

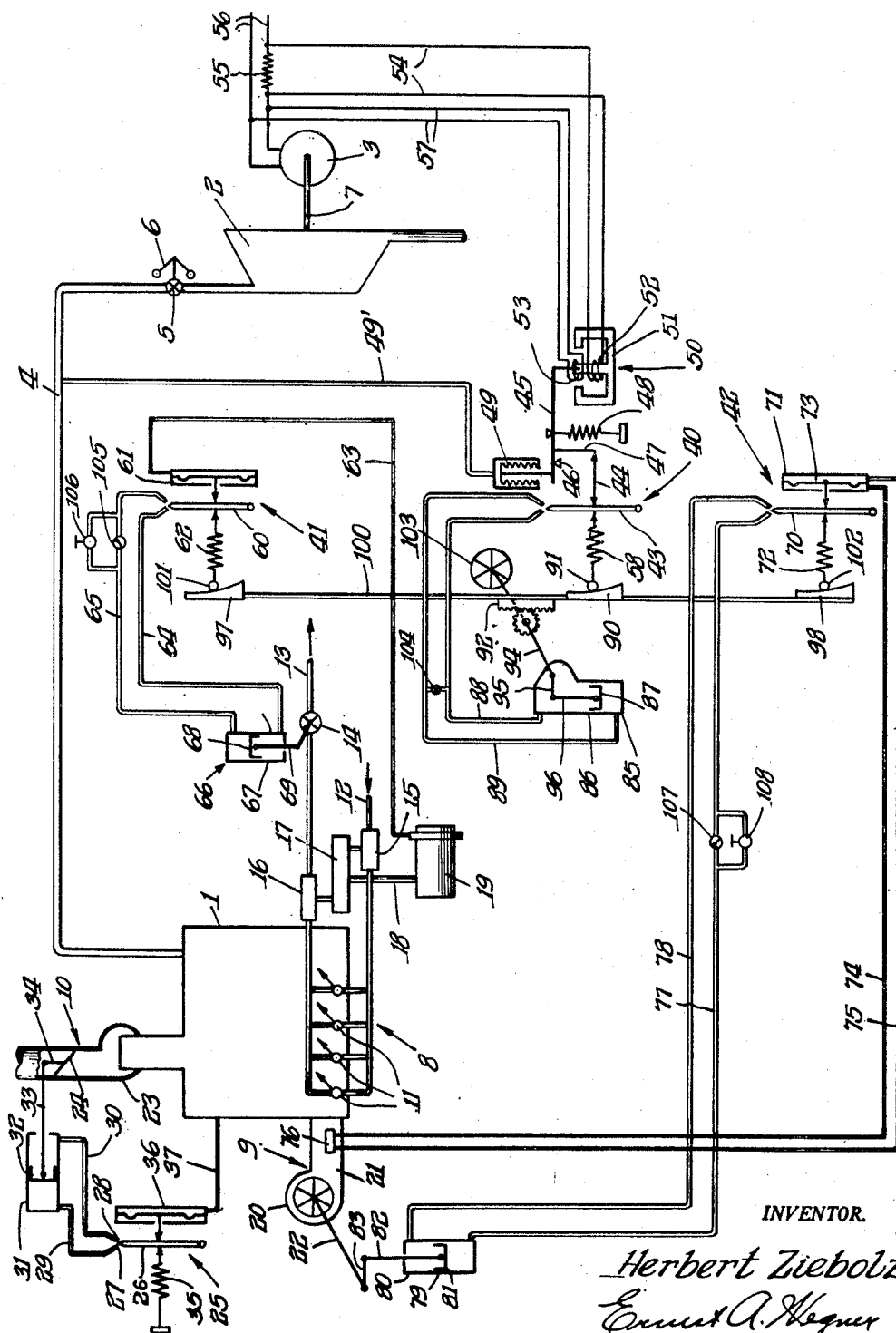
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H. ZIEBOLZ

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CONTROL MEANS FOR POWER GENERATING SYSTEMS

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INVENTOR.

Herbert Ziebolz  
Ernest A. Hegner  
att'y.

## UNITED STATES PATENT OFFICE

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CONTROL MEANS FOR POWER  
GENERATING SYSTEMSHerbert Ziebolz, Chicago, Ill., assignor to Askania  
Regulator Company, Chicago, Ill., a corpora-  
tion of Illinois

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The invention relates generally to control means for a power generating system and, more particularly, to the control of a steam generating means forming a part of an electric power generating system.

In any steam generating system, proper operation requires that the energy supply to the steam generating means, that is, fuel and air less the heat losses, equal the energy consumed by the load. Means responsive to various indications, such as the speed of a prime mover driven from the steam generating means, change in steam consumption, or change in steam pressure, have in the past been employed to govern the energy supply. These means are not completely satisfactory, however, because the indications are too long delayed, or are not responsive to the energy level of the steam source, or result in a supply of steam to the load at decreasing pressure as the load increases. Hereinafter, when equality of energy supply and energy consumption are mentioned, the inclusion of heat losses is implied unless otherwise specifically stated.

A general object of this invention, therefore, is to provide a new and improved control means for a power generating system overcoming the shortcomings above set forth.

A more particular object is to provide a new and improved control means for a steam generating system which is quickly responsive to changes in load, maintains a proper energy level, and assures delivery of steam to the load at proper pressure.

