BOILER CLEANING CONTROL METHOD

Filed Jan. 31, 1967 3 Sheets-Sheet 1

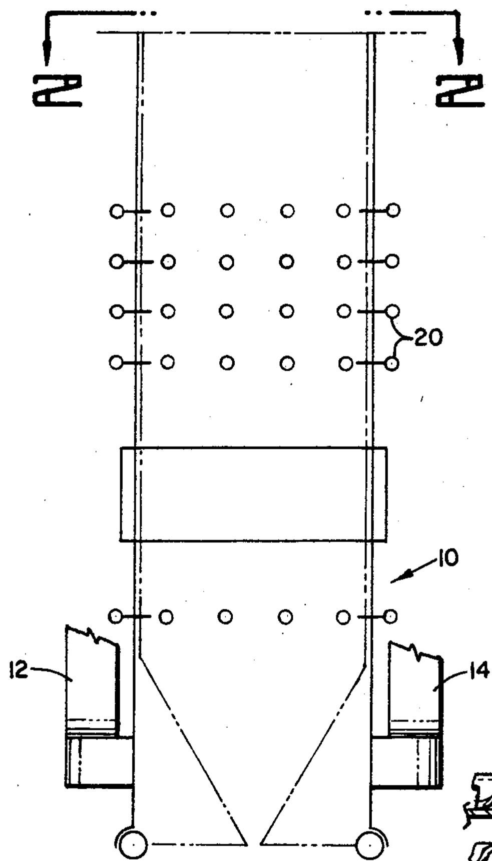

FIG. 1

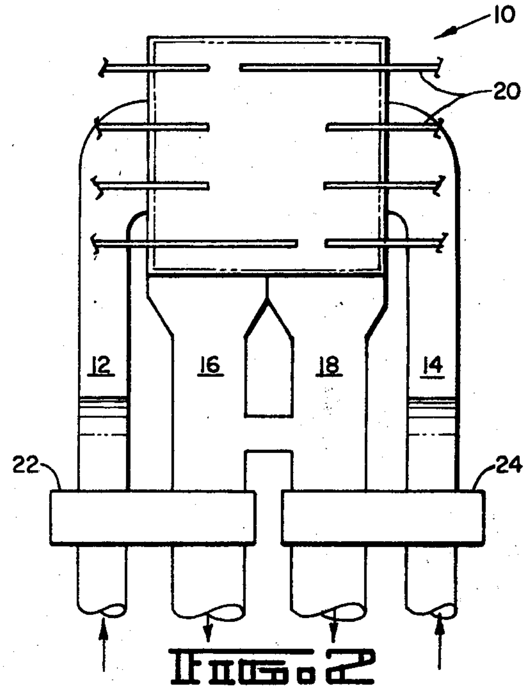

FIG. 2

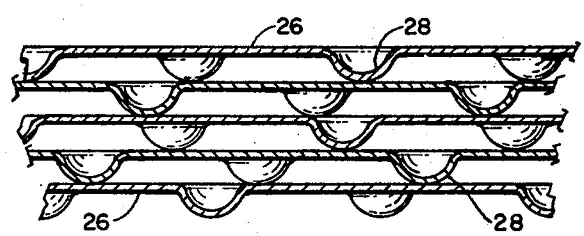

FIG. 3

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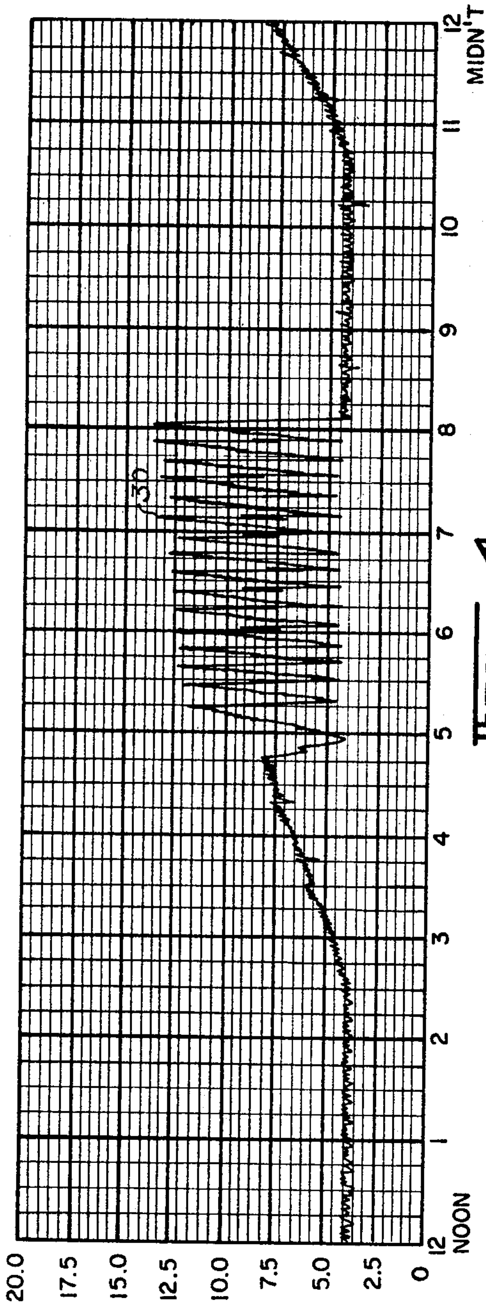

