

Oct. 27, 1953

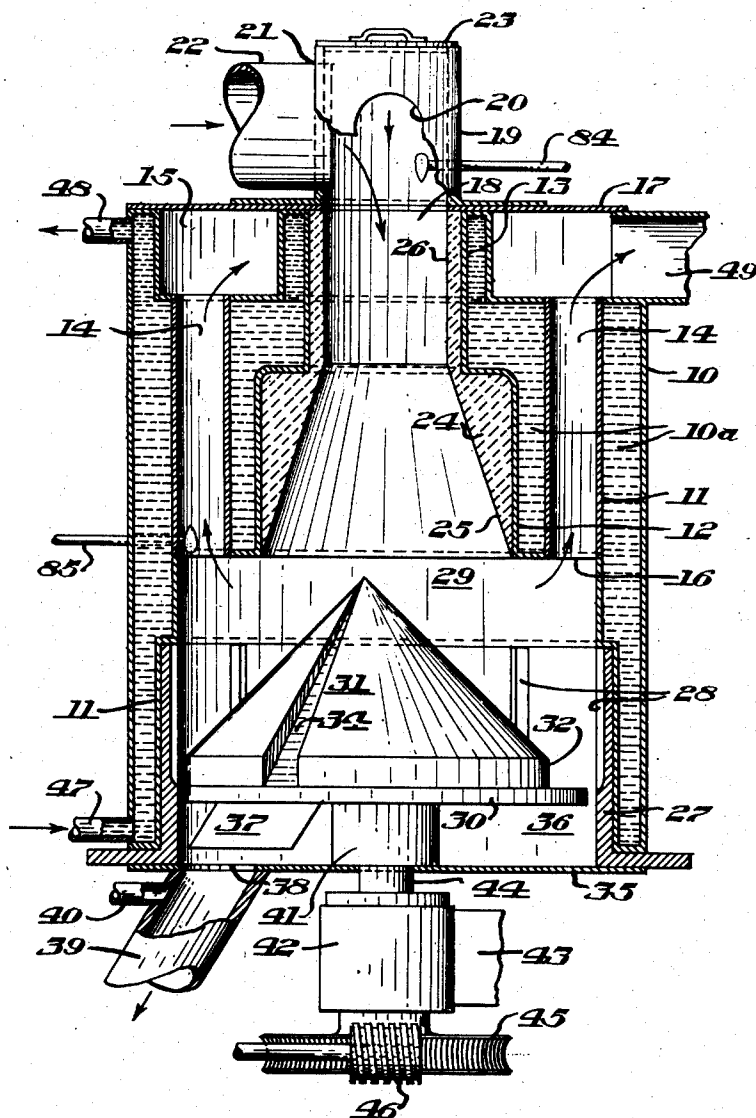
W. J. HATTON
CONTROL SYSTEM FOR AUTOMATICALLY FED
FURNACES FOR SOLID ORGANIC FUELS

2,656,799

Filed Sept. 9, 1949

3 Sheets-Sheet 1

Fig. 1.



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Fig. 2.

