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FEED WATER TEMPERATURE COMPENSATOR

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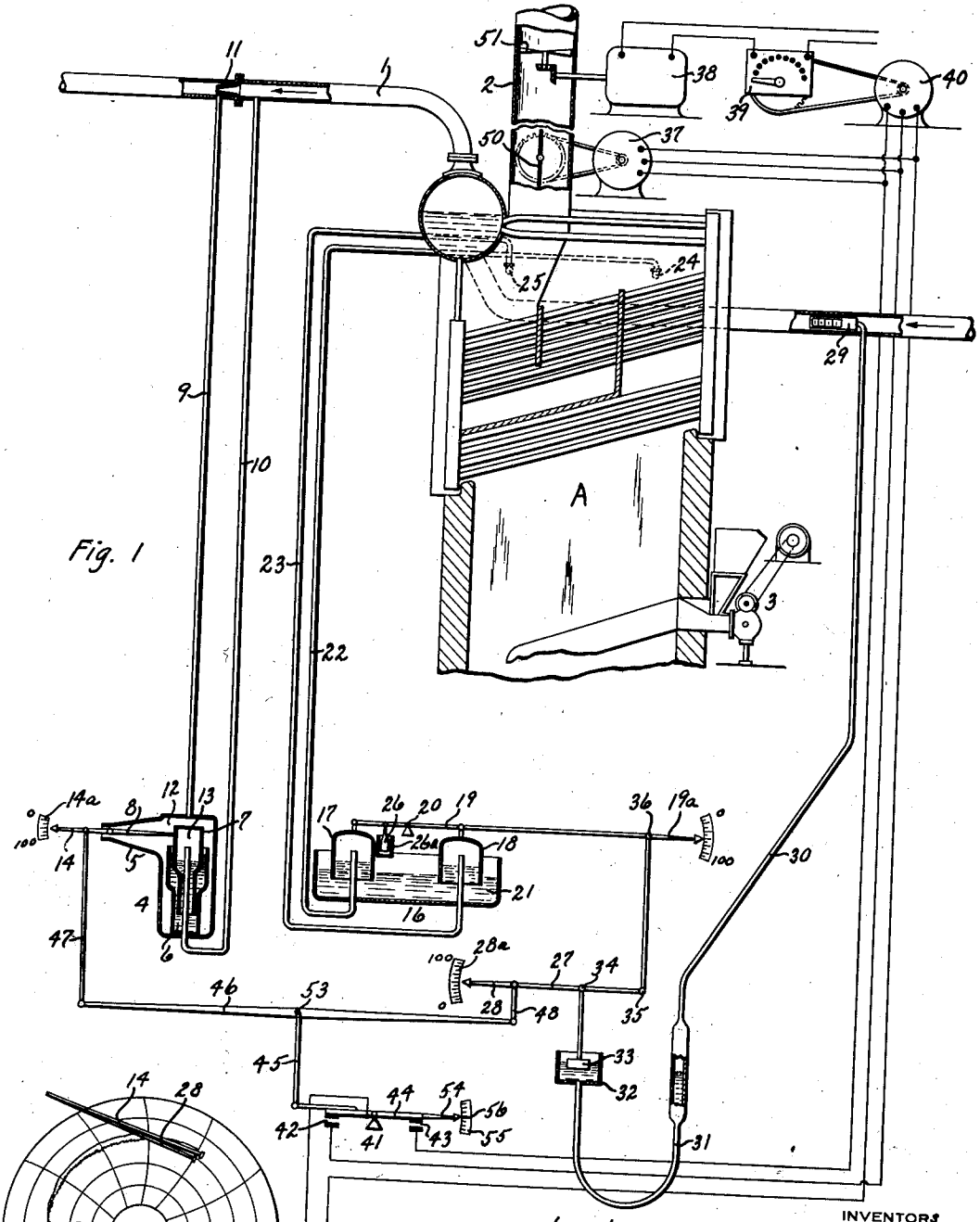


