June 25, 1946. G. A. SHORT 2,402,705

CONTROL MECHANISM

Filed Oct. 22, 1943 2 Sheets-Sheet 1

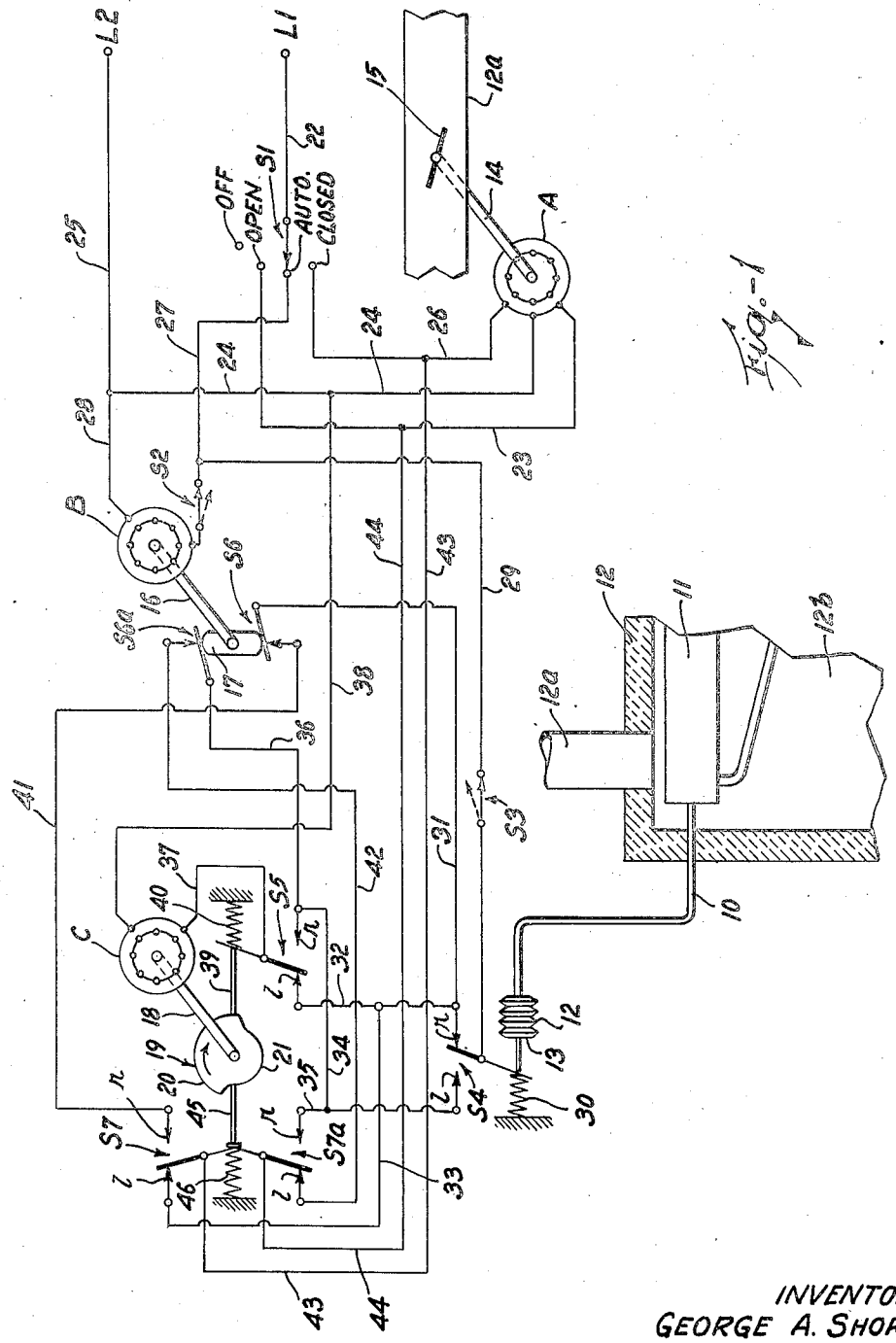


Fig. 1

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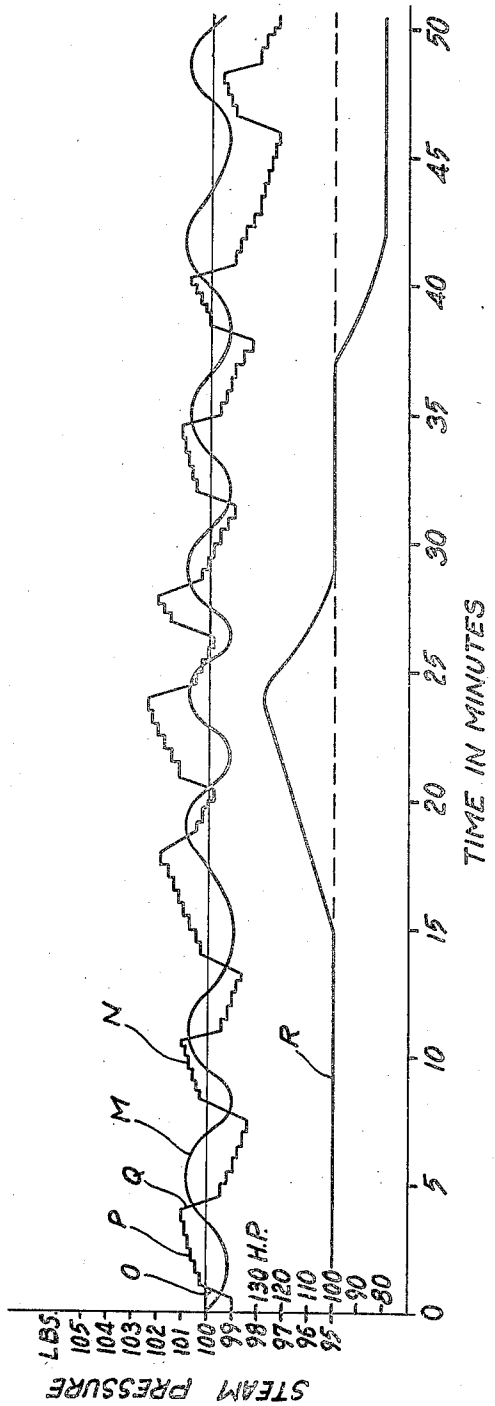


Fig. 2

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2,402,705

CONTROL MECHANISM

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3 Claims. (Cl. 236—46)

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This invention relates to control mechanism, such as is used for the control of furnaces, boilers, hot water or steam heating equipment, or the like, by regulation of the draft, fuel feed or the like, by or in accordance with variations in some suitable factor of boiler or furnace operation, such as temperature, pressure, flow or the like. The invention is an improvement upon that shown, described, and claimed in the patent for Pressure controller, No. 2,304,802, granted December 15, 1942, to Morris W. Crew.

In said patent the control is responsive to changes, for example, in the steam pressure, which become effective to control a suitable operating motor which produces a correcting influence upon the boiler, such as by operation of a draft damper. When a correcting effect is required or called for it is not produced either suddenly or continuously to completion, but by protracted step control, or in other words, by a series of equal short increments or steps repeated and distributed at regularly recurring intervals over a fairly long period of time until full correction is completed or the opposite correcting effect is called for, whereupon the control system operates reversely or in the other direction.

One object of the present invention is to provide an improved control system of this general type, so constructed and arranged as to be sensitive to comparatively small variations in the controlling function, such as steam pressure, and which nevertheless is operative to produce all necessary correcting effect with considerable reduction in the total swing or maximum variation in the variable boiler function incident to or consequent upon this kind of boiler control.

