March 26, 1929. C. H. SMOOT 1,706,753

TURBINE REGULATION

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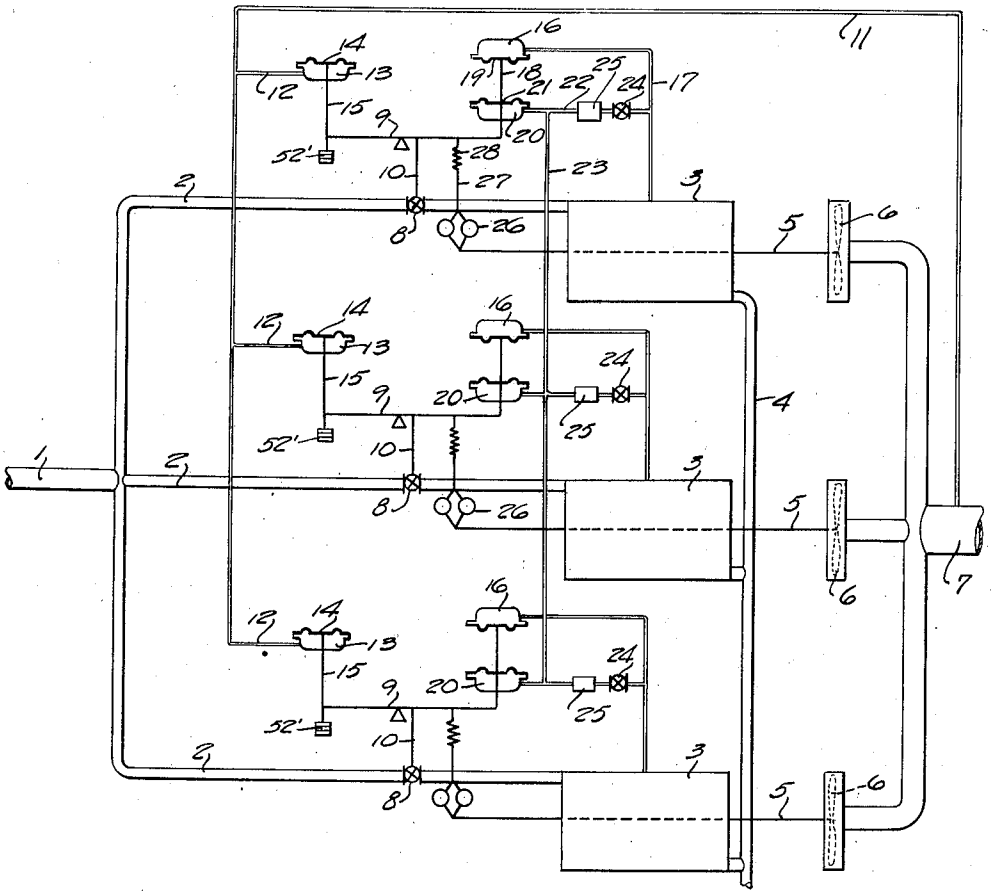


FIG. 1.

