length of the passage.

The heat absorbing surface, or flow path for the working medium, is comprised of one or more long small-bore tubes with an enlargement, preferably at the end of the generating section, which acts as a separator to divide liquid and vapor. The vapor is then passed through a superheater, while the excess liquid carried through the tubes for the purpose of wetness and preventing scale deposit, is diverted out of the separator under regulated conditions, as will be hereinafter set forth. From the separator there is a normal continuous and an additional regulated spillover or diversion of a part of the liquid entering the economizer under pressure, so that there is always being fed to and through the economizer and vapor generating sections more liquid than can be converted into vapor in a single passage therethrough, although the pro-

portion of such excess liquid represents but a small part of the total volume of fluid passing through the vapor generator and is at most times only sufficient to insure tube wetness and to carry off scale forming material.

In vapor generators of the character mentioned having small liquid and heat storage with high heat release capabilities, the liquid inflow must of necessity be continuous and at all times proportioned to the vapor outflow, at the same time taking into account the desired diversion of excess liquid from the flow path. Furthermore to accomplish the wide range in heat release with substantially instantaneous response and to perform the combustion process efficiently, a method and means for operating such a vapor generator in accordance with varying conditions must be provided.

A principal object of the invention is to so control the operation of such a vapor generator as to satisfactorily produce wide changes in heat release rate with great speed, through proper regulation of liquid inflow and of the elements of combustion.

A further object is to maintain the efficiency of combustion uniformly high, regardless of sudden and wide variations in rating.

Still another object is to provide a sequence and protective system for maximum safety of operation.

Further objects will become evident from a study of the specification and of the drawings, in which:

Fig. 1 diagrammatically illustrates a drumless forced flow vapor generator to which the present invention is directed.

Fig. 2 diagrammatically illustrates a drumless forced flow vapor generator, combined with the requisite apparatus to control the functioning thereof, and such apparatus shown in partially diagrammatic fashion.

Fig. 3 is similar to Fig. 2 except as to certain details.

In the various drawings, identical parts bear the same reference numerals.

The drumless forced flow vapor generator to which the present invention is directed is diagrammatically illustrated in Fig. 1 to indicate gas flow, working fluid flow, and heat absorbing surface arranged as contained within the enclosure represented by the dot and dash lines.

The flow path for the working medium is comprised of long small-bore tubes brought together at suitable headers. The generator includes an economizer 202 at the cooler end of the gas pas-

sage and which receives liquid from a positive displacement pump as shown connected to the hot well.

The liquid from the economizer outlet header 201 is conveyed by a tube 203 to a manifold tube 204 from which the liquid is distributed to the generating section through, in this instance, five fluid flow resistors 205, each of which has a greater resistance drop than the particular fluid flow passage which it serves and whereby the liquid is proportionately distributed to each of the tubular fluid flow passages 206, 207, 208, 209 and 210 constituting the generating section of the assembly, which comprises floor, wall, screen and roof portions as indicated.

These five flow circuits comprising the vapor generating surface tangentially enter a bulge in the fluid flow path which is in the form of a separating chamber 232 for dividing the fluid into liquid and vapor; the vapor passing to a superheater 242, and the excess liquid being diverted from the fluid flow path through a pipe 1 to the hot well or to waste. A normal continuous spillover occurs through the restriction 2 while a variable spillover occurs through the regulating valve 3.

The "heat source" (Fig. 1) includes an oil burner 4 supplied by a pipe 5 (Fig. 2) and an air chamber 6 supplied by a conduit 7. In order to provide for initial ignition of the oil-firing means, a gas-firing device 8 is supplied by a pipe 9 with flow of gas under the control of a solenoid actuated valve 10.

Referring now in particular to Fig. 2, I illustrate the fluid flow path as a single sinuous tube, to the economizer section 202 of which, liquid is supplied under pressure through a pipe 11 from a pump 289, which while it is illustrated in Fig. 1 as a positive displacement pump may be of any suitable type, and which I have therefore illustrated in Fig. 2 merely diagrammatically. From the economizer section the fluid passes to and through the generating section discharging into the separator 232. From the separator, vapor passes to and through the superheater 242, leaving by the conduit 244 to a main turbine 12 illustrative of a vapor consuming device. Products of combustion pass successively through the generating section, superheater, and economizer and may contact a part or all of the separator.