Fig. 1

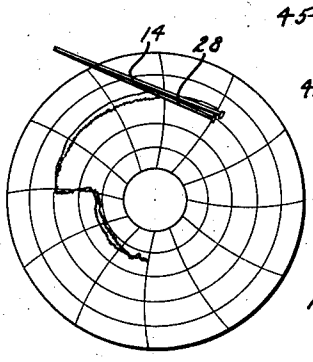


Fig. 2

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FEED WATER TEMPERATURE COMPENSATOR

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This invention relates to meters and recorders, such as are used for indicating, recording and sometimes for control purposes in the operation of boilers or other forms of power producing plants or like devices, where two or more factors must be taken into consideration if proper indication, record or control is secured. The invention has more particular relation to those instances in which, for example, two factors must bear a desirable relation, such as a unity relation, to each other whether the output is great or small, its object being to modify the operation or effect upon the meter of one or the other or both of the two factors to compensate for any variable influence thereon of some third factor, to the end that to all intents and purposes an otherwise distorting or interfering influence of a third factor, may be disregarded or eliminated, as a result of which the desirable unity relation between the first two factors indicated, recorded or made use of for control purposes always may be considered to be accurate.

Speaking for purposes of illustration with reference to boiler operation, where the unity relation between steam flow and air flow is indicated or recorded as useful information for proper boiler operation, or is made use of for automatic control of the air flow, a further object of the invention is to safeguard such relation, as it may be indicated, recorded or made use of, against the possible interfering effect of variation in feed water temperature or some other factor of boiler operation which might or does introduce error into the steam flow-air flow relation.

Further objects of the invention are in part obvious and in part will appear more in detail hereinafter.

In the drawing, which represents more or less diagrammatically one suitable embodiment of the invention, Fig. 1 is a sectional elevation, showing a boiler with our control system applied thereto; and Fig. 2 is a detail view of a chart or record.

The present invention is useful in a wide variety of instances and indeed, in any case where the relations between two or more factors of a problem, such as a problem of power output, are to be indicated or recorded or used for control purposes. To some extent it is an improvement upon the invention described and claimed in the prior patent to E. G. Bailey, granted March 5, 1918, No. 1,257,965, to which reference may be had for a more complete description if necessary. The present invention is useful for all purposes described in said patent and the mechanism herein described is capable of adaptation and adjustment according to the constants of any given installation to which it may be adapted. For convenience, and in no sense of limitation, the invention will herein be described with particular reference to its use in connection with boiler operation.

In the drawing, the boiler A shown is equipped with a steam output header 1, a stack pipe 2 through which all excess air and products of combustion travel to the stack, and with any suitable fuel feeding mechanism, generally indicated at 3. According to the aforesaid Bailey patent, it is equipped with means for recording and indicating the steam flow-air flow relation. For this purpose, any mechanical, electrical, fluid pressure or other suitable form of metering device or devices may be employed, such as those referred to in said patent.

Briefly described, these instruments include a steam flow meter, marked generally 4 and an air flow meter, marked generally 16, the former including a sealed chambered casing 5 containing a liquid 6, such as mercury, in which floats an inverted hollow bell 7 connected to an arm 8. Rise and fall of the bell within the liquid is controlled by and is sensitive to the flow of steam through the header 1. In the drawing, this effect is accomplished by suitable pipes 9, 10 communicating with the conduit 1 on opposite sides of a Venturi restriction or orifice 11 therein, the pipe 9 communicating with the chamber 12 on the outside of the bell 7 and the pipe 10 communicating with the chamber 13 within said bell. With this arrangement the bell rises and falls with rise and fall of steam flow, and by properly shaping the bell as to its volume, wall thickness, form of surface, etc., and by proper selection of other

constants, such as lever arms, etc., the arm 8, or some member actuated by it or associated with it, may be caused to move an indicator 14 over a scale 14*a* for the purpose of indicating variation in steam flow.