FIG. 4

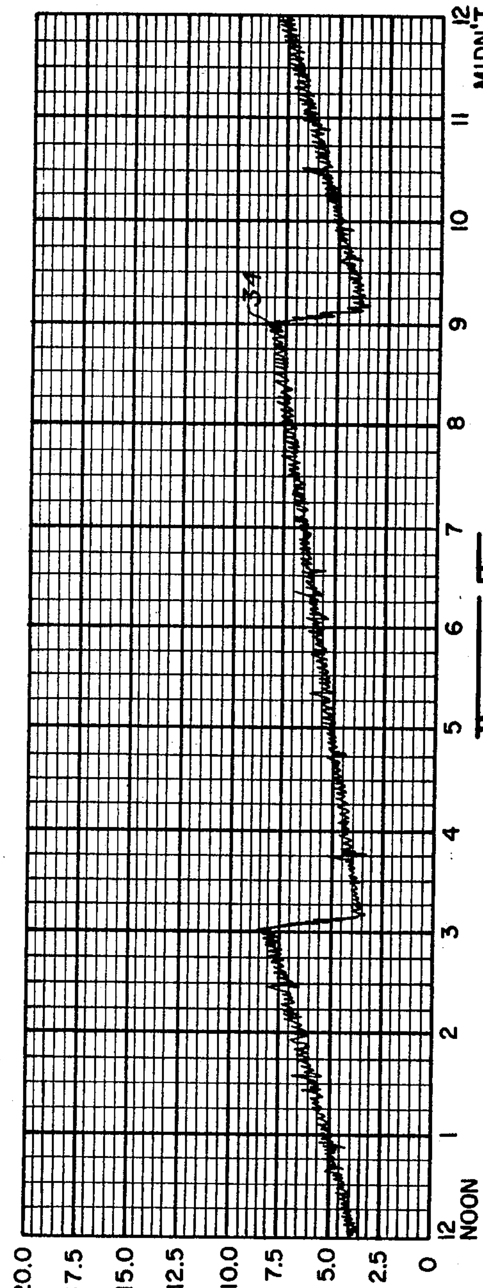

FIG. 5

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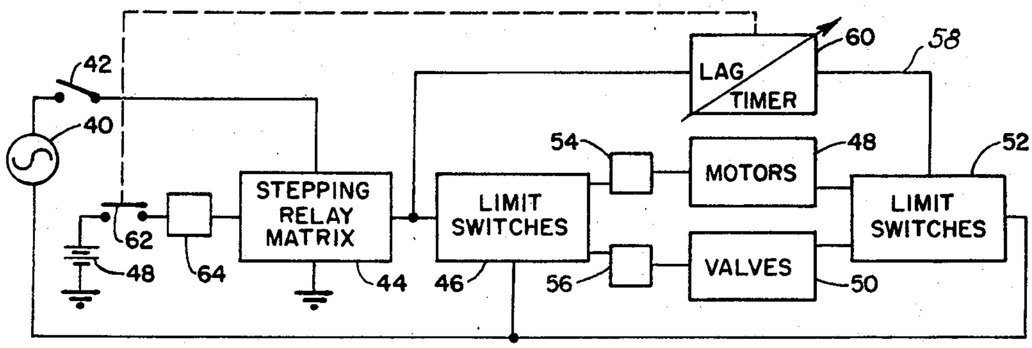

