

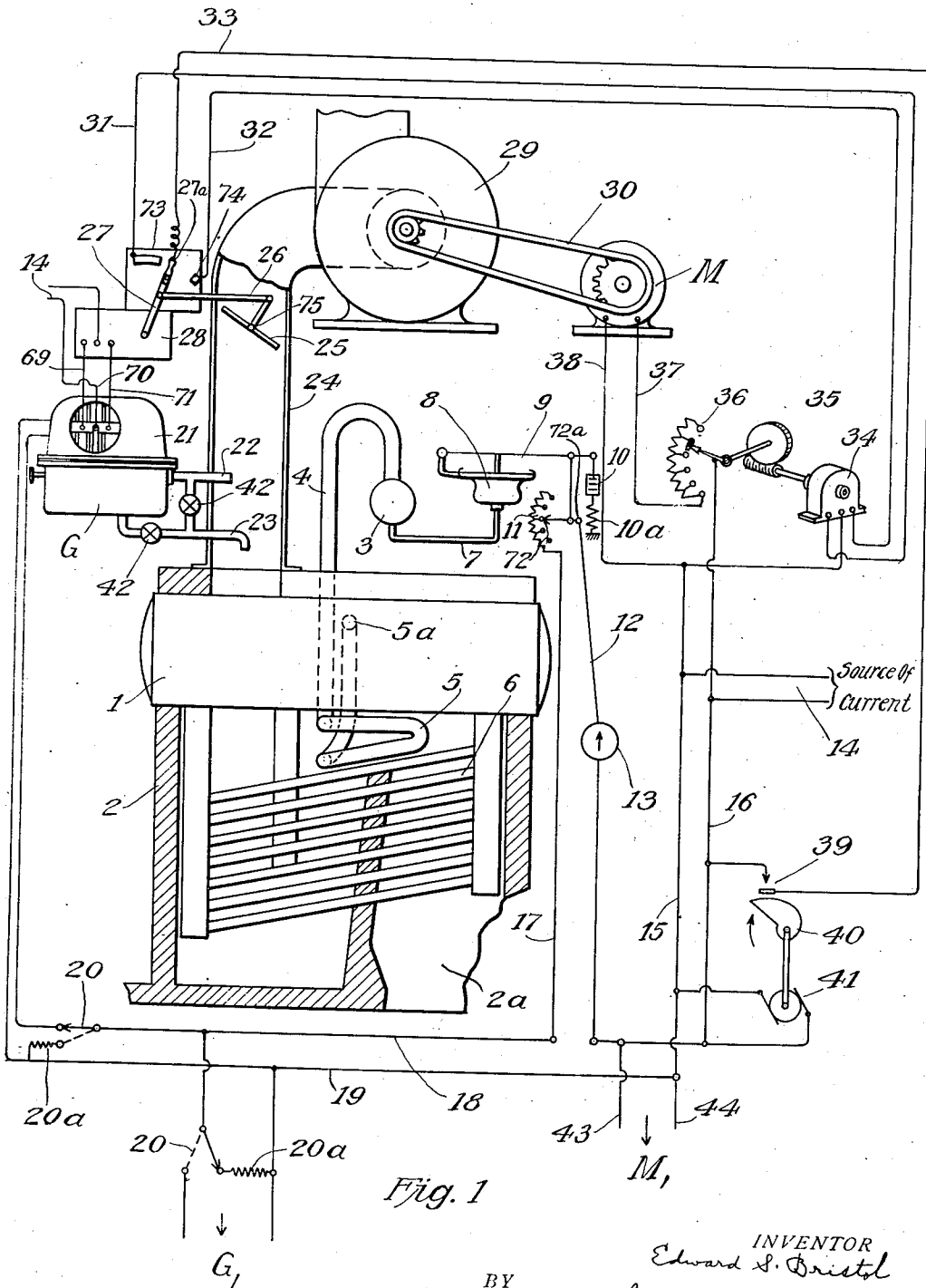
Aug. 9, 1932.

