June 11, 1968 W. CHAN ET AL 3,387,589

MULTIPLE BOILER CONTROL SYSTEM

Filed Sept. 12, 1966 2 Sheets-Sheet 1

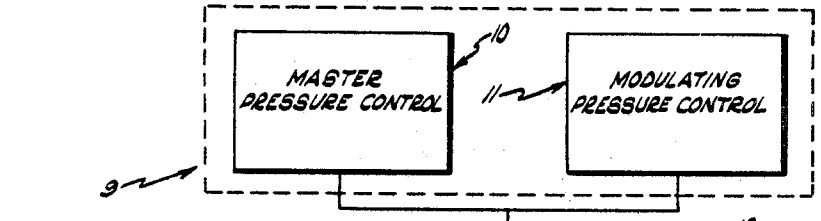


FIG. 1

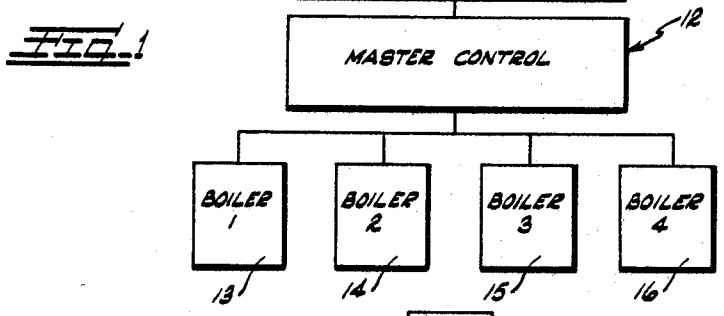


FIG. 2

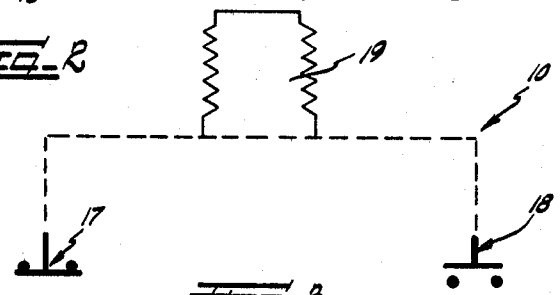
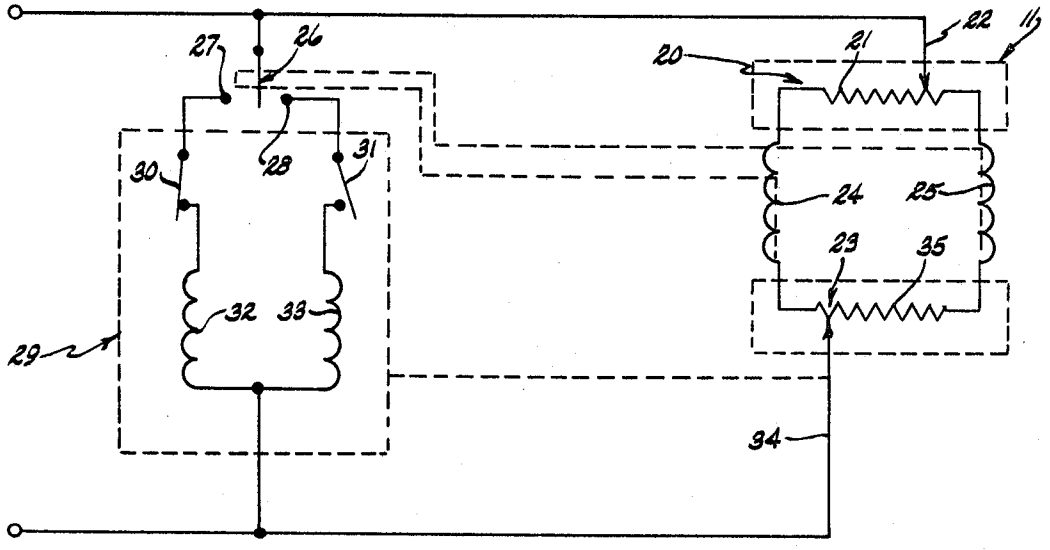


FIG. 3



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MULTIPLE BOILER CONTROL SYSTEM