FIG. 6

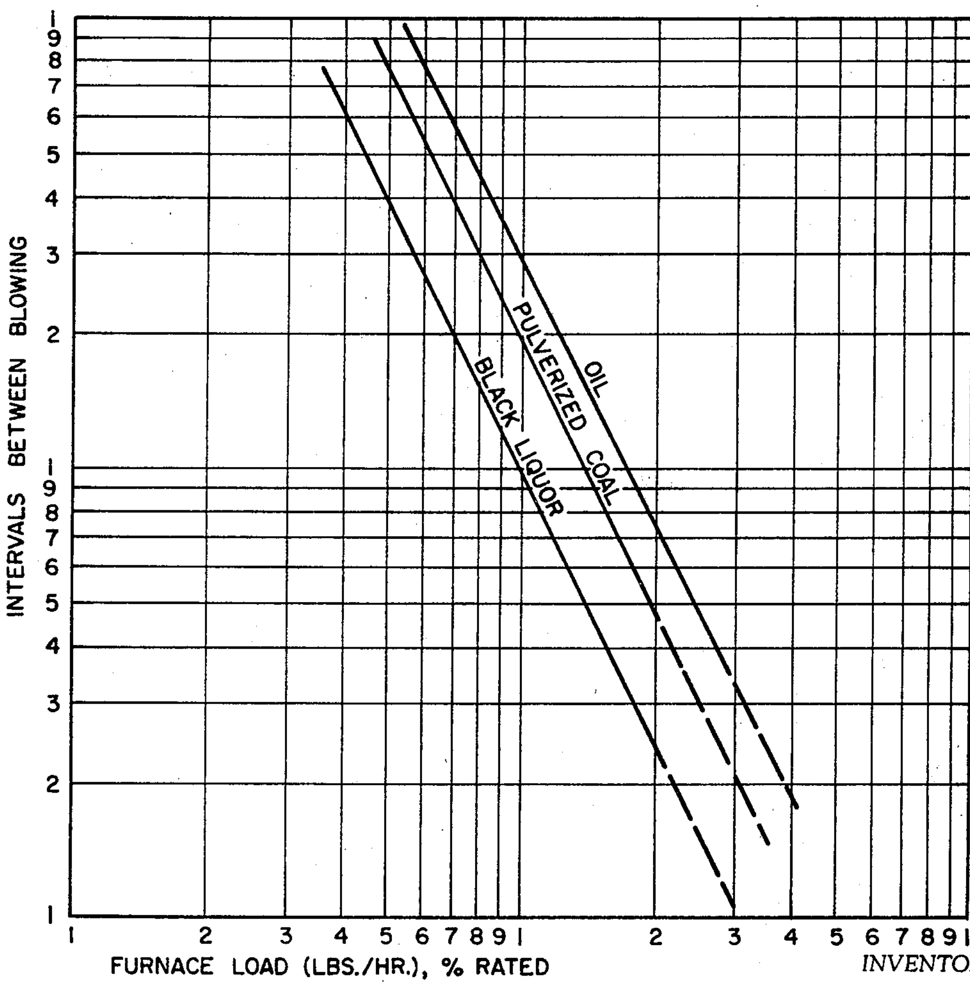

FIG. 7

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United States Patent Office 3,396,706
Patented Aug. 13, 1968

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3,396,706

BOILER CLEANING CONTROL METHOD

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Filed Jan. 31, 1967, Ser. No. 613,020
4 Claims. (Cl. 122—379)

ABSTRACT OF THE DISCLOSURE

Method of and apparatus for prolonging the life of heat exchangers positioned in boiler exhaust gas streams by means of programming the operation of boiler internal cleaning devices as a function of boiler load and fuel type to thereby simulate continuous cleaning.

BACKGROUND OF THE INVENTION

(1) *Field of the invention*

The present invention relates to the control of boiler cleaning devices. More particularly, the present invention is directed to the control of soot blowers and other cleaning devices associated with a furnace, said control scheme having as one of its principal objects the prolonging of the life of heat exchanger devices positioned in the furnace exhaust stream. Accordingly, the general objects of the present invention are to provide new and improved methods and apparatus of such character.

