The present invention relates to a continuous completely automatic system for selectively and sequentially controlling the operation of a plurality of fluid heater cleaners in heat exchanging apparatus.

In modern power boilers a continuing problem has been the effective control and regulation of the temperature of the final steam produced, particularly in view of such variables as boiler load, the type of fuel employed, and variations in temperature of the fuel gas entering the convection passes of the steam heating section as affected by the slagging conditions of the furnace. In view of the fact that the furnace walls of large capacity power boilers constitute a high percentage of the total heating surface and the heat absorption characteristics of the furnace walls have a major influence on the final steam temperature, selective controlled cleaning or deslagging of the furnace walls provides an extremely effective method of controlling the temperature of the final steam produced in the steam heating section in combination with conventional steam control devices. Conversely, haphazard cleaning of the furnace walls by manual operation of fluid heater cleaners, or soot blowers as they are usually referred to, or automatic haphazard operation as provided by systems heretofore proposed can and have resulted in drastic disruptions of the thermal equilibrium conditions of the power boiler resulting in large fluctuations in the final steam temperature. Although modern power boilers incorporate one or more steam temperature control mechanisms such as, for example, titling burner mechanisms, attemperation or desuperheater systems, and recycle flue gas damper controls, haphazard operation of the soot blowers as has been heretofore existing disrupted the thermal equilibrium conditions to the extent that the steam temperature controls have been unable to prevent the large fluctuations in final steam temperature. Such large fluctuations in the final steam temperature are undesirable particularly when the superheated or reheated steam is employed to drive a turbine for the generation of electricity, for example, preventing optimum design efficiency of the turbine from being attained and producing fluctuations in the output power thereof.

In addition to avoiding large and abrupt deviations in the thermal equilibrium conditions of a power boiler by the operation of the soot blowers, of equal importance is the necessity of preventing excessive slagging conditions from occurring along the furnace walls and convection passes which materially reduce the efficiency of the boiler and can possibly result in permanent fouling necessitating a shut-down and physical cleaning of the fouled heat absorption surfaces. This necessitates that the automatic sequential operation of the soot blowers is the automatic sequential operation of the soot blowers is the automatic sequential operation of the soot blowers is the automatic sequential operation of the soot blowers is the automatic sequential operation of the soot blowers is the automatic sequential operation of the soot blowers is the automatic sequential operation of the soot blowers is the automatic sequential operation of the soot blowers is the automatic sequential operation of the soot blowers is the automatic sequential operation of the soot blowers is the automatic sequential operation of the soot bl...
3 of the steam generating section 10 are provided with a plurality of wall blowers generally indicated at 12, which are arranged operable in a coiled section of the system subsequently to be described, to discharge a suitable cleaning medium such as air, steam, or mixtures thereof, for example, against the heat absorption surfaces of the steam generating section to remove the accumulation of slag and the like therefrom. A typical soot blower construction suitable for this purpose is disclosed in U.S. Patent No. 2,662,241 which is of the short-travel retracting type whereby the discharge nozzle thereof is projected into the boiler during operation and is retracted to a position beyond the furnace wall during the intervals between blowing operations. The projecting and retracting movement of the soot blower nozzle can be conveniently achieved by a suitable electric motor drivingly connected to the soot blower operating mechanism providing for remotely controlled operation.

The typical power boiler 8 shown in FIGURE 1 is also provided with a superheater section generally indicated at 14 including a pendant type superheater bundle 16 extending downwardly from the upper end of the first pass and a series of superheater bundles 18 disposed one above each other in the second pass of the boiler. Inasmuch as the tubes of the superheater bundles 16 and 18 extend across the first and second passes of the boiler, soot blowers of the long-travel retractable type are usually employed to provide cleaning and deslagging of the heat absorption surfaces thereof. A suitable soot blower of the foregoing type is described in U.S. Patent No. 2,685,711 and incorporates a lance having a nozzle at one end thereof which is projected into the boiler during operation and is thereafter retracted to a position beyond the surface of the boiler wall during intervals of nonuse. The lance tubes are generally adapted to rotate during their projecting and retracting travel whereby the cleaning medium discharged from the nozzle is directed against the heat absorption surfaces of the tube bundles causing the effective removal of soot and slag accumulations thereon. A suitable driving means such as an electric motor is employed enabling remote controlled operation thereof. The long-travel soot blowers 20 and the short-travel wall blowers 12 are generally arranged in a series of rows at a prescribed spacing so as to achieve a slight overlapping between the cleaning patterns of adjacent blowers thereby assuring proper deslagging of all of the heat absorption surfaces. The soot blowers are generally operated one at a time to avoid overloading the capacity of the blowing system.

In addition to the wall blowers 12 and long-travel blowers 20 for cleaning the furnace water wall tubes and superheater tube bundles, respectively, additional soot blowers usually of the long-travel type are also provided for deslagging a slag screen generally indicated at 22 and any reheater bundles in power boilers provided with a reheater section. The operation of the soot blowers adjacent to the slag screen 22 can be conveniently tied in with the operating sequence of the wall blowers 12. In power boilers provided with an economizer section generally indicated by the economizer tube bundle 24 one or more additional soot blowers can be provided to deslag the economizer tube bundle and which can be operated independently of the remaining soot blowers and preferably on a straight time cycle. In addition an air heater section generally indicated at 26 can be provided with a plurality of soot blowers which are also independently operable on a straight time cycle to remove soot and other extraneous material from the heat exchange surfaces thereof.

The automatic soot blower operating sequence control system as specifically shown and described herein functions to control the sequential operation of the wall blowers disposed along the furnace wall water tubes of the steam generating section as one group which also can include soot blowers along the slag screen 22 if present, and a second group comprised of the long-travel soot blowers 20 disposed adjacent to the superheater bundles 16 and 18 of the superheater section 14 in response to the temperature of the superheated steam produced. It is also contemplated within the scope of the superheater steam boiler having a combined superheater section and reheater section.

