July 15, 1930. S. LOFFLER 1,770,489

METHOD OF REGULATING THE OPERATION OF STEAM GENERATORS

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Fig. 1

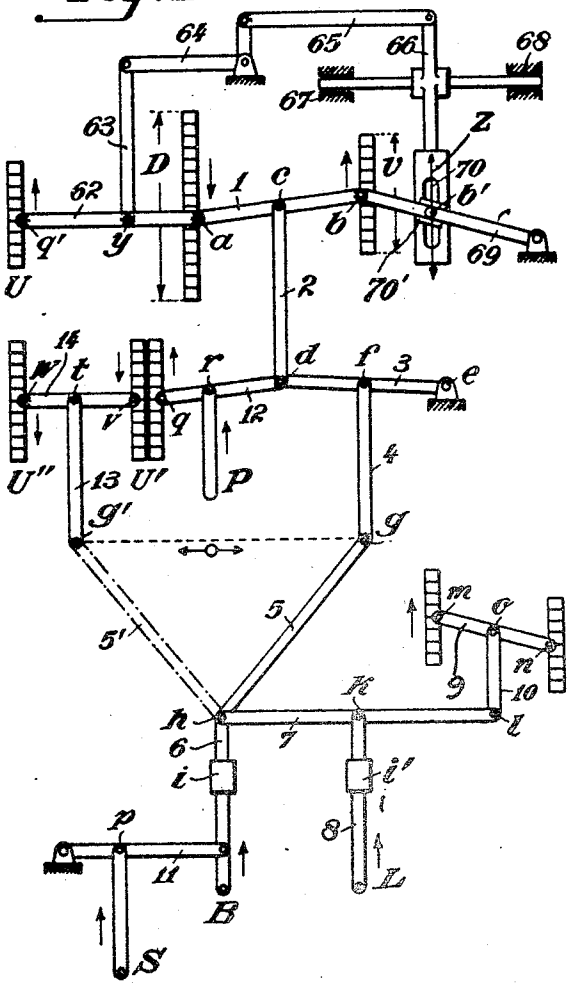


Fig. 9

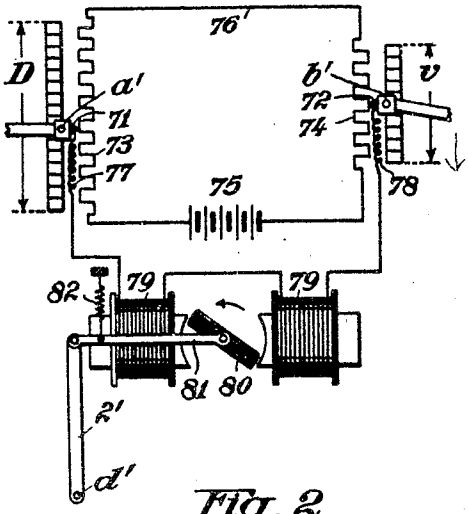


Fig. 2

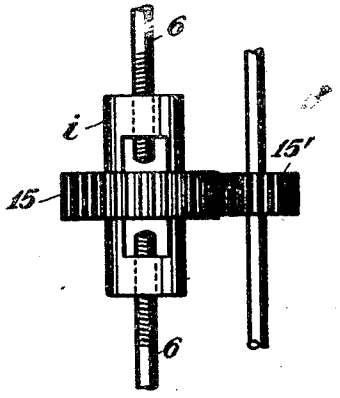


Fig. 4

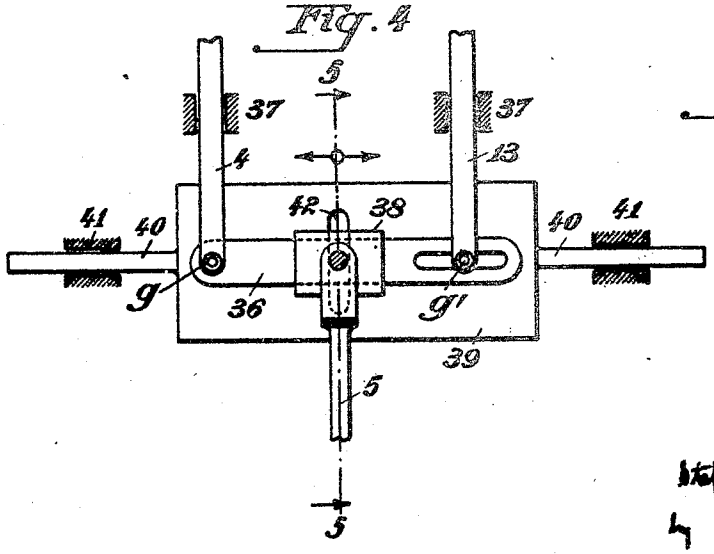
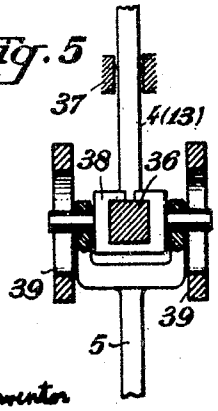