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1,870,984

CONTROL SYSTEM

Original Filed Jan. 20, 1928 2 Sheets-Sheet 1



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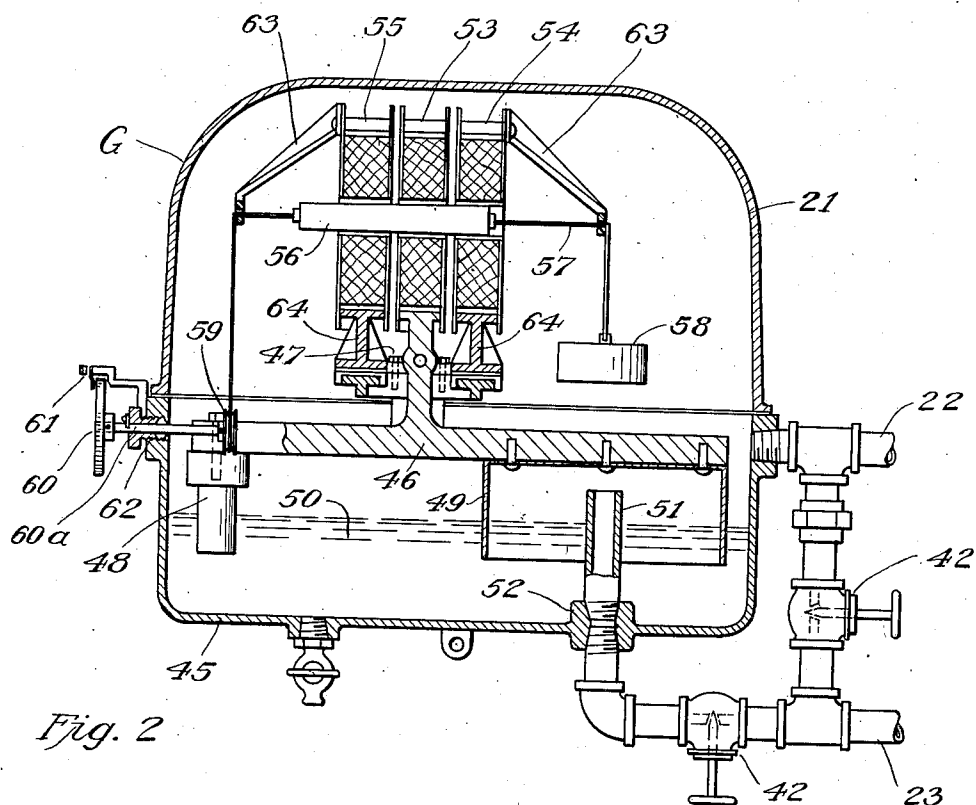
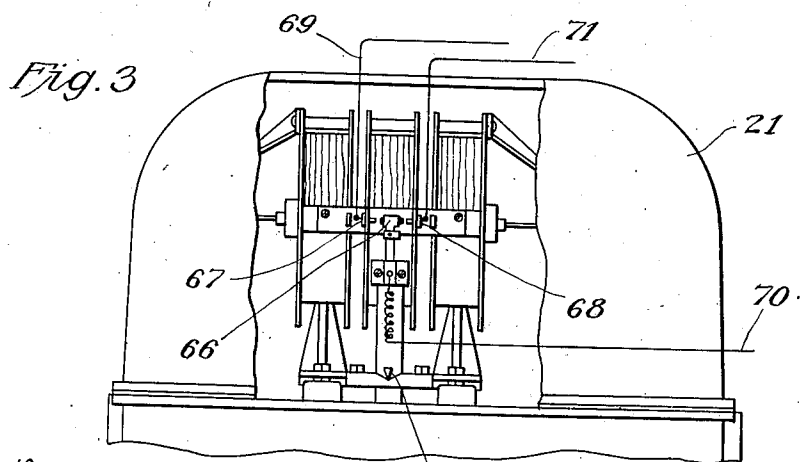
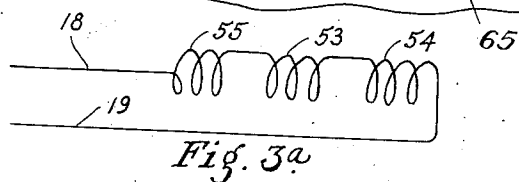
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CONTROL SYSTEM

Original Filed Jan. 20, 1928 2 Sheets-Sheet 2



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CONTROL SYSTEM

Application filed January 20, 1928, Serial No. 248,144. Renewed May 22, 1931.

My invention relates to a method of and apparatus for controlling fluid flow, and more particularly to fluid flow through a steam generator.

My invention resides in a method of and apparatus for effecting a graduated control by interrelated primary and secondary controls for maintaining a predetermined ratio between two separate fluid conditions.