The automatic control of the operation of the soot blowers is predicted on the heat absorption characteristics of the steam generating section 10 and the steam heating section or superheater section 14 as specifically shown in the steam generating section to accumulate on the surfaces of the walls in the steam generating section the absorption of heat in this section decreases with a corresponding rise in the temperature of the flue gases passing through the superheater bundles 16 and 18. In addition, the soot on the surfaces of the steam generating section is heat against the pendant type superheater bundles 16 causing a further increase in the temperature of the superheated steam produced. Conversely, the accumulation of soot and slag on the surfaces of the tubes of the superheater bundles 16 and 18 decreases their heat absorption and increases reflection of the heat thereagainst tending to reduce the temperature of the superheated steam. Accordingly, by controlling the slacking conditions in the steam generating section 10 and the superheater section 14, a dynamic equilibrium can be established with respect to the heat absorption characteristics of the heat transfer surfaces wherein the resultant temperature of the superheated steam can be maintained within a relatively small range. Since in modern power boilers the furnace walls of the steam generating section constitute a high percentage of the total heat transfer surface, the slacking condition of the furnace wall has a greater effect on the superheated steam temperature than does the slacking condition of the superheater tube bundles. For this reason, the operation of the wall blowers in the steam generating section 10 constitutes the primary control of the superheated steam temperature while the operation of the long-travel blowers of the superheater tube bundles constitutes a secondary control.

Under typical boiler operation conditions when the final steam temperature rises to a predetermined level indicating low heat absorption in the steam generating section a suitable sensing device actuated in response to the temperature of the final steam is operative to cause successive and sequential operation of the wall blowers 12 in the steam generating section thereby progressively increasing the heat absorption characteristics thereof with a corresponding reduction in the temperature of the flue gases entering the convection passes and a reduction in the temperature of the final steam. After a period of sequential operation of the wall blowers, the heat absorption in the steam generating section is increased to the point where the temperature of the flue gases is reduced to a level where the temperature of the final steam decreases to a preset limit wherein the sensing means are operative to discontinue operation of the wall blowers and initiate operation of the long-travel blowers 20 in the superheater section increasing the heat absorption characteristics thereof with a corresponding rise in the final steam temperature. This is followed by sequential operation of the wall blowers 12 or the long-travel blowers 20 providing an incremental increase in the heat absorption characteristics of the furnace walls or superheater bundles, respectively. Since the incremental increase in heat absorption is not immediately reflected in the temperature of the superheated steam, suitable delay timers are incorporated in the control circuits of the wall blowers and the long-travel blowers providing for a period of inactivity between
the operation of successive blowers to enable stabilization and re-establishment of thermal equilibrium conditions within the boiler thereby enabling the effect of the operation of each soot blower to be reflected in the temperature of the superheated steam. Accordingly, in the preferred practice of the present invention a delay-time period between the operation of successive wall blowers usually ranging from about 15 seconds to about 3 minutes enables re-establishment of thermal equilibrium conditions while a delay-time period ranging from about 5 to about 30 minutes is usually employed between the successive operation of the long-travel blowers in the superheater section. The necessity and duration of the delay-time period are, of course, dependent on the specific design characteristics of a boiler in which the system is employed and can be varied to achieve optimum operation. In some power boilers, all or certain groups of blowers can be operated to rapid succession without any appreciable delay-time period between successive blowers. In the usual and preferred practice, however, delay-time periods are provided in the system of the general magnitude set forth above.

By virtue of the delay-time period between successive soot blower operation and selective correlated operation of the wall blowers and long-travel blowers, large disturbances in the thermal balance of the boiler are avoided enabling accurate control of the final steam temperature. In manual systems and automatic soot blower systems heretofore proposed it has been common practice to operate all of the soot blowers in each section in rapid succession causing an abrupt change in the thermal balance of the boiler and a corresponding large fluctuation in the temperature of the final steam which frequently is as high as 30° F. attemperator. The foregoing compensating devices may be employed singly or in combination to prevent aggravated disruptions in the temperature of the final steam. Generally, burner tilts ranging up to about 30° above and below a horizontal position are usually satisfactory to effect a substantial change in the radiant heat directed against the water wall tubes in the steam generating section affecting the heat absorption thereof with a resultant effect on the temperature of the final steam. It will be apparent that by tilting the burner upwardly the radiant heat transmitted to the superheater section is increased and the heat absorption in the steam generating section is reduced resulting in a rise in the temperature of the final steam. Conversely, by tilting the burner downwardly an increase in the absorption of heat by the steam generating section is achieved with a concurrent reduction in the radiant heat to the superheater section producing a decrease in the temperature of the final steam. It is also contemplated within the practice of the present invention that the actuation of the selector switch TS as shown schematically in FIG. 3 can be achieved by or in response to the automatic control system comprising the present invention in a modern large capacity boiler has provided extremely close control of the final steam temperature with deviations thereof restricted to a range of usually from about 0° F. to 5° F. Moreover, the automatic control system has provided a conservation of the soot blower blowing medium, a minimum of labor for regulation and observation, and less corrective action by the steam temperature control mechanisms.

The alternate selective operation of the wall blowers in the steam generating section and the long-travel blowers in the superheater section 44 controlled by conventional steam temperature controls which are arranged in accordance with the arrangement illustrated in FIGURE 1 and the schematic diagram shown in FIG. 2. As shown in FIGS. 1 and 2, a suitable temperature sensing device 29 such as a thermocouple, resistance thermometer, or bulb-like pyrometer, for example, is associated with the superheater or reheater steam outlet 29, as the case may be, which is electrically connected to a suitable controller 30 of the type well known in the art which converts the intelligence communicated thereto to an actuating energy such as a variable air loading pressure which is directly fed to a suitable steam temperature compensating mechanism such as an attemperator 31 in the steam outlet line and a variable flue gas recirculation damper mechanism 32 as shown in FIG. 1 or a tilting burner mechanism 33 as shown in FIG. 2. The actuating air loading pressure can also be directly fed to a preset or operable selector switch TS which is responsive to the pressure applied to operate to alternately select and energize the wall blower operating sequence in the steam generating section or the long-travel blower operation in the superheater section.