Another object is to provide control means for a power generating system in which the energy supply to the system is governed by a plurality of variable factors integrated into a common signal.

Another object is to provide a control means for a power generating system in which the energy supply to the system is governed by a plurality of factors integrated into a common signal, one of which is immediately and solely indicative of the demand on the system and the other of which is indicative of demand and also indicative of the energy level of the system.

Another object is to provide control means for a steam generating system in which the energy supply to the system is governed by a plurality of factors, one of which is indicative of the energy level of the steam generating means and change in which is indicative of demand, the control means including regulating means responsive to the factor described and operable in response to that factor to equalize energy supply and energy

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consumption and maintain the energy level, the other of the factors being solely and immediately indicative of demand and functioning through the regulating means and in conjunction with the first factor to govern the energy supply and, particularly, to govern the energy supply in such manner as to raise the energy level of the steam source as the load increases, so as to maintain more nearly constant the pressure at which steam is supplied to the load.

Still another object is to provide control means for a steam generating system having a master regulator for governing the energy supply which is jointly responsive to the pressure in the steam header and to the load, as indicated by means immediately responsive to changes in the load.

Still another object is to provide control means for a steam generating system having means for governing the energy supply which is responsive to the pressure in the steam header and means immediately and solely responsive to changes in load for varying the setting of said pressure responsive means.

Yet another object is to provide control means for a power generating system composed of a boiler, a prime mover and an electric generator, including a master regulator for governing the energy supply to the boiler which is jointly responsive to the pressure in the steam header and to the load on the generator.

Other objects and advantages will become apparent from the following detailed description taken in connection with the accompanying drawing, in which one embodiment of the invention is illustrated diagrammatically.

While the invention is susceptible of various modifications and alternative constructions and adaptable for the control of a variety of systems, it is herein shown and will hereinafter be described in a preferred embodiment and as applied to an electric power generating system. It is not intended, however, that the invention is to be limited thereby to the specific construction or to the specific use disclosed. On the contrary, it is intended to cover all modifications and alternative constructions and all applications falling within the spirit and scope of the invention as defined by the appended claims.

In the exemplary embodiment of the invention shown in the drawing, it is illustrated as applied to the control of an electric power generating system. Such a system comprises generally a steam generator or boiler 1, a prime mover 2 driven by the steam generated in the boiler and usually in the form of a turbine, and

an electric generator 3 driven by the prime mover 2. The electric generator 3 may be either a direct current or an alternating current generator, but is here represented as a direct current generator. Steam is supplied from the boiler to the prime mover through a steam header or conduit 4 which has interposed therein a valve 5 operated by a governor 6 responsive to the speed of operation of the prime mover 2 and functioning to maintain the prime mover operating at a constant speed despite variations in load that may be placed thereon as a result of variations in load on the generator 3. When, as here illustrated, the prime mover is a turbine, it is coupled to the generator 3 through the medium of a shaft 7.

The boiler 1 has means, generally designated 8, for supplying fuel thereto, means, generally designated 9, for supplying combustion air, and also has means, generally designated 10, for removing the products of combustion. The boiler here shown is adapted to employ oil as fuel and, to that end, has a plurality of recirculating oil burners 11, the fuel oil being supplied through a conduit 12 and the excess and unburned fuel oil being returned through a conduit 13. For purposes of obtaining a measure of the fuel consumption, there is interposed in the supply conduit 12 a positive displacement meter 15, and similarly interposed in the return conduit 13 is a positive displacement meter 16. These meters are connected to a differential gearing 17 so arranged in conventional and well known manner that the revolutions of a shaft 18 represent the rate of fuel consumption. For a purpose which will later become more apparent, the rate of fuel consumption, as indicated by the rate at which the shaft 18 is revolving, is further translated by a device 19 into pressure values proportional to and indicative of the rate of fuel consumption. The device 19 is a pneumatic tachometer of the type disclosed and claimed in the patent to Ziebolz, No. 2,185,970.

The combustion air supply means 9 may take any of several well known forms and is here diagrammatically illustrated as comprising a blower 20 discharging combustion air to the boiler through an air supply conduit 21. The quantity of air supplied may be controlled in any of the conventional manners, such as by varying the speed of the blower, or by shutters, with such air supply controller here represented by the oscillatory shaft 22.

Leading from the combustion chamber of the boiler, to permit escape of the products of combustion, is a stack 23 with the natural draft of the boiler usually aided by an exhaust fan or blower (not here shown). The draft and hence the pressure within the combustion portion of the boiler is preferably controlled by some means such as a damper 24 located in the stack 23. The damper 24 is under the control of an "Askania" jet type regulator, generally designated 25. The regulator comprises a pivoted jet pipe 26 directing a jet at an orifice plate having two closely adjacent orifices 27 and 28 connected respectively by conduits 29 and 30 with opposite ports of a fluid motor which herein is shown as of the reciprocatory piston type having a cylinder 31 and a piston 32. The piston is connected to the damper 24 through a link or rod 33 pivotally connected at one end to the piston and, likewise, pivotally connected at the other end to an arm 34 rigid with the damper 24. A compression spring 35 urges the jet pipe 26 in one direction

while a pressure responsive device 36 acts on the jet pipe 26 in opposition to the spring 35. The pressure responsive device is, through a conduit 37, made responsive to the pressure within the combustion portion of the boiler, and the spring 35 is adjustable so as to permit of the maintenance of any desired pressure within a conventional range.