An auxiliary turbine 287 drives the liquid feed pump 289, the air blower 288, and the fuel supply pump 290. While I have illustrated these devices diagrammatically and as though all are located to be driven by the same shaft and at the same speed, it will be understood that the necessary gear reduction, or driving connections between the several devices, are known and would be properly designed as to relative speed, power, etc., and that I merely intend to indicate that the auxiliary turbine 287 drives the devices 289, 288, and 290 simultaneously and in unison.

The rate of supply of fuel oil to the burner 4 is primarily controlled by the speed of the oil pump 290, but the supply of oil is further regulated by the throttling of a regulating valve 13 located in the pipe 5; and the rate of flow is continuously measured by a meter 14.

The rate of supply of air to support combustion is primarily determined by the speed of the blower 288 but is further under the control of a damper 15 positioned in the conduit 7 at the inlet to the blower. The rate of supply of air is continually measured by a flow meter 16.

The rate of supply of liquid under pressure

through the conduit 11 is primarily controlled by the speed of the pump 289, but is further influenced through the positioning of the regulating valve 17 at the suction side of the pump and by a regulating valve 18 in a by-pass around the pump.

In the operation of such a vapor generator certain variables are measured, indicated, and utilized as the basis for automatically controlling the supply of liquid thereto and the supply of the elements of combustion to the heating furnace.

I indicate at 19 a pressure responsive device such as a Bourdon tube connected to the conduit 244 and having an indicator pointer 20 adapted to cooperate with an index 21 for advising the instantaneous value of the vapor outflow pressure. At 22 is indicated a temperature responsive device such as a Bourdon tube, forming part of a temperature sensitive system adjacent the conduit 244 and having an indicator pointer 23 adapted to cooperate with an index 24 for advising the instantaneous value of the vapor outflow temperature.

As an indicator of generator output, or load upon the vapor generator, I provide a Bourdon tube 25 adapted to position an indicator pointer 26 relative to an index 27. The Bourdon tube 25 is connected by means of a capillary 28 with the turbine 12 at a location such that the Bourdon tube will be sensitive to first stage shell pressure of the turbine, which pressure bears a substantially straight line relation to rate of steam flow. Thus the pointer 26 will indicate, relative to the scale 27, a reading representative of rate of flow of steam from the vapor generator and thereby an indication of output or load upon the generator.

29 represents means responsive to liquid level within the separator 232 and constitutes a pressure casing enclosing a mercury U-tube connected across the vertical elevation of the separator. A float is adapted to rise and fall with the surface of the mercury in one leg and to thus cause a positioning of a pointer 30 relative to an index 31 to advise the instantaneous value of liquid level within the separator.

The flow meter indicated in general at 14 for providing a measure of the rate of supply of fuel to the furnace is of a known type such as is disclosed in the patent to Ledoux No. 1,064,748. Such a meter is a differential pressure responsive device adapted to correct for non-linear relation between differential pressure and rate of flow, to the end that angular positioning of a pointer 32 relative to the index 33 is by increments directly proportional to increments of rate of flow. I illustrate by dotted lines within the flow meter 14 the outline of the internal construction wherein is a liquid sealed bell having walls of material thickness and shaped as described and claimed in the above mentioned Ledoux patent.

The flow meter 16 for measuring the rate of supply of air for combustion is similar to the meter 14 and positions a pointer 36 relative to an index 37 to provide a continuous indication of the instantaneous rate of flow of air to the furnace.

I preferably primarily control the supply of liquid to the fluid flow path and the elements of combustion to the furnace, through variation in speed of the auxiliary turbine, utilizing the liquid inflow as the basis for such control. Realizing, however, the possible difference in characteristics of the pumps and blower, as well as

variations in conditions of operation, I provide readjusting means to supplement the primary control of the elements of combustion. For the air, such readjusting means comprises the damper 15 positioned at the inlet to the blower 288 by a pneumatic actuator 38. For the fuel, the readjusting means comprises the regulating valve 13 positioned in the pipe 5 responsive to departure from desired relation of the measure of fuel flow and the measure of air flow.

The speed of the auxiliary turbine is regulated through varying the opening of governor valves 39 adapted to admit relatively low pressure steam to the turbine, and at certain rates of operation to supplement this by additionally supplying relatively high pressure steam. For example, the low pressure steam may be the exhaust from the main turbine 12 or extraction steam therefrom, while the high pressure steam may be direct from the vapor generator. A pneumatic actuator 40 positions the valves 39 under the influence of an air loading pressure established by a standardizing relay 41 illustrated in detail in Fig. 8.