10 Further in accordance with my invention, the primary and secondary control means are so regulated that the primary means operate through a definite range without change in operation of the secondary means, and
15 changes are effected in the operation of the secondary means only in accordance with limiting positions of said primary means.

Further in accordance with my invention, the magnitude of an electric control current
20 is varied in response to variations in magnitude of a condition, as fluid pressure or rate of flow of fluid, to effect the control of one or more apparatus in turn controlling by primary and secondary regulating means, corresponding changes in the magnitude of a
25 condition, as rate of flow of fluid.

My invention further resides in a method of and apparatus of the character herein-
after described and claimed.

30 The invention is shown in a separate instance as applied to a steam generator control so as to effect a graduated control of the air flow by draft fan and throttling means with respect to the generator load, and to thereby
35 maintain a predetermined ratio between the generator load and air or flue gas flow through the combustion chamber and stack. To effect this control, the draft fan and its damper are so cooperatively related as to secure quick and exact regulation of the draft pressure or volume, and to economize in the power required to drive the draft fan. The draft fan which is called the secondary regulating means, has its speed adjusted to im-
pel approximately the volume of air or flue gas required by the furnace, and the damper adjustment or primary regulating means, acts as a vernier to effect close adjustments of air or flue gas flow between increments of fan speed.

Formerly it has been customary to regulate the damper and fan blower by independent mechanism in order to effect certain ratios between the conditions of furnace operation. In a case where the blower for instance, is dependent on charges in steam pressure for effecting changes in speed, there will obviously be an appreciable time lag in regulation due to inertia of the rotating parts and "hunting" will inevitably result from such regulation. My invention is devised to overcome this difficulty by effecting a damper control without necessitating a pick-up or change in the fan speed.

A specific form of my invention is herein disclosed in which:

Fig. 1 shows a diagrammatic illustration of my control system as applied to a steam generator.

Fig. 2 shows a cross-sectional view of the fluid flow controller shown in Fig. 1.

Fig. 3 shows the circuit controlling arrangement of the fluid flow controller.

Fig. 3a is a diagram of circuit connections.

Referring to Fig. 1 the boiler drum is designated as 1 having furnace setting 2 therefor, forming a heat transfer chamber having the superheater 5 and boiler tubes 6 disposed therein. The superheater 5 as connected, transmits steam from the boiler drum from opening 5a in the drum, through the pipe 4 to the main header 3 from which steam is delivered to the various loads required. The header 3 is connected through tube 7 to a pressure operated rheostat 11, actuated by diaphragm-operated element 8 which moves a lever 9 in opposition to weight 10 and spring 10a for effecting, through suitable linkage, operation of the movable contact 72 about pivot 72a along the variable resistance of the rheostat 11.

The rheostat 11 controls the magnitude of a control agency or current in circuit 12 energized from a source of potential 14 and having an electric meter 13 therein, such as an indicating, recording or integrating ammeter, for instance. The steam pressure in header 3 is less than that in boiler drum 1 by an amount depending upon the rate of flow through superheater 5 and pipe 4.

Changes in rate of flow are thus instantly accompanied by corresponding changes of header pressure, since boiler drum pressure changes at a relatively slow rate because of the heat storage capacity of the boiler and its setting. It will be apparent that, since the position of the movable contact of the rheostat is dependent on the steam pressure the contact action and the rheostat arrangement can be so combined as to proportion the current changes in circuit 12 to the load changes on the steam generator. If this regulation directly in response to load change is insufficient to maintain boiler pressure there will be a further response of the movable contact to the header pressure change occasioned by the change of boiler drum pressure. When equilibrium is reached the current in circuit 12 will bear a value proportioned to the existing load demand. Such equilibrium position will be attained with a definite and different position for each load, because of the effect of spring 10a. Methods for effecting a supplementary control upon a pressure regulator of this general type, so as to maintain substantially constant pressure at any load, are shown in my copending application Serial No. 756,856, filed December 18, 1924, for control system.

It will be understood that applicant may vary the position of the rheostat setting by well known apparatus operating in other ways in response to steam flow and to boiler steam pressure. It is possible to employ separate rheostat instrumentalities functioning, one in response to steam flow and the other in response to pressure at some point in the system, to jointly control the current in the control circuit.