Control means is provided herein for governing the energy supply to the boiler, that is, fuel and combustion air, which results in improved operation and regulation of the system. The control means is not responsive or dependent upon such delayed indications as change in speed of the prime mover or change in pressure in the boiler drum, nor is it dependent upon a single factor or indication, with the partial regulation resulting. Herein the control means is responsive to a plurality of factors integrated into a common signal and with the factors so chosen as to result in improved and complete regulation. Generally a first one of such plurality of factors is affected both by the demand or load and also by the energy supply to the boiler, and is indicative of the energy level of the boiler, while change in this factor is indicative of the load or demand. This factor is, therefore, herein employed through suitable translating devices to govern the energy supply to the boiler, and functions to maintain a desired and predetermined energy level in the boiler, as well as to equalize energy supply and energy consumption. The other factor is chosen to be immediately and solely indicative of the load or demand and is so integrated with the first factor, through the translating means, as to effect a very prompt change in the energy supply in accordance with change in load, and, more important still, as to increase the energy level of the boiler with increases in load so as to prevent the supply of steam to the load, herein the prime mover 2, at decreasing pressure as the load increases. These two factors are readily measured and employed, the first being the pressure in the header 4 and the other being the load on the generator 3.

Herein the control means comprises a master regulator, generally designated 40, a fuel supply regulator, generally designated 41, and a combustion air supply regulator, generally designated 42. The master regulator is responsive to the two factors above described, namely, the header pressure and the load, and integrates the two factors into a single or common pulse or signal constituting a measure of the energy supply necessary to obtain the desired energy level in the boiler, as well as equality between energy supply and energy consumption. This signal is applied to the fuel supply regulator 41 and to the combustion air supply regulator 42 which thus bring about the called for adjustment in fuel and combustion air supply. Herein the master regulator 40 is of the "Askania" jet type having a pivoted jet pipe 43. Engaging the jet pipe 43 is a rod 44 of a lever system which additionally includes a beam 45 mounted on a pivot 46 and having rigid therewith and extending at right angles thereto an arm 47. The rod 44 is interposed between the arm 47 and the jet pipe 43 so as to transmit movement of the arm 47 to the jet pipe. Engaging the beam 45 to one side, herein the right side, of the pivot 46 is a tension spring 48 which thus acts to tend to pivot the jet pipe 43 in a counterclockwise direction. The spring 48 is adjustable and provides for a basic loading of the master regulator. Specifically it represents the basic,

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no-load, boiler drum pressure and hence the basic or normal no-load energy level.

Engaging the beam 45 to the other side, that is, the left, of the pivot 46 is a pressure responsive device 49. This device is by a conduit 49' connected to the steam header 4 so as to be responsive to the steam pressure in the header and serves in conjunction with the spring 48 to constitute a measure of the energy supply necessary to maintain the basic boiler drum pressure, as predetermined by adjustment of the spring 48, and equality between energy supply and energy consumption. The pressure responsive device 49 and the spring 48 operating through associated devices are thus alone capable of controlling the energy supply to the boiler in a manner maintaining basic boiler drum pressure and equality between energy supply and energy consumption. However, with boiler drum pressure maintained as determined by adjustment of spring 48, the pressure of the steam supplied to the prime mover 2 drops as the load increases. This is an undesirable condition.

To eliminate this drop in pressure of the steam supplied to the prime mover and to provide regulation of the energy supply to the boiler which is even more promptly responsive to change in demand than is the header pressure, the second of the factors, namely, the load on the generator, is here employed and, like the header pressure, acts through the master regulator. This second factor accomplishes the end sought by raising the energy level of the boiler as the load increases, that is, it adds to the loading of the master regulator by the spring 48. By proper selection and coordination of values, any desired relationship between boiler drum pressure and drop in header pressure may be obtained, including such relationship as will maintain constant at all loads the pressure of the steam supplied the prime mover.

Herein, the electrical load on the generator 3 is translated into a force applicable to the lever system of the master regulator through the medium of a wattmeter coil arrangement. To that end, an electrically responsive device 50 is provided composed of a core 51, and surrounding a leg of this core, in well known manner, to make the pull on the core proportional to the output of the generator is a current coil 52 and a voltage coil 53. The first of these, namely, the current coil, is by a pair of leads 54 connected in shunt around a resistance 55 interposed in one of the power leads 56 leading from the generator 3. The voltage coil 53 is by a pair of leads 57 connected across the power leads 56. The device just described is connected to act on the beam 45 in the same manner as the tension spring 48 and is, moreover, so arranged that the force tending to rotate the lever system in a clockwise direction increases as the load on the generator increases.

Engaging the jet pipe 43 on the opposite side and tending to pivot the jet pipe 43 in opposition to the spring 48 is a compression spring 58, the force of which is varied by follow-up means, presently to be described in detail, under the control of the jet pipe 43. The follow-up means comes to rest when the jet pipe 43 is restored to its neutral or normal position, that is, when by increased or decreased compression of the spring 58 its force equals the combined forces of spring 48, pressure device 49 and electrical means 50. Hence movement of the follow-up device bears a definite relationship to the combined factors in-

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dicating load or demand and is a measure of the change in energy supply needed.