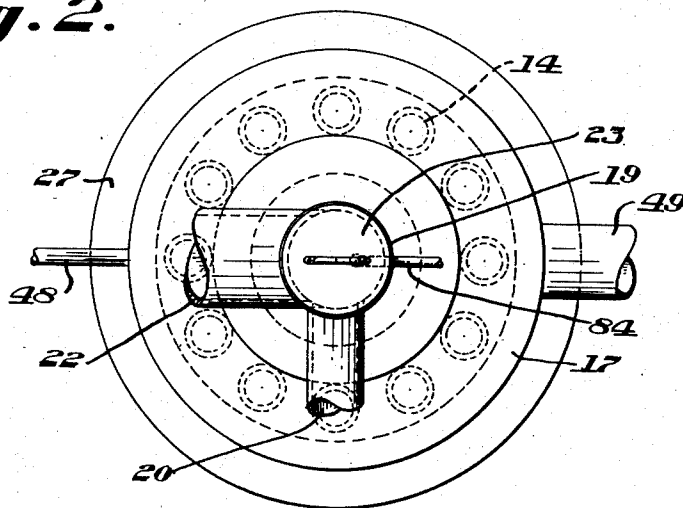
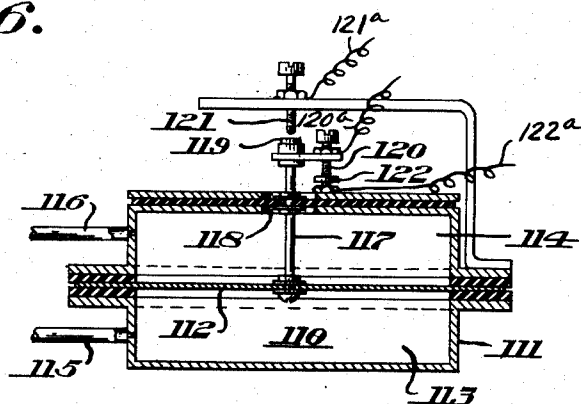


Fig. 6.



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Fig. 3.

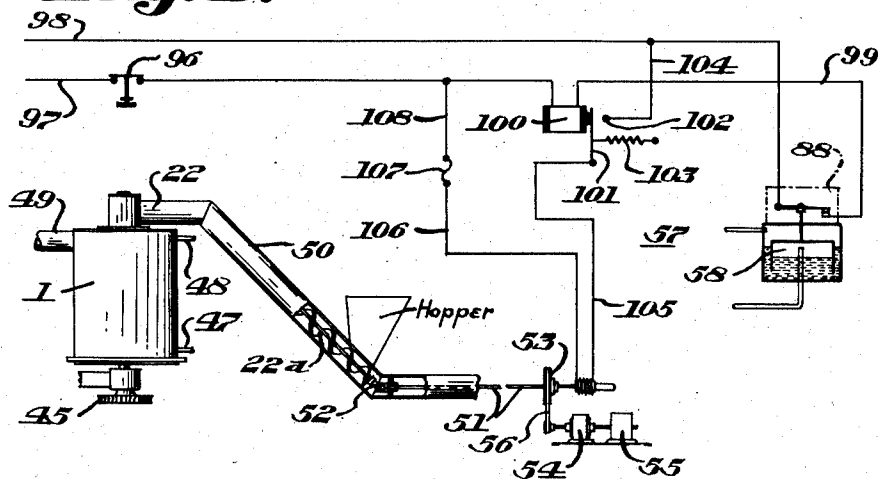


Fig. 5.

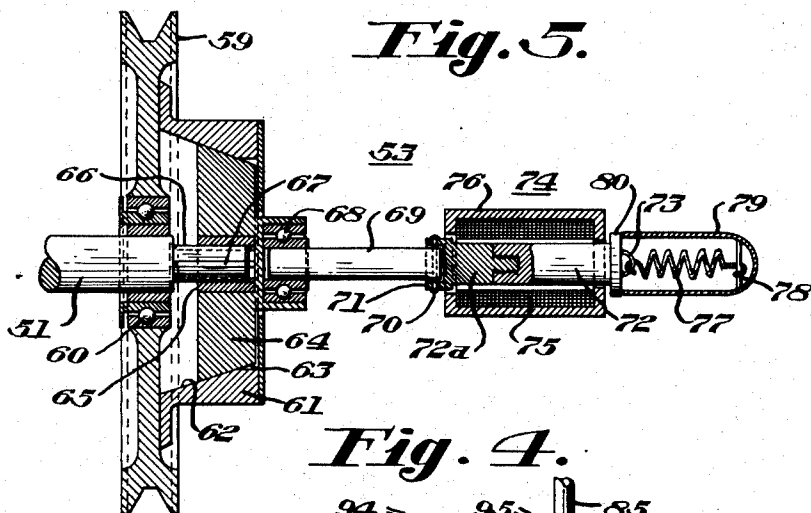
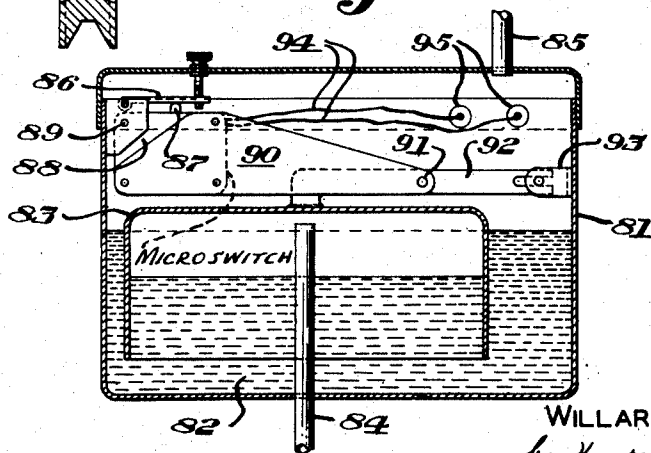