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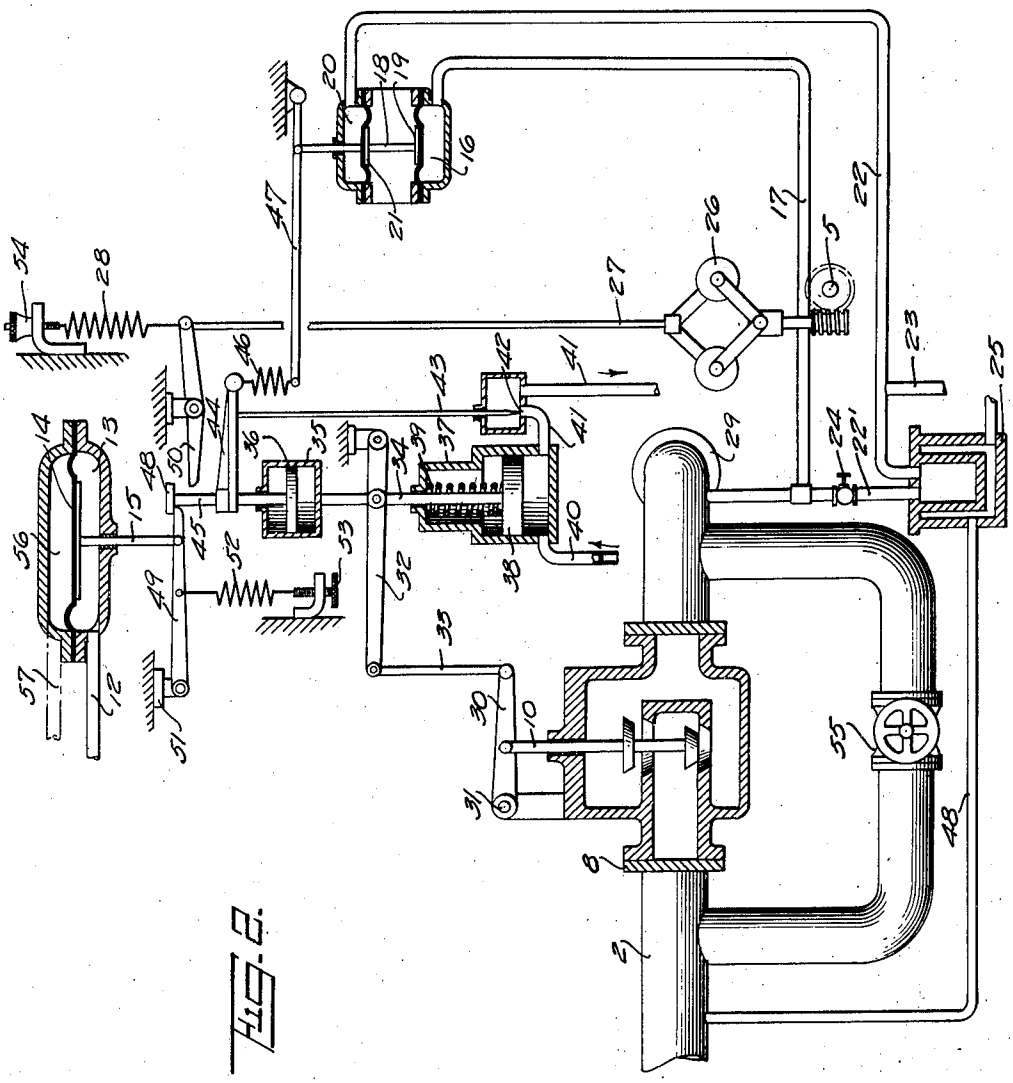


Fig. 2.

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Patented Mar. 26, 1929. 1,706,753

UNITED STATES PATENT OFFICE.

CHARLES H. SMOOT, OF MAPLEWOOD, NEW JERSEY.

TURBINE REGULATION.

Application filed April 20, 1927. Serial No. 185,144.

My invention is concerned with a system of regulation for turbines operating in parallel and comprises novel apparatus that efficiently and automatically insures the proper distribution of the load between the individual turbines.

When several turbines are operating in parallel receiving steam from a common source and contributing in their operation to a common result, a few only of the turbines may do practically all of the work which should be distributed between all of the turbines in proportion to their capacities. This occurs even when the turbine speeds are maintained equal and results in a forcing of some turbines and an idling of others with loss of efficiency throughout.

The present invention consists in so controlling the admission of steam to each turbine that the admission pressures of all of the turbines are equal and yet are permitted to vary with the load. With the exhaust pressure of the turbines equal, the equality of admission pressure insures that all of the turbines are operating at the same rating. To effect this equality of admission pressure I provide each turbine with an individual regulator that is sensitive to the average steam pressure at all of the turbines and also to the admission pressure at the particular turbine with which the regulator is associated. The individual regulators are also sensitive to the load upon all of the turbines and are provided with means responsive to the speed of the particular turbine being regulated to prevent racing thereof. The individual regulators are of the balanced type and are constructed to permit of rapid operation without racing or hunting.

For a better understanding of my invention, reference should be had to the accompanying drawings of which Fig. 1 is a diagrammatic layout of one application of my regulating system and Fig. 2 is a representation partly in section of one embodiment of my individual turbine regulator.