It will be seen from the foregoing that the forces imparted to the master regulator by the pressure device 49, spring 48 and electrical device are, by the lever system, integrated into a common force acting on and imparting movement to the jet pipe 43 and, in conjunction with the follow-up means and spring 58, generate a signal having a definite relationship to the change in energy supply required. If the sum total of the forces tending to rotate the lever system in a clockwise direction increases, the jet pipe 43 is pivoted in a counterclockwise direction and a signal is generated calling for a definite increase in fuel and air supply proportional to the changed demand. Conversely, when the sum total of the forces tending to rotate the lever system in a clockwise direction decreases, the jet pipe 43 is rotated clockwise and a signal is generated calling for a definite decrease in the fuel and air supply proportional to the changed demand.

The fuel supply regulator 41 is herein also shown as of the "Askania" jet type. It comprises a pivoted jet pipe 60, a pressure device 61 and a compression spring 62. The pressure device 61 is by a conduit 63 connected to the device 19, previously described as operable to convert revolutions of the shaft 18 into proportional pressure values. The device 61 is so arranged and associated with the jet pipe 60 as to tend to rotate the same in a counterclockwise direction with increases in pressure. The spring 62 acts on the jet pipe 60 in opposition to the pressure device 61, the force of the spring 62 being variable in accordance with the signal generated by the master regulator, as will presently be described. The jet pipe 60 discharges against a plate having two closely adjacent orifices connected by conduits 64 and 65 to the ports of a fluid motor 66. Herein this motor is in the form of a reciprocating piston type having a cylinder 67 and a piston 68 reciprocable therein. The piston is by a rod 69 connected to the valve 14 which is the fuel supply controller.

The air supply regulator 42, likewise, is here shown as of the "Askania" jet type. It has a pivoted jet pipe 70, a pressure responsive device 71 and a compression spring 72. The pressure responsive device 71 is intended to be indicative of the actual flow of combustion air to the boiler and hence it has the chambers on opposite sides of its diaphragm 73 connected by conduits 74 and 75 to appropriate points in the boiler. As here shown, the conduits are connected to pressure differential creating means, such as a flow nozzle or pilot tube, indicated at 76, and located in the combustion air supply duct 21. The jet pipe 70, in well known manner, discharges against a plate having a pair of closely adjacent orifices formed therein, these orifices being by conduits 77 and 78 connected to the ports of a fluid motor 79. This motor herein again takes the form of a cylinder 80 and a piston 81 reciprocable therein. The piston is by means of a rod 82 connected to an arm 83 rigid with the shaft 22 which is herein employed to represent the air supply controller. The rod 82 is pivotally connected at both ends so as to permit of the required movement.

Means is provided to translate the signal of the master regulator into a signal impressed upon each the fuel supply and the air supply regulators 41 and 42. This means includes the follow-up means generally referred to above and herein takes the form of a fluid motor 85 composed of

a cylinder 86 and a piston 87 reciprocable therein. Ports at opposite ends of the cylinder 86 are by conduits 88 and 89 connected one to each of a pair of orifices located in a plate against which the jet 43 discharges, all of which is a well known construction of "Askania" jet regulators. Driven by the motor is a first element 90 which acts on the spring 58 to change the force thereof so that after a predetermined movement of the element 90 the unbalance created by change in force of one or both of the devices acting on the lever system is overcome and the jet pipe 43 restored to its neutral position. Thus, for reasons previously pointed out, movement of the element 90 is a measure of change in demand. Herein the element 90 takes the form of a cam and the spring 58 is provided with a cam follower 91. The cam is mounted to move with a rack 92 driven in opposite directions by a pinion 93 fast on a shaft 94 which has rigid therewith an arm 95. This arm is by a rod 96 connected to the piston 87, the rod having a pivotal connection with both the arm 95 and the piston so that reciprocation of the piston serves to oscillate the shaft 94. It is clearly seen from the drawing that when the jet pipe 43 is pivoted counterclockwise to call for an increase in energy supply to the boiler, the cam 90 is moved in a direction to compress the spring 58 and thereby strengthen the spring sufficiently to restore the jet pipe 43 to neutral position after a predetermined movement of the cam has taken place. Conversely, when the jet pipe 43 is pivoted clockwise, the cam 90 is moved in a direction to reduce the force of the spring 58 until the forces are again balanced with the jet pipe in neutral position.

Also associated with the rack 92 are elements 97 and 98 acting through the springs 62 and 72, respectively, to impart thereto a signal proportional to and of the same character as the signal generated by the master regulator. Herein these elements are also shown as cams and, for simplicity, are shown connected by a common rod 100 so as to partake of the exact same movement as the cam 90 and the rack 92, though it is to be appreciated that in practice the movements may be proportional but either greater or less than the movement of the cam 90. Each the spring 62 and the spring 72 is provided with a cam follower 101 and 102, respectively. The employment of cams 90, 97 and 98 as the elements for varying the compression of the corresponding springs has the advantage that the contours of the cams may readily be varied to bring about desired relationship between the fuel supply and air supply in a convenient and facile manner. If it is desired, a hand wheel 103 may be affixed to the shaft 94 to permit of manual adjustment and control, such as may be desirable during test runs or the like. To facilitate this, a valve 104 is connected between the conduits 88 and 89. This valve is normally closed but is opened when hand wheel 103 is to be actuated to permit transfer of fluid from one to the other end of motor 85.