The temperature compensating mechanism may comprise any one of a variety of control devices intended to compensate for changes in the final steam temperature such as, for example, a conventional burner tilt mechanism, variable damper control for regulating the recirculation of spent flue gases to the first pass of the boiler or the amount of excess combustion air, or attemperation of the final steam by either a surface or direct contact type attemperator. The foregoing compensating devices may be employed singly or in combination to prevent aggravated disruptions in the temperature of the final steam. In a tilting type burner mechanism 33 as shown schematically in FIG. 3, the air loading pressure derived from the controller 30 is effective to actuate suitable reversible motor means 34 connected to a burner 36 causing the burner to tilt upwardly or downwardly in response to the temperature of the final steam. Generally, burner tilts ranging up to about 30° above and below a horizontal position are usually satisfactory to effect a substantial change in the radiant heat directed against the water wall tubes in the steam generating section affecting the heat absorption thereof with a resultant effect on the temperature of the final steam. It will be apparent that by tilting the burner upwardly the radiant heat transmitted to the superheater section is increased and the heat absorption in the steam generating section is reduced resulting in a rise in the temperature of the final steam. Conversely, by tilting the burner downwardly an increase in the absorption of heat by the steam generating section is achieved with a concurrent reduction in the radiant heat to the superheater section producing a decrease in the temperature of the final steam. It is also contemplated within the practice of the present invention that the actuation of the selector switch TS as shown schematically in FIG. 3 can be achieved by or in response to the automatic control system comprising the present invention in a modern large capacity boiler has provided extremely close control of the final steam temperature with deviations thereof restricted to a range of usually from about 0° F. to 5° F. Moreover, the automatic control system has provided a conservation of the soot blower blowing medium, a minimum of labor for regulation and observation, and less corrective action by the steam temperature control mechanisms.

The alternate selective operation of the wall blowers in the steam generating section and the long-travel blowers in the superheater section 44 controlled by conventional steam temperature controls which are arranged in accordance with the arrangement illustrated in FIGURE 1 and the schematic diagram shown in FIG. 2. As shown in FIGS. 1 and 2, a suitable temperature sensing device 29 such as a thermocouple, resistance thermometer, or bulb-like pyrometer, for example, is associated with the superheater or reheater steam outlet 29, as the case may be, which is electrically connected to a suitable controller 30 of the type well known in the art which converts the intelligence communicated thereto to an actuating energy such as a variable air loading pressure which is directly fed to a suitable steam temperature compensating mechanism such as an attemperator 31 in the steam outlet line and a variable flue gas recirculation damper mechanism 32 as shown in FIG. 1 or a tilting burner mechanism 33 as shown in FIG. 2. The actuating air loading pressure can also be directly fed to a preset or operable selector switch TS which is responsive to the pressure applied to operate to alternately select and energize the wall blower operating sequence in the steam generating section or the long-travel blower operation in the superheater section.

The temperature compensating mechanism may comprise any one of a variety of control devices intended to compensate for changes in the final steam temperature such as, for example, a conventional burner tilt mechanism, variable damper control for regulating the recirculation of spent flue gases to the first pass of the boiler or the amount of excess combustion air, or attemperation of the final steam by either a surface or direct contact type attemperator. The foregoing compensating devices may be employed singly or in combination to prevent aggravated disruptions in the temperature of the final steam. In a tilting type burner mechanism 33 as shown schematically in FIG. 3, the air loading pressure derived from the controller 30 is effective to actuate suitable reversible motor means 34 connected to a burner 36 causing the burner to tilt upwardly or downwardly in response to the temperature of the final steam. Generally, burner tilts ranging up to about 30° above and below a horizontal position are usually satisfactory to effect a substantial change in the radiant heat directed against the water wall tubes in the steam generating section affecting the heat absorption thereof with a resultant effect on the temperature of the final steam. It will be apparent that by tilting the burner upwardly the radiant heat transmitted to the superheater section is increased and the heat absorption in the steam generating section is reduced resulting in a rise in the temperature of the final steam. Conversely, by tilting the burner downwardly an increase in the absorption of heat by the steam generating section is achieved with a concurrent reduction in the radiant heat to the superheater section producing a decrease in the temperature of the final steam. It is also contemplated within the practice of the present invention that the actuation of the selector switch TS as shown schematically in FIG. 3 can be achieved by or in response to the automatic control system comprising the present invention in a modern large capacity boiler has provided extremely close control of the final steam temperature with deviations thereof restricted to a range of usually from about 0° F. to 5° F. Moreover, the automatic control system has provided a conservation of the soot blower blowing medium, a minimum of labor for regulation and observation, and less corrective action by the steam temperature control mechanisms.

In a similar manner in the case of a variable damper control compensating mechanism for controlling the temperature of the flue gases by regulating the rate of recirculation of the flue gases to the first pass of the furnace, the angularity of the dampers between a fully closed and fully open position can be utilized to actuate suitable limit switches associated therewith or the selector switch TS directly where the selective operation of the wall blowers or long-travel blowers is accomplished. The actuation of the selector switch TS can also be accomplished by a flow switch incorporated in the attemperator water line of surface or direct contact type attemperator which is presettable to be tripped when the water flow rate attains a preselected rate. A suitable overlapping area similar to that utilized in the case of the tilting burner mechanism as shown in FIG. 3 can also be employed in the case of the variable recirculating flue gas damper and the flow switch in the attemperator water system.

Although the foregoing compensating mechanisms are effective to regulate the temperature of the final steam, they are nevertheless susceptible to causing substantially large fluctuations in the final steam temperature. The automatic sequential soot blower operating sequence comprising the present invention operating in conjunction with the compensating devices of the type described is effective to substantially reduce these temperature fluctuations providing for a substantially uniform final steam temperature. Moreover, the automatic sequential soot blower control system in combination with a direct-contact type attemperator reduces the amount of water sprayed into the superheated or re-
heated steam to reduce and control the temperature there of. This constitutes another advantage because large quantities of water are undesirable since any unevaporated droplets in the final steam introduce a serious erosion problem of the steam turbine blades.