(2) *Description of the prior art*

As is well known, most modern furnaces, and particularly chemical recovery furnaces, are equipped with devices known as soot blowers which will remove deposits from the internal surfaces of the furnace which are exposed to combustion products. For an example of a chemical recovery unit, the soot blowers not being shown, reference may be had to U.S. Patent No. 3,170,442, issued Feb. 23, 1965, to F. W. Hochmuth, and assigned to Combustion Engineering, Inc. For an example of the type of soot blower which might be used with a recovery furnace of the type disclosed in the aforementioned Hochmuth patent, reference may be had to U.S. Patent No. 3,069,715, issued Dec. 25, 1962, to the same inventor and assigned to the same assignee. As is well known, the provision for internal soot blowers obviates the need for periodic hand lancing of the furnace.

In the prior art, the furnace soot blowers were manually activated in accordance with a predetermined schedule. For example, it was typical to instruct the equipment operators to initiate a soot blowing operation at predetermined intervals. Upon initiation of the soot blowing cycle, the plurality of individual blowers in the furnace would be operated either singly or in groups in a predetermined order until all the blowers had been operated. Thereafter, the soot blowers would remain deenergized for a substantial period of time. For example, in a typical black liquor recovery operation, the recovery furnace soot blowers were energized every eight hours and the entire soot blowing operation took approximately two hours. Accordingly, in the prior art, it was common to have a period of six or more hours during which there was no soot blowing occurring within the furnace.

The hot exhaust gases from the furnace can be passed through a regenerative type heat exchanger which serves to preheat the incoming air which supports combustion within the furnace and, in so doing, the heat exchanger also cools the furnace exhaust gases so that they may be passed through an electrostatic precipitator or like device. The regenerative heat exchanger or air preheater

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may generally be of the rotary type such as is shown in U.S. Patent No. 2,802,646, issued Aug. 13, 1957, to W. F. Jetter, and assigned to the same assignee as the present invention. As the dirty furnace exhaust gases pass through the heat exchanger, deposits build up on the plates which define the passages through the heat exchanger for the exhaust gases and inflowing air. Accordingly, it is usually necessary, and in the case of a recovery furnace of the type disclosed in the aforementioned Hochmuth Patent 3,170,442, essential, that the heat exchanger device also be equipped with soot blowers or other self-cleaning apparatus.

The heat exchanger sectors or compartments are typically comprised of pressure packed plates oriented parallel to each other and separated from each other by dimples or bearing surfaces on the plates. In the case of a soot blower type cleaner, steam at 100 to 140 p.s.i., and high velocity will be directed against the heat exchanger to loosen and remove deposits therefrom during the self-cleaning operation. This high pressure, high velocity steam, due in part to the clogging effect of the deposits, results in high pressure being developed between the heat exchanger plates. This high pressure tends to force the plates apart and, if sufficiently great, the elastic limit of the material comprising the plates may be exceeded. In any event, the distorting or expanding of the heat exchanger plates which occurs on each soot blowing operation tends to loosen the plates which, as indicated above, are pressure packed. When the plates get loose, they begin to flutter and cracks due to metal fatigue will occur at the trailing edges. There is, of course, also the problem of erosion of the plates by the high velocity steam jets. Thus, it may be seen that the life of a heat exchanger positioned to have furnace exhaust gases passed therethrough is a function of the cleaning frequency of the heat exchanger. It therefor follows that, if means could be provided to prevent the necessity of performing a soot blowing operation on the heat exchanger as often as required in the prior art, the life of the heat exchanger would be extended. In addition, the reduction of the frequency of blowing of the heat exchanger associated soot blowers would reduce the steam requirements for the regenerative heat exchanger-furnace system thus further increasing the efficiency thereof.

SUMMARY OF THE INVENTION

In accordance with the present invention, the frequency of performing a cleaning operation on a heat exchanger positioned to receive contaminated furnace exhaust gases is drastically reduced. This reduction in heat exchanger cleaning cycle frequency is a result of a novel manner of control of the cleaning devices in the furnace itself which is associated with the heat exchanger. This novel manner of controlling furnace internal soot blowers is predicated upon the discovery that the rate of fouling of a heat exchanger in the furnace exhaust gas stream is related to the frequency of operation of the furnace internal soot blowers. That is, for reasons which are not entirely understood, it has been discovered that the rate of build up of deposits upon a heat exchanger positioned in a furnace exhaust gas stream is much less during the period that a soot blower or blowers within the furnace are operating. It is theorized that, when a soot blower is operating, the steam or other cleaning fluid breaks up large dirt or ash particles which tear loose from the furnace walls due to the velocity of the furnace gases. The present invention contemplates the sequencing of furnace internal soot blowers so that the lag time between the operation of successively energized blowers is controlled as a function of furnace load and fuel type and there are no substantial time periods during which soot blowing is not occurring at some point within the furnace.