Fig. 5



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Fig. 3

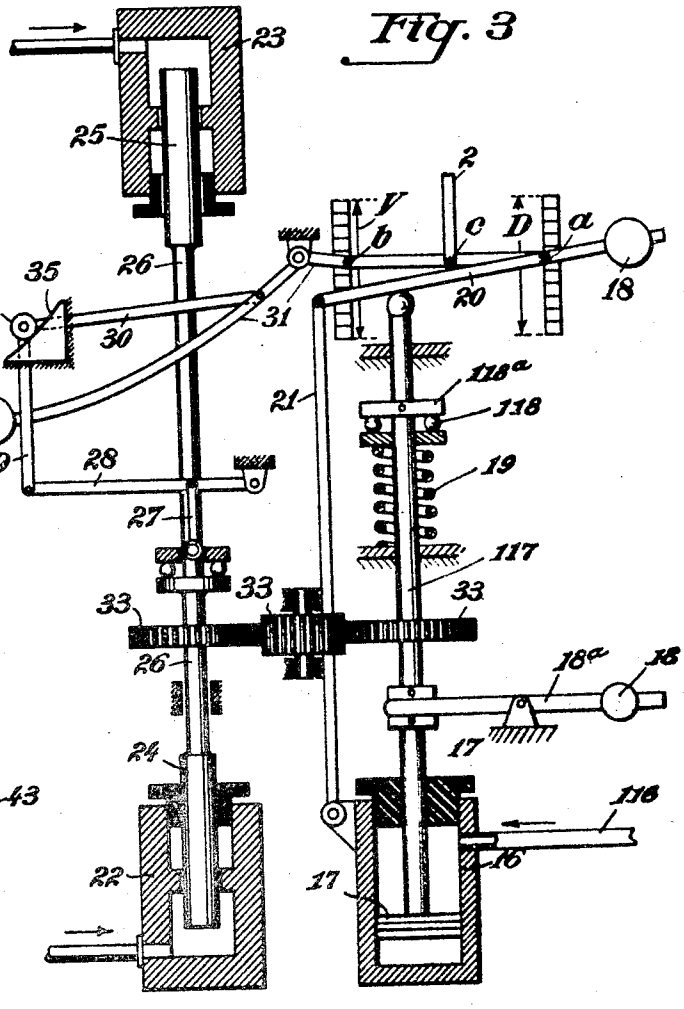


Fig. 6

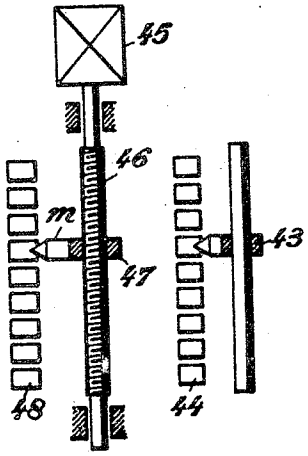


Fig. 7

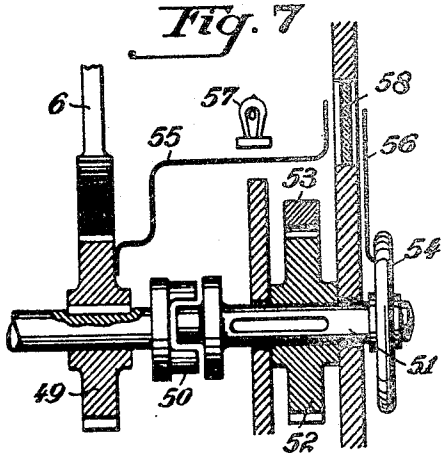
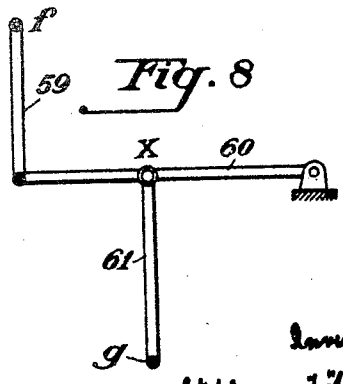


Fig. 8



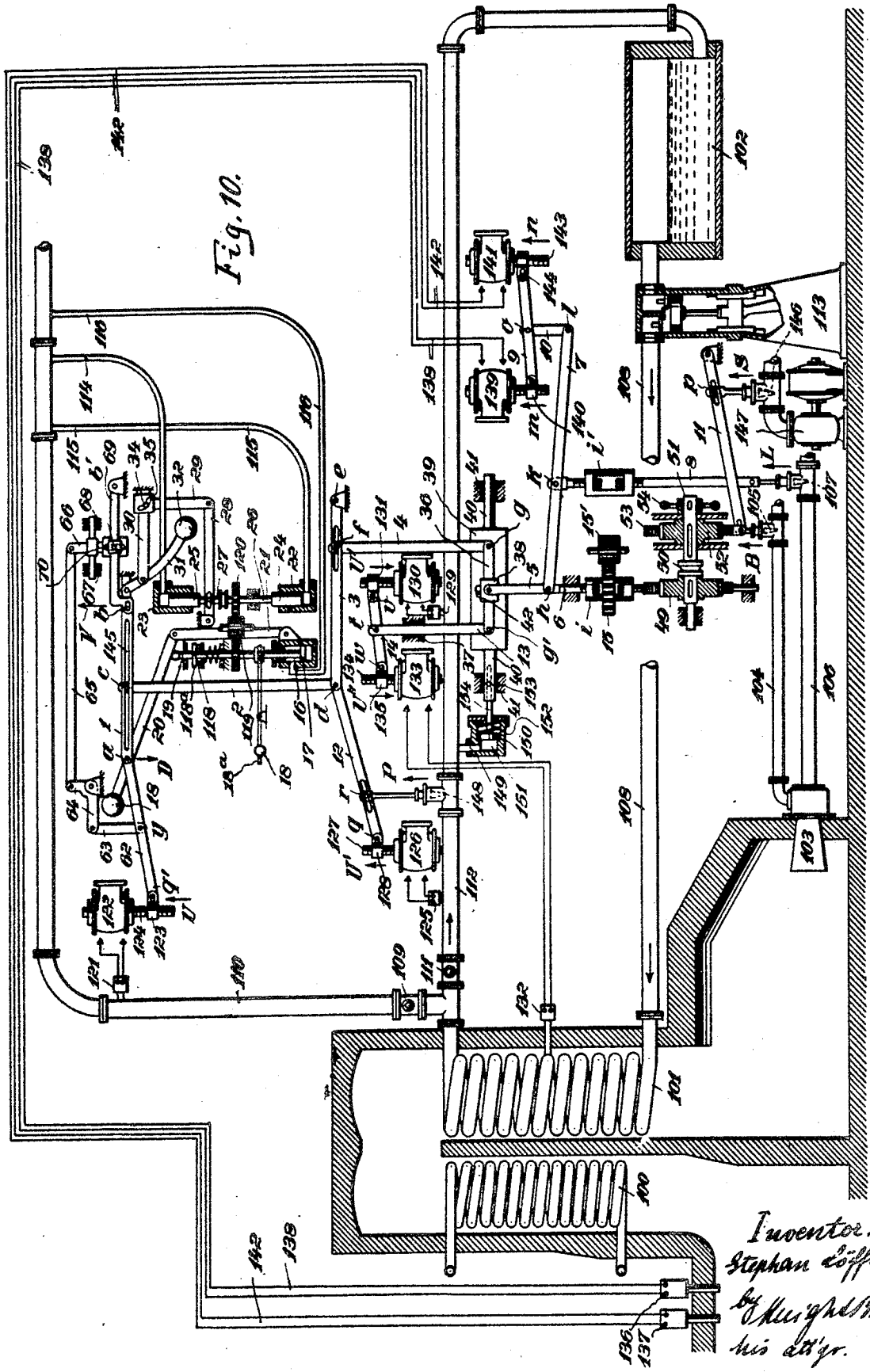
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METHOD OF REGULATING THE OPERATION OF STEAM GENERATORS

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Fig. 10.