Referring to Fig. 1, a main 1 delivers steam through branch pipes 2, to turbines 3. The steam passes from the turbines into the common exhaust pipe 4. In the particular application illustrated the shafts 5 of the turbines 3 drive fans 6 supplying air under pressure to a common duct 7. Valves 8 in the branch supply pipes 2 control the admission of steam to the turbines. Each of the individual regulators for the valves 8 is shown diagrammatically in Fig. 1 as a conventional balanced lever 9, the position of which directly controls a valve 8 through a tie rod 10. The pressure in the conduit 7 acts upon the levers 9 through a pipe connection 11 and branches 12 which transmit this pressure to chambers 13 where it acts upon diaphragms 14 which are rigidly connected to the levers 9 by rods 15. Movements of the levers by the diaphragms 14 are opposed by weights 52′. The pressure at each turbine, either at entrance to the turbine or as here illustrated, at a later convenient stage is led to a chamber 16 through a pipe 17 where it acts upon the lever through a rod 18 attached to the lever and to a diaphragm 19 closing one side of the chamber 16. Opposing the action on the lever of the pressure in the chamber 16 is a pressure in a chamber 20 acting upon a diaphragm 21 closing one side of this chamber and also attached to the rod 18. The chambers 20 of the regulators are connected through pipes 22 with the pipes 17 and with each other through a pipe 23. Each pipe 22 is provided with a needle valve 24 which serves to transmit with a definite time delay the average pressure in the pipes 17 to the chambers 20. A reheater 25 which will be described in connection with Fig. 2, is inserted in the line 22 to prevent condensation of the steam after passing through the valve 24. The shafts 6 of the turbines are provided with centrifugal governors 26, each of which is connected to the corresponding lever 9 by a rod 27 and spring 28 to operate upon the lever to close the valve 8 upon excessive speed of the turbine.

The operation of the system shown diagrammatically in Fig. 1 is as follows:

Assuming first that the steam pressure in the main 1 is steady and that each turbine is taking its full share of the load, the pressure in the air main 7 will be constant and have the value for which the weight 52′ is adjusted and the pressures in all the chambers 16 and 20 will be equal. If now for any reason one turbine begins to take less than its share of the load, the effect will be a decrease in the pressure in pipe 17 and chamber 16 associated with that particular turbine. This decrease in pressure causes an unbalance upon the corresponding lever 9 tending to open the valve 8 until the pressure in the particular chamber 16 returns to that of the chamber 20,

at which time the turbine is again performing its share of the work.

If the available pressure in the steam main decreases the pressure in all of the chambers 16 decreases and the valves open until the pressure in chambers 16 increases to its former value. The temporary drop in pressure which occurred in pipe 17 due to the pressure drop in the steam main 1 will be felt a little later as a decrease in pressure in chambers 19; the time interval of the delay depending upon the setting of the valves 24. The temporary drop in steam pressure will also react after a short interval upon the pressure generated by the fans causing a decrease in pressure in chambers 14. The temporary pressure changes in chambers 14 and 20 may counteract each other in their effect on the valve through the lever 9. If this is not the case, the adjustment of the valves will continue until complete balance on the lever is again effected. If at any time during the operation of the system the speed of any turbine becomes excessive the governor 26 acting through rod 27 and spring 28 acts to close the valve of the particular turbine whose speed is too great.

In Fig. 2 a more complete illustration of one embodiment of the individual regulator is given. In this figure parts corresponding to like parts of Fig. 1 are indicated by like numerals. For convenience a turbine is not illustrated, it being deemed sufficient to indicate the steam entrance thereto at 29 and the shaft thereof at 5. The regulating apparatus for the valve 8 will now be described. A member 10 controlling the setting of the valve 8 is carried by an arm 30, one end of which is pivoted to a fixed support at 31 and the other end of which is connected to an arm 32 through link 33. The arm 32 is hinged at one end to a fixed support and is moved by a vertical rod 34 to which it is linked. The rod 34 carries a chamber 35 at its upper end serving as a dash pot to a movable piston 36 therein. The lower end of the rod 34 passes through a casing 37 and is attached to a power piston 38, the position of which is controlled by fluid pressure acting within the casing and upon the lower side of the piston and by a spring 39 acting upon the upper side thereof. Any desired auxiliary fluid such as oil enters the interior of the casing through a pipe 40 and drains therefrom through pipe 41 and leakage valve 42. The leakage through valve 42, regulated by a rod 43 in response to the various controlling forces thus controls the setting of the valve 8 by controlling the upward pressure exerted upon the piston 38.

The rod 43 is carried by a vertically movable arm 44, one end of which is attached to a vertical rod 45 and the other end through a spring 46 to the movable end of a hinged arm 47. The arm 47 is attached to the rod 18 which transmits to the arm a force corresponding to the differential of the pressures in the chambers 16 and 20.