The control agency or current passes through the differential flow meter G having conductors 18 and 19 leading thereto. Switches 20 are inserted in the circuit to connect individual fluid flow controllers in the control circuit if a bank of boilers is used. In such a case the fluid flow controller of each boiler will be connected in parallel in the control circuit. In the off position of any switch 20 a resistance 20a, equivalent in value to the electrical resistance of a flow meter G, is switched across the control circuit to prevent disturbance of the current passing through the flow meters G remaining in use.

The fluid flow controller comprises a lower casing 45 and an upper casing 21 having enclosed therein Kelvin balance coils and a differential pressure balance. The differential pressure means is connected to the stack 24 in the manner shown in Fig. 1 so that the difference in pressures in the pipes 23 and 22 will be a measure of the rate of air flow through the stack. Valves 42 are employed in the piping as shown connected between

pipes to permit regulating the ratio of the difference in pressure transmitted to the balance within the controller.

As shown by Figs. 2 and 3, the controller balance arm 46 is pivoted at 47 on knife edges 65 and has an inverted cup-shaped member 49 subjected to the pressure in pipe 51 connected by boss 52 to the conduit 23. On the opposite end of said lever is a float 48 for balancing purposes. The member 49 is sealed from the controller chamber as by a liquid 50, so that the velocity pressure will be transmitted through pipe 23 entirely to the underside of the balance. The static pressure through pipe 22 therefore will be exerted on the upper side of the balance and will oppose the first mentioned force.

Magnetic coils 53, 54 and 55 are connected in series across the control circuit to conductors 18 and 19 as shown in Fig. 3a, and have a magnetizable member 56 positioned centrally thereof. Coils 54 and 55 are fixed by brackets 63 with respect to the casing of the controller, while coil 53 is mounted on an upright of the balance arm 46 extending above pivot 47. The position of coil 53 therefore will depend both on the strength of current through the balance coils and the difference in fluid pressure between the upper and lower sides of balance arm 46. The position of magnetizable core member 56 may be adjusted for varying the reluctance of the magnetic circuits of different coils by rotating adjusting dial 60 having a fixed index 61 cooperating therewith. Dial 60 controls through sheave wheel 59 and cord 57 the position of the core. Weight 58 is utilized as tension means in opposition to the operating dial, whose operating shaft 60 is sealed with respect to the casing by gland 62.

Since the force of magnetic attraction varies approximately as the square of the current through the balance coils, and furthermore since the difference in fluid pressure forces exerted on the balance arm also varies approximately as the square of the rate of air or flue gas flow through the stack, it will be seen that the differential flow meter functions in effect to directly balance the control current, and hence the generator load, against the air or flue gas flow through the furnace.

The movable coil 53 has a contact 66 associated therewith for making contact with terminals 67 and 68, (see Fig. 3), which control the circuits of a reversible motor or the like 28. The contact 66 is connected by a common conductor 70 to one side of the source 14 and is adapted to be connected with either of the conductors 69 or 71 depending on the position of the movable coil.

The reversible motor element 28, which is connected to the other side of source 14 has its field windings controlled by movable con-

tact 66 so as to rotate arm 27 in either clockwise or counterclockwise direction, depending on whether 69 or 71 is energized. Incorporated within the motor device 28 is suitable reduction gearing for effecting motion of arm 27 at a desired rate. The arm 27 has a damper 25 pivoted at 75 positively connected thereto by linkage 26. Operation of the control arm 27 may therefore actuate the damper in either direction. Suitable limit switches, not shown, are provided to open the corresponding motor circuits at the open and closed limits of damper travel. The control arm 27 also has mounted thereon an insulated sliding contact 27a connected to a flexible conductor 33, and adapted to contact with either contact strip 73 or 74 thereby controlling the field circuits of a reversible motor 34. The motor 34 controls, through gearing 35, the rheostat 36 which directly controls the speed of the fan motor M. The motor M is connected by suitable drive means 30 to the draft fan 29, which approximately regulates the rate of air or flue gas flow through the stack and therefore through the furnace. It is contemplated that contact strips 73, 74 may be varied in length or position or may be made adjustable with respect to the casing of motor unit 28, in order that the damper positions at which the contact action becomes effective may be varied as desired.

The motor M is energized through conductors 37 and 38 connected to the source of supply 14.

Periodic control of the system may be effected by a cam operated switch 39 having a cam 40 operated by the motor 41, which is in turn energized through conductors 15 and 16 from source 14.