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UNITED STATES PATENT OFFICE

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METHOD OF REGULATING THE OPERATION OF STEAM GENERATORS

Application filed September 29, 1926, Serial No. 138,493, and in Germany October 12, 1925.

My invention relates to a novel arrangement for regulating the operation of steam generators, particularly high pressure steam plants, which permits the entirely automatic operation of the plant without human attendance.

Arrangements are known in the art in which the steam pressure is used for exerting a controlling effect, whereby in some instances not the pressure in the boiler itself is used for initiating the regulating movements, but the pressure of the steam at the output side of the superheater. Thereby the steam pressure is somewhat influenced by the steam consumption. This influence of the steam consumption upon the pressure is dependent upon the steam consumption at a square ratio and varies in every plant, so that under these conditions the simple and reliable regulation of the plant, especially in case of high pressure steam plants, is greatly impaired. This quadratic ratio has the effect that the influence of the steam consumption at a low consumption rate does not exert itself at all, and at a high rate of consumption it manifests itself to an exaggerated extent. If it is desired to have a reliable control, it becomes necessary to combine the influence exerted by the steam consumption with that exerted by the steam pressure in a linear way. Accordingly, the pressure responsive means must operate per se independent from the steam consumption indicator, and both, while operating independently of each other, must be coupled for the control purpose in such manner that the control paths for these values may also be influenced by additional variable conditions of the plant, such as, for instance, by the carbon monoxide or carbon dioxide contents of the fuel gases, or by the temperature of the steam or of the fuel gases, or of the combustion air, or of the boiler walls, or the like.

The steam consumption in this case may be measured by the pressure drop in the service pipe supplying the consumers, or still better at a special point in the service pipe at which, for instance, a Venturi tube or a throttle disc or the like may be located. By these provisions a regulation apparatus of the same design may become applicable to steam generators of various kinds and sizes.

There are also arrangements known in which the pressure drop of the combustion air in the heating flues may be made use of for exerting a control. Such an expedient, however, requires on account of the small differences in pressure prevailing in these flues, extremely sensitive measuring instruments which are very expensive and extremely delicate.

According to my invention I propose to vary primarily the air supply, together with the fuel supply, in dependency from the steam consumption and pressure at a linear ratio. It would be possible, however, that such a regulation might be disturbed by uncontrollable influences, and that it would not always result in the most economical fuel consumption at the most favorable carbon dioxide content in the fuel gases. Therefore, according to the present invention, if necessary, the control of the air supply is to be additionally influenced by the carbon dioxide and carbon monoxide content in such manner that the carbon dioxide content of the flue gases is kept as nearly constant as possible, and that the formation of carbon monoxide is avoided as much as possible. However, also, other variable conditions of the plant, such as the temperature of the steam, of the fuel gases, of the combustion air, and also the temperature of the tube walls of the heater, and other similar variables, may be enlisted as adjuncts for correcting the regulation.

I have illustrated in the accompanying drawings, and described in more or less diagrammatic formation, a form in which my invention may be reduced to practice, and in

which the individual effects are transmitted and coupled mechanically.

In these drawings—

Fig. 1 represents a general diagrammatic layout illustrating the cooperation of the levers and links coupling the operations of the different measuring elements;

Fig. 2 represents a detail showing a turn buckle by which the control rods for the fuel and air supply can be lengthened or shortened automatically;

Fig. 3 represents in larger scale, and more detailed, a device for utilizing the variations of the steam pressure and steam consumption for the control purposes;

Fig. 4 represents a side elevation in larger scale of a device for shifting the control device from its setting from firing-up to a continuous operation of the plant;

Fig. 5 represents a transverse section through Figure 4 on the line 5—5;

Fig. 6 represents an arrangement for electrically transmitting the control effects;

Fig. 7 represents an arrangement for temporarily removing the automatic control and substituting it by hand operation;

Fig. 8 represents an arangement for adjusting the influence exerted by the steam consumption and steam pressure upon the fuel and air supply;

Fig. 9 represents a modification of the invention in so far as electric transmitting devices are used instead of mechanical devices, as shown in Figure 1; and

Fig. 10 represents an assembly of the different individual regulating devices in the manner in which they would be used in a practical steam plant.

The variation of the steam consumption and of the pressure are made use of within certain limits for exerting a controlling or regulating effect. For the steam consumption a range including the minimum and maximum consumption is used. With this difference in consumption corresponds a certain path V which the instrument traverses. For the response to pressure variation, the range including the lowest practically admissible pressure and the highest pressure consistent with safety is used, with which corresponds an indication range of the instrument equal to the path D.

The fundamental layout, represented in Figure 1, is shown reduced to a practical form in the general layout of the steam plant, in Figure 10. Referring to the latter figure, the steam generator plant consists of a superheater 100, of a superheater 101, and of a vessel 102, in which the steam is generated. As fuel, powedered coal is assumed, which is injected through a nozzle 103. The coal is supplied to the nozzle by a conduit 104, which can be controlled by means of a valve 105. A duct 106, through which the combustion air is supplied, may be controlled by means of a valve 107. The superheater 101 consists of a tubular coil to which the saturated steam generated in vessel 102 is supplied by means of a conduit 108. The steam superheated in this coil partly passes through a valve 109 into service pipe 110, from which the consuming devices have been omitted. The other portion of the superheated steam passes through valve 111 into conduit 112, through which it is conducted into the steam generator 102, in which it transfers its heat to the water contents of the generator, through which constantly new steam is generated. Such a method of steam generation is very well fitted for operating at high steam pressures. The circulation of the steam between the superheater 101 and the generator 102 is brought about by means of transfer pump 113. From conduit 110 a pipe line 116 leads into a cylinder 16 in which the steam pressure exerts itself through its condensate upon a piston 17 of a pressure responsive device. The cylinder and the plunger are illustrated in detail in Figure 3.

To the piston 17 is connected a piston rod 117 to which is splined a gear wheel 33. The upper end of piston rod 117 is spherically shaped and abuts against lever 20, which is pivotally attached at one end to a link 21 pivoted at its lower end to cylinder 16, which in this respect represents a fixed point. A spring 19 resting at its lower end upon a fixed support, presses with its upper end through a step ball bearing 118 against a disk 118^a fixed to piston rod 117, tending to move the piston rod upward against lever 20. Gear wheel 33 meshes with a pinion 119 by which the plunger 17 is constantly rotated at a moderate speed in order to reduce in well-known manner to a minimum the frictional resistance offered against its longitudinal movement. Pinion 119 may be driven from any suitable motor. In particular, it may be driven from the same motor which drives the transfer pump 113, because this pump is uninterruptedly in operation so long as the steam generator is in operation.