In order to regulate the liquid inflow (through variation in speed of the water pump) I preferably accomplish the regulation responsive to liquid inflow, vapor outflow, and level of liquid in the separator.

As previously mentioned, the Bourdon tube 25 is positioned responsive to turbine shell pressure representative of vapor outflow from the vapor generator and is adapted to vertically position a pilot stem 42 relative to a pilot casing 43, to which a supply of compressed air may be available as indicated by the small arrow. Such a pilot valve forms the subject matter of a patent to Clarence Johnson, No. 2,054,464.

I indicate pipes or capillaries for transmitting such air loading pressures, throughout the drawings, by dotted lines to distinguish from electrical connections, or other pipes or conduits. In Fig. 2 then, such a connection is illustrated at 46 for transmitting an air loading pressure bearing a known relation to rate of vapor outflow to a differential relay device 47.

In similar manner the liquid level indicator 29 vertically positions a pilot stem 48 to establish at the relay 47, through the connection 49, an air loading pressure representative of liquid level.

Certain features of the differential relay 47 are disclosed and claimed in my Patent No. 2,098,913.

It will be observed that variations in the loading pressure effective through the connection 46, or that effective through the connection 49, will be effective upon the positioning of the valve 17.

The valve 17 acts as a variable orifice across which there will exist a pressure differential bearing a known relation to the rate of flow of liquid through the valve 17. Pressures on opposite sides of the valve are effective through the pipes 63, 64 respectively in chambers 65, 66 of the standardizing relay 41. Certain features of the standardizing relay 41 are disclosed and claimed in the patent to Harvard H. Gorrie No. 2,098,914.

In general the valve 17 is positioned responsive to vapor outflow and to liquid level within the separator and forms a variable orifice in the suction line to the water pump. The device 41 receiving the differential pressure across the valve 17 positions the actuator 40 and the tur-

bine valves 39 to control the speed of the water pump in such manner that the differential pressure across the valve 17 will be held constant regardless of the opening of valve 17 and thus the liquid flow to the water pump is controlled proportional both to vapor outflow and to liquid level within the separator.

If vapor outflow increases, then the pilot stem 42 is raised proportionally, thus proportionally increasing the loading pressure effective through the connection 46, causing a downward movement of the relay stem 54 and a corresponding opening of the valve 59 to additionally admit air under pressure within the chamber 57, thus increasing the air loading pressure through the connection 62. The resulting change in opening of the valve 17 varies the pressure differential effective upon the relay 41, changing the loading pressure effective through the actuator 40 to position the turbine throttle valves 39, and results in an increased flow of water through the conduit 11 commensurate with the increase in vapor outflow from the vapor generator.

Should the liquid level within the separator 232 tend to fall, the pilot stem 48 will be raised, thus increasing the loading pressure in the relay chamber 56, and in like manner further opening the valve 17 to result in an increase in the supply of liquid to the vapor generator.

It will then be observed that the valve 17 is positioned responsive to vapor outflow from the generator and liquid level in the separator, while the speed of the water pump is not only responsive to these two variables but additionally to the rate of flow of water to and through the pump.

The liquid level responsive device 29 further controls, through the pilot stem 48, the positioning of the variable spillover valve 3 in such manner that upon a rise in liquid level within the separator 232 above a predetermined elevation there will be a regulated opening of the valve 3 to supplement the normal spillover 2 to the pipe 1.

Under the control of vapor outflow pressure acting upon the Bourdon tube 19, I provide a pilot valve 69 for establishing an air loading pressure through the connection 70 to position the by-pass valve 18 and the damper 15. Upon a fall in vapor pressure from predetermined value the valve 18 and the damper 15 both tend to open, each from a predetermined position. This action is particularly desirable upon sudden material increases in load upon the unit as a whole, thus causing a marked decrease in vapor pressure. When such sudden and material increases in vapor outflow occur, thereby lowering the vapor pressure, the auxiliary turbine speed is increased and the damper 15 is opened. At such time it is desired to increase the supply of fuel and air without immediate increase in supply of liquid. By-passing the pump by means of the valve 18 reduces liquid flow through conduit 11 and valve 17 and causes the auxiliary turbine to speed up to restore the original liquid flow and in so speeding up increases the air flow and fuel flow. Without the by-pass, not only would this advantage be lost, but the momentary increase in liquid inflow when the auxiliary turbine speed is increased, would be more than would be desired to utilize the available heat storage of the unit. The adjustment of the actuator 38 and of the actuator of the valve 18 is preferably such that they will be responsive only to predetermined variations in vapor pres-

sure and corresponding air loading pressure in the connection 70. For example, the damper 15 may be regulated as to position upon any departure of vapor pressure from predetermined value in either direction, while the valve 18 may be completely closed until vapor pressure has fallen a predetermined amount below the desired standard. Beyond that point the valve 18 would begin to open and the damper 15 may, or may not, be completely open while the opening of the valve 18 is being regulated.