Another object of the present invention is to improve the control mechanism of said prior patent by the inclusion of means adapted, when a correcting effect is called for, and entirely regardless of the position of the controlled device at the time, to introduce, ahead of the protracted or step control, an immediate substantial adjustment of the device to be controlled, resulting in a prompt substantial correcting effect in boiler operation, but usually short of the total correction necessary, followed by sufficient gradual, protracted, or step control, until reverse operation of the controlling equipment is called for.

Still another object of the invention is to provide an improved control system of this kind in which, upon a demand for it, effective operation of the protracted control means is delayed or withheld pending prompt production of a substantial correcting influence upon the control

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system in the right direction, whichever that may be.

Another object is to provide an improved control system of the character described, which not only tends to maintain the desired boiler function, such as steam pressure, within a narrower zone or range of variation than heretofore, but which also is fully self-accommodating to variations in boiler load.

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

In the drawings Fig. 1 is a diagram conventionally illustrating the invention applied for boiler control by actuation of a damper; and Fig. 2 is a diagram graphically illustrating operation of the control system and its effect upon boiler operation.

Experience in practice with control systems of this kind shows that when, upon a call for a correcting effect, full correction is produced without delay, the control system is constantly hunting, as it were. It is unreliable and unstable in the sense that the controlled device, such as a damper, is always moving to one or the other of its extremes of movement, or is in one of those extremes, and the boiler function, such as steam pressure, fluctuates rapidly and widely.

On the other hand, when the correcting effect is protracted or is distributed over a fairly long period, such as 10 or 15 minutes, as in said prior patent referred to, the gradual application of the controlling effect may succeed in more or less stabilizing the operation. The controlled device, such as a damper, may float or become more or less stabilized in an intermediate position, but nevertheless the maximum swing in the boiler function is still undesirably large. For example, in one specific instance, when the control is set to operate on a fluctuation of ½ pound in steam pressure in either direction from normal, the actual total maximum swing of pressure may be as much as 6 pounds or more.

The present invention is designed for use in those cases where in ordinary use the variation in load demand or in the production of combustion effect is such that the function to be controlled, such as boiler steam pressure, tends to vary considerably more than the amount necessary to produce a correcting effect. In other words, the invention is applied, for example, where the control system is set to operate on a fluctuation of ½ pound of steam pressure in either direction from the normal and yet boiler pressure actually

may tend to swing over a total range of 6 to 10 pounds or more.

According to my invention, for the purpose of maintaining the function to be controlled, such as boiler pressure, more nearly uniform, or to prevent undesirably wide swing in the boiler function, my control system is so arranged that upon any demand for a correcting effect, no matter what is the position of the controlled part, that effect, in the proper direction, is immediately produced to a material exent, to-wit, to as much as 25 to 50 or more per cent of the total possible correction, the controlling system thereafter continuing to function, with a correcting effect stili in the same direction, but protracted or distributed over an extended period of time. The initial substantial correction is made immediately, in one step, and is assumed to extend over a relatively short period, such as a matter of say seconds. The succeeding more protracted correction may be either continuous, or may occur by steps as in said prior patent referred to, but in either case is protracted or distributed over 5 or 10 minutes of time. In either case the prompt substantial correction immediately tends to change the combustion rate, either up or down, so as to produce steam in the specific form being referred to, either faster or slower as may be desirable. But this first correcting effect usually is not sufficient to stabilize the boiler. That is accomplished by the subsequent more protracted correcting effect, which is distributed over a sufficient length of time to enable the change in the operative condition of the burners or boiler to reflect back upon the control system and stabilize it, in due course, according to the nature of the original source of the demand for correction.

For convenience the system will be described as contemplating the more protracted latter portion of the correcting effect as produced by step control, according to said prior patent, although the invention is not so limited.