Fig. 4.



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UNITED STATES PATENT OFFICE

2,656,799

CONTROL SYSTEM FOR AUTOMATICALLY
FED FURNACES FOR SOLID ORGANIC
FUELS

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Application September 9, 1949, Serial No. 114,771

2 Claims. (Cl. 110-101)

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This invention relates to a control system for automatically regulating the depth of a live fuel bed in an automatically fed furnace for solid organic fuels. More particularly, it relates to a differential pressure control to achieve such regulation in a stoker-fed coal furnace for residences and small buildings.

This invention is of especial value when used in connection with the downflow stoker-fed furnace system for bituminous coals which is more fully disclosed in United States patent application Serial No. 93,562, filed May 16, 1949, in the name of Willard J. Hatton and Ralph A. Sherman, and assigned to Bituminous Coal Research, Inc. By means of the furnace system of said application Serial No. 93,562, the substantially fully automatic heating of average size residences and small buildings with bituminous coals and the like was made feasible using conventional control circuits.

In the said furnace system, a small furnace is provided to which bituminous coal and air in correlative amounts are periodically or continuously fed as demand requires to the top of a live fuel bed, the upper part of which is confined and remains in a restricted zone within the furnace. A zone of discontinuity is provided substantially at the plane of ignition so that the coal remains relatively cool until it is actually subjected to kindling conditions at the time it is so fed. Under the high rate of burning (relative to the rates of burning in conventional furnaces) that ensures at least during the "on" periods of heat demand and hold-fire, all volatile and tarry matter released passes through the fuel bed whence the heat release potentiality thereof is recovered and smoke emission which might otherwise be caused thereby is prevented. The agglomerating properties of such volatile and tarry matter are suppressed or destroyed during such active burning and remaining agglomerating tendency, if any, is nullified by ignition suppression obtained by predetermining the setting of the control circuit. The particles in the fuel bed gravitate downwardly into the unconfined lower portion of the combustion chamber where gaseous combustion products escape through the upper surface of said bed around the restricted zone. Ash also gravitates downwardly through the fuel bed and out of the combustion chamber before any material clinkering thereof can take place.

The aforesaid system makes it possible to burn strongly agglomerating coals in equilibrium which may be defined as that condition in which

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the fuel bed, for a constant rate of primary air, maintains the same character of combustion and thickness. In other words, the rate of burning and the rate of ignition remain substantially equal and free burning results with the plane of ignition staying in the restricted zone during heat demand and hold-fire periods. The restricted zone is the upper confined portion of the combustion chamber which opens unrestrictedly into the lower unrestricted portion of the combustion chamber. The fuel bed, which is substantially entirely a live fuel bed, extends upwardly into and fills at least the lowermost end of the restricted zone. It is inherent in furnace systems employing a variation of the underfeed principle that some thinning of the fuel bed occurs when the air rate is increased. Such a change will shift the plane of ignition to some extent within the restricted zone which is generally not sufficient, however, to disturb the bed's equilibrium.