The operating sequence of the soot blowers as provided by the automatic control system comprising the present invention will now be described in connection with the control wiring diagrams shown in FIGURES 5 and 6. The wiring diagram of FIGURE 5 illustrates the control circuit regulating the operation of the long-travel blowers 29 in the superheater section and is interlocked with the wiring diagram of FIGURE 6 which comprises the control circuit regulating the selective sequential operation of the wall blowers 12 in the steam generating section of the boiler. The wiring diagrams of FIGURES 5 and 6 are electrically connected together at junctions J1–J1, J2–J2, J3–J3, J4–J4, and J5–J5, respectively. The exemplary circuit as shown in FIGURES 5 and 6 incorporates stepping switches for selecting specific sub groups of soot blowers within the long travel soot blower group and the wall blower group and a second stepping switch for sequentially selecting an individual soot blower for operation within the selected sub group. A suitable time delay is further incorporated to provide for a pre-selected time delay period between the operation of successive soot blowers within each sub group. A minimum cycle timer is provided to prevent the operation of the soot blowers too frequently and a maximum cycle timer is provided to assure that all of the soot blowers operate within the selected maximum time period. Interlocking circuitry is provided between the wiring circuits of FIGURES 5 and 6 to prevent energization of a soot blower such as a wall blower, for example, before a long travel soot blower has completed its operation and vice versa. Since the wiring diagram of the control circuit shown in FIGURE 5 for controlling the selective and sequential operation of the long-travel blowers is essentially identical to the wiring diagram of FIGURE 6, the numbers and letters employed in FIGURE 5 to designate components of the control circuit have also been employed in FIGURE 6 with a prime affixed thereto. The system is energized by closing main disconnect switch 38 whereby electrical power received through main transmission conductors L1, L2, and L3, is transmitted to the open starter contacts of each of the soot blower motors 40, 40 of the long-travel blowers such as the blower 29a and wall blowers such as the blower 12a, respectively, as shown diagrammatically in FIGURES 5 and 6. In addition the closing of the main disconnect switch 38 energizes the control circuits through a control power transformer 42 initiating the selected automatic sequential operation of the soot blowers. In order to facilitate a review of the circuit diagrams shown in FIGURES 5 and 6, the individual components have been labeled in accordance with the following letter code:

**CR**—control relay
**CRR**—reverse control relay
**CRP**—forward control relay
**TD**—time delay relay
**TM**—time motor
**TC**—time clock
**LSR**—reverse limit switch
**LSF**—forward limit switch
**TSR**—transfer stepping switch (for selecting a particular group of soot blowers for operation)
**SR**—stepping switch (for selecting individual sequential operation of soot blowers within a group)
**S**—socket
**P**—plug
**SW**—manual group selector switch
**IC**—interrupting contact
**ONC**—off normal contact
**T.C.**—time closed contact

8

Under a boiler operating condition wherein the temperature of the final steam is in the lower portion of a preselected operating range, the selector switch TS has closed its contact TS-I in the control circuit of the long-travel soot blowers as shown in FIGURE 5. Under these conditions, one or a combination of the supplementary steam time proportional compensating device 55, if the boiler is so equipped, have also assumed an operating condition so as to promote an increase in the temperature of the final steam. For the purposes of illustrations each control circuit is designed to operate two groups of soot blowers comprising two soot blowers in each group. For example, in the long-travel soot blower circuit shown in FIGURE 5, the control circuits of the two soot blowers comprising group 1 are respectively connected to the terminals D1 and D2 and the two soot blowers comprising group 2 are individually connected to the terminals indicated at D3 and D4, respectively. It will, of course, be appreciated that the particular automatic control system herein shown and described is adapted to operate a large number of soot blowers in both the steam generating section and superheater section such as, for example, in numbers as high as about 60 which may be arranged in four individual groups comprising 15 soot blowers in each group.

Selection among the various groups within the long-travel soot blowers in the superheater section or within the wall blowers in the steam generating section is achieved by a conventional 26 position transfer stepping switch of the type employed in telephone switching apparatus and the like incorporating a bridge rectifier and condenser and generally indicated at TSR, TSR'. The sequential stepping movement of the transfer stepping switch from one contact to the next contact is achieved by a solenoid actuated mechanism which is energized after all the blowers in each group have been operated. Sequential selection of the soot blowers within any one group is achieved by a similar 26 position transfer stepping switch which is generally designated at SRI, SRI'. It is usually convenient but not necessarily restrictive to combine the soot blowers in one general area of the power boiler within the same group. Frequently the soot blowers are positioned in a series of vertically spaced horizontal rows comprising a plurality of soot blowers in each row. Each horizontal row or tier of soot blowers can be conveniently incorporated within one group which is selected by the transfer stepping switch TSR, TSR' and corresponds to successfully operate in accordance with the preselected sequence as provided by stepping switch SRI, SRI'. In some instances it may be desirable to operate the groups of soot blowers sequentially commencing with the lowermost row and moving therefrom to the next row and so on until all of the groups have been operated. Alternatively, it may be desired to scramble the operating sequence of the individual groups whereby the groups are operated in random sequence jumping from one level of the power boiler to another depending on the specific scrambling sequence desired.

To enable scrambling between the groups of soot blowers as shown in FIG. 5, plugs P1 through P4 are provided which can be alternately connected in sockets S-1A, S-1B, S-2A and S-2B to achieve the desired group sequence. In the specific arrangement shown in FIG. 5, the connection of the plugs P1 to P4 to the socket S-1A, S-1B, S-2A and S-2B, effects successful energization of the plugs P1 through P4 as established by the transfer stepping switch TSR which will cause alternate operation of the groups 1 and 2. It will be appreciated that where a large number of groups are provided a large number of variations in the group sequence is feasible merely by interchanging the connections between the plugs and the corresponding sockets.

In the specific control circuit shown two sets of sockets are provided for each group of soot blowers which causes each soot blower in each group to operate twice during
each sequencing cycle of the control system. However, each group circuit is provided with a group selector providing further flexibility and versatility of the operating sequence of the soot blowers and can be positioned in either one of three positions. The group selector switch in the circuit of group 1 is provided with contacts SW1-A, SW1-B, SW1-C and SW1-D, and the group selector switch in the circuit of group 2 is provided with contacts SW2-A, SW2-B, SW2-C, and SW2-D. When in an Off position, the group selector switch in the group 1 circuit for example, closes contacts SW1-A, SW1-C whereby the group circuit is bypassed and the transfer stepping switch TSR is quickly step transferred to the next group whereby the soot blowers in group 1 are not operated during the operating cycle of the control system.