The control system of the present invention is of electromechanical form in that in the specific form chosen for purposes of illustration and not in any sense of limitation the control system includes electric circuits controlling electric motors which mechanically operate switches and other boiler controlling members. Such electric equipment may be used to control a furnace or boiler draft damper, a fan used for draft purposes, stoker speed, such as the speed of a chain grate stoker, fuel supply such as the position of the valves of oil or gas burners, or the position of burner airports or dampers therefor, or other type of fuel bed control, or even an electric heater of resistance or other type used to produce heat for similar purposes. These devices, by variation or adjustment, all affect the rate of heat production in such a manner as to increase or decrease steam pressure, steam temperature, steam flow, air temperature, or some other function of furnace or boiler operation.

In the particular arrangement chosen for purposes of illustration steam pressure has been selected as the controlling function. A conduit 10, communicating with the steam 11 of the water tube boiler 12 conventionally shown, communicates with a suitable servomotor 12 including a movable abutment 13, the motion of which is utilized to produce a controlling effect upon the controlling system to be described.

Said system includes an operating motor A, the shaft of which is connected, as by chain 14, to operate a damper 15 in a pipe 12*a* connected to the fire box 12*b*, the position of which damper controls the flow of air or gas through the combustion chamber and consequently the rate of heat production.

The controlling system includes two electric motors or motor units B, C, as well as electric circuits including said motors and a series of switches marked respectively S_1, S_2, S_3, S_4, S_5, S_6, S_{6a}, S_7, S_{7a}.

Motor A is a reversible motor, or motor unit, including reducing gearing turning in one direction to close and in the other direction to open the damper 15.

Motor or motor unit B is unidirectional and operates continuously. It includes reducing gearing so that its operating shaft 16 turns slowly, say once each minute. Its shaft 16 is connected to operate a two-lobed cam 17, the lobes of which are diametrically disposed and simultaneously become effective to close the normally open switches S_6, S_{6a}. This motor, in the specific form illustrated, may be presumed to produce rotation of its cam 17, one revolution every 60 seconds, and the cam lobes are of such circumferential extent as to close and hold closed the switches S_6, S_{6a} for intervals of three seconds each, so that in a complete rotation of the cam each switch is closed during two periods of three seconds each and is opened during two periods of 27 seconds each.

Motor unit C is like motor unit B and is also unidirectional. It is operated only intermittently, each time a correcting influence upon the boiler is required or called for. Its shaft 18 is connected to operate a cam 19 having high and low lobes 20, 21, each approximately 180° in circumferential extent, the lobes of said cam actuating the several switches S_5, S_7, S_{7a}. Motor C and cam 19 also may be assumed to be so arranged as to produce a 180° rotation of cam 19 in 30 seconds. In effect this is a half revolution mechanism, because to produce any correcting influence called for, the switches and circuits are so arranged and operated as to cause the cam to start, to turn 180°, and then to stop, pending another operation.

Switch S_1 is the main switch. It may be located on the door of the housing (not shown) enclosing motors B and C and their cams and some of the other switches, the operating knob for switch S_1, of course, being accessible from the outside of the door. The blade of the switch, connected by conductor 22 to terminal L_1, may be moved to any of four positions, which here for convenience are marked as follows:

"Off," the position in which the switch is open, deenergizing all circuits.

"Open," the position in which the switch directly connects motor A to L_1 by conductor 23 to cause it to turn in a direction to open the damper 15. The motor, of course, is provided with a ground wire 24 connecting it by lead conductor 25 to L_2.

"Closed," the position in which the switch connects the motor A by conductor 26 to L_1, to turn in a direction to close damper 15.

"Auto." the position in which the switch energizes all of the circuits for automatic control of the damper by variations in boiler pressure, in a manner to be described.

Switch S_2 is manually operated and is in a conductor 27 from "Auto" to motor B, which in turn is connected by conductor 28 to L_2. When this switch is closed the motor B operates continuously, with operation of the cam 17 as before described.

Switch S_3 is also manually operated. It is in

a conductor 29 which connects the blade of switch S_4 to the conductor 27 and L_1. This switch and switch S_2 may be located either inside or outside of the housing, as desired.