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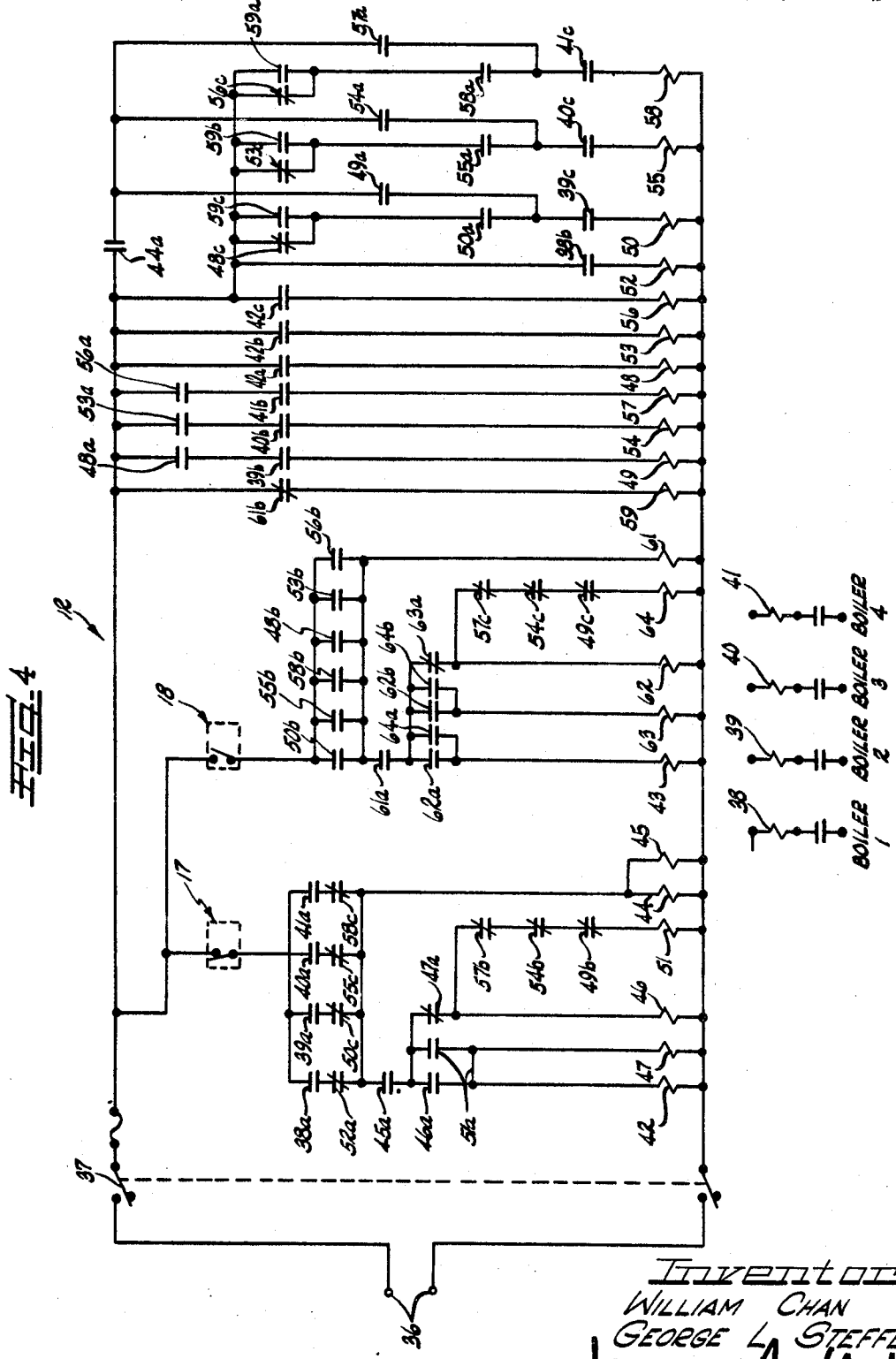


FIG. 4

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MULTIPLE BOILER CONTROL SYSTEM

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ABSTRACT OF THE DISCLOSURE

Multiple boiler control system for controlling the operation of a series of boilers connected to a common header and including a master pressure responsive switch responsive to the pressure in the header and having high and low pressure contacts for adding or subtracting boilers to the system, and a modulating pressure responsive switch responsive to the pressure in the header for modulating the operation of one of the boilers on the line between high and low fire conditions.