In the particular embodiment illustrated in Fig. 2 the pressure in chamber 16 is the turbine admission pressure, instead of that at some later stage of the turbine as in Fig. 1. The reheater 25 consists in a double walled chamber between the walls of which flows a stream of steam received from any available point of the steam line through a pipe 48 and drained therefrom through a pipe 48'. The inner chamber of the reheater is in communication with the pipes 22 and 22' leading to the chamber 20 and the pipe 17 respectively. The reheater 25 serves to prevent condensation of the steam after passage through the needle valve 24 and should be located as near to the steam line 2 as is possible.

The vertical rod 45 carries the piston 36 of the dash pot at its lower end and a projecting head 48 at its upper end. The rod is supported and lifted by either of two movable members 49 or 50 adapted to move into contact with the underside of the head 48. The positions of the members 49 and 50 depend upon the pressure in the chamber 13 and the speed of the shaft 5 respectively. The member 49 comprises an arm hinged at a fixed support 51 and linked to the rod 15 attached to the diaphragm 14 of the chamber 13. A spring 52 the tension of which may be adjusted by means of a screw 53 opposes the movement of the arm 49. The member 50 comprises a pivoted lever, one end of which is hinged to the rod 27 attached to the governor 26. The spring 28, the tension of which may be adjusted by a screw 54, opposes the movement of the lever 50.

At 55 is shown a by-pass starting valve for the turbine.

When the regulator of Fig. 2 is used to control a turbo-blower to maintain constant pressure, as in the embodiment of Fig. 1, the chamber 13 is connected to the air duct by pipe 12, and a chamber 56, the pressure in which acts upon the opposite side of the diaphragm 14, is connected to the atmosphere through a pipe 57. If it is desired to maintain other than constant pressure in the air duct the pipe 57 would be connected to any source of regulated pressure, such as a master controller of the type described in my Reissue Patent No. 16,507 dated December 21, 1926. If the turbine is driving an exhauster instead of a booster the pipe 57 would be connected to a point of negative pressure maintained by the exhauster and the pipe 12 would be open to the atmosphere if constant negative pressure is desired, or to a source of controlling pressure if variable exhaust pressure is desired.

The operation of the regulator of Fig. 2 will be readily understood from the description already given in connection with the

system of Fig. 1 and from the following description. During unchanging steam pressure the pressures in chambers 20 and 16 are equal and as these pressures act upon the regulator in opposite directions they will completely counteract each other. Upon a change in steam pressure, however, for instance a decrease thereof, the pressure in chamber 16 will immediately decrease and permit the pressure in chamber 20 to move the arm 47 downward. The downward movement of the arm 47 lowers the rod 43 through the spring 46 and member 44 resulting in a decrease in leakage through port 42 and a consequent increase in fluid pressure beneath the piston 38, causing the piston to rise and to thereby open the valve. The upward movement of the piston 38 together with the downward movement of the member 44 will be checked by the action of the dash pot 35 before the balanced condition of the regulator is reestablished. By the time the valve has been thus moved to increase the steam admission pressure, and therefore the pressure in chamber 16 as well, the original pressure decrease will be felt within chamber 20, causing an unbalance of the pressures in chambers 20 and 16 and a further checking of the opening of the valve, or even a slight closure thereof, depending upon whether or not the steam pressure decrease was sufficient to be reflected in a drop in the blower pressure as measured in chamber 13. The arrangement of the chambers 16 and 20 with diaphragms of equal area and with their pressures acting in opposition upon the regulator, with that in chamber 16 immediately responsive to the admission steam pressure, and that in chamber 20 responsive to this admission pressure after a definite time delay adjustable by valve 27 is thus such as to make the regulation sensitive to the rate of change of the steam pressure while independent of the actual value thereof.

It will be observed that the arrangement of arm 49 and lever 50 with the projecting head 48 of the valve controlling member is such as to permit the speed of the turbine to vary without effecting the setting of valve 8 so long as this speed does not exceed a definite maximum for each pressure in chamber 13. This arrangement is also such that by proper adjustment of the springs 52 and 28 the turbine speed could be made the main controlling factor with the pressure in chamber 13 allowed to vary below a definite maximum value for each turbine speed. Preferably, however, the spring 28 is so adjusted that the regulation of the turbine is independent of the speed of the turbine unless racing occurs.