A weight 18, which is attached to one end of a double armed lever 18^a, produces by the other arm of this lever a constant counter-pressure against the medium operating in cylinder 16 against plunger 17. Only when the steam pressure overcomes this counter-pressure can it exert its controlling influence upon the automatic regulating device. The excess steam pressure exerted in cylinder 16 is counteracted by spring 19, whose compression is denoted by the indicating path D (see also Figures 1 and 3), such that the point *a* of lever 20 traverses the path D, the length of the path traversed in each case corresponding with the prevailing steam pressure.

From the service main 110 are further branched two pipes 114 and 115, which lead respectively to pressure cylinders 23 and 22.

In these cylinders are disposed respectively plungers 25 and 24, whose detail construction is shown more fully in Figure 3. These plungers serve for measuring the differential pressure for the purpose of ascertaining the steam consumption or rate of flow. The differential pressure is transferred by rods, links and levers 26, 27, 28, 29 and 30 to a double-armed lever 31, at one arm of which is attached the operating bar 30 and a weight 32 which counterbalances the differential pressure existing at the time, and to the other arm of which is attached at the point *b* a regulating lever 1. By the throw of lever 31 the total steam consumption V is measured. The links 29 and 30, which are pivotally joined at 34 in a roller, operate so that this roller rolls off on a stationary curved abutment 35. By the lever and link arrangement 27, 28, 29 and 31 the differential pressure which varies with the square of the steam consumption, is transformed into a linear value represented by the path V at the point *b* of regulating lever 1.

Such a transformation from a quadratic indication into a linear indication may, of course, be brought about by other devices of similar character such as by lever arrangements or by electric or hydraulic transmission.

The total regulating effect is derived at the point *c* and is further transmitted by means of link 2. The piston rod 26 which carries the two plungers 24 and 25, should preferably also be rotated from pinion 119 through a gear wheel 120, keyed to the piston rod, in order to reduce the frictional losses and resistances offered against their longitudinal movement.

In the service pipe 110 is further provided a temperature responsive device 121 which electrically affects servo-motor 122 in such manner that the latter will adjust nut 123, threaded on shaft 124, so that the position of nut 123 varies with the temperature U in service pipe 110, and so that each position of the nut corresponds with a certain temperature. A similar temperature measuring device 125 is inserted in steam conduit 112. It controls servo-motor 126, which in similar manner adjusts the nut 128 threaded on to its shaft 127 in accordance with the temperature U′, existing in conduit 112. In conduit 112, a second temperature measuring device 129 is provided, which controls a motor 130, which adjusts a nut 131, threaded on to its shaft, and which is also positioned by its motor in accordance with temperature U′. A further temperature measuring device 132 is provided in the middle of the superheater coil 101. This device controls a motor 133, which adjusts by means of its threaded shaft 134 a nut 135, so that its varying positions correspond respectively with varying temperatures U″ prevailing in the middle of the superheater 101.

The chemical composition of the flue gases is measured by two flue gas indicators 136 and 137. The indicator 136 measures the contents of carbon dioxide. It controls a servomotor 139 with which it is connected by line wires, the motor, in a manner similar to that described with reference to the other servomotors, adjusting a nut 140 threaded on to its shaft such that each position of the nut corresponds with a certain percentage of carbon dioxide content in the flue gases. The arrangement is such that nut 140 travels in the direction of the arrow *m* when the carbon dioxide contents rises. Flue gas indicator 137 measures the carbon monoxide content of the flue gases. It controls in a similar manner motor 141 with which it is connected by line wires 142. Motor 141 adjusts, by means of its threaded spindle, nut 144 in such manner that the latter travels in the direction of the arrow *n* at increasing carbon monoxide content.

Point *a* of lever 20, in the upper portion of Figure 10, which is adjusted in accordance with the steam pressure, and point *b* of lever 31, which is adjusted in accordance with the steam consumption, are coupled together by means of lever 1 linked to the respective elements on which these two points are located. This lever 1 is slotted, and in this slot the end *c* of a bar is disposed and made adjustable by hand. When the pressure or the steam consumption varies, this bar 2 is operated with lever 1. Bar 2 is pivotally attached at the point *d* to a one-armed lever 3, pivoted at a fixed point *e*. In a slotted portion *f* is disposed the end of link 4, so that it can be adjusted by hand, another link 36 being pivotally attached at *g* to link 4. The other end of link 36 is pivotally attached at *g′* to a bar 13, which in turn is attached at its upper end at *t* to a coupling bar 14, which couples the nuts 131 and 135, adjusted respectively by motors 130 and 133, as previously described. The coupling points of bar 14 with the nuts are respectively *v* and *w*. So long as point *g′* remains stationary, and when link 4 is moved in vertical direction, link 36 swings on pivot *g′*. This latter pivot, by reason of the previously described construction, is however floating, varying in vertical direction in accordance with the temperatures U″ and U′ measured respectively at the middle and at the end of the superheater. Vertical bar 13 is guided at 37, so that it only moves in the direction of its longitudinal axis.

On line 36, suspended on bar 13, and link 4, is disposed a sliding sleeve 38, which is provided with trunnions, to which is pivotally attached rod 5 (see Figures 4 and 5). By means of the frame 39, in which the trunnions of slide 38 are disposed, the slide can be moved to the left and right on link 36.

For this purpose, frame 39 is provided with two guide rods 40, one at each end, which in turn are journalled at 41. The slide 38 might be shifted to the extreme left-hand position near the point g, or to the extreme right-hand position near point g' (this represents respectively the control of the device during the continuous operation of the plant or the control of the device during the firing-up period).