This invention relates in general to a boiler system, and more particularly to a control for use with a series of boilers connected to a single output for adding or subtracting boilers to the line in response to load requirements, although other uses and purposes may be apparent to those skilled in the art.

The control system of the present invention is especially suitable for controlling the operation of a plurality of boilers all having their outputs connected to a common header where each boiler may have a capacity of about 100 to 300 boiler horsepower so that boilers in the system may be added or subtracted in response to load requirements thereby eliminating the need for having a single boiler of large capacity or a system whereby all boilers are on the line at the same time. Further, the control system of the present invention is such that one of the boilers may be modulated between low and high fire conditions depending upon load requirements. Pressure responsive switches are employed in the common header for the boilers to sense the need to add or subtract boilers from the line depending upon load requirements, and to optionally modulate one of the boilers between high and low fire conditions again depending upon load requirements. The control system operates to add and subtract the boilers on a timed basis which can be adjusted according to need. Although the system contemplates controlling a series of boilers of the 100 to 300 boiler horsepower capacity, it should be appreciated that a combination of any number of boilers of the same or varying capacity may be controlled by the system of the present invention where all of the boilers are connected into the common header or the same output line. Further, the system is especially useful where the boiler capacity needs range from a very small capacity to a large capacity, such as from 100 to 1500 boiler horsepower.

It is therefore an object of the present invention to provide a control system for adding or subtracting boilers from a series of boilers that are connected to a common header or output line.

Another object of this invention resides in the provision of a control system for automatically handling the firing of a series of boilers connected to a common header in response to the load requirements.

Still another object of this invention is in the provision of a control system for handling the adding or subtracting of boilers on a time basis to a common header, wherein the timed basis may be adjusted according to needs of the system.

Other objects, features and advantages of the invention

will be apparent from the following detailed disclosure, taken in conjunction with the accompanying sheets of drawings, wherein like reference numerals refer to like parts, in which:

FIG. 1 is a block diagram of the control system according to the invention;

FIG. 2 is a diagrammatic view of the master pressure control which determines whether a boiler need be added or subtracted from the system;

FIG. 3 is a schematic diagram of a modulating control for a boiler as connected into the modulating pressure control for the system of the invention; and

FIG. 4 is a schematic electrical diagram of the master control according to one embodiment of the invention for illustrating the invention where three boilers in a system are programmed to be added or subtracted in accordance with the load requirements.

While the present invention may be applied to any system of boilers, it is illustrated herein applicable to a system of four boilers where the first boiler is always on the line except when the entire system is shut down and the other three boilers are programmed to be automatically added or subtracted to the line depending upon load requirements. Thus, the output of all boilers will be connected to a common header or output **9**, FIG. 1, wherein a pressure sensitive master control switch **10** and a pressure sensitive modulating pressure control switch **11** will be located. A master control **12** receives signals from the master pressure control switch **10** and modulating pressure control switch **11** for controlling operation of boilers 1 to 4 indicated respectively by the numerals **13**, **14**, **15** and **16**. Both pressure sensitive switches **10** and **11** will be suitably mounted in the common header **9** for the boilers to determine the load requirements of the line and thereby maintain a maximum and minimum power supply from the boilers consistent with the requirements. While the boiler number **1** will always be in operation, boilers **2**, **3** and **4** may be added or subtracted according to need if these boilers are otherwise ready although the system could be programmed so that more than one boiler or no boiler would be in continual operation and the remaining boilers in readiness for operation.

As an example of operation, the master pressure control switch **10**, which operates to add or subtract boilers from the line, would have a low pressure switch **17** and a high pressure switch **18** both operated by a pressure sensing element **19**, wherein the low pressure switch **17** would close at a predetermined pressure such as 175 p.s.i. and remain closed as long as the pressure is no greater than 175 p.s.i., and thereafter operate a circuit to cause another boiler to be placed on the line to raise the pressure, and the high pressure switch **18** would close in response to a predetermined pressure, such as 200 p.s.i. and remain closed as long as the pressure is 200 p.s.i. or greater, and cause operation of a circuit to remove a boiler from the line to lower the pressure. The upper and lower pressure limits may be adjusted to the needs on the line. Thus, no boiler would be added or subtrated as long as the pressure is between 175 and 200 p.s.i.