It is intended, of course, that in actual operation the various parts of the control system will be so adjusted that for an increase in load the air supply will lead the fuel supply and that for a decrease in load the fuel supply will lead the air supply, so as to have smokeless combustion at all times. This lead in change of air supply upon increase in load, and this lead in change of fuel supply upon decrease in load is herein readily and conveniently effected through the employment of check valves and adjustable meter-

ing valves. To that end, there is interposed in the conduit 65 a check valve 105 arranged to close upon attempted flow of fluid from the jet pipe 60 to the motor cylinder 67 and to open upon flow in the reverse direction. Connected in shunt around this check valve 105 is an adjustable metering valve 106. Similarly, conduit 77 has incorporated therein a check valve 107 and connected in shunt around this check valve is an adjustable metering valve 108. The check valve 107 is arranged to close and prevent flow from the jet pipe 70 to the motor cylinder 80, and to open and permit free flow in the opposite direction. It will be seen that when the master regulator calls for an increase in energy supply to the boiler the adjustment of the fuel supply regulating valve 14 will be retarded, for the fluid flowing through the conduit 65 will have to flow through the metering valve 106, whereas flow of fluid through conduit 78 for adjusting the air supply is unrestricted, as is also the discharge of fluid from the lower end of cylinder 80, for check valve 107 opens to permit free flow of fluid through the conduit 77 in that direction. When the master regulator calls for a decrease in energy supply to the boiler, the fuel adjustment is effected first, for now flow through the conduits 64 and 65 is unrestricted, whereas flow through the conduit 77 is through the metering valve 108.

While it is believed that the invention is readily understood from the foregoing description, a brief statement of the operation will be made, further to facilitate such understanding. Let it be assumed that the system is already in operation at small load with a balance between the demand and the energy supply momentarily attained. Under this condition, all of the regulators 40, 41 and 42 will be in balanced condition with their jet pipes in neutral position, and hence maintaining equal pressures on opposite ends of the motors 85, 66 and 79.

Moreover, despite the reduction in header pressure, which occurs as a result of steam flow, the pressure of the steam supply to the prime mover is substantially that predetermined as the normal or basic boiler drum pressure. This results because the electrical means 50 has raised the energy level of the boiler by providing an additional loading on the master regulator in addition to the spring 48. With such additional loading, the pressure responsive device 49 can balance the forces of the spring 48 and electrical device 50 only if the header pressure is increased, and since a given increase in flow of steam through the header, due to increased load, results in a fixed pressure drop, the actual pressure in the steam header 4 can attain the increased value necessary only if the boiler drum pressure is increased.

If now an increased demand is assumed, such increased demand will immediately be indicated by the electrically responsive device 50 which acts as above pointed out additionally to load the master regulator. As an incident to such additional loading, the electrically responsive device 50 acts through the lever system of the master regulator to rotate the jet pipe 43 in a counterclockwise direction since the spring 48 and the device 50 now overbalance the pressure device 49. This results in the generation of a signal calling for a definite increase in energy supply, for upon such rotation of the jet pipe 43 the piston 87 of motor 85 is forced downwardly, with the result that the rack 92 and the rod 100 associated therewith, as well as the three cams 90,

97 and 98, are moved upwardly. Upward movement of the cam 90 increases the compression of the spring 58 which tends to restore the jet pipe 43 to its neutral position, and such restoration is effected when the cam has been moved a predetermined amount proportional to the change in load on the generator 3, as indicated by the electrical means 50.

With such movement of the cam 90, the cams 97 and 98 each compress their respective springs 62 and 72, thereby resulting in a pivoting of the jet pipes 60 and 70 in a clockwise direction. As a consequence, piston 68 of motor 66 is moved downwardly to increase the supply of fuel to the burners 18 which, in this instance, is accomplished by closing the valve 14, while the piston 81 of the motor 79 also is moved downwardly to increase the quantity of combustion air supplied to the boiler. With increased consumption of fuel, the shaft 18 will rotate more rapidly and hence the device 19 will produce a higher pressure which will, through conduit 63, be transmitted to the pressure responsive device 61 and will, when the quantity of fuel supplied corresponds to the amount called for, restore the jet pipe 60 to its normal or neutral position. Similarly, the pressure responsive device 71 will restore the jet pipe 70 to neutral position when the air supply has been increased sufficiently to meet the demand.

Thus there is an immediate change in the energy supply in accordance with change in demand, though it will be appreciated from what has gone before and what will follow that this change in energy supply does not constitute the entire change in energy supply called for by the change in demand, but represents merely that change necessary to raise the energy level of the boiler an amount to compensate or nearly compensate for the change in header pressure which will occur as a result of the change in steam flow.