The regulator of Fig. 2 is preferably used in a system such as illustrated in Fig. 1, that is for the control of turbines operating in parallel, for the connecting pipe 23 which equalizes the pressures in chamber 20 serves to maintain equal steam pressure at all of the turbines. This regulator may be used to advantage however even when only one turbine is being employed as it will prevent wide variations in the operation of the turbine by its sensitiveness to the rate of change of steam pressure, thus effecting the regulation prior to the reflection of such change upon the result of the turbine's operation.

Although I have described my invention as applied to the control of turbo blowers, it is apparent that my invention is not limited to such use but may be advantageously employed in the control of any kind of turbine either to maintain a constant operation or a variable one. When used in the control of marine turbines, for instance, the lever 49 and pressure chambers 13 and 56 would not be necessary as the speed element would be a sufficient measure of the operation of the turbine. When applied to the regulation of turbines driving generators, preferably the lever 49 would be moved in response to a force varying with the voltage or current generated. Obviously many other variations could be made to suit particular requirements without departing from the spirit of my invention.

It is not essential that each of the turbines of a group regulated according to my invention should have the same capacity, as my method of regulation insures that all turbines will be operating at the same fraction of their respective capacities.

I claim:

1. A regulator for controlling a valve in the steam admission line to a turbine comprising in combination means responsive to variations from a given value of a force developed through the operation of said turbine, means responsive to a change in, but unaffected by a steady value of the steam pressure, means responsive to the speed of said turbine, and means for controlling said valve by the joint action of all of said responsive means.

2. A regulator for controlling the admission of steam to a turbine including in combination means for creating a pressure varying substantially simultaneously and proportionately with the pressure of the steam, means for creating a second pressure likewise varying proportionately with said steam pressure but delayed with respect thereto and means for varying the steam admission to maintain a definite ratio between the simultaneous values of said created pressures.

3. In a system of regulation for turbines operating in parallel from a common source of steam, the combination comprising means for controlling the admission of steam to each turbine in response to its speed and in response to the variation from a given value of a force developed through the operation of all of the turbines, means for maintaining the admission pressure of the steam at each turbine equal to that at every other turbine

including a device at each turbine reacting upon said controlling means and responsive both to the momentary admission pressure at the turbine with which said device is associated and to a pressure that varies with the average of the admission pressures at all the turbines but with a definite time delay.

4. In a system of regulation of turbo-blowers operating in parallel from a common source of steam and delivering air to a common duct, the combination including a valve for each turbine controlling the admission of steam thereto, a regulator for said valve comprising means responsive to the variation in the pressure in said duct from that desired, means responsive to the speed of the turbine controlled by said valve, and means responsive to the rate of change of the pressure of the steam at a point between said valve and the turbine exhaust, and means for controlling said valve by said regulator.

5. A regulator for a valve in the admission steam line to a turbine comprising in combination an element acted upon by a device responsive to the rate of change of steam pressure, means responsive to the speed of the turbine, means responsive to a force developed through the operation of the turbine, and means for acting on said element by the respective responsive means in a direction to close said valve when the speed of the turbine or said force increases over the value desired therefor, and means for controlling said valve by the position of said element.

6. A regulator for a valve in the admission steam line to a turbo-blower comprising in combination an element acted upon by a device responsive to the rate of change of the pressure of the steam, means for acting upon said element by a force varying with the pressure generated by the blower, means for creating a force varying with the speed of the turbine and acting to control the position of said element independently of said first mentioned means when the speed of the turbine increases beyond a value depending upon the pressure generated by the blower, and means for controlling said valve by said element.

7. A regulator for controlling the operation of a turbo-blower comprising in combination a device responsive to the rate of change of pressure of the steam admitted to the turbine, an element acted upon by said device, means responsive to the pressure generated by said blower for normally acting upon said element to maintain a desired pressure, and means responsive to the speed of the blower for acting upon said element only when said speed exceeds a desired value, and means for controlling the operation of said turbine by the position of said element.

8. A system of regulation for steam turbines operated in parallel from a common source of steam comprising in combination a regulator for each turbine, said regulator including an element acted upon by a device responsive to the rate of change of the pressure of the steam, means responsive respectively to a force developed through the operation of all the turbines and to the speed of the particular turbine controlled by said regulator, means for normally acting upon said element by the first of said responsive means, means for acting upon said element by said speed responsive means when said speed exceeds a desired value, and means for controlling the admission of steam to the turbine by the position of said element.

In testimony whereof, I have signed my name to this specification.

CHARLES H SMOOT.