As to air flow, any suitable apparatus may likewise be used, the drawing showing the meter 16 including two hollow inverted bells 17, 18 connected to opposite arms of a lever 19 pivoted at 20 on a stationary support, said bells working in a suitable liquid 21, such as oil, and the chambers therein respectively communicating by means of pipes 22, 23 with openings 24, 25 in the boiler, such openings being separated along the direction of travel of the hot gases in any manner so as to be sensitive to the pressure drop between the two openings. For instance, and as shown, the first opening 24 is in the first pass and the second opening 25 in the last pass, just in advance of the stack, and the various tubes and baffles in the boiler passages produce essentially the same effect as a Venturi restriction or an orifice, as is well known. The lever 19 carries a displacing member 26, of suitable material, which rises and falls in a suitable liquid, such as mercury, in a vessel 26*a*. As in said Bailey patent, this meter 16 as a whole is sensitive to the flow of gases through the boiler, and the lever 19, or some member operated thereby or associated therewith, such as the pointer 28, may be caused to travel over a scale 28*a*, and again, with proper selection of constants, such as the shape of member 26 and other constants, according to said Bailey patent, may be made to indicate variations in flow of gases with due regard for the desirable relation to steam flow. Member 26, of course, may be shaped to take account of any or all laws determining the relation between steam flow and air flow.

Of course, it should be understood that for convenience and simplicity of language in the description and claims, all gases which flow through the boiler and to and through the stack or stack pipe, including the air, carbon dioxide, carbon monoxide, and any other gaseous products of combustion that may in any manner reach and travel with the gas stream, are generally referred to herein as "gases" or "air".

It should also be understood that, as shown in said Bailey patent, the steam flow and air flow indicating pointers 14 and 28 may be caused to travel across the same scale, and, by equipping them with pens, to produce their respective traces upon the same rotating or other time operated chart, such a common chart being indicated in Fig. 2. The traces of the two pens may be parallel and separated by any suitable distance, but preferably the parts are so arranged that most efficient furnace operation causes the traces of the two pens to be coincident, or nearly so, a condition in which they may be said to be in unity relation. Unity relation, therefore, in this application refers to a condition of which an indication, by pens or otherwise, is produced jointly by two factors of boiler operation, such as steam flow and air flow, when the boiler is operating under the most efficient conditions; and when the unity relation is no longer indicated, such as by separation of the two nearly coincident pen traces, their separation indicates departure from most efficient boiler operating conditions.

The scale of the steam flow meter may be graduated in any desirable units, but is usually graduated in terms of pounds per hour, so that the steam flow pen, by its position on such scale, affords an actual and accurate indication of the steam flow. The parts are also so arranged that the air flow pen, by its position on the same or a similar scale, indicates the amount of gases flowing through the furnace per hour to give the most efficient furnace operation, all factors in such operation being taken into consideration. The air flow indication is therefore relative and not absolute, although both air flow and steam flow meters are operated on rate of flow principles, such as ordinary water or gas meters.

In the past, when feed water was heated in feed water heaters open to the atmosphere, it is obvious that the water never exceeded a temperature of 212° F. and variations in the temperature of the feed water were more or less immaterial. However, with modern boiler practice, feed water is heated under pressure to temperatures of 400° F. or more, steam being taken from one or more of the stages of a turbine for heating purposes. If the supply of heating steam is suddenly cut off for any reason, obviously the temperature of the water fed to the boiler may vary as much as 100° F. or more.

In practice it is found that such wide variations of feed water temperature not only render indication and record of the steam flow-air flow relation, as in the Bailey patent, more or less inaccurate, but if the steam flow-air flow relation is utilized as a guide for correct adjustment of the air flow, either manually or automatically, a material loss in efficiency occurs. This may be readily understood if in a given instance it is assumed that in a given boiler steam pressure, steam temperature, and steam flow are permitted to remain constant; that most efficient furnace operation produces coincident traces of the steam flow and air flow pens on the chart; and that feed water temperature suddenly increases.

Under such circumstances, since the steam flow is constant, the steam flow pointer 14 in Fig. 1 of the drawings remains at the same point and reads correctly on a pound basis