However, there are variation factors which would materially tend to change the level of the plane of ignition in a given furnace if such tendency were not counteracted. Important factors of this character arise from the differing agglomeration properties of bituminous coals from different beds, from the different reactivities of the respective sizes of coal fed to the furnace system, and from fluctuations in heat demand. On the subject of size, bituminous coal supplied for domestic stokers, for example, may vary between the approximate size limits from about $1\frac{1}{4}$ " maximum to $\frac{1}{8}$ " minimum, a wide size consist in terms of the combustion reactivity of the size gradations in that consist. Since the furnace in the system disclosed in application Serial No. 93,562 is relatively small, any tendency towards its becoming "upset" by disturbing its equilibrium must be counteracted that much more quickly. Any tendency to lose equilibrium is particularly present during hold-fire operation, as distinguished from heat demand operation.

In providing the furnace system of application Serial No. 93,562 with a frusto-conical section in the restricted zone as more fully disclosed in United States patent application Serial No. 98,484 filed June 11, 1949, in the name of Willard J. Hatton and Henning M. Carlson, and assigned to Bituminous Coal Research, Inc., inherent counteraction to any material change in the depth of the fuel bed is obtained. Under this last-mentioned invention any tendency for the fuel bed to deepen in turn tends to reduce the

approximate cross sectional area of the plane of ignition and thus increase the rate of burning; conversely, in the event of any tendency in the bed to thin, this last-mentioned invention tends to decrease the rate of burning to again counteract a change in the depth of the bed.

The present invention provides another novel control for the depth of the fuel bed which has particular application in combination with either or both of the disclosures in the aforesaid applications. Thus, in this invention it has been found that in the event of the deepening of the fuel bed, such as may be brought about by a tendency to initial agglomeration of bituminous coals particularly when in the plastic stage, that there is an increase in the resistance to the flow of gases through the bed which is substantially in proportion to such change in depth. Heretofore, in conventional stoker-fed furnaces, any change in the depth of the fuel bed has not been accompanied by any reliably proportionate change in such resistance. As a consequence, in conventional furnaces, flow resistance is not generally an appropriate basis for a control of the character disclosed by this invention.

The importance of the discovery in this invention is evidenced by the importance of maintaining equilibrium burning and hence, fuel beds of substantially constant depth, particularly with agglomerating fuels. Otherwise, a deepening bed, even if it does not "upset" the furnace system or spill out of the furnace, still results in poorer combustion due to lowered temperatures, decreased surface for contact with combustion air and decreased combustion air supply resulting from increased resistance to the flow of gases through the bed. In the operation of conventional stokers employing the underfeed principle, there is also a possibility of loss of ignition especially during hold-fire operation if there are large "coke trees" in the bed when the air fan is turned on at the beginning of an "on" period.

By means of this invention, the possibility of the furnace system becoming "upset" or causing other difficulty with agglomerating coals is materially reduced. Moreover, this invention provides assurance against the presence of fresh, raw fuel remaining in relatively inactive contact with a live fuel bed. In such cases, especially during "off" periods of the temperature demand thermostat control system the possibility of detrimental smoke emission is increased. Other objects and advantages of this invention will be apparent from the following description and from the drawings, which are illustrative only, in which

Figure 1 is a vertical cross sectional view of a residential downflow stoker-fed furnace suitable for use in combination with the system of this invention;

Figure 2 is a plan view of the entire furnace shown in cross section in Figure 1;

Figure 3 is a schematic view of a preferred embodiment of the control system of this invention applied to a furnace such as is shown in Figures 1 and 2;

Figure 4 is a vertical cross sectional view of the differential pressure device illustrated in the control system shown in Figure 3;

Figure 5 is a vertical cross sectional view of the clutch assembly used in the control system illustrated in Figure 3; and

Figure 6 is a vertical cross sectional view of a modified differential pressure device which may

be used in a modified control system constructed in accordance with this invention.