Within the range of 175 to 200 p.s.i., the modulating pressure control **11** would operate to modulate one of the boilers on the line in accordance with present pressure limits, such as where the boiler would operate at high fire condition at 178 p.s.i. and at low fire condition at 198 p.s.i. and modulate between high and low fire condition between 178 and 198 p.s.i.

The modulating pressure control **11** includes a variable potentiometer **20** having a resistance **21** over which a wiper **22** moves responsive to the pressure in the header to change the balance in a bridge circuit that also in-

cludes a variable potentiometer 23 and magnet coils 24 and 25, the latter of which operate a switch arm 26 into contact with one of the contacts 27 or 28 or in a neutral position. The contacts 27 and 28 by engagement with the switch arm 26 cause actuation of a reversible motor 29 which is mechanically connected to the boiler controls of a boiler to modulate the boiler between low and high fire conditions. Limit switches 30 and 31 are provided to prevent continued operation of the motor at extreme limits even though the switch arm 26 is in contact with one of the contacts 27 and 28. For illustrative purposes, the motor winding 32 may be considered the low fire winding while the winding 33 may be considered the high fire winding, wherein operation of the motor through the winding 32 causes the controls to move toward low fire position while operation of the motor through the winding 33 causes the controls to move toward high fire position. The variable potentiometer 23 is operated by the motor, wherein it includes a wiper 34 movable back and forth on a resistance 35 in response to operation of the motor 29. Thus, as the motor is operated through the potentiometer 23, the bridge circuit is being re-balanced.

In operation, as the resistance of the circuit in series with one of the coils 24 and 25 is reduced by movement of the wiper 22, the current flow through the one coil will increase thereby increasing its magnetic field strength and pulling the switch arm 26 towards it to close one of the contacts 27 or 28. When the one contact is closed, the motor 29 is energized to rotate in one direction to accordingly move the boiler controls toward lower or higher fire conditions. While the motor rotates, the wiper 34 of the balance potentiometer 23 moves across the resistance 35 to re-balance the bridge circuit and stop further rotation until a change in steam pressure once again causes the pressure responsive poteniometer to unbalance the bridge circuit. It will be understood that each boiler capable of modulation will include modulating control circuitry as shown in FIG. 3 responsive to the modulating pressure control 11, although the circuitry will be arranged so that only one boiler will be responsive to the modulating pressure control at any one time, and that normaliy being the last boiler on the line.

Referring now to FIG. 4, the master control 12 for the illustrated embodiment of the invention operates to add or substract boilers from the line depending upon the load requirements, and includes control power terminals 36 for connecting the circuitry to suitable power and a main control switch 37 that must be in the "on" position to condition the master control 12 for operation. The low pressure switch 17 is shown in closed position, while the high pressure switch 18 is shown in open position although their conditions are dictated by the pressure in the header. Further, each boiler is provided with a control switch to determine whether it is in readiness for operation, and this must be in the "on" position for any particular boiler to operate in the line. Boiler ready relays 38, 39, 40 and 41 are respectively provided for boilers 1 to 4, and must receive a signal from the control switches of these boilers and be energized if the boiler is ready for operation. Therefore, if a boiler ready relay is not energized for any one boiler, that boiler cannot be programmed into the system, yet the system will function as will be hereinafter seen. Energization of boiler ready relay 38 closes contacts 38*a* and 38*b*, while energization of boiler ready relay 39 closes contacts 39*a* and 39*b* and 39*c*. Energization of boiler ready relay 40 closes contacts 40*a*, 40*b* and 40*c*, while energization of boiler ready relay 41 closes contacts 41*a* 41*b* and 41*c*.