if the chart is graduated in terms of pounds per hour. The air flow pen 28 also remains at the same point and reads correctly the volume of gases passing through the boiler, but its position falsely indicates by coincident record with the steam flow pen that the desired unity relation and most efficient boiler operating conditions exist. At a higher feed water temperature less B.t.u.'s per pound are required to put out steam at the same delivery conditions of pressure and temperature, meaning that less B.t.u.'s are absorbed for any given number of pounds of steam. To maintain the boiler at the same efficiency less B.t.u. liberation is required and correspondingly, a less total volume of air ought to be supplied for combustion of the fuel with the same excess of air. The air flow meter therefore should receive a compensating adjustment to move its pen up to indicate that too great air flow exists for best economy under the new conditions and if it or an associated part automatically controls the air flow, the adjustment should reduce the air flow. Otherwise, if the steam flow-air flow unity relation as indicated, by the preferably coincident traces, as stated, or as recorded or used, is maintained exactly the same upon an increase in feed water temperature, an unnecessary excess of air will pass through the furnace and carry away heat and reduce efficiency without notice of the change either to the operator or to the automatic control mechanism, if any. In other words, under the given conditions a rise in feed water temperature should raise the value indicated by the air flow pen so that either the fireman or the automatic controlling device will have notice of departure from unity relation and will bring the steam flow-air flow relation back to unity by decreasing the volume of gases passing through the boiler.

To produce these results, the boiler indicating and control system shown is supplied with mechanism for causing proper compensation for variations in feed water temperature in one or the other or both of said meters and in the specific arrangement shown in the air flow meter. For this purpose, we provide a thermometric element 29 located in or near the feed water supply pipe so as to be sensitive to the temperature of the water fed to the boiler, whereby variations in feed water temperature expand or contract the gas in a gas filled manometer system connected by a capillary 30 to a mercury U-tube 31, the open end of which communicates with the mercury in a vessel 32 and carries on its surface a float 33 pivotally connected at 34 to the lever 27.

With this arrangement, the pivots 34 and 35 both float, as does also the pivot 36. Assuming feed water temperature to remain constant, the pivot 34 becomes stationary and meter 16 operates in the usual manner to indicate and record variations in air flow. However, assuming air flow to remain constant, the pivot 35 becomes stationary, and with a variation in feed water temperature, the arm 27 is moved around pivot 35. The result of the coupling of the two sets of forces to the same member 27 is to compensate in the air flow indication at 28 for variations in feed water temperature, according to the principles above referred to.

When steam flow and air flow are indicated by preferably coincident traces on the same chart for the purpose of showing by their separation departures from a unity relation between them, as in said Bailey patent, it is clear that in the present arrangement such relation will still be accurate even though the feed water temperature varies by material amounts, even as much as 100° F. or more. If the feed water temperature does vary, the air flow pointer 28 is moved to a new position, causing a departure from the normal unity relation between the traces of the two pens and notifying the operator of the necessity of varying air flow to restore the desirable unity relation.

In addition to the above, it is also desirable in some cases to utilize the meters so far shown and described for automatic control purposes, so that the services and constant supervision of the fireman are unnecessary. Such an arrangement requires the two arms 8, 27, or members associated therewith, to conjointly produce proper actuation of the air flow controlling device or devices. Air flow may be controlled in the arrangement shown in the drawing by the position of the damper 50 or by varying the speed of the blower or fan 51. The damper is actuated by a reversible motor 37 and the fan by a variable speed motor 38 whose speed may be controlled by a rheostat 39 operated by a reversible motor 40. The two reversible motors 37 and 40 are in a three-wire circuit including a reversing switch 41 having two sets of cooperating contacts 42, 43 actuated by opposite arms of a lever 44 connected by a link 45 to a cross bar 46 connected by links 47, 48 to the arms 8, 27 respectively.

With this arrangement the beam or bar 46 as a whole is a floating member. Rotation of said member about its center pivot 53 produces no effect upon the control apparatus. This motion occurs with variations in steam output but with proper variation of air flow according to the variation in steam flow so as to maintain the desirable unity relation between them. However, if the pivot 53 moves up or down it closes one or the other of the sets of switch contacts 42, 43 and rotates one or the other or both of the control motors 37, 40 either forwardly or reversely to either increase or diminish the air flow.