Switch S_4 is a snap switch stable in either of two positions engaging one or the other of its two contacts *l* and *r*. It is operated by the movable abutment 13, the position of which is sensitive to boiler pressure. The switch blade, of course, is moved in one direction by increase in boiler pressure and in the opposite direction by a suitable spring 30.

Contact *r* of switch S_4 is connected by conductor 31 to the blade of switch S_6, by conductor 32 to the contact *l* of switch S_5, and by conductor 33 to the contact *l* of switch S_7.

Contact *l* of switch S_4 is connected by the conductor 34 to the contact *r* of switch S_5, by the conductor 35 to the contact *r* of switch S_{7a}, and by conductor 36 to the blade of switch S_{6a}.

The blade of switch S_5 is connected by conductor 37 to one terminal of motor C, the opposite terminal being connected by conductors 38, 24 and 25 to L_2. The operating arm of the blade of this switch is provided with a member 39 yieldably held in contact with the lobes of cam 19 by spring 40.

Switch S_6, normally biased to open position, cooperates with switch S_7. Its contact is connected by conductor 41 to the contact *r* of switch S_7.

Switch S_{6a}, similar to S_6, cooperates with switch S_{7a}. Its contact is connected by conductor 42 with the contact *l* of switch S_{7a}.

The blade of switch S_7 is connected by conductors 43, 26, to motor A, to supply current for operating it in the damper closing direction.

The blade of switch S_{7a} is likewise connected by conductors 44, 23, to motor A, for supplying current to operate it in a direction to open the damper 15.

Switches S_7 and S_{7a} are arranged for simultaneous operation by the lobes of cam 19. As shown their arms are connected to a member 45 held by a compression spring 46 in contact with the cam lobes.

The system described operates as follows:

Let us assume the parts in the position shown. Switch S_1 is on the contact "Auto," so that the entire controlling system is connected for automatic control of the damper 15 by variations in boiler pressure.

Switch S_2 is closed, so that motor B is operating continuously, the effect of its cam 17 being to close each of the switches S_6, S_{6a} for a period of three seconds during each interval of 30 seconds.

Switch S_3 is closed, energizing switch S_4, which we will assume has just been moved to its contact *r* as the result of an increase in boiler pressure beyond the maximum controlling value. The damper 15 is either open or is nearer open than closed position, depending upon how far it was adjusted during the preceding operation of the control apparatus. In any event increase of boiler pressure demands that the damper be closed or partly closed to reduce the draft air for combustion in the particular arrangement illustrated.

With the cam 19 and switch S_5 in the positions shown, movement of switch S_4 to contact *r* completes a circuit from L_1 by way of switch S_1, conductors 27, 29, switch S_4, conductor 32, contact *l* and the blade of switch S_5, and conductors 37, 38, 25 to L_2, through motor C, which begins to rotate in the direction of the arrow. Switch S_7 is on contact *l*, so that no current flows through switch S_6 by way of conductors 31 and 41. However, current flows from S_4 through conductor 33 to contact *l* and the blade of switch S_7 and by conductors 43 and 26 to motor A, operating said motor in a direction to close the damper 15. This operation continues until the cam 19 has been rotated 180°, or for 30 seconds, completing a substantial portion of total possible adjustment of the damper 15. Thereupon, the blades of all three of switches S_5, S_7 and S_{7a} are moved to their opposite positions.

Usually, in any concrete embodiment of the invention the cam 19 and its lobes and the mechanical connections to the several switches are so arranged, and the switches themselves are of such character, that the motion of switches S_7 and S_{7a} is completed before that of switch S_5, insuring full 180° rotation of cam 19 during each operation.

Since the position of switch S_7 has changed, this switch is now open at contact *l* and closed at *r*. Current cannot flow continuously to motor A by way of conductor 43. However, it is now supplied intermittently from switch S_4 by way of conductor 31, switch S_6, conductor 41, contact *r* and blade of switch S_7, to the same conductor 43. Therefore, every time the switch S_6 is closed (for three seconds during every 30 seconds) a further impulse is given to motor A and slow or more protracted adjustment of the damper 15 toward closed position proceeds. In the arrangement shown, this protracted later portion of the adjustment is by steps, as in said prior patent, although it may be continuous, though very gradual, as before described.