It is, therefore, an object of the present invention to increase the life of heat exchangers positioned in a furnace exhaust gas stream.

It is another object of the present invention to decrease the frequency at which it is necessary to perform a cleaning operation on heat exchangers positioned in a furnace exhaust gas stream.

It is yet another object of the present invention to provide increased efficiency of operation of cleaning devices associated with a heat exchanger.

It is also an object of the present invention to control the operation of cleaning devices located in or associated with a furnace in such a manner that the life of a heat exchanger positioned in the furnace exhaust gas stream is prolonged.

It is a further object of the present invention to sequence recovery furnace internal soot blowers in such a manner that the rate of build up of deposits on a heat exchanger positioned in the furnace exhaust gas stream is minimized.

It is still another object of the present invention to lower the overall consumption of cleaning fluid of a boiler-air preheater combination.

It is another object of the present invention to control the lag time between successive soot blower energizations in a chemical recovery unit in accordance with the load on the recovery furnace and the material being burned in the furnace.

As indicated above, these and other objects of the present invention are accomplished by controlling the operation of the internal soot blowers of a furnace or boiler so as to simulate continuous cleaning. The desirable simulation is effected by sequencing the internal blowers in such a manner that there are no time periods of substantial length wherein a soot blowing or self-cleaning operation is not occurring at some point within the furnace. The duration of these time periods when no cleaning fluid is being delivered into the furnace is controlled as a function of load and fuel. In accordance with the present invention, the control exercised over the furnace soot blowers is such that their individual total operating time remains approximately the same and thus the consumption of steam or other cleaning fluid by these cleaning devices is not increased. However, due to the minimization of the build up of deposits upon the heat exchangers positioned in the furnace exhaust gas streams, the frequency at which the cleaning operation has to be performed upon the heat exchangers is substantially decreased and thus the consumption of steam or other cleaning fluid by the cleaning devices associated with the heat exchangers is substantially decreased and the efficiency of the total system thus increased.

BRIEF DESCRIPTION OF THE DRAWING

The present invention may be better understood and its numerous advantages will become apparent to those skilled in the art by reference to the accompanying drawing wherein like reference numerals apply to like elements in the various figures and in which:

FIGURE 1 is a schematic representation of a recovery furnace shown in side elevation and including a plurality of soot blowers.

FIGURE 2 is a top view of the furnace of FIGURE 1 showing the furnace exhaust gas exit ducts with regenerative heat exchangers positioned therein.

FIGURE 3 is a partial cross sectional view of a sector of one of the heat exchangers of FIGURE 2.

FIGURE 4 is a graph representing the rate of fouling of one of the heat exchangers of FIGURES 2 and 3 when the furnace of FIGURES 1 and 2 was operated in accordance with the prior art practices.

FIGURE 5 is a graphical representation of the degree of fouling of one of the heat exchangers of FIGURES 2 and 3 when the furnace of FIGURES 1 and 2 is operated in accordance with the present invention.

FIGURE 6 is a block diagram of a recovery furnace soot blower control in accordance with the present invention.

FIGURE 7 is a plot of blower lag time versus furnace loading for a plurality of fuels.

DESCRIPTION OF A PREFERRED EMBODIMENT

Referring now to FIGURE 1, a recovery furnace is indicated generally at **10**. If, for example, furnace **10** is part of a black liquor chemical recovery unit as might be found in a kraft paper mill, black liquor evaporated to the required density would be introduced into the furnace by suitable nozzles adjacent a hearth or smelting zone. The preheated air for supporting combustion within the furnace is supplied thereto by means of ducts **12** and **14**. The hot combustion gas generated by the burning of the black liquor within the furnace pass into the upper portions of the furnace, flowing first over steam generating tubes and then over the tubes of a plurality of superheater sections. The combustion gases, after passing over the heating surfaces comprising the steam generating and superheater tubes, leave the upper portion of the furnace through exhaust ducts **16** and **18** (FIGURE 2). As the combustion gases pass upwardly through the furnace debris carried thereby is deposited on the surfaces of the furnace exposed thereto. In the case of a black liquor recovery furnace, the combustion gases have a heavy content of a fine white ash which is deposited upon the steam generator and superheater tubes. To provide for efficient operation of the furnace, the surfaces of the tubes must be kept clean and thus furnace **10** is provided with a plurality of soot blowers **20**.