The operation of the apparatus is as follows:

Assuming a certain load condition of the boiler plant, the rheostat 11 will be adjusted accordingly to allow a certain control current to pass through the magnetic balance coils of the controller G. The air or flue gas through the furnace will be assumed at this point to bear a satisfactory ratio to the boiler load, and the movable balance coil 53 will therefore be in neutral position as indicated in Fig. 3. The damper 25 will be at some position within its normal range of travel and the rheostat controlling motor 34 will be idle, with the fan motor M running at constant speed and delivering constant volume of air or flue gas. If now the load should suddenly increase or decrease, the rheostat 11 would correspondingly vary the control current through the balance coils and the differential air or flue gas flow pressure will be opposed by a greater or less force than before, and coil 53 will be moved to complete either circuit 69 or 71. Upon this occurrence the reversible mechanism 28 will move the control

arm 27 accordingly so as to vary the position of damper 25. If the degree of unbalance between the load and air flow is comparatively small, adjustment of the damper 25 alone will be sufficient to restore the proper ratio between the two said conditions. In case however such ratio cannot be restored without moving the damper outside its desired range of action, the control arm 27 will bring contact 27a into engagement with either 73 or 74, thereby energizing the corresponding field of rheostat motor 34 and changing the fan speed until the damper returns to its normal range of action. The action of cam-operated switch 39 results in intermittent adjustments of fan speed, one step at a time, whenever such adjustments are required. This intermittent action is advantageous because it prevents overshooting due to fan lag. The cam can be shaped and timed so as to secure any desired duration and frequency of contact.

It will be seen therefore that the fan motor drives the fan at a speed which is approximately the speed desired for effecting a predetermined ratio between the generator load and the air flow, and that the damper 25 acts as a vernier or close-adjusting means between certain limits for effecting exact ratios of said conditions without changing the fan speed.

This system is not limited to a single boiler as shown but may be obviously incorporated in a bank of boilers, each having a separate controller G and its individual draft fan. Conductors 43 and 44 are shown leading from the source of supply 14 for connection to a second fan motor if so desired. As previously stated a plurality of controllers G may be connected in parallel in the control circuit and in each boiler therefore, the air or flue gas flow will bear a certain ratio to the steam load on the system.

It will also be evident that the system is adapted to the control of an admission damper and a blower for supplying air to a furnace. Where a furnace is equipped with both forced and induced draft fans and dampers the draft control for each furnace can comprise means of the type described at length above, together with similar means for the forced draft control. In such a combination the two flow controllers G for each furnace would be connected in series. Instead of employing both the elements G as flow controllers in such a combination, one might be so employed and the other connected so as to control the pressure in furnace chamber 2a with respect to atmosphere. For this latter purpose pipe 23 of the corresponding controller could be connected to atmosphere and pipe 22 to chamber 2a. The flow control might be applied to either the forced or the induced draft fan and damper, with the furnace pressure control acting upon the other. The coils on the furnace pressure controller

can be omitted where it is desired to hold a constant pressure difference between the furnace and atmosphere at all loads.

Although electricity is employed as the controlling medium in the examples cited, it will readily be understood that my method is equally applicable to control systems in which fluid pressure or flow is employed to transmit control forces and impulses.

The method can also be employed for the control of fluids other than air or flue gas, as for instance a liquid discharged into a pipe line by a variable speed pump with an adjustable throttle valve for primary regulation, etc.

What I claim is:

1. In a control system for fluid flow, valve regulating means interposed in the path of said fluid flow, a variable speed fluid impeller for effecting said fluid flow, and means for varying the speed of said impeller by and in accordance with the position of said valve regulating means.

2. In a control system for fluid flow, valve regulating means interposed in the path of said fluid flow, a variable speed fluid impeller for effecting said fluid flow, and means responsive to the operation of said valve regulating means at predetermined positions for varying the speed of said impeller.

3. A fluid flow control system, comprising a variable speed fluid impeller for secondary control of said flow in combination with valve means for effecting fine adjustments of fluid flow between increments of impeller speeds, the action of said impeller and valve means being interdependent.

4. In a control system, a fluid impeller adapted to be operated at variable speeds to effect fluid flow, a valve cooperating therewith for effecting fine adjustments of fluid flow between increments of impeller speed, said valve being operatively connected with the fan speed control means whereby change in speed of said impeller is effected in accordance with a predetermined position of said valve.