Should the pressure in the main header 9 drop below the setting of the low pressure switch 17, which in the illustrated example is 175 p.s.i., closing of the low pressure switch will operate a stepper switch in the master control to add a boiler to the line for the purpose of bringing the pressure up above the lower limit that causes the low pressure switch 17 to close. Similarly, assuming there is a boiler in the system in operation that can be subtracted, that boiler will be subtracted or removed from the line through the master control circuitry upon closing of the high pressure switch 18 that would be caused when the pressure in the line reaches 200 p.s.i. or the high pressure setting of that switch. The stepper switch includes and "add" coil 42 and a "subtract" coil 43, the "add" coil being energized through the closed low pressure switch 17 to program another boiler into the system while the "subtract" coil is energized during closing of the high pressure switch 18 to subtract or remove a boiler from the system. As above explained, the master control 12 is capable to programming boilers 2, 3 and 4 in and out of the system, while boiler 1 is always maintained in the system although any number of boilers may be included. Further, boilers 2, 3 and 4 must have their boiler ready relays energized in order to be capable of being programmed in and out of the system. However, as already mentioned, it is not necessary to have each of the boilers 2, 3 and 4 ready for progrmming into and out of the system in order to permit proper operation of the master control 12.

Assuming that all of the boiler ready relays are energized, the circuitry will operate as follows when the master pressure control 10 detects a pressure in the common header below 175 p.s.i. which will cause closing of the low pressure switch 17. This closure energizes a low pressure relay 44 through the closed boiler ready relay contact 39*a*, and after a predetermined delay the timer relay 45. For purposes of illustration, a typical time setting of this relay might be three seconds and prevents calling a boiler unit on the line because of a temporary drop in pressure. Energization of the timer relay 45 closes contact 45*a*, while energization of the low pressure relay 44 closes the contact 44*a*, the latter of which functions as a safety to prevent adding of a boiler unless the low pressure switch 17 is closed. Closing of the contact 45*a* causes energization of a timer relay 46 after a predetermined time delay. A typical setting for this relay is 120 seconds which defines the timing rate at which boilers can be added. Energization of the timer relay 46 closes contact 46*a*, thereby causing energization of the stepper switch "add" coil 42, and after a predetermined time delay energization of a timer relay 47. A typical time setting for relay 47 is 3 seconds. This time delay permits the stepper switch "add" coil 42 sufficient time to advance the stepper switch before opening of contact 47*a* by energization of relay 47 that causes deenergization of the timer relay 46 and opening of contact 46*a* that causes deenergization of the "add" coil 42 and timer relay 47.

Energization of the stepping switch "add" coil 42 which causes advancing of the stepper switch one step also closes stepper switch contact 42*a* that energizes stepper relay 48 closing contact 48*a* which through previously closed contact 39*b* energizes fire boiler relay 49. Contact 49*a* is closed by operation of the relay 49, and through previously closed boiler ready relay contact 39*c* causes energization of an automatic relay 50. Contact 49*b* is also opened during energization of the relay 49 to prevent operation of a stepper override "add" relay 51. The stepper relay 48 also causes closing of contact 48*b* and opening of contact 48*c*, while the automatic relay 50 also closes contacts 50*a* and 50*b* and opens contact 50*c*. Closing of contact 50*a* holds the automatic relay 50. Further, the fire boiler relay 49 causes opening of contact 49*c* to prevent operation of a stepper override "subtract" relay 64.

An automatic relay 52 is energized through the closed contact 38*b* of the boiler number 1 after it is put into operation, thereby opening contact 52*a* and preventing the stepper switch from advancing prematurely.

Should the low pressure switch 17 remain closed because of the pressure in the common header subsequent to the firing of boiler number 2, the low pressure relay 44 will

remain energized holding contact 44*a* closed and timer relay 45 will remain energized holding contact 45*a* closed to again initiate the timing cycle of timer relay 46. At the expiration of the time delay of the relay 46, the contact 46*a* will be closed to start the time delay cycle of the timer relay 47 and to advance the stepper switch by energizing the stepper switch "add" coil 42. Energization of the stepper switch "add" coil 42 to the next position now closes the stepper switch contact 42*b* to energize the stepper relay 53 and opens stepper switch contact 42*a* that deenergizes relay 48, opening contacts 48*a* and 48*b* and closing contact 48*c*. Closed contact 48*c* holds automatic relay 50 energized during the high pressure cycle. Opening contact 48*a* deenergizes fire boiler relay 49 which in turn opens contact 49*a* and closes contacts 49*b* and 49*c*. Energization of the stepper relay 53 closes contact 53*a* to energize the fire boiler relay 54, closes contact 53*b* in the subtract circuit, and opens contact 53*c*. The relay 54 causes closing of contact 54*a*, and opening of contacts 54*b* and 54*c* in the override circuits. Closing of contact 54*a* energizes the automatic relay 55 through previously closed contact 40*c* to close contacts 55*a* and 55*b*, while opening normally closed contact 55*c*. Closing of contact 55*a* holds the automatic relay 55. Now the second programmed boiler (number 3) is on the line and in operation.