In the usual instance, the soot blower system will comprise a steam generator and plurality of retractable nozzles which extend into the furnace. The ash deposited on the walls of the furnace chambers is removed by short single nozzle retractable blowers. The ash in the superheater sections is removed by long retractable soot blowers, usually of single nozzle design, which traverse the complete width of the units. The retractable soot blower nozzles may be introduced from both sides of the furnace as shown in FIGURES 1 and 2, or from one side only. There will, of course, be a plurality of soot blowers for each superheater section and these blowers will be positioned at desired points along both the width and height of the sections. It should be noted that while steam is generally preferred, the cleaning medium may be compressed air. It is also worthy of note that the power drives for causing both retraction and sweeping of the individual blower nozzles may be either air, hydraulic fluid or electric motor operated.

As may be seen from FIGURE 2, air preheaters which comprise rotary regenerative heat exchangers are so positioned that the heat exchanger elements, as they rotate, will alternately be exposed to the exhaust gases from furnace **10** and the inflowing cool air in the supply ducts **12** and **14**. As the exhaust gases pass through the heat exchanger, they give up heat to the metallic plates which define the passages therein for gas and the gases are thus cooled sufficiently to enable their passage through a precipitator. The heated plates are then rotated into the air inflow ducts and are cooled by transferring heat to the inflowing air thus preheating the air. As previously noted, as the hot furnace gases pass through the heat exchangers, debris carried by the gases is deposited on the exposed surfaces of the heat exchangers. The build up of deposited material on the heat exchanger plates causes fouling of the heat exchanger and a reduction in the efficiency of the recovery system. Restated, as fouling occurs, in order to maintain a fixed weight flow of gas through the furnace as called for by the furnace control, the fans which force air through intake ducts **12** and **14** require more power to deliver the same volume of air. Eventually, if the build up was allowed to continue, the furnace would be starved for lack of air. Accordingly, it is necessary to provide blower means, not shown, for removing the deposits from the heat exchanger plates. The principal object of the present invention is to minimize the frequency at which it is necessary to energize the cleaning means for the heat exchangers.

FIGURE 3 depicts, in cross section, a portion of a single sector of a regenerative heat exchanger fabricated of pressure packed plates. The plates which comprise the sectors which form heat exchangers **22** and **24** are pressed together with a force in the neighborhood of 10 p.s.i. to form a plurality of sectors and the sectors are combined to define a rotary heat exchanger structure of the type shown in the aforementioned patent to W. F. Jetter. The plates **26** are formed with dimples **28** which provide bearing surfaces and which define the spacing between the plates, such spacing in turn defining gas passages through the heat exchanger. When the degree of fouling of the heat exchanger becomes sufficient to warrant the cleaning thereof, steam or compressed air at 100 to 140 p.s.i. and high velocity will be directed at one or both ends of the heat exchanger; the blowers being located adjacent the heat exchanger within the exhaust duct. Due in part to the deposits which form on plates **26**, the high pressure, high velocity cleaning medium may cause a pressure as high as 50 p.s.i. to build up between the plates. This pressure will tend to force the plates apart and will cause flexing thereof in the regions between the dimples **28**. Ultimately, since the plates are pressure packed, they will begin to get loose and will flutter. The flutter in turn causes fatigue cracks at the edges of the plates and, of course, the cracked plates must be replaced.

As noted above, in the prior art, the sooth blowing of the furnace was perfomed in accordance with a schedule. For example, it was typical to instruct the equipment operators to initiate a soot blowing operation in a black liquor recovery furnace once each shift or every eight hours. Once started, the cleaning of the recovery furnace would progress in accordance with a predetermined schedule with the furnace soot blowers being energized either singly or in groups until all the blowers had been operated. The total blowing operation would generally take between 1½ and 2 hours. Thereafter, the furnace soot blowers would remain inactive for six hours or more until the next cleaning operation was commanded by the operator on the next shift. Operation of the furnace soot blowers in accordance with this standard prior art technique resulted in heat exchanger fouling as shown in FIGURE 4. FIGURE 4 is a measure of the pressure drop ΔP in inches of water across a rotary regenerative type heat exchanger associated with a black liquor recovery furnace for a 12 hour period. Each of the peaks such as indicated at **30** on FIGURE 4 indicates the initiation of a cleaning operation performed on the heat exchanger itself. FIGURE 4 indicates that there were 17 cleanings (soot blowings) of the heat exchanger in the 12 hour period. In the example depicted in FIGURE 4, the initiation of a cleaning cycle for the heat exchangers was sensed and automatically commanded. What is most significant, however, is that there was little build up of deposits (increase in the degree of fouling or pressure drop) on the heat exchanger in the periods between 12:00 and 2:30 and between 8:15 and 10:45. At 12:00 and 8:15 recovery furnace cleaning cycles were initiated and at least one soot blower within the furnace was operating at all times in the period between 4:30 and 6:30. This shows conclusively that the rate of build up of deposits upon a heat exchanger positioned so as to be impinged upon by recovery furnace exhaust gases is at a minimum during times when the soot blowers within the furnace are operating. It is also worthy of note that for a period of approximately two hours (2:30 to 4:30) after the termination of the soot blowing operation the ΔP across the heat exchanger increased slowly. However, after 5:00 the rate of ΔP buildup was very rapid. This pattern may be attributable to the buildup of deposits on the furnace walls to a point where large particles of ash will begin to tear loose into the gas stream and pass in the exhaust ducts. The larger particles would, of course, cause rapid fouling of the heat exchangers.