5. In a control system for a vapor generator, means for effecting a finely graduated control for maintaining a predetermined ratio between the load on said generator and the air or flue gas flow therethrough, comprising a variable speed draft impeller, throttling means, and a controller jointly responsive to changes in the generator load and air or flue gas flow, said controller adapted to normally vary said throttling adjustment between certain limits and to change the impeller speed when said limits are reached.

6. In a control system for a generator, a control circuit, fluid actuated means dependent on the generator load for varying the control current, means jointly actuated by fluid flow and said current for controlling apparatus adapted to maintain a predeter-

mined ratio between the generator load and said fluid flow, said apparatus comprising a valve for effecting fine adjustments of said flow cooperating with a draft impeller adapted to operate at constant speed between predetermined normal limits of said valve control.

7. A system of control comprising a control circuit, a controller jointly responsive to changes in fluid flow and a control current, said controller adapted to normally operate a valve through a limited range to effect changes in fluid flow, and said controller also adapted to vary the speed of a draft impeller in intermittent steps for obtaining changes in fluid flow only when the limits of the normal range of valve operation have been reached.

8. In a control system for a vapor generator, a control circuit whose current is proportional to a load condition of said generator, a fluid flow controller comprising a balance upon which opposing forces, due respectively to the control current and the fluid flow, act and circuits controlled by said balance for controlling interdependently a valve and draft impeller to effect regulation of said fluid flow, whereby a predetermined ratio between said generator load and fluid flow is maintained.

9. In a control system for a vapor generator, a variable speed draft impeller, a damper cooperating therewith and effecting a graduated adjustment of fluid flow between increments of impeller speeds, and means controlling the cooperation between said impeller and damper comprising a balance upon which forces proportional to the generator load, and to said fluid flow respectively, act in opposition so as to maintain a predetermined ratio between said generator load and fluid flow.

10. In combination, a furnace draft impeller for effecting fluid flow, a controller for said impeller, said controller being energized by circuit controlling means having a positive connection to a valve which is adapted to influence said air flow by and in accordance with variations in the furnace operation.

11. The method of controlling fluid flow which consists in normally regulating a flow of fluid by throttling or the like between predetermined limits, said fluid being impelled at substantially constant force, and varying said impeller force by and in accordance with attainment of said predetermined limits.

12. The method of controlling fluid flow in a vapor generator, which comprises balancing two forces against each other, said forces depending in magnitude upon the generator load and air flow therethrough respectively, and utilizing the resultant of said forces to normally regulate by throttling said air flow between certain limits, and also to effect changes in the force impelling said

flow by and in accordance with the throttling regulation.

13. The method of controlling fluid flow which comprises impelling a fluid by a constant force and normally regulating the flow by throttling or restricting the fluid passage within predetermined limits, and varying the impeller force in intermittent stages by and in accordance with the attainment of said predetermined limits.

14. The method of controlling fluid flow in a vapor generator, which comprises normally throttling or restricting the passage of said flow between predetermined limits by and in accordance with variations in the steam pressure or flow in said generator, and effecting intermittent variations in the force impelling said fluid by and in accordance with attainment of said predetermined limits.

15. A control system for a vapor generator comprising a control circuit, means responsive to change in load on said generator for varying the magnitude of the control current, and means jointly affected by an operating condition of said generator and said control current for effecting a primary or graduated control of said operating condition within predetermined limits and for effecting a secondary control thereof by and in accordance with the limiting positions of the primary control.

16. In a control system, a valve adjustable between predetermined positions, a fluid impeller operable conjointly with said valve to influence fluid flow in said system, and means operable only when said valve is in one of said positions to effect variation in speed of said impeller.

17. In a system of the character described, a conduit for fluid, fluid-pressure means responsive to variations in pressure conditions to which the same is subjected, a valve operable to control rate of fluid flow in said conduit, means operating to induce fluid flow in said conduit, and means responsive to both operating action of said fluid-pressure means and to conditions of fluid flow in said conduit and operable in accordance with the joint influence thereof to provide a primary control with respect to said valve and a secondary control with respect to said fluid-flow-inducing means.

18. In a system of the character described, a conduit for fluid, an electrical circuit, means for varying the current in said circuit, a valve for controlling rate of fluid flow in said conduit, a fluid impeller for inducing fluid flow in said conduit, variable speed means for driving said impeller, and means responsive to both current conditions in said circuit and conditions of fluid flow in said conduit and operable in accordance with the joint influence thereof to adjust said

valve between certain limits without variation in the speed of said driving means and to effect such variation when said valve is in either of its limit positions.

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