In the number 1 position of the group 1 selector switch, contacts SW1-B and SW1-C are closed whereby the soot blowers in group 1 are operated once per cycle on energization of socket S-1A and are bypassed on energization or socket S-1B. When the group selector switch is in the number 2 position contacts SW1-B and SW1-D are closed whereby the soot blowers in group 1 is operated twice during each operating cycle of the control system.

With the selector switch contact TS-1 closed, the transfer stepping switch TSR in the number 2 position, for example, and with the stepping switch SRI in its number one position, for example, the long travel soot blower such as SBI-55, energizes control relay CRI and energizes the terminal A-2 of the soot blower circuit and simultaneously opens its contacts CRF-1 and CRF-2 which extinguishes the forward indicator light 50a and deenergizes the terminal A-2 in the blower circuit. Simultaneously, the normally closed contact CRF-3 is closed energizing the reverse control relay CRR. 

Energization of a reverse control relay CRR causes it to open normally closed contact CRF-3 to prevent energization of the forward control relay CRF and closes reverse indicator light 52a, contact CRR-2 and reversing motor contacts CRR-3 causing a reversal in the direction of rotation of the blower motor 40 whereby the lance tube 4Q commences its retracting movement. After the initial retraction movement of the lance tube, the forward limit switch LSF is released permitting normally closed contact LSF-1 to close and the lance tube continues its retracting movement until reverse limit switch LSR is tripped when the fully retracted position is attained.

The tripping of limit switch LSR causes the opening of normally closed contact LS-1A in the control relay circuit which energizes the reverse control relay CRR which opens its contacts CRR-2 and CRR-3 extinguishing the reverse indicator light 52a and deenergizing the blower motor 40, respectively, and simultaneously closes normally closed contact CRR-1. In addition, the tripping of reverse limit switch LSR causes the normally open contact LS-1A to close thereby energizing relay CRF-3 which energizes the forward limit switch LSF in the series circuit (G-G) which energizes time delay relay TDI which commences to time a predetermined time period. It is the function of the time delay relay TDI to provide a predetermined delay time period between the successive operation of the blowers to extinguish stabilization and reestablishment of thermal equilibrium conditions within the power boiler as hereinbefore set forth. As hereinbefore set forth, the delay period can be varied for any one specific boiler installation from a duration of substantially zero to an appreciable time delay period.

At the completion of the predetermined time delay period, time closed contacts TDI-1 are closed thereby energizing control relay CRI which opens its normally closed contacts CRI-1. Simultaneously, control relay CRI closes its contacts CRI-1 and CRI-1 wherein the coil of stepping switch SR1 is energized through contacts CRI-1 and CRI-3 and normally closed contact LSR-2A. Energization of stepping switch SR1 causes its interrupting contact IC-1 to open whereby control relay CRF is deenergized. Deenergization of control relay CRF causes its contact CRF-3 to open thereby deenergizing the solenoid coil of the stepping switch SR1 causing step transfer thereof to the number two position and in which position it again closes its interrupter contact IC-SR1-1 and closes number 2 position contact SR1-2A energizing the terminal D-2 connected to the second one of the blowers in group 1 through a conductor similar to conductor 41 connected to the A-2 terminal (not shown) of the second soot blower control circuit. Accordingly, the long travel blower such as a soot blower 20b (not shown) connected to terminal D-2 will commence its projecting travel in accordance with the cycle hereinabove described in connection with the first long travel blower.

After the second long travel blower has completed its operation and has attained the fully retracted position stepping switch SR1 is step transferred to its third position whereby contact SR1-3A is closed and power is applied to the coil of stepping switch SR1 through contacts SR1-3A and off normal contact ONC-SR1-2. Thereafter the
rapid opening and closing of interrupter contact IC-SR1-1 will cause the stepping switch SR1 to fast step transfer through spare contacts SR1-4A to SR1-24A which are connected in parallel to each other as indicated in dotted lines to its 25th position on attainment of which will cause its contact SR1-2SK to close energizing the coil of the transfer stepping switch TSR. Energization of the TSR coil causes its normally open interrupting contact IC-TSR-2 to close energizing the coil of stepping switch SR1 through contact ONC-SR1-2. Energization of SR1 in turn causes its contact IC-SR1-1 to open deenergizing the coil of TSR which in turn opens its interrupting contact IC-TSR-2 deenergizing the coil of stepping switch SR1. Accordingly, the transfer stepping switch TSR step transfers to its third position and the stepping switch SR1 step transfers to its 26th or Off position. In the third position, stepping switch TSR closes its contact TSR--3C and contact IC-TSR--I thereby energizing plug P2. Accordingly, power is now applied to the coil of the stepping switch SR1 through interrupting contacts IC-SR1-1, CR1-1, CR2-1, CR3-1, TS-1, TD1--2, TSR--3C, plug P2, socket S-2A, group selector switch contact SW-B, and contact SR1-26. Energization of the coil of stepping switch SR1 causes its interrupting contact IC-SR1-1 to open causing the stepping switch SR1 to transfer to its number one position. Accordingly, the terminal D-3 connected to the first blower of group 2 will be energized on closing of contact IC-SR1-1 and SR1-1B which will undergo its projecting and retracting travel in accordance with the cycle hereinbefore described. Thereafter the long-travel soot blower connected to terminal D-4 will be caused to operate in the same manner after which the stepping switch SR1 will fast transfer to its 25th position wherein the transfer stepping switch TSR will be caused to step transfer to its number four position causing its contact TSR--4C to close thereby energizing plug P3. The soot blowers of group 1 having their socket S-1B connected to plug P3 will undergo sequential operation followed thereafter by subsequent energization of plug P4 to which the group 2 blowers are connected causing their sequential operation.