As a result, assuming feed water temperature to remain uniform, an increase in steam flow moves over the arm 8 and closes the contacts 42 to actuate the control motors and cause corresponding increase in air flow with a corresponding movement of the other arm of the beam 46 until the switch is restored to neutral position. Assuming steam flow and air flow to remain the same, an increase in feed water temperature raises the arm 27 and closes the contacts 43 to thereby actuate the control motor in the proper direction to decrease the air flow. The first effect of the temperature responsive device is to move the air flow indicator away from its unity relation to the steam flow indicator and the correcting effect upon the air flow meter corrects the air flow and returns the air flow indicator to the unity position. It will be observed, therefore, that the position of the switch member 44 is more or less a function of the presence or absence of the desirable unity relation between steam flow and air flow, with due regard for the effect upon said relation of variations in feed water temperature. When the switch arm is in neutral position with both sets of contacts 42, 43 open, the unity relation exists, and if the switch lever departs in one direction or the other from the neutral, so also is there a departure from the unity relation and from the most efficient boiler operating conditions. The position of the switch lever 44, or some member associated therewith, may therefore be taken advantage of to directly indicate the presence or absence of the unity relation, as well as whether a departure therefrom is in one direction or in the other. This result may be secured, for example, by providing the switch lever 44 with an extension forming a pointer 54 cooperating with a scale 55 on which is a unity relation graduation 56. Movement of the pointer 54 in one direction or the other from this graduation indicates a corresponding variance in boiler operating conditions, and is equivalent to the unity relation indication afforded by the two nearly coincident pen traces on the chart, Fig. 2.

The foregoing is based upon graduation of the chart, Fig. 2, according to weight, or, for example, in terms of pounds per hour, but such form of graduation is not essential because the chart may be made to read, for example, in percent of boiler rating, which is based upon rate of heat absorption rather than rate of steam production. Under such conditions, let us again assume that steam pressure, steam temperature, and steam flow remain constant; that coincident pen traces mean most efficient operation; and that the feed water temperature rises. Then the steam flow pen remains at the same point on the chart and reads correctly on a pound basis. That is, the chart constant may be assumed to be on the basis that 100% rating equals a given number of pounds of steam per hour. Since the total number of pounds of steam per hour has not changed, then the same chart reading times this chart constant gives the true rate of steam output. However, on a B. t. u. basis the steam flow pen reads incorrectly and higher than it should, for, at a higher feed water temperature less B. t. u.'s per pound of steam are required to put out steam at the same delivery conditions of pressure and temperature. To make the steam flow pen read correctly on a percent of boiler rating basis, for an increase in feed water temperature its reading should be decreased by an amount proportional to the change in B. t. u. absorption per pound of steam produced.

The air flow pen reads correctly the relative volume of air passing through the boiler to steam produced under the new conditions, but the steam flow-air flow relation of unity observed is inaccurate and should be corrected to take account of the actual excess air conditions desired to be produced. This may be accomplished by causing the feed water temperature compensator to make a proper adjustment of the steam flow meter and pen to make it read lower, or of the air flow pen to make it read higher, either such adjustment necessarily causing proper indication or control of the boiler.

The apparatus described may be used in various ways, several of which will be referred to in detail, but not in any sense of limitation, because the invention is capable of use in any manner whatever within the scope of the claims appended hereto.

1. It may be used as an indicator or as an indicator or recorder by causing the steam flow meter to actuate its pointer 14 and the air flow meter its pointer 28, with a proper compensating effect upon one or the other thereof, such as the air flow pointer, according to variations in feed water temperature.

2. The same system may be employed for automatic control and compensation by inclusion with the same parts of the beam 46 and its connection to the switch mechanism shown.

3. Steam flow and air flow meters properly associated by their design or construction, as stated, may be caused to actuate two pointers 14, 19*a*, the two meters being coupled to automatic control mechanism of the kind described, and including compensating means sensitive to variations in feed water temperature and effective upon the automatic control mechanism, but not upon the pen traces or indications. In this arrangement the pen traces would be coincident only at one feed water temperature. At other feed water temperatures there would be a departure of the pen traces from each other, seeming to indicate lack of the unity relation, but nevertheless a proper compensating effect would actu-

ally be introduced into the control mechanism and become effective upon the boiler.

4. Any or all of the pointers 14, 19*a* and 28 may be omitted, but the linkage thereto would be retained and caused to actuate the control switch and its pointer 54, which would therefore become an indicator of the existence of the unity relation between steam flow and air flow, and with such arrangement, the feed water temperature compensator could be included, with its effect upon the pointer 54 and the boiler control device, such as the damper or the like.