In accordance with the present invention, the furnace soot blowers are energized in accordance with a predetermined schedule so as to eliminate long periods during which there is no soot blowing within the furnace. In a typical situation involving a black liquor recovery furnace with 32 cleaning statations (soot blowers), the blowers are operated individually in a predetermined sequence and in such a manner that each blower operates for a period of 5 minutes and there is a predetermined delay (lag time) between deenergization of a first blower and energization of the succeeding blower. This results in a fouling characteristic curve as shown in FIGURE 5. FIGURE 5 represents a 12 hour period of operation of the same furnace with which the graph of FIGURE 4 was plotted. However, in the FIGURE 5 situation, the soot blowers were operated individually, in a predetermined order, for a short period of time and with a short delay between operation of each succeeding blower. As will be discussed below, the predetermined delay is calculated and is a function of furnace load and fuel type. This operation continued as long as the furnace was in use. As may be seen from FIGURE 5, the gradual rate of build up of deposits on the heat exchanger when operating the furnace soot blowers in accordance with the present invention resulted in the necessity of cleaning the heat exchanger only twice, as indicated at points **34**, during the period. FIGURE 5 thus shows that the present invention substantially prolongs heat exchanger life while improving system efficiency by reducing the amount of steam or compressed air needed for heat exchanger cleaning. It should be noted that the frequency of cleaning the air preheater will vary inversely with load variation on the boiler. For example, the period may vary from twelve hours at light loads to as low as three hours at high overload. The frequency is also a function of fuel type.

It is worthy of note that, in accordance with the present invention, it is desirable and, in the case of a recovery furnace having a pair of exhaust ducts **16** and **18** as shown in FIGURE 2 mandatory, to energize the furnace soot blowers in such a manner that blowers on alternate sides of the furnace are alternately operated. Thus, in a typical example, the lower left soot blower would be operated for 5 minutes and predetermined period after deenergization of the lower left blower, the lower right blower would then be operated for five minutes. This procedure would continue alternating from the left to right and bottom to top until all blowers had been operated at which time the soot blowing sequence would be repeated.

Referring now to FIGURE 6, circuitry for controlling a furnace soot blowing operation in accordance with the present invention is shown in block form. The circuitry comprises a source of alternating current **40** which provides power for operation of the soot blower driving motors and valves in the manner to be described below. Upon the closing of a start switch **42**, current from source **40** is delivered to a stepping relay matrix **44**. Upon the closing of switch **42**, stepping relay matrix **44** will deliver current from source **40**, via one of a plurality of limit switches **46**, to a drive motor and cleaning medium supply valve associated with a first one of the furnace soot blowers. The motor and valve will thus be energized so as to drive the soot blower across the furnace while simultaneously supplying the cleaning medium to the soot blower nozzle. In FIGURE 6, the drive motors are indicated at **48** while the solenoid operated valves are indicated at **50**. When each of the soot blowers has been driven to its full limit of motion, it operates an associated one of limit switches **52** thus deenergizing the associated valve and reversing the electrical connections to the motor. The soot blower will then retract to its starting point at which time the original circuit will be established by one of limit switches **46**. However, the current supply path to the motor and valve for the just operated soot blower will remain interrupted through the action of latching relays **54** and **56**. Latching relays **54** and **56** are energized by the reclosing of one of switches **46** and remain energized until stepping relay matrix **44** steps to its next position.