At the completion of the second cycle of the group 2 soot blowers, the stepping switch transfer TSR transfers from its fifth position to its sixth position and will be caused to fast transfer through its interrupting contact IC-TSR--1 and spare contacts TSR--6D through TSR--24D which are connected in parallel to each other until it reaches its 25th position. At this point the transfer stepping switch TSR is prevented from fast transferring to its 25th position by the minimum cycle timer comprising timer clutch TC--2 which may be of the electromagnetic or solenoid actuated type well known in the art, contact T2, and timer motor TM2, has completed the timing of a predetermined time period thereby preventing the initiation of another complete cycle so as to assure that the system is not operated too frequently. If the minimum cycle timer has completed its timing period or upon expiration of that timing period its contact TM2--1 is closed whereby the transfer stepping switch TSR transfers to its 26th position through contacts TSR--25D and TD3--1.

On attaining its 26th position the off normal contact ONC-TSR--3 of the transfer stepping switch TSR is closed energizing time delay relay TD3 which opens its time closed (T.C.) contact TD3--1 having a two second delay enabling the resetting of minimum cycle timer. On opening of contact TD3--1, the maximum cycle timer comprising timer clutch TC--3, contact T3, and timer motor TM3, is also reset. In addition, after a delay period, time closed contact TD3--2 closes whereby the coil of the transfer stepping switch TSR is energized through contacts TSR--26D and TD3--2. Energization of the coil of the transfer stepping switch causes its interrupter contacts IC--TSR--1 to open deenergizing the TSR coil and causing the transfer stepping switch to step transfer to its number one position. The entire operating sequence as hereinbefore described is thereafter repeated.

In the event the maximum cycle timer has completed the timing of a predetermined time period before the transfer stepping switch has attained its 26th position, the control relay CR3 is energized through normally open contact TM3--1 whereby contact CR3--2 disposed in parallel around the selector switch contact TS--1 and time delay relay contact TD1--2 will close to keep the system operating. It is the function of the maximum cycle timer TM3 to assure that each of the soot blowers in the superheater section undergo a complete operating cycle within a prescribed time period such as, for example, 24 hours. Simultaneously, energization of control relay CR3 causes its normally closed contacts CR3--1 and CR3--3 which are disposed and interlocked in the control circuit of the wall blowers as shown in FIGURE 6 preventing the operation of the wall blowers in spite of the closing of contact TS--1 in the wall blower circuit until the long-travel blowers have completed their operating cycle. Accordingly, the long-travel blowers complete the remaining portion of their cycle after which the transfer stepping switch TSR is fast transferred to its 26th position. On attaining the 26th position the transfer stepping switch off normal contact ONC-TSR--3 closes whereby contact TD3--1 which opens its contact TD3--3 and causes the minimum cycle timer and maximum cycle timers to reset. Simultaneously, the control relay CR3 is deenergized thereby closing its contacts CR3--1 and CR3--3 in the wall blower circuit enabling that circuit to function should the temperature sensing selector switch contact TS--1 be closed calling for wall blower operation. In addition, control CR3--2 disposed in parallel with the temperature sensing contact TS--1 in the long-travel blower circuit is opened restoring the circuits to normal selective operation.

The operation of the wall blower circuit is essentially identical to that hereinbefore described in connection with the control circuit for the long-travel soot blowers. The wall blower circuit similarly incorporates a minimum cycle dwell timer comprising a timer clutch TC2 and timer motor TM2 and an adjustable limit switch contact T2 which opens deenergizing the timer motor TM2 on the expiration of the prescribed time. Similarly, the maximum dwell timer includes timer clutch TC3, timer motor TM3 and timer limit switch contact T3 assuring that all of the wall blowers will operate within a prescribed time period. In the same manner as hereinbefore described when the maximum cycle timer times out and the transfer stepping switch TSR‘ transfer to its 26th position, control relay CR3 is energized overriding the selector switch contact TS--1 and causing the remaining unoperated wall blowers to complete their operating cycle. Control relay CR3 is interlocked in the control circuit of the long-travel blowers whereby on energization thereof normally closed contact CR3--3 opens deenergizing the maximum cycle timer motor TM3 halting its timing until the wall blower cycle has been completed. The mutual interlocking relationship of the maximum cycle timers in each circuit prevents interference between the operation of soot blowers in the steam generating section and in the steam heating section.

In typical well designed and properly controlled power boilers, the completion of the cycle of the operation of the wall blowers and the cycle of operation of the long-travel blowers generally falls within the time range provided between the minimum cycle timer and the maximum cycle timers. Accordingly, the wall blowers and the long-travel blowers are operated essentially all of the time in the sequence provided by the control circuit and in accordance with the selectivity of the selector switch TS in response to the temperature of the final steam. The system as disclosed is essentially capable of being operated in either one of the wall blowers is operating or one of the long travel blowers is operating. Brief periods of in-
activity are of course provided by virtue of the delay timers operative to space the successive operation of the soot blowers to provide for stabilization and optimization of the soot conditions throughout the boiler. Inasmuch as the selector switch TS is operative to open and close its contacts TS-1, TS-2' at any point in the operating cycle of the soot blowers or the long-travel blowers, the control circuits shown in FIGS. 5 and 6 are mutually interlocked by time delay contacts TDI-2' and TDI-2, respectively, to prevent operation of a blower in one boiler section while a blower is still operating in the other boiler section. For example, the deenergization of time delay relay TDI in the control circuit for the long-travel blowers by the opening of a reverse limit switch contact LSR-2a' in the series circuit (G-G') causes the opening of its instantaneous contact TDI-2' enabling operation of the appropriate section of the boiler in accordance with the sequence provided by the control circuit of FIG. 6. Similarly, the moment the soot blower initiates operation with the limit switch contact opens in the series circuit (G-G') and time delay relay TDI' opens its instantaneous contact TDI-2' in the control circuit of FIG. 5 preventing initiation of the operation of a long-travel blower as selected by the closing of selector switch contact TS-1 or TS-2' until the completion of the operating cycle in boiler section.

By virtue of the group selection and individual boiler selection provided by transfer stepping switches TSR, TS'R and selector switches SR1 and SR1', deenergization and energization of the control circuits of FIGS. 5 and 6 causing interruption and resumption of the respective operating cycle assures that the receiver blower in the cycle is operated in each control circuit on resumption of operation in accordance with the sequence at the time the control circuit was interrupted. By this arrangement the soot blowers in the steam generating section and in the steam heating section undergo a prescribed operating sequence in accordance with the predetermined operating cycle which is interrupted and resumed by the selector switch actuated in response to the temperature of the final steam.