Should the pressure in the line still stand below the minimum setting to maintain the low pressure switch 17 closed, the low pressure relay 44 and the time cycle for the timer relay 45 remain energized through the previously closed contacts 41*a* and the normally closed contact 58*c* of the automatic relay 58 of boiler number 4. The closed contact 45*a* thereby energizes the timing cycle of the timer relay 46. At the expiration of the time delay of relay 46, the contact 46*a* is closed to start the time delay period of the relay 47 and energize the stepper switch "add" coil 42 to advance the stepper switch to the next position. At the expiration of the time delay of relay 47, the contact 47*a* is opened to deenergize the relay 46 and prevent operation of the override "add" circuit. The stepper switch "add" coil 42 in the next position closes the contact 42*c* to energize the stepper relay 56 which in turn closes contacts 56*a* and 56*b*, while opening contact 56*c*, and opens stepper switch contact 42*b* that deenergizes relay 53, the latter causing opening of contacts 53*a* and 53*b* and closing of contact 53*c*. Closed contact 53*c* holds automatic relay 55 energized during the high pressure cycle. Opening contact 53*a* deenergizes fire boiler relay 54 which in turn opens contact 54*a* and closes contacts 54*b* and 54*c*. Closing of contact 56*a* energizes the fire boiler relay 57 through previously closed contact 41*b* to close contact 57*a*, and open contacts 57*b* and 57*c* in the override circuit. Closing of contact 57*a* energizes automatic relay 58 through previously closed contact 41*c*, thereby closing contacts 58*a* and 58*b* while opening contact 58*c*. Closing of contact 58*a* holds the relay 58. Now all boilers are on the line and in operation.

With all boilers operating, the automatic relays 50, 52, 55 and 58 are energized to maintain the normally closed contacts 50*c*, 52*a*, 55*c* and 58*c* open, thereby opening all circuits to the stepper switch "add" coil 42, preventing the stepper from seeking more boilers to put on the system. Thus, the automatic relay 58 is held in through the closed contact 41*c* of the boiler ready relay 41 of boiler number 4, and the closed contact 59*a* of the high pressure relay 59, the latter of which is maintained in energized form through the normally closed contact 61*b* of a timer relay 51 in the "subtract" circuit. The automatic relays do not have the parallel circuit established when adding boilers since the low pressure relay is deenergized thereby opening the low pressure relay contact 44*a*. Further, the circiut through the normally closed contact 56*c* of the stepper relay 56 is open since this relay is energized at this time with the stepper in the fourth position. But, the relays 53 and 48 are deenergized these becoming energized when the stepper is in the third and second positions, respectively.

Sensing of a high pressure in the line causes closure of the high pressure switch 18 thereby energizing a timer relay 61 after a predetermined time delay which may be typically 3 seconds. The time delay period of relay 61 serves to prevent a boiler from being removed because of a momentary high pressure surge, and thus when the time delay expires, contact 61*a* closes thereby energizing the time cycle for a timer relay 62. This time cycle may typically be 10 seconds to dictate how fast the boilers can be removed from the system. Setting of relay 61 also opens normally closed contact 61*b* to energize high pressure relay 59 and open contact 59*a* causing deenergization of automatic relay 58 and removal of boiler number 4 from the system in 3 seconds. When the timing of relay 62 expires, it will close contact 62*a* and contact 62*b* energizing the stepper switch "subtract" coil 43 causing the stepper to backstep one position and to energize the timer relay 63 starting its 3 seconds time cycle. Relay 63 opens contact 63*a* after 3 seconds, deenergizing relay 62, thereby opening the circuit to the stepper switch "'subtract" coil 43 and prohibiting the stepper from taking another backstep until another cycle is accomplished as above. When the stepper back steps one position, its contact 42*c* opens while contact 42*b* closes. Opening of contact 42*c* deenergizes the stepper relay 56 opening contact 56*a* to deenergize the fire boiler relay 57 and thereby opening contact 57*a*. Closing of contact 42*b* energizes the stepper relay 53 opening normally closed contact 53*c* while closing contacts 53*a* and 53*b*. If the high pressure switch 18 continues to be closed because of high steam pressure, the stepper will step every 10 seconds and remove the remaining programmed boilers until all programmed boilers are removed from the load.