The correcting influence upon damper 15 continues until the damper is fully closed, when further operation of the motor is usually interrupted by suitable automatic stop mechanism (not shown and forming no part of this invention) or it may proceed to a point short of full adjustment until a reverse correcting influence is demanded, as by a reduction in steam pressure below the minimum value required for operation of the control system.

If operation of motor A is stopped by automatic stop mechanism, the control system lies dormant awaiting a correcting influence in the opposite direction.

Whenever an opposite correction is required, as by reduction in steam pressure, requiring opening of the damper, the effect of the reduced steam pressure moves switch S_4 to its opposite position on contact *l*. The circuit to motor C is now completed from switch S_4 by way of conductor 34, switch S_5 and conductor 37. Cam 19 begins to rotate and turns through another 180° and then stops. While it is turning, current is supplied to motor A by way of conductor 35 switch S_{7a} and conductors 44 and 23, rotating the motor A in the opposite direction continuously until cam 19 completes its 180° of motion. The effect is to produce an immediate substantial adjustment of the damper 15. Thereupon switches S_5, S_7 and S_{7a} are returned to their original positions, and current is supplied to motor A from switch S_4 by way of conductors 34, 36, switch S_{6a}, conductor 42, switch S_{7a} and conductors 44 and 23, as before, with step control (three seconds in every 30 seconds) by intermittent closing of switch S_6 by the cam 17. This effects the more protracted adjustment of the damper as before.

The operation of the present system is well illustrated by the diagram, Fig. 2, in which the horizontal abscissas represent time in minutes and the vertical ordinates represent boiler pres-

sure. The wavy line M represents variations in boiler pressure incident to boiler operation. The jagged line N represents motion of the controlling motor A and damper 15 in one direction or the other, as the result of operation of the control system.

It is assumed that the boiler pressure is to be maintained at 100 pounds and that variation of such pressure by a half pound above or below normal will produce operation in one direction or the other of the movable abutment 13 and the switch S_4 which it controls. It is assumed that at the beginning of the operation represented, the damper is closed or partly closed and the boiler pressure is falling. When the pressure line drops below 99.5 the control system responds by promptly moving the damper a substantial amount toward open position, such operation continuing for 30 seconds, as indicated at O. Then, when the cam 19 has completed its 180° movement, further more gradual or protracted adjustment of the damper continues by a series of steps, as represented at P. The boiler pressure finally begins to rise, crosses the mean or normal value of 100 and when it exceeds 100.5 produces similar immediate and protracted adjustments of the damper in the opposite direction, as at Q.

Thus, whenever a correcting influence is called for it is immediately produced to a material extent, depending upon the time value of cam 19, and in the present instance possibly more than 50% of the total possible correction, although the invention is not limited to any particular proportion. Thereafter the correcting influence continues more slowly or gradually until the boiler pressure begins to vary in the opposite direction and finally produces its own call for correction in the opposite direction.

The net effect of operation of the entire system is to reduce the maximum swing or variation in boiler pressure from a total of six or more pounds, when the correcting influence is produced entirely by protracted control, as in said prior patent, to a maximum of two pounds, according to the present invention.

Although motor A always rotates at the same speed, expressed in R. P. M., nevertheless it is so controlled that over its full range of operation in one direction or the other the rate of operation of both the motor and the damper which it controls is considerably greater during the initial adjustment than during the final adjustment. In the example given, assuming that motion of the damper from full open to full closed position requires 180° of angular travel, accomplished by motor operation for 60 seconds, the initial prompt adjustment is at the rate of 90° of travel in 30 seconds. The final more protracted adjustment, however, is much slower at the rate of 90° of travel in 300 seconds, because the motor operates for only 3 seconds in every 30 seconds.