While the specific control system shown and described herein embodies the alternate operation of the wall blowers in the steam generating section and the long-travel blowers in the steam heating section such as the superheater section or reheater section, it will be appreciated by those skilled in the art that a basic form of the control system is one which is effective to control the operation of only the wall blowers in the steam generating section. In such an event, the selector switch would be operative to energize the control circuit as shown in FIG. 6 at such times as the final steam temperature increased to a preselected level and to deenergize the control circuit by moving to an off position when the steam temperature decreased to a preselected level. The operation of the soot blowers in the steam generating section and other sections of the boiler under such circumstances, could be controlled on a straight time cycle sequence or by a slag sensing device subsequently to be described and operable independently of the automatic selective control sequence of the wall blowers, or during those periods when the wall blowers were operational.

It is also contemplated within the scope of the present invention that a suitable slag sensing device of the type schematically shown in FIG. 4 can be employed in lieu of the maximum cycle timer and is particularly applicable to operation of the long-travel blowers in the superheater section of the power boiler. However, the slag sensing device can be incorporated at any heat exchange surface to provide automatic controlled operation depending upon the accumulation of a predetermined sludge layer of the slag in the like. Instead of assuring that each of the long-travel blowers is operated within a preselected time period, the slag sensing device is operative to override the temperature sensing selector switch TS calling for selective automatic sequential operation of the long-travel blowers whenever a predetermined slagging condition exists in the superheater section. In the event of such a slagging condition, the slag sensing device operates in a manner similar to the maximum cycle timer heretofore described causing operation of the long-travel blowers either to the completion of their cycle or until the slagging condition is alleviated. It is also contemplated that several slag sensing devices can be incorporated at various locations each of which is adapted to operate a selected group of soot blowers.

The slag sensing device as shown in FIG. 4 is installed along the surface of a superheater tube 52, the periphery of which is coated with a relatively thin layer of slag 54 as shown in solid lines. A pair of temperature sensing elements such as thermocouples 56a, 56b, for example, are disposed with the ends thereof in radially spaced relationship relative to the boiler tube 52. The end portion of the thermocouple 56a is affixed to the peripheral surface of the superheater tube 52 such as shown or brazing while the end portion of the thermocouple 56b normally projects into and is exposed to the hot flue gases passing through the superheater tube bundle. The distance separating the end portions of the thermocouples 56a, 56b, is adjustable and establishes the thickness of the layer of slag on the superheater tube 52 which will cause the temperature sensing device to be actuated causing the overriding sequential operation of the long-travel blowers in the superheater section. The thermocouples 56a, 56b are suitably mounted on a suitable strap or hanger assembly 58 providing for adjustable radial movement of the thermocouple 56b relative to the periphery of the superheater tube 52 and maintaining the thermocouples in appropriate adjusted relationship. The current or voltage generated at the end junctions of the thermocouples 56a, 56b, is fed into a suitable differential amplifying means 60 of any one of a number of types well known in the art to which reference is made, the arrangement of which is such that the ampoulements set forth above are effective to cause the energization of control relay CR3 in the control circuits of the long-travel soot blowers.

In operation, the thermocouple 56a registers the temperature substantially equal to the superheated steam passing through the tube which may range, for example, in the order of about 1000° F. to about 1500° F. On the other hand, the thermocouple 56b will register the temperature of the flue gases adjacent to the superheater tube 52 which can range for example, from about 1700° F. to about 2200° F. Accordingly, as long as the layer of slag 54 around the superheater tube 52 does not encompass the thermocouple 56b a differential temperature reading between the thermocouples 56a and 56b will be transmitted to the differential amplifying means 60. When the layer of slag 54 builds up to a thickness as shown in phantom in FIG. 4 and exaggerated for the purposes of illustration, wherein the end portion of the thermocouple 56b becomes coated with and insulated from the surrounding flue gases, the temperature reading of the thermocouple 56b will rapidly approach that of the thermocouple of 56a. When the differential temperature readings of the two thermocouples 56a, 56b approach each other within a predetermined difference, the differential amplifying means 60 is operated and is effective to override the automatic sequential operation of the soot blower system causing the wall blowers 20 to be operated regardless of the position of the temperature selector switch TS.

The slag sensing device can also be satisfactorily em-
ployed in the independent control systems such as, for example, in the economizer section which normally uses a straight time cycle for operating the soot blowers. In addition, the slag sensing device can be employed on the slag screen of the power boiler to operate a series of long-travel blowers independently of the control system hereinbefore described in connection with the steam generating section and superheater section.

While it will be apparent that the preferred embodiments herein illustrated are well calculated to fulfill the objects above stated, it will be appreciated that the invention is susceptible to modification, variation and change without departing from the proper scope or fair meaning of the appended claims.

What is claimed is:

1. In a heat exchanging apparatus producing steam having a plurality of remotely actuatable soot blowers adapted to clean the heat absorption surfaces thereof, the combination including a control system for providing automatic sequential operation of the soot blowers in response to the cleanliness of the heat absorption surfaces as indicated by the temperature of the final steam, said control system comprising sensing means for sensing the temperature of the final steam, control means for successfully operating the soot blowers in a cycle having a preselected sequence when energized, second control means for successively operating the second plurality of soot blowers, and selector means for regulating the frequency of the operating cycle of the soot blowers within a prescribed time interval.

2. In a heat exchanging apparatus comprising a steam generating section and a steam heating section having a first plurality of soot blowers in the steam generating section and a second plurality of soot blowers in the steam heating section, the combination including a control system for providing continuous automatic sequential operation of the soot blowers in response to the temperature of the final steam produced, said system comprising sensing means for sensing the temperature of the final steam, first control means for successively operating the first plurality of soot blowers in a prescribed sequence when energized, second control means for successively operating the second plurality of soot blowers in a prescribed sequence when energized, and selector means for alternatively energizing and deenergizing said first control means and said second control means responsive to said sensing means.