Sleeve 38 of link 36 is in turn attached by means of rod 5 to a vertical rod 6. The latter is guiding at its upper and lower end in fixed guides, and carries a rack bar engaging pinion 49. The length of rod 6 can be varied by means of a turn buckle i, which can be rotated by means of the pair of gear wheels 15 and 15'. When rod 6 performs a vertical motion, thereby rotating pinion 49, the latter drives by means of a coupling 50 a shaft 51, to which is keyed a pinion 52 and a hand wheel 54, as shown in detail in Figure 7. Pinion 52 operates a rack bar 53, which is attached to the slide valve 105, provided in the fuel supply duct 104. When the hand wheel is pulled in the direction of its shaft 51 to the right, the coupling 50 is disengaged. To rack bar 51 is pivotally attached a lever 11, which influences a valve 146, attached at p to lever 11, and disposed in the feed water supply line connected to feed water pump 147. If the coupling is released by pulling out the hand wheel, as described hereinbefore, the amount of fuel supplied through duct 104 can now be controlled by hand. The extent to which the manual or the automatic control has taken effect, may be indicated by the hands 56 and 55 respectively, such that in case of manual operation only the pointer 56 is visible from the outside, while in case of automatic operation, a lamp 57 may be lighted (by means not shown here) through which the shadow of pointer 55 becomes visible on the frosted glass 58 which may be provided with graduations.

The end h of link 5 has pivotally attached to it a lever 7, which is linked at its end l, by means of a link 10, to the point o of a horizontal bar 9, which latter connects the two traveling nuts 140 and 143. The position of point o is thus determined by the amount of carbon monoxide and carbon dioxide content in the flue gases. At the point k of lever 7, is pivotally attached a control rod 8, whose length can be varied by means of a turn buckle i', and the lower end of which rod is attached to a gate valve 107, provided in combustion air supply duct 106. If desired, turn buckle i' might be automatically operated in a manner similar to that described with reference to turn buckle i.

At the junction point d between vertical link 2 and lever 3, previously mentioned, another lever 12 is pivotally attached which has its fulcrum at the point q, which is part of the traveling nut 128 operated by motor 126 in accordance with the temperature conditions in conduit 112. Thus, a floating fulcrum for this lever is established. The point of application of the lever is in a slot in which the control rod of a steam gate valve 148 is attached. Thus the position of the point r at any time is determined by the position of point d, which depends upon the steam pressure and consumption, and is determined also by the position of the point q which depends upon the temperautre U' of the superheated steam.

The devices and arrangements for measuring and utilizing the steam pressure and consumption, described hereinabove, may be utilized to a particular advantage for measuring the weight of the steam passing into the service line 110 for consumption. In Figure 10 is illustrated a mechanical indicating arrangement suited for this purpose and which includes levers 62, 63, 64, 65, 66 and 69. These elements, correspondingly numbered, will be found in the general layout of Figure 1, from which the influence of this arrangement upon the system may be clearly ascertained. At the intermediate point v of lever 62, which is connected at one end with the point a of the pressure measuring device, and at the other end to the point q' which is located at the traveling nut 123 of the temperature measuring device 121, a link 63 is pivotally attached, which in turn operates bell crank 64, and the latter through push rod 65 operates a slide 66, which can be horizontally shifted in its bearings 67 and 68. This slide has a downward extension in the form of a frame provided with two vertical slots 70 (see more detailed Figure 1), in which the pins b' of a sleeve 70' are disposed. This sleeve slides on lever 69 of the pressure responsive device, previously described. By this arrangement, the steam consumption is indicated by the position of the point b' in kilogram after the indication has been corrected percentually and linearly with respect to the varying pressure and temperature conditions. Such an indication is correct because with falling steam pressure and rising temperature of the superheated steam, the ratio at which the motion of point b of the steam consumption indicator is transmitted to the point b' is diminished.

In certain cases, if desired, also an apparatus may be used for measuring the actual quantity of the consumed steam, for the purpose of measuring it in kilogram, with the correction by the pressure and temperature responsive device.

For instance, for the purpose of explanation, if it is assumed that the steam consumption at constant pressure rises in accordance with the arrow z (Figure 1), lever 1 rises, and through the cooperation with the levers

and rods 2, 3, 4, 5, 6, and the geared couplings 49, 50, 51, 52 and 53, which in Figure 10 appear in the lower central portion, the fuel supply is increased in the direction of the arrow B by opening the gate 105 of the fuel supply duct. The effect is similar if at constant steam consumption the pressure drops. In all cases, simultaneously with the variation in fuel supply, the quantity of combustion air is increased in the direction of the arrow L by the operation of lever 7 and vertical movement of rod 8, which controls the gate of air valve 107.

For the purpose of further explanation of the function of this device, so far described, under what will be termed hereafter in the claims the "varying operating conditions of the plant", the following two main variations in the operating conditions are assumed, and the functions of the device are traced.

I. Falling pressure in the steam main and increasing steam flow: Point *b* moves upward, point *a* moves upward.

As a result, the fuel valve 105, the air valve 107, the steam circulating valve 148, and the feed water valve 146 open. As a consequence, the amount of steam circulation through 108, 101, 112 increases and more steam becomes available for the service main.

II. Increasing pressure in the steam main and decreasing steam flow: Point *b* moves downward, point *a* moves downward.

The result is the downward (closing movement) of fuel valve 105, air valve 107, steam circulating valve 148, and feed water valve 146. The decreasing steam temperature at 125 closes valve 148, and less steam is supplied to the steam main.

In case the aid of the composition of the flue gases is enlisted for controlling the fuel consumption—for instance, by abstracting them from the flue and mixing them with the combustion air—also the amount of this flue gas is varied simultaneously with the variation of the combustion air. The extent to which air gate 107 is influenced is, besides, determined also by the carbon monoxide and dioxide content of the flue gases. With increasing monoxide and dioxide content, the traveling nuts 140 and 143 rise in the direction of the arrows *m* and *n*. When this occurs, lever 9 lifts link 10 and brings about by way of lever 7 and rod 8 a motion of gate 107 in the direction of the arrow L, and thus an increase in air supply. The effect which the carbon dioxide content exerts upon this control must preponderate to such an extent that a decrease in carbon dioxide content, resulting from this above-mentioned regulation, is more than balanced by the surplus, in order to avoid an appreciable formation of carbon monoxide.

Simultaneously with the fuel also the feed water supply is increased by means of lever 11 operating valve 146 in the direction of the arrow S. This feed water control may also be brought about by connecting the gate valve to other points of the fuel control device, which serves for actuating valve 105.

The control motion for influencing the amount of steam P transferred from the superheater to the steam generator 102, and which control is exerted by valve 148, is derived from the point *d*. At increasing fuel supply, the lever 12 and slide 148 are moved in the direction of the arrow at P, and thus the amount of steam transferred to the generator is increased. This quantity is still further increased if, at rising superheater temperature, the traveling nut 128 should rise in the direction of U'. This would again bring the superheating of the steam to the desired value.