I preferably primarily control the supply of the elements of combustion through varying the speed of the auxiliary turbine and thereby the speed of the blower and the oil pump in unison with the liquid inflow. Having readjusted the air supply through a positioning of the damper 15, and provided a measure of air flow by the meter 16, I then utilize the regulating valve 13 in the oil supply line to properly proportion fuel to air. To this end the meters 14, 16 are interconnected with linkage 71 for positioning a pilot stem 72 to establish an air loading pressure through the connection 73 to the chamber 65 of a standardizing relay 74 in general construction similar to that illustrated at 41. The air loading pressure resultant from operation of the relay 74 is effective through a connection 75 for positioning the regulating valve 13 upon departure of air flow-fuel flow relation from predetermined value, and simultaneously is effective for positioning a regulating valve 76 for control of atomizing steam supplied to the oil burner 4 through a pipe 77.

Referring now to Fig. 3, I show therein an arrangement similar to that of Fig. 2, but herein I actually measure the vapor outflow through the pipe 244 to a turbine or other utilizer, rather than utilizing shell pressure as in Fig. 2. To this end, I provide a flow meter 78, similar to the flow meter 14, and connected to the pipe 244 across an orifice or other restriction 79. The flow meter is adapted to vertically position a pilot stem 42 relative to a pilot casing 43 to vary an air loading pressure effective upon the relay 47 proportional to the rate of vapor outflow.

The Bourdon tube 22 positioned responsive to variations in vapor outflow temperature, is adapted to vertically position a pilot stem 80 for varying an air loading pressure through the connection 81 upon a pneumatic actuator 82 for positioning a set of dampers 83. The dampers 83 are preferably so located relative to the fluid path through the vapor generator as to control the relative heating of different portions of the fluid path, and thus control the vapor outflow temperature.

Referring to Fig. 3, the secondary control of fuel supply is by the regulating valve 13 from fuel-air ratio. If air flow varies, the fuel supply

varies proportionately. I have provided a solenoid operated valve M in a by-pass around the fuel pump 290, regulating valve 13, and meter 14. This solenoid is electrically in parallel with the solenoid of valve J, so that when J is tripped out and closes the by-pass, valve M automatically opens, thus bypassing oil during that part of the lighting cycle when the main solenoid valve J is closed. If flame fails the valve J closes, which shuts off the supply of fuel to the burner. If I did not provide the by-pass and valve M there would then be a tendency for the meter 14 to decrease to zero and the fuel-air ratio would open the regulating valve 13 wide. If then the recycling opened the valve J there would be a wide open valve 13 which would immediately send a heavy volume of oil through J to the burner far in excess of what was desired. By providing the by-pass and valve M, then when the fire goes out and J is closed, the valve M opens and the flow through the meter 14 is maintained approximately as it was before in ratio with the air but the oil is now bypassing back through the valve M. The valve 13 does not open excessively or materially further than it was before and thus the flow available at J when J next opens is not excessive.

Referring particularly to Fig. 3, it is sometime desirable to maintain the level within the separator 232 variable (directly or inversely) with rating. This may be accomplished through relative adjustment of the range and sensitivity of the control from the steam outflow meter 78 (representative of rating) and of the level recorder 29. Such adjustment will allow of control tending to maintain the level within the separator at a predetermined value, or at a level increasing with rating or at a level decreasing with rating in desired manner.

While I have chosen to illustrate and describe certain preferred embodiments of my invention, it is to be understood that this is by way of illustration only and that I am not to be limited thereby except as to the claim in view of prior art.

This application is a division of my co-pending application Serial No. 55,023 filed December 18, 1935, now Patent No. 2,170,346.

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

In combination, a vapor generator of the forced flow type heated by combustible fuel and air and having a liquid supply, a separator between the generating and superheating portions of the fluid flow path, and common means for regulating the supply of liquid and fuel and air to the vapor generator responsive to liquid level within the separator.

PAUL S. DICKEY.