3. In a boiler having a first plurality of remotely actuatable soot blowers in the steam generating section and a second plurality of remotely actuatable soot blowers in the steam heating section, the combination comprising a control system for providing continuous automatic sequential operation of the soot blowers in response to the cleanliness of the heat absorption surfaces as indicated by the temperature of the final steam produced, said system comprising sensing means for sensing the temperature of the final steam, steam temperature compensating means actuatable responsive to said sensing means for regulating the final steam temperature within a prescribed range, first control means for successively operating the first plurality of soot blowers in a cycle having a preselected sequence when energized, second control means for successively operating the second plurality of soot blowers in a cycle having a preselected sequence when energized, and selector means associated with said compensating means and said second control means responsive to the degree of steam temperature compensation provided thereby for alternately energizing and deenergizing said first control means and said second control means for recommencing and interrupting the operating cycle thereof.

4. The control system as set forth in claim 3 wherein said steam temperature compensating means comprise a tilting burner mechanism and wherein said selector means are actuatable responsive to a preset angularity of tilt of the burner.

5. The control system as set forth in claim 3 wherein said steam temperature compensating means comprise a damper mechanism for controlling the recirculation rate of the flue gases and wherein said selector means are actuatable responsive to a preset opening of said damper mechanism.

6. The control system as set forth in claim 3 wherein said steam temperature compensating means comprise an attenuator and wherein said selector means are actuatable in response to a preselected degree of attenuation of the final steam.

7. In a boiler having a first plurality of remotely actuatable soot blowers in the steam generating section and a second plurality of remotely actuatable soot blowers in the steam heating section, the combination comprising a control system for providing a continuous automatic sequential operation of the soot blowers in response to the cleanliness of the heat absorption surfaces as indicated by the temperature of the final steam, said control system comprising sensing means for sensing the temperature of the final steam, first control means for successively operating the first plurality of soot blowers in a cycle having a preselected sequence when energized, second control means for successively operating the second plurality of soot blowers in a cycle having a preselected sequence when energized, and selector means for alternatively energizing and deenergizing said first control means and said second control means responsive to said sensing means, time delay means for providing a predetermined time delay between the operation of successive soot blowers of the first plurality and successive soot blowers of the second plurality, and means for controlling the frequency of the operating cycle of the first plurality of soot blowers and the second plurality of soot blowers within a preselected range.

8. In a boiler having a first plurality of remotely actuatable soot blowers in the steam generating section and a second plurality of remotely actuatable soot blowers in the steam heating section, the combination comprising a control system for providing continuous automatic sequential operation of the soot blowers responsive to the cleanliness of the heat absorption surfaces as indicated by the temperature of the final steam, said control system comprising sensing means for sensing the temperature of the final steam, first control means for successively operating the first plurality of soot blowers in a cycle having a preselected sequence when energized, second control means for successively operating the second plurality of soot blowers in a cycle having a preselected sequence when energized, and selector means responsive to said sensing means, time delay means for providing a predetermined time delay between the operation of successive soot blowers of the first plurality and successive soot blowers of the second plurality, and interlocking means preventing operation of a soot blower in the second plurality while a soot blower in the first plurality is operating and vice versa.

9. In a boiler having a first plurality of remotely actuatable soot blowers in the steam generating section and a second plurality of remotely actuatable soot blowers in the steam heating section, the combination comprising a control system for providing continuous automatic sequential operation of the soot blowers in response to the cleanliness of the heat absorption surfaces as indicated by the temperature of the final steam, said control system comprising sensing means for sensing the temperature of the final steam, first control means for successively operating the first plurality of soot blowers in a cycle having a preselected sequence when energized, second control means for successively operating the second plurality of soot blowers in a cycle having a preselected sequence when energized, and selector means responsive to said sensing means, time delay means for providing a predetermined time delay between the operation of successive soot blowers of the first plurality and successive soot blowers of the second plurality.
energized, selector means for alternatively energizing and
deenergizing said first control means and said second con-
trol means responsive to said sensing means, time delay
means for providing a predetermined time delay between
the operation of successive soot blowers of the first plu-
rality and successive soot blowers of the second plurality,
slag sensing means associated with the heat absorption
surfaces of the steam heating section and operable on the
accumulation of a predetermined thickness of slag thereon
for overriding said selector means and energizing said sec-
ond control means thereby successively operating the sec-
ond plurality of soot blowers until the accumulation of
slag has been reduced to a predetermined level.

10. In a boiler having a first plurality of remotely actua-
ble soot blowers in the steam generating section and a
second plurality of remotely actuable soot blowers in
the steam heating section, the combination comprising a
control system for providing continuous automatic se-
quential operation of the soot blowers in response to the
cleanliness of the heat absorption surfaces as indicated
by the temperature of the final steam, said control system
comprising sensing means for sensing the temperature of
the final steam, first control means for successively op-
erating the first plurality of soot blowers in a cycle having
a preselected sequence when energized, second control
means for successively operating the second plurality of
soot blowers in a cycle having a preselected sequence when
energized, selector means for alternately energizing and
deenergizing said first control means and said second con-
trol means responsive to said sensing means, time delay
means for providing a predetermined time delay between
the operation of successive soot blowers of the first plurality
and successive soot blowers of the second plurality, first
timer means for controlling the maximum frequency of
the operating cycle of the first plurality and the second
plurality of soot blowers, second timer means for con-
trolling the minimum frequency of the operating cycle
of the first plurality of soot blowers, and slag sensing means
associated with the heat absorption surfaces of the steam
heating section operable in response to the accumulation
of a predetermined thickness of slag thereon for over-
riding said selector means and energizing said second con-
trol means for causing the second plurality of soot blowers
to operate until the accumulation of slag is reduced to a
predetermined thickness.

References Cited in the file of this patent

UNITED STATES PATENTS

20 Re. 21,569 Crago ______________ Sept. 17, 1940
1,143,381 Gibson _______________ June 15, 1915
2,077,839 Hundemer _____________ Apr. 20, 1937
2,638,687 Southworth _____________ Nov. 10, 1953
2,811,954 Hibner et al. ___________ Nov. 5, 1957
2,902,707 Bearer _________________ Sept. 8, 1959
2,948,013 Bearer _________________ Aug. 9, 1960
2,962,264 Enerus _________________ Nov. 29, 1960

FOREIGN PATENTS

529,909 Great Britain ____________ Dec. 2, 1940