Instead of mechanically coupling the control effects exerted by the steam pressure and consumption, and by the carbon monoxide and dioxide content of the flue gases, also electrically, hydraulically or similarly operated devices may be used.

The variation of the fuel quantity B is brought about usually by varying the cross-sectional area of the fuel duct, sometimes also by apportioning the volume of fuel, for instance, by means of a worm or the like.

In both cases, the degree of granulation of the fuel, or the varying heat value of different fuels, or the varying water contents or similar factors, may disturb the exactness of the fuel supply control, since under those varying conditions for the same amount of regulation of valve 105, different heating effects would be produced. Without additional regulation to counteract these defects, the desired normal steam pressure of the plant would be considerably disturbed. In such cases, for instance, the point *a* of lever 1 would rise or drop until a change in heating effect is equalized by additional adjustment of the fuel supply B. Such change, however, according to the general arrangement heretofore described, would be desirable only at temporary variations of the heating effect, but not for permanent variations or changes as would, for instance, be brought about by using a granulated fuel of different heating value, or having other variables, previously mentioned. If, therefore, such changes in operation will last presumably for a longer period, the undesired variation of the pressure can be largely prevented by deriving the movement for varying the fuel amount B from a different point *f* of the one-armed lever 3 (lever 3, as will be remembered, is pivotally attached to the point *d* in the center of Figure 10). For this reason the point of application *f* is disposed in a slot in lever 3, so that it can be shifted to a certain extent.

It is not of advantage to control the fuel supply—besides in dependency from the

pressure—also in dependency from the steam consumption during the firing-up period of the plant. Furthermore, in view of maintaining the apparatus, in particular the pressure responsive device, in as simple a form as possible, and yet maintain the operation as exact as possible, it is of advantage to limit the range of this apparatus only within the operating pressures. For this purpose, the control of the plant by the pressure and by the steam consumption is entirely eliminated during the firing-up, and restored only when a desired operating pressure is attained. This might be brought about by hand, or also automatically, by the steam pressure—preferably derived at the pressure responsive device.

In high pressure steam plants, in which the steam is circulated by a pump and superheated during this circulation, it is advisable during the firing-up period to utilize a special firing-up regulating device while the normal controlling device is cut out. In such an auxiliary control device, the heating effect might be regulated by varying the fuel and air supply merely in dependency from the temperature of the steam, measured for instance at the end of the superheater. Since, however, during the firing-up under certain conditions the temperature in the middle of the superheater might be higher than at its output side, it is advisable to enlist for the firing-up control, besides, the temperature effect derived at the middle of the superheater. In Figure 1, the cutting out of the normal regulation during the firing-up period is indicated by the dash and dot lined rod 5', through which is indicated that rod 5 has been shifted from the point g, at which it is located at normal operation, to the point g' (see also Figure 10). By this shifting, the effect of the normal control by the steam consumption and pressure is removed, and the control of the fuel and air supply is exerted solely by the vertical bar 13, which connects at t with the coupling bar 14, which couples the two thermostatic devices which are actuated respectively by the temperature at the output end of the superheater and in the middle of the superheater. By this arrangement, the supply is decreased at rising temperature, when the points v and w descend in the direction of the arrows.

In the modification of the arrangement for shifting the control shown in Figures 4, 5 and 10, the shifting from the firing-up condition to normal operating condition occurs by shifting slide 38 from the limit position g' into the other limit position g. Of course, during the regulation at normal operation, control bar 13 still will perform vertical motions in accordance with the varying positions which traveling nuts 131 and 135 may assume, but this motion has no effect upon control bar 5 for obvious reasons.

Of course, also for this arrangement, other modified forms may be substituted with similar effect. For instance, the shifting from firing-up control to normal control may be brought about by hand or by an electromagnet, by an electric motor, by a hydraulic servo-motor, or similar auxiliary expedients which come into function as soon as the desired pressure has been attained in the service main.

In the modification according to Figure 10, the sleeve 38 is shifted by shifting frame 39 in its bearings 41 by means of a piston 150 which is disposed in a pressure cylinder 151 connected with the steam conduit 112 by a pipe connection 149. This piston is checked by means of control spring 152 which exerts a counterpressure equal to the desired pressure at which the control should be shifted so that when this pressure is exceeded the shifting of the control will take place. Piston 150 is coupled with shifting bar 140 by means of a coupling pin 153, which may be removed if desired, so that the control may be shifted by hand.

Instead of the mechanical apparatus for indicating and utilizing the steam pressure and steam consumption for the control operations, also an ordinary pressure gauge and one of the commonly used steam volume indicators may be used in connection with an electric or hydraulic distance transmission, whereby such indicators are coupled with each other only at the distant receiving point so that their combined function may be exerted with the same effect with which the direct mechanical coupling, shown in Figure 10, accomplishes this result. Also, in the measuring device shown in Figure 3, the position of the plunger 17 and of the rod 26 may be electrically individually transmitted to a distant point and then the two effects can be combined to bring about the same result which is brought about mechanically by the direct coupling shown in Figure 3. During the distance transmission also, instead of the proportional motion of the lever point a in dependency from the pressure, several other devices such as compensation—over compensation—and similar devices may be used by which the desired normal pressure is always obtained under any condition.

In the modification shown in Figures 1, 3 and 10, the regulating path is proportional to the pressure, and presumes accordingly for each variation of the operating conditions which might affect the pressure, a definite, admissible, small variation of the pressure above or below the normal pressure which remains until the causes for the change in the operating conditions are removed.

So far as the idea involved in the invention is concerned, the transmission of the pressure variations for control purposes may be employed in similar manner for all other va-

riable values, so that they may exert controlling influences, such as the carbon dioxide and oxide indicator, the temperature indicator of the superheater, or the like.

The forces in which the control is brought about may be transmitted in a particular simple manner electrically, and may be coupled together with the same effects which are brought about by the described mechanical direct transmission.

A modification of a proportional transmission by means of an electric servo-motor is diagrammatically illustrated in Figure 6, for instance, for the purpose of transmitting the controlling effect of the carbon dioxide indicator. The servo-motor 139, which in Figure 10 mechanically moves the traveling nut 140, operates in Figure 6 a contact shoe 43 which slides over a group of contacts 44, and thereby through suitable connection of this group with servo-motor 45 (not shown) compels this latter motor to shift a traveling nut 47, threaded on to motor shaft 46, along contacts 48, such that it will stop on the contact element of group 48, which corresponds with a particular value of the carbon dioxide content. Of course, any other control device capable of regulating the fuel or air supply, may be operated by the traveling nut 47.