5. All devices shown and described herein, and their equivalents, of course may be used in one and the same apparatus, such as in the complete arrangement illustrated in Fig. 1.

What we claim is:

1. A relation indicator to show whether or not unity relation exists between three coactive variable factors in the operation of a power producing or using apparatus, comprising a first device sensitive to variations in an operating factor which cooperates with steam flow and air flow in the operation of said apparatus and which factor is widely variable and is not controllable by but affects operation of said apparatus, a second device controlled in accordance with variations in steam flow, a third device controlled in accordance with variations in air flow, indicating means sensitive to variations in the resultant of said widely variable factor and one of the other two factors in the operation of said apparatus, and indicating means for the other of said two other factors in the operation of said apparatus, said two indicating means being associated in such manner that conjointly they produce a further indication of unity relation between said three variable factors and departures therefrom.

2. A relation indicator to show whether or not unity relation exists between three coactive factors in the operation of a vapor generator, of which three factors the feed liquid temperature is one and varies widely and is not controllable by but affects operation of said apparatus, comprising a first device sensitive to the wide variations in feed liquid temperature, a second device sensitive to variations in vapor flow, a third device sensitive to variations in air flow, indicating means sensitive to the resultant of the operation of the first and one of the other two of said devices, and indicating means for the remaining one of said three devices, said two indicating means being associated in such manner that conjointly they produce a further indication of unity relation between said three factors and departures therefrom.

3. Apparatus of the character described, including a relation indicator to show whether or not unity relation exists between three coactive variable factors in the operation of a steam generating boiler, of which three factors the feed water temperature is one and varies widely and is not controllable by but affects operation of said apparatus, comprising a first device sensitive to the wide variations in feed water temperature, a second device sensitive to variations in steam flow, a third device sensitive to variations in air flow, indicating means sensitive to the third and one of the other two devices to indicate variations in the resultant of the widely varying feed water temperature and one of said other factors, indicating means for the remaining one of the three devices, said two indicating means being associated in such manner that conjointly they produce a further indication of unity relation between said three factors and departures therefrom, and automatic means controlled conjointly by said three devices and adapted upon any departure from unity relation to vary air flow and thereby restore unity relation.

4. A relation indicator to show whether or not unity relation exists between three coactive variable factors in the operation of a power producing or using apparatus, comprising a first device controlled in accordance with variations in steam flow, a second device controlled in accordance with variations in air flow, a third device sensitive to variations in a third factor cooperating with steam flow and air flow in the operation of said apparatus and which third factor is widely variable and is not controllable by but affects operation of said apparatus, indicating means for said steam flow device operating to indicate variations in steam flow, and indicating means sensitive to variations in the resultant of air flow and the widely variable factor in operation of said apparatus, said two indicating means being associated in such manner that conjointly they produce a further indication of unity relation between said three variable factors and departures therefrom.

5. A relation indicator to show whether or not unity relation exists between three coactive variable factors in the operation of a vapor generator, of which three factors the feed liquid temperature is one and varies widely and is not controllable by but affects operation of said apparatus comprising a device sensitive to variations in vapor flow, a second device sensitive to variations in air flow, a third device sensitive to the wide variations in feed liquid temperature, indicating means for said first device operating to indicate variations in vapor flow, and indicating means sensitive to said other two devices to indicate variations in the resultant of air flow and the widely varying feed liquid temperature, said two indicating means being associated in such manner that con-

jointly they produce a further indication of unity relation between said three factors and departures therefrom.

6. Apparatus of the character described, including a relation indicator to show whether or not unity relation exists between three coactive variable factors in the operation of a steam generating boiler, of which three factors the feed water temperature is one and varies widely and is not controllable by but affects operation of said apparatus, comprising a device sensitive to variations in steam flow, a second device sensitive to variations in air flow, a third device sensitive to the wide variations in feed water temperature, indicating means for said first device operating to indicate variations in steam flow, indicating means sensitive to said other two devices to indicate variations in the resultant of air flow and the widely varying feed water temperature, said two indicating means being associated in such manner that conjointly they produce a further indication of unity relation between said three factors and departures therefrom, and automatic means controlled conjointly by said three devices and adapted upon any departure from unity relation to vary air flow and thereby restore unity relation.

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