In the system illustrated, the additional boilers may be programmed in and out of the line even when one of the boilers 2, 3 or 4 is down and not ready to be used in the system. For example, if boiler number 3 were not to be used, its boiler ready relay 40 would not be energized, and contacts 40*a*, 40*b* and 40*c* would remain open. Open contacts 40*b* and 40*c* would prevent energization of fire boiler relay 54 and automatic relay 55. Assuming that boilers 2 and 4 are ready with boiler 2 on the line and a low pressure condition is sensed by the low pressure switch 17, the low pressure relay 44 would energize through the normally closed contact 58*c* and the closed boiler relay contact 41*a* to close the contact 44*a* a following the time delay of timer relay 45, the contact 45*a* would close. This would cause, after the predetermined time delay, energization of relay 46 which would close contact 46*a* causing the stepper switch "add" coil 42 to be energized to upstep the stepper switch, and after the time delay, energization of the relay 47. Closing of stepper switch contact 42*b* by advancing of the stepper switch would cause energization of the stepper relay 53. However, closure of contact 53*a* would not energize the fire boiler relay 54 because the boiler ready relay contact 40*b* would be open. This would therefore leave the contact 54*b* in closed position and allow the stepper override "add" coil 51 to be energized before expiration of the time delay of relay 47 to step the stepper switch up into the next position and thereby place boiler number 4 on the line. Energization of the stepper override "add" coil 51 would close contact 51*a* to bypass the timing of relay 46 and immediately energize stepper "add" coil 42 to upstep the stepper switch and add the next boiler.

Similarly, upon receiving a signal to remove a boiler from the line through high pressure switch 18, after boiler number 4 has been removed, the high pressure relay 61 would be energized after a time delay. Closing of contact 61*a* would cause operation of the stepper override "subtract" relay 64 since the fire boiler relay 54 would not be energized to open contact 54*c*, thereby overstepping the position of boiler number 3 and moving to the posi-

tion of boiler number 2 to remove it from the line. Energization of the stepper override "subtract" coil 64 causes closing of the contacts 64*a* and 64*b* to directly operate the timer relay 63 and stepper switch subtract coil 43 and bypass the time delay of relay 62.

It should be appreciated that any number of programmed boilers may be provided with the system of the present invention wherein each of the boilers may be of different capacities, and the time cycles for adding and subtracting of the boilers may be varied depending upon the needs of the system.

It will be understood that modifications and variations may be effected without departing from the scope of the novel concepts of the present invention, but it is understood that this application is to be limited only by the scope of the appended claims.

The invention is hereby claimed as follows:

1. A boiler system including a plurality of boilers in a line each having their outputs connected to a common header and a control system, wherein manual controls are provided for starting and stopping the first of said boilers and automatic controls are provided for starting and stopping the other boilers by said control system, said control system comprising a first pressure responsive switch responsive to the pressure in said header having high and low pressure contacts closing respectively at predetermined high and low pressure settings, circuit means connected to said contacts and to said boiler controls of said other boilers for starting and stopping and adding or subtracting the other boilers respectively to and from the system one at a time in response to the pressure in the header and the closing of one of said contacts, and a second pressure responsive switch responsive to the pressure in said header for modulating the operation of the last boiler of the line connected to said header between high and low fire conditions to maintain the header pressure between the high and low pressure settings of said first pressure responsive switch.

2. The combination as defined by claim 1, wherein said circuit means includes a stepper switch connected to the controls of the boilers and responsive to said add and subtract circuits to upstep or downstep to add or subtract boilers to the header.

3. The combination as defined in claim 2, wherein said circuit means includes a stepper override add circuit and a stepper override subtract circuit to bypass a non-operative boiler when adding or subtracting boilers from the header.

4. A boiler system as defined by claim 1, wherein said circuit means includes add circuit means connected to said low pressure contact for starting and adding a boiler to the system when the pressure is such to close the low pressure contact and subtract circuit means connected to said high pressure contact for stopping and subtracting a boiler from the system when the pressure is such to close the high pressure contact.

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