Simultaneously with this adjustment an immediate response to change in load, a second train of effects is taking place, though slightly belatedly, to bring about that change in energy supply to the boiler actually required to balance the change in energy consumption. With increased load on the generator 3, the prime mover 2 drops somewhat in speed, whereupon the governor 6 opens the valve 5 in order that an increased flow of steam necessary to maintain the prime mover at a constant speed, despite the increased load, will take place. Such increased flow of steam in the header 4 causes a drop in header pressure, and hence the spring 48 and the electrical device 50 will again overcome the device 49 and pivot the jet pipe 43 in a counterclockwise direction. Hence again the cam 90 driven from the motor 86 will be given a definite movement such that the added force of the spring 58 will compensate for the decreased force of the pressure device 49, thereby restoring the jet pipe 43 to normal position and simultaneously causing a signal to be generated which is precisely proportional to the change in load as indicated by change in header pressure. Such signal will, as previously described, act upon the fuel supply regulator and the air supply regulator to increase the energy supply to the boiler the called for amount. The jet pipes of the fuel and air regulators will, after the fuel supply and combustion air supply have reached their called for values, also be returned to neutral position. As the energy level of the boiler is raised to the level determined by the electrical device 50 responsive to the load, the actual header pressure

will, of course, increase a proportional amount and, as a result, the pressure device 49 will overcome the spring 48 and the electrical device 50 and thus effect a slight reduction in the energy supply just sufficient to eliminate that excess of energy supply over consumption which was temporarily required to raise the energy level of the boiler. The system has now again reached a state of stable operation and remains in this state until further change in load occurs. It will be appreciated that a decrease in load will cause the same operations to take place, but in the opposite direction. While adjustment of the energy supply, as a result of the electrical device 50 and the pressure responsive device 49, have herein, for purposes of more ready understanding, been treated as occurring separately, it is to be appreciated that actually, of course, the adjustment is a single operation, with the indication of the electrically responsive device 50 and the pressure responsive device 49 integrated by the master regulator into a common signal.

I claim as my invention:

1. In a power generating system, a boiler, a steam header leading from the boiler, means for supplying energy in the form of fuel and air to said boiler, a load supplied from said boiler, and control means for governing the supply of energy to said boiler including a single master regulator operable to integrate a plurality of factors into a common signal calling for a definite change in energy supply to the boiler having a first device uniformly responsive to the static pressure only in the steam header so as to be subject both to change in demand, as reflected by droop in steam header pressure, and change in boiler pressure, a second device independent of boiler pressure and of loading said regulator to main a predetermined basic boiler pressure, and a third device connected to the load to receive primary indication of change in demand and in anticipation of a drop in steam header pressure operable to increase the loading of said regulator, with an increase in demand, so as to raise the energy level of the boiler above that maintained by said second device so as to maintain substantially constant the steam pressure supplied to the load.

2. In a power generating system, a boiler, a steam header leading from the boiler, means for supplying energy in the form of fuel and air to said boiler, a load supplied from said boiler, and control means for governing the supply of energy to said boiler including a single master regulator operable to integrate a plurality of factors into a common signal calling for a definite change in energy supply to the boiler having a pressure responsive device connected to be subjected and to respond only to the static pressure in the steam header and reacting uniformly to changes in pressure, a first loading device independent of boiler pressure and of load connected in opposition to said pressure device and operating in conjunction with said pressure device to maintain a predetermined boiler pressure, and a second loading device connected to the load to receive primary indication of change in demand having its effect additive to the effect of said first loading device so as to vary the energy level of the system to maintain substantially constant the pressure of the steam supplied to the load despite the "droop" in the steam system at load.

3. In an electric power generating system, a boiler, a steam header leading from the boiler, means for supplying energy in the form of fuel and air to said boiler, a prime mover driven from

said boiler, an electric current generator driven by the prime mover, and control means for governing the supply of energy to said boiler including a master regulator operable to integrate a plurality of factors into a common signal calling for a definite change in energy supply to said boiler having a first device responsive to the static pressure only in said steam header, a second device loading said regulator to maintain a predetermined boiler pressure, said second device being manually adjustable and independent of any factor varying with change of load on the generator and a third device, electrically connected to said generator to be responsive to the load thereon, associated with said master regulator directly and independently of said second device to increase the loading on said regulator, with increases in load on said generator, by amounts sufficient to maintain substantially constant the pressure of the steam supplied to said prime mover.

4. In a power generating system, a boiler, means for supplying energy in the form of fuel and air to said boiler, a load supplied from said boiler, and control means governing supply of energy to said boiler including a master regulator of the jet type having a pivoted jet, a lever system engaging the jet to pivot the same, a first device responsive to change in demand, as reflected by droop in steam header pressure, and to boiler pressure acting on said lever system in one direction, a second device acting in opposition to said first device and serving to load said regulator to maintain a predetermined boiler pressure and a third device independent of steam flow connected to the load to receive primary indication of change in demand operable to increase the loading on said regulator with increases in demand, and means controlled by the jet pipe for restoring the jet pipe to normal position and in so doing generating a signal calling for a definite change in energy supply to the boiler proportioned to the demand as indicated by the condition of the three devices of said master regulator.

5. Control means for a power generating system having a boiler, a fuel supply means therefor, an air supply means therefor and a load driven from the boiler, comprising a fuel supply regulator, an air supply regulator, a master regulator responsive to a plurality of factors, integrated into a common signal proportional to the demand, one of which factors is immediately indicative of the demand on the system and influenced only by the load and the other of which is belatedly indicative of the demand and is also influenced by the energy level of the system, a device connected to the load to receive primary indication of change in demand producing the one of the factors, a second device producing the other of the factors, and means for translating the common signal of said master regulator into a signal, definite and proportional to the demand, applied to said fuel supply and said air supply regulators including means operating in advance of ultimate change in boiler pressure to restore said master regulator as an incident to generation of the signal.