A device by which the indications and responses of the steam volume indicator and the steam pressure indicator are electrically transmitted and combined into a common resulting regulating motion, is illustrated in Figure 9.

The element a' (corresponding to point a in Figure 1) and which is controlled in its motion by the pressure responsive device, and the element b' controlled by the steam volume indicator, are each connected individually with a separate sliding contact 71 and 72 respectively. The former passes over a resistance 73, and the latter over a resistance 74. The two resistances are connected in circuit with a battery 75 and form a closed circuit therewith. The sliding contacts 71 and 72 are connected by flexible conductors 77 and 78 with a magnet system 79. In this system an electric field is produced by the current passing through it, in which field the armature 80 rotates. This armature is connected by means of an arm 81 with a control bar 2', which is suspended by a spring 82. This control bar 2' corresponds with the control bar 2 in Figures 1 and 10. This arrangement operates in the following manner.

If one or both of the sliding contacts 71 and 72 move towards the battery 75, the potential difference existing between the two contacts increases. Accordingly, the electromagnetic field produced in coil 79 increases in intensity and rotates armature 80 in the direction of the arrow. By this motion vertical bar 2' is operated and the point d' is moved downward, the same as point d in Figures 1 and 10, in order to actuate the control mechanism at that point.

The controlling effects derived from the steam pressure variations, and from the varying steam consumption, represent to a certain extent a safety device, in so far as in case the steam consumption indicator should fail to properly function (for instance, in case point b should remain stationary), the heating is influenced alone by the pressure responsive device from the point a, which might then travel the greater part of the path D, which is ordinarily not used when both control devices cooperate. By the parallel guiding of, for instance, the points a, b and c of the control gear, the proportional transmission of the motions of a and b to c is attained. There are, however, other modifications possible in which, for instance, the point c is not guided in parallel to the paths traversed by a and b, but in such manner that the distance of point c from the point a, measured on lever 1, remains constant. While thus the movement deviates from a linear one, the advantage is obtained that the effect in the extreme end positions is intensified, which might be of importance, for instance, in case the response of the steam consumption indicator should fail.

All the above described individual devices for regulating the steam plant such as the pressure indicator, steam consumption indicator, and all the others mentioned may also serve the purpose of optically indicating the changes of the values to which they respond, such as the pressure or the steam consumption or others, and they may even record these variations. In so using these devices, in addition to their other functions previously described, the commonly employed electric distance transmitters may be dispensed with, because the existing movements of the indicators may be used directly for recording the particular values.

If in such a plant a number of steam generators is installed, all of which deliver steam into a common service main, it is advisable to use only one regulating device for the steam pressure and steam consumption, for instance, a device such as is shown in Figure 3. Each generator would in such case receive an automatic regulating system along the general lines illustrated in Figure 1, which is designed so that the resulting path of the regulating elements, which respond to the pressure and steam consumption, and which are operated by the common regulator, actuate in each steam generator directly the point d of lever 3 respectively of lever 12 (Figure 4) so that for each generator a control is brought about similar to the one shown and described with respect to the single generator, shown in Figure 10. If the operating conditions, and thus the output of the individual steam generators, vary for in-

stance owing to the different sizes of the several generators, or the different construction of the plant such as, for instance, the different arrangements of the piping or the heating flues or the like, it becomes necessary in each case to adapt controlling elements and mechanism to the particular character of the steam generator which it controls. For this purpose, as is shown in Figure 8, the coupling between the points *f* and *g* which, for instance, in Figure 1 is effected by bar 4, is substituted by a lever transmission through bar 59, lever 60 and bar 61. By shifting the point of application *x* along lever 60, the length of the regulating path can be adjusted in accordance with the prevailing conditions of the generator controlled by the particular device.

It is also possible, as is shown in Figure 10, to adapt the control device to the heat values of different fuels by shifting the point of application *f* on lever 3, and to adapt the general regulation of the steam generator to the output by shifting the point *x* on lever 60 (Figure 8), both displacements being made by a common means which is actuated by one of the two devices.

Various modifications and changes may be made without departing from the spirit and the scope of the present invention, and I desire, therefore, that only such limitations shall be placed thereon as are imposed by the prior art.

What I claim is:—

1. A device for automatically controlling steam generators comprising a first indicating control device for controlling and indicating the steam pressure in said generator, a second controlling and indicating device, for indicating with a quadratic movement the rate of flow of the steam delivered for consumption, and means for transforming said quadratic movement into a linear movement, both of said devices being interlinked to regulate by their change of position the heat supplied to said generator, at least one instrument responsive to flue gas conditions, and means interlinking both of aforementioned control devices with said instrument for correcting the heat supply controlled by said two control devices in accordance with prevailing flue gas conditions.

2. In a device for automatically regulating steam generators, in combination an indicating instrument for indicating the steam pressure in said generator, a measuring instrument for measuring the rate of steam supplied to the consumer, a control device adapted to regulate by its change of position the quantity of fuel supplied to said generator, and means for mechanically coupling the movements of said indicating and measuring instruments, comprising a coupling element connected at one point to one instrument and at another point, independent of the first, to the other instrument, and a link element connected to a third point of said coupling element and being also connected to said fuel control member for making the position of said control device dependent on the said indicating and measuring instruments, at least one instrument responsive to the condition of the flue gases of said steam generator and means for connecting said last-named instrument to said link element to render the position of said fuel control device responsive to the movements of said indicating and measuring instruments and to said flue gas responsive instrument.

3. In a device for automatically regulating steam generating plants, in combination, a steam pressure indicator, a steam consumption indicator, means for combining the movements of both indicators of these variable plant operating conditions into a resultant motion, a third device responding in its movements to a third variable operating condition which may exist in the plant, a coupling element for coupling the first named resultant motion with the motion of said third device to produce a final resultant motion at said coupling element, a control device adapted to regulate by its movements the heat supply to said plant and means for connecting said control device with said coupling element to operate said control device by said final resultant motion.

4. In a device for automatically regulating steam generating plants, in combination, a steam pressure indicator, a steam consumption indicator, means for combining the movements of both indicators of these variable plant operating conditions into a resultant motion, a third device responding in its movements to a third variable operating condition which may exist in the plant, a coupling element for coupling the first named resultant motion with the motion of said third device to produce a final resultant motion at said coupling element, a control device adapted to regulate by its movements the heat supply to said plant and a variable connection between said control device and said coupling element for operating said control device by said final resultant motion, whereby through said variable connection the effect of the first resultant motion and of the third device motion upon the final control motion may be varied.