The line R on the chart, Fig. 2, represents the load line of the boiler in horsepower per hour. It may be assumed in this boiler, that the normal load is 100 horsepower. The diagram indicates a rise in load from 15 minutes to 24 minutes followed by a decrease to normal at 29 minutes.

Upon any such variation in normal load, up or down, the initial rapid, substantial adjusting effect, when correction is demanded, is continued for 30 seconds, as before, under the control of cam 19. However, the slower, protracted control persists for a longer period or is reduced to a shorter period, to accommodate the control mechanism to variations in load, as indicated by the line N during the interval mentioned from 15 to 29 minutes. The boiler pressure, however, is maintained at the mean value of 100 pounds, plus or minus ½ pound, as before.

The main purpose of the invention, of course, is to control the rate of production of heat, whether the heat is used merely for heating purposes such as for heating air, water or the like, or for the production of power, such as in a steam boiler. When the heating unit is of the electrical form the control system will either vary or adjust resistance or throw one or more heaters or heating elements into or out of operation. When it controls a heat producing unit utilizing solid fuel, it can control dampers or motors regulating or producing air supply, or the rate of supply of solid fuel. When used to control a heating device employing liquid or gaseous fuel, it can also be made to control fuel valves or the position or size of airports, or dampers or motors for regulating or producing air flow, as will be readily understood.

It should also be noted that the system is operative, as described, with the damper or other device to be regulated lying in any position, either in its two extreme positions, or in any intermediate position. Whatever be its position, when a correcting influence is called for, it is produced, in the proper direction, in two stages, first with a substantial adjustment amounting to from 25 to 50 or more percent of the total possible adjustment, and second by a more protracted adjustment until total adjustment is reached or the heat producing element becomes stabilized before full adjustment is produced. Also, the system operates equally well in either direction, i. e., whether more or less steam is required, in the case of boiler operation.

Other advantages of the invention will be apparent to those skilled in the art.

What I claim is:

1. Control means for a heat producing unit, comprising an adjustable device for regulating the rate of heat production by said unit, an actuating motor therefor, governing means sensitive to and actuated by variations in an operating function of said unit, an electric circuit for said motor having two branches each including switch means, a cyclic controller for closing the switch means in the first of said branches and maintaining it closed for a sufficient period to cause said motor to effect a substantial proportion of the total possible adjustment of said device, means governed by said governing means for starting and stopping the cyclic controller, means operated by said controller for closing the switch means in the second branch of said circuit when the cyclic controller comes to rest, an independent switch in said second branch, and continuously operating means for intermittently closing said independent switch to cause said motor to produce intermittent adjustment of said device after its said substantial adjustment.

2. Control means for a heat producing unit, comprising an adjustable device for regulating the rate of heat production by said unit, an actuating motor therefor, governing means sensitive to and actuated by variations in an operating function of said unit, a continuously operating control motor, control means operated thereby and operatively connected to said actuating motor and adapted when effective thereon to intermittently cause actuation thereof, and a cyclic controller arranged when energized to start and stop and operatively connected to said governing means to be governed and thereby rendered effective thereby, said cyclic controller being also so

operatively connected to said actuating and control motors that during its cycle it causes and maintains operation of said actuating motor and at the conclusion of its cycle renders said control motor effective upon said actuating motor.

3. Control means for a heat producing unit, comprising an adjustable device for regulating the rate of heat production by said unit, an actuating motor therefor, governing means sensitive to and actuated by variations in an operating function of said unit, a continuously operating motor, control means operated thereby and connected to said actuating motor and adapted when

effective thereon to intermittently cause actuation thereof, control means governed by said governing means and arranged to render said continuously operating motor effective upon said actuating motor, said control means including cyclically operating means arranged to start and stop and adapted during its cycle to cause operation of said actuating motor independently of said continuously operating motor and to delay effective operation of said actuating motor by said continuously operating motor pending completion of the cycle.

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