6. Control means for an electric power generating system having a boiler, a steam header leading from the boiler, a fuel supply means and an air supply means for the boiler, a prime mover driven from the boiler and an electric generator driven by the prime mover, comprising a fuel supply regulator, an air supply regulator, a master regulator having a first device responsive to the steam pressure of the header and operable to call for an

increase or a decrease in the energy supply to the boiler respectively as the header pressure drops or rises, a second device loading said master regulator to maintain a predetermined boiler pressure, a third device responsive only to the load on the generator and operable to call for an increase or a decrease in the energy supplied to the boiler respectively as the load on said generator is increased or decreased and means integrating the responses of said devices into an unbalance of said master regulator producing a signal proportional to the change in demand, and means for translating the signal into a signal applied to each said fuel supply regulator and said air supply regulator, said last named means including a cam operatively associated with said fuel supply regulator, a cam operatively associated with said air supply regulator, and a cam operatively associated with said master regulator and functioning to restore balance to said master regulator upon predetermined movement of said cam, said cams being interconnected to have a common movement.

7. Control means for an electric power generating system having a boiler, a steam header leading from the boiler, a fuel supply and an air supply for the boiler, a prime mover driven from the boiler and an electric generator driven by the prime mover, comprising a fuel supply controller, a fuel supply regulator operatively associated with said controller to govern the same, an air supply controller, an air supply regulator operatively associated with said air supply controller to govern the same, a master regulator having a first device responsive to the steam pressure of the header and operable to call for an increase or a decrease in the energy supplied to the boiler respectively as the header pressure drops or rises, a second device loading said master regulator to maintain a predetermined boiler pressure, a third device responsive only to the load on the generator and operable to call for an increase or a decrease in the energy supplied to the boiler respectively as the load on said generator is increased or decreased and means integrating the responses of said devices into an unbalance of said master regulator producing a signal proportional to the change in demand, and means for translating the signal of said master regulator into a signal applied to each said fuel supply and said air supply regulators including a first cam operatively associated with said master regulator and operable upon movement proportional to the demand to restore balance to said master regulator and a second and a third cam operatively associated respectively with said fuel supply regulator and said air supply regulator and connected to have a movement common with the movement of said first cam to produce an unbalance in said fuel and said air supply regulators resulting in adjustment of said fuel and said air supply controllers in accordance with the change in energy supply called for by said master regulator, each said fuel and said air supply regulators having a device respectively responsive to the actual fuel consumption and the actual air supply acting in opposition to said cams to restore the balance of said regulators and arrest adjustment of said fuel and said air supply controllers when the fuel consumed and the air supplied reaches the values called for.

8. Control means for an electric power generating system having a boiler, a steam header leading from the boiler, a fuel supply means and an air supply means for the boiler, a prime mover driven

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from the boiler and an electric generator driven by the prime mover, comprising a fuel supply regulator, an air supply regulator, a master regulator of the jet type having a pivoted jet pipe, a lever system associated with said jet pipe to swing the same about its pivot, a pressure responsive device connected to the system to be responsive to the pressure of the header and operatively connected with said lever system, a spring acting on said lever system in opposition to said pressure device and adjustable to vary the pressure at which the forces of said pressure device and said spring are balanced, and an electrical device responsive to the load on the generator and operatively associated with said lever system to combine its effect with that of said pressure device, and means for translating change in the forces acting on said lever system into a signal applied to said fuel supply and said air supply regulators including a fluid motor the position of which is governed by said jet pipe, a cam driven by said motor, a compression spring interposed between said cam and said jet pipe acting in opposition to said first mentioned spring, and means movable in proportion to said cam operable to influence said fuel supply and said air supply regulators.

9. Control means for an electric power generating system having a boiler, a steam header leading from the boiler, a fuel supply and an air supply for the boiler, a prime mover driven from the boiler and an electric generator driven by the prime mover, comprising a fuel supply controller, a fuel supply regulator operatively associated with said controller to govern the same, an air supply controller, an air supply regulator operatively associated with said air supply controller to govern the same, a master regulator having an electrical device responsive to the load on the generator and operable to call for an increase or a decrease in the energy supplied to the boiler respectively as the load on said generator is increased or decreased, a pressure device responsive to the pressure of the header and operable to call for an increase or a decrease in the energy supplied to the boiler respectively as the steam pressure drops or rises, means for loading said master regulator to maintain a predetermined no-load boiler pressure and means integrating the responses of said devices into an unbalance of said master regulator producing a signal, and means for translating the signal of said master regulator into a signal applied to each said fuel supply and said air supply regulators including a reversible motor driven as a result of said signal, a first element driven by said motor, a spring interposed between said element and said master regulator operable upon predetermined movement of said element to restore balance to said master regulator, and a second and a third element operatively associated respectively with said fuel supply regulator and said air supply regulator and connected to have a movement proportional to the movement of said first element to produce an unbalance in said fuel and said air supply regulators resulting in adjustment of said fuel and said air supply controllers in accordance with the change in energy supply called for by said master regulator, each said fuel and said air supply regulators having a device respectively responsive to the actual fuel consumption and the actual air supply acting in opposition to said second and third elements to restore the balance of said regulators and arrest adjustment of said fuel and said air supply controllers when the fuel

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consumed and the air supplied reaches the values called for.