When one of limit switches **52** is closed by a soot blower nozzle completing its travel into the boiler, current will be supplied via normally deenergized conductor **58** to a lag timer **60**. Timer **60** is preset, in accordance with the criteria to be discussed below, to disable all the soot blowers for a predetermined time interval. This disabling is effected by normally closed switch **62** which is connected between source **48** (switch **46**) and relay matrix **50** (differentiator **64**). Switch **62** is mechanically coupled to timer **60** and is opened for the desired period after each blower has shut down. Reclosing of switch **62** after the preset lag period will cause differentiator **62** to deliver a pulse to stepping relay matrix **44**. This results in the matrix stepping to its next position thus energizing the next blower after the termination of the set lag period.

Means, not shown, may be provided if desired to enable the operator to bypass any one soot blower. The bypassing means will shorten the time required to cycle all of the soot blowers. That is, if means are provided so as to enable the bypassing of individual soot blowers, the bypassing means will provide for the automatic stepping onto the next soot blower. The time delay between successive deliveries of the cleaning medium to the furnace remains constant due to the action of lag timer **60**.

FIGURE 7 depicts, on a logarithmic scale, the determination of the proper lag time between successive operations of individual furnace internal soot blowers. As may be seen from FIGURE 7, the period of the intervals between individual blower operations is a function of the fuel and the square of the reciprocal of the boiler load. Fuels are, of course, characterized by combustion products having known degrees of "dirtiness." As may be seen from FIGURE 7, three examples being given, oil burns cleaner than pulverized coal. Black liquor, as will be burned in a recovery furnace of a kraft paper mill, is a much dirtier fuel than either coal or oil. Accordingly, for the same degree of boiler load in pounds per hour of fuel being supplied to the boiler, the lag time will vary inversely with the dirtiness of the fuel; the lag time for black liquor being shorter than that for the other fuels (all other conditions being the same). Similarly, it may be seen that the lag time for each of the fuels represented by the curves of FIGURE 7 varies inversely with the square of the boiler load. Thus, for a given furnace, with a boiler load of 50 percent rated and a pulverized coal fuel, the lag time may be as great as 4 times that for the same fuel with the furnace at 100 percent load. This relationship may be expressed as follows:

$$T=A\left(\frac{1}{\text{load (percent rated)}}\right)^2$$

where:

T=lag time in minutes,
A=an empirical constant dependent upon the type of fuel, boiler design and operation.

While a preferred embodiment of the present invention has been described, it is to be understood that various modifications may be made thereto without departing from the spirit and scope of the present invention. Accordingly, it is to be understood that the present invention has been described by way of illustration and not limitation.

What is claimed is:

1. A method of reducing the frequency of cleaning of a heat exchanger positioned so as to be impinged upon by contaminated furnace exhaust gases; said contaminated exhaust gases emanating from a chemical recovery furnace, said furnace including a plurality of movable nozzles for delivering a cleaning fluid against internal surfaces thereof; the method comprising the steps of:
   - causing a first nozzle to traverse the interior of the furnace;
   - simultaneously delivering a cleaning fluid through the first nozzle to the interior of the furnace;
   - terminating delivery of the fluid through the first nozzle; and
   - causing a second nozzle to traverse the interior of the furnace while simultaneously delivering the cleaning fluid therethrough a predetermined time period after termination of the delivery of fluid through the first nozzle, the time period being a function of the type of material being burned in the furnace and the rate at which the material is being burned.

2. The method of claim 1 wherein the second and other of the plurality of nozzles are individually caused to traverse the interior of the furnace while the cleaning fluid is delivered therethrough in accordance with a predetermined sequence, the time period between termination of the delivery of fluid through each nozzle and the initiation of the delivery of fluid through the succeeding nozzle remaining constant.

3. The method of claim 2 wherein the time period between successive deliveries of cleaning fluid to the furnace is a function of the dirtiness of the material being burned and the square of the reciprocal of the furnace load.

4. A method of reducing the cleaning frequency of a heat exchanger; the exchanger being at least partly positioned in a boiler exhaust gas stream, the exhaust gas having debris entrained therein, the boiler including a plurality of internal cleaning devices; said method comprising the step of:
   - delivering cleaning fluid to the interior of the boiler via the internal cleaning devices individually so as to simulate continuous boiler cleaning, there being a predetermined time lag between the operation of successive cleaning devices, said time lag being a function of the type of material being burned in the boiler and the boiler load.

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