5. In a device for automatically regulating steam generating plants, in combination, a steam pressure indicator, a steam consumption indicator, means for combining the movements of both indicators of these variable plant operating conditions into a resultant motion, a third device responding in its movements to a third variable operating condition which may exist in the plant, a coupling element for coupling the first-named resultant motion with the motion of said

third device to produce a final resultant motion at said coupling element, a control device adapted to regulate by its movements the heat supply to said plant and means for connecting said control device with said coupling element to operate said control device by said final resultant motion, a device responding to the varying carbon-dioxide content of the flue gases, a device responding to the varying carbon-monoxide content of the gases, means for combining said two responses into a resultant motion, and means for combining said last-named resultant motion with said final resultant motion for correcting the influence of said final resultant motion upon said control device in accordance with the variation in the flue gas composition.

6. In a plant for generating steam by superheated steam and having a circulating pump for the superheated steam, a device for automatically regulating the operation of the plant, comprising a steam pressure indicator, a steam consumption indicator, means for combining the movements of both indicators of these variable plant operating conditions into a resultant motion, a third device responding in its movements to a third variable operating condition which may exist in the plant, a coupling element for coupling the first-named resultant motion with the motion of said third device to produce a final resultant motion at said coupling element, a control device adapted to regulate by its movements the heat supply to said plant and means for connecting said control device with said coupling element to operate said control device by said final resultant motion, and a control device for the amount of steam circulated by said pump actuated by the motion resulting from the combination of the steam pressure and steam consumption indicator movements.

7. In a plant for generating steam by superheated steam and having a circulating pump for the superheated steam, a device for automatically regulating the operation of the plant, comprising a steam pressure indicator, a steam consumption indicator, means for combining the movements of both indicators of these variable plant operating conditions into a resultant motion, a third device responding in its movements to a third variable operating condition which may exist in the plant, a coupling element for coupling the first-named resultant motion with the motion of said third device to produce a final resultant motion at said coupling element, a control device adapted to regulate by its movements the heat supply to said plant and means for connecting said control device with said coupling element to operate said control device by said final resultant motion, and a control device for the amount of steam circulated by said pump actuated by the motion resulting from the combination of the steam pressure and steam consumption indicator movements, and a device responsive to the temperature of the superheated steam, coupled with said steam control device for correcting the actuating by said last-named resultant motion in accordance with the superheated steam temperature.

8. In a plant for generating steam by superheated steam, and having a circulating pump for the superheated steam, a device for automatically regulating the operation of the plant, comprising a steam pressure indicator, a steam consumption indicator, means for combining the movements of both indicators into a resultant motion, a third device responsive in its movements to temperature variations of the superheated steam, a coupling element for coupling the first-named resultant motion with the movements of said temperature responsive device to produce a final resultant motion at said coupling element, a control device adapted to regulate by its movements the heat supply to said plant, a variable connection between said control device and said coupling element, whereby said control device can be operated normally by said final resultant motion but whereby the control device may also be actuated alone by said third temperature responsive device during the firing-up period of the plant only in accordance with the steam temperature in the superheater.

9. In a plant for generating steam by superheated steam, and having a circulating pump for the superheated steam, a device for automatically regulating the operation of the plant, comprising a steam pressure indicator, a steam consumption indicator, means for combining the movements of both indicators into a resultant motion, a third device responsive in its movements to temperature variations of the superheated steam, a coupling element for coupling the first-named resultant motion with the movements of said temperature responsive device to produce a final resultant motion at said coupling element, a control device adapted to regulate by its movements the heat supply to said plant, a variable connection between said control device and said coupling element, whereby said control device can be operated normally by said final resultant motion but whereby the control device may also be actuated alone by said third temperature responsive device during the firing-up period of the plant only in accordance with the steam temperature in the superheater, and means operated by the steam pressure in the superheater for shifting said variable connection from said firing-up control position to a position in which the first named resultant control motion, which is due to steam-pressure and consumption, preponderates as soon as the desired pressure of the superheated steam is attained.

10. In a device for automatically regulating steam generating plants, in combination, a steam pressure indicator, a steam consumption indicator, means for combining the movements of both indicators of these variable plant operation conditions into a resultant motion, a third device responding in its movements to a third variable operating condition which may exist in the plant, a coupling element for coupling the first-named resultant motion with the motion of said third device to produce a final resultant motion at said coupling element, a control device adapted to regulate by its movements the heat supply to said plant and means for connecting said control device with said coupling element to operate said control device by said final resultant motion, and means for adjusting the extent of said final resulting motion for normal plant operation to compensate for the different heat values of different fuels consumed in the plant.

11. In a device for automatically regulating steam generation plants in combination a steam pressure indicator, a steam consumption indicator, means for combining the movements of both indicators of these variable plant operation conditions into a resultant motion, a third device responding in its movements to a third variable operating condition which may exist in the plant, a coupling element for coupling the first-named resultant motion with the motion of said third device to produce a final resultant motion at said coupling element, a heat supply device and a heat control device for controlling said supply device, means for connecting said control device with said coupling element for actuating said control device by said final resultant motion, and hand operated means for disconnecting said heat supply device from its control device and for controlling it by hand, and means for visibly indicating the extent of the control of said supply device during automatic as well as during hand control.

12. A device according to claim 3 having an auxiliary indicating device connected with the steam consumption indicator and means controlled by the pressure and temperature of the consumed steam for varying the ratio of motion between the consumption and the auxiliary indicator causing the latter to indicate the rate of steam consumption in weight units.

13. In a device for automatically regulating steam generators, in combination an indicating instrument for indicating the steam pressure in said generator, a measuring instrument for measuring the rate of steam supplied to the consumer, a control device adapted to regulate by its change of position the quantity of fuel supplied to said generator, and means for mechanically coupling the movements of said indicating and measuring instruments, comprising a coupling element connected at one point to one instrument and at another point, independent of the first, to the other instrument, and a link element connected to a third point of said coupling element and being also connected to said fuel control member for making the position of said control device dependent on the said indicating and measuring instruments, the connection of said link elements to said coupling element being adjustable, to permit the preponderance of the movement of one or the other instrument upon said link element.

In testimony whereof I affix my signature.

STEPHAN LÖFFLER.