10. In an electric power generating system, a boiler, a steam header leading from said boiler, means for supplying energy in the form of fuel and air to said boiler, a prime mover driven from said boiler, an electric current generator driven by the prime mover, and control means for governing supply of energy to said boiler including a master regulator operable to integrate a plurality of factors into a common signal calling for a definite change in energy supply to said boiler having a first device wholly independent of steam pressures in the system and of load on said generator operable to call for a predetermined energy level in said boiler, a second device responsive to static pressure only in the steam header and operable in conjunction with said first device to control the supply of energy to said boiler in accordance with the load on said generator, and a third device electrically connected to said generator to be responsive to the load thereon and operable with varying loads on said generator to vary the energy level of said boiler by amounts to maintain substantially constant the pressure of the steam supplied to said prime mover at varying loads on said generator by acting directly on said master regulator and independently of said first and second devices.

11. In an electric power generating system, a boiler, a steam header leading from said boiler, means for supplying energy in the form of fuel and air to said boiler, a prime mover driven from said boiler, an electric current generator driven from the prime mover, and control means for governing supply of energy to said boiler including a master regulator operable to integrate a plurality of factors into a common signal calling for a definite change in energy supply to said boiler having a pivoted beam with a stationary fulcrum, a first device responsive to the static pressure only in said steam header and acting on said beam to pivot the same in one direction, a second device wholly independent of steam pressures and of the load on said generator acting directly on said beam to tend to rotate the same in the opposite direction from said first device and loading said regulator to maintain a predetermined energy level in said boiler, and a third device electrically connected to said generator to be responsive to the load thereon engaging said beam to tend to rotate the same in the same direction as said second device and operable with changes in load on said generator to vary the loading of said regulator by amounts maintaining substantially constant the pressure of the steam supplied to said prime mover at the varying loads.

12. Control means for a power generating system having a boiler, a steam header leading from the boiler, a fuel supply and an air supply for the boiler and a load supplied from the boiler comprising a fuel supply controller, a fuel supply regulator operatively associated with said controller to govern the same, an air supply controller, an air supply regulator operatively associated with said air supply controller to govern the same, a master regulator having a first device responsive to the steam pressure of the header and operable to call for an increase or a decrease in the energy supplied to the boiler respectively as the header pressure drops or rises, a second device loading said master regulator to maintain a predetermined boiler pressure, a third device connected to the load to receive primary indication of change in demand operable to call for an increase or a

decrease in the energy supplied to the boiler respectively as the load is increased or decreased and means integrating the responses of said devices into an unbalance of said master regulator producing a signal proportional to the change in demand, and means for translating the signal of said master regulator into a signal applied to each said fuel supply and said air supply regulators including a first cam operatively associated with said master regulator and operable upon movement proportional to the demand to restore balance to said master regulator and a second and a third cam operatively associated respectively with said fuel supply regulator and said air supply regulator and connected to have a movement common with the movement of said first cam to produce an unbalance in said fuel and said air supply regulators resulting in adjustment of said fuel and said air supply controllers in accordance with the change in energy supply called for by said master regulator, each said fuel and said air supply regulators having a device respectively responsive to the actual fuel consumption and the actual air supply acting in opposition to said cams to restore the balance of said regulators and arrest adjustment of said fuel and said air supply controllers when the fuel consumed and the air supplied reaches the values called for.

13. Control means for a power generating system having a boiler, a steam header leading from the boiler, a fuel supply and an air supply for the boiler and a load supplied from the boiler comprising a fuel supply controller, a fuel supply regulator operatively associated with said controller to govern the same, an air supply controller, an air supply regulator operatively associated with said air supply controller to govern the same, a master regulator having a device independent of steam flow in the header connected directly and only to the load to receive primary indication of change in demand and operable to call for an increase or a decrease in the energy supplied to the boiler respectively as the load is increased or decreased, a pressure device responsive to the static pressure only of the header and operable to call for an increase or a decrease in the energy supplied to the boiler respectively as the steam pressure drops or rises, means for loading said master regulator to maintain a predetermined

no-load boiler pressure and means integrating the responses of said devices into an unbalance of said master regulator producing a signal, and means for translating the signal of said master regulator into a signal applied to each said fuel supply and said air supply regulators including a reversible motor driven as a result of said signal, a first element driven by said motor, a spring interposed between said element and said master regulator operable upon predetermined movement of said element to restore balance to said master regulator, and a second and a third element operatively associated respectively with said fuel supply regulator and said air supply regulator and connected to have a movement proportional to the movement of said first element to produce an unbalance in said fuel and said air supply regulators resulting in adjustment of said fuel and said air supply controllers in accordance with the change in energy supply called for by said master regulator, each said fuel and said air supply regulators having a device respectively responsive to the actual fuel consumption and the actual air supply acting in opposition to said second and third elements to restore the balance of said regulators and arrest adjustment of said fuel and said air supply controllers when the fuel consumed and the air supplied reaches the values called for.

HERBERT ZIEBOLZ.

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#### Certificate of Correction

Patent No. 2,433,725.

December 30, 1947.

HERBERT ZIEBOLZ

It is hereby certified that errors appear in the printed specification of the above numbered patent requiring correction as follows: Column 10, line 38, claim 1, before the word "loading" insert *load*; same line, strike out "main" and insert instead *maintain*; and that the said Letters Patent should be read with these corrections therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 13th day of April, A. D. 1948.

[SEAL]

THOMAS F. MURPHY,  
Assistant Commissioner of Patents.