Referring to Figures 1 and 2 of the drawings, a furnace 1 is illustrated which has a casing 10 forming the outer wall of a jacket or boiler 10a. Jacket 10a contains a heat absorbing fluid such as water and has an inner wall consisting principally of a lower tubular inner wall section 11, an offset intermediate inner wall section 12 and an upper inner wall section 13. A plurality of vertical flue pipes 14 are concentrically positioned around inner wall sections 12 and 13, and extend from offset wall portion 16 to an annular flue collar 15 thus connecting the latter to the lower portion of a combustion chamber 29. Flue pipes 14 are sealed around their respective edges to keep boiler 10a fluid tight.

A cover plate 17 rests on the top of casing 10 and closes flue collar 15 to which respective portions of the furnace it is bolted or otherwise affixed. A central opening 18 is provided in cover plate 17 which opening is in registry with the opening at the top of tubular wall section 13. A turret head 19 closes opening 16 and has a port 20 therein for the admission of combustion air. A further port 21 in head 19 is connected to the delivery end of a conveyor conduit 22 within which a feed screw 22a operates to feed bituminous coal or other fuel in predetermined amounts dependent upon the heat demand and control conditions operative at the time being. A cover 23 tightly closes a corresponding opening in the top of head 19. This cover may be removed to insert and ignite kindling at the commencement of operations if automatic ignition apparatus should not be provided.

Wall section 12 is lined with a refractory material 24 so disposed that the innermost surface 25 thereof is substantially in the form of a frusto-conical part substantially forming an upper restricted portion of combustion chamber 29. This refractory 24 thereby increases in lateral thickness in an upward direction and generally inversely to the reduction in internal horizontal cross sectional area of the frusto-conical part defined by surface 25. Uppermost inner wall section 13 may be lined with a substantially vertical layer of refractory 26 which, at its lowermost edge, meets the uppermost edge of refractory layer 24. The interior space within refractory lining 26 may be regarded as the very top of combustion chamber 29 although the plane of ignition is adapted to remain within surface 25 which confines the upper part of the live fuel bed.

The upper portion of combustion chamber 29 opens unrestrictedly into its lower portion, substantially forming the top of an inverted T. This lower portion broadens out around a conical grate 31. Grate 31 is supported in fixed, eccentric position on a rotating base 30. Ash passes between base 30 and the lower section of jacket 10a into an ash pit 36 where it is removed. The lower section of jacket 10a behind wall section 11 absorbs heat directly from the lower portion of the fuel bed, thereby aiding in the maintenance of temperatures at least in the lower portion of the fuel bed which discourages any material formation of clinker by the melting or fusion of ash. Additional cooling in the lower portion of combustion chamber 29 may be obtained if desired by the provision of some supplemental combustion air through a line 40 and ash pit 36. Such supplemental combustion air will also mix up and burn combustible which might otherwise tend to be present in the ash and in the gaseous com-

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bustion products. Normally, such supplemental combustion air would not be in excess of one-quarter by weight of the downflow primary combustion air supplied to the furnace through port 20.

A metal liner 27 surrounds the lower portion of combustion chamber 23 in contact with lower wall section 11. The inside of liner 27 is in vertical registry with wall 11 above it so that fly ash may have substantially no non-vertical surface or "land" on which to deposit in the furnace. A series of vertical grooves 28 are disposed around the inside of liner 27 and cooperate with a plurality of grooves 34 in grate 31 and with its lower vertical edge 32 to break up such small clinker particles as may form. Sufficient clearance is left between the edge of base plate 30 and the interior of liner 27 so that only readily removable ash falls into ash pit 36. A sweep 37 is adjustably affixed to the underside of base 30 and pushes ash out of ash pit 36 through an opening 38 leading into an ash removal duct 39. A bottom plate 35 closes the bottom of ash pit 36 and casing 10. Suitable lagging may be provided for all exposed portions of the furnace.

Base 35 is rigidly mounted on a hollow rotatable shaft 44 having passages therein (not shown) through which cooling water may be circulated if, under the particular circumstances of a given furnace, the temperature in the lower portion of the fuel bed tends to be too high. A hub block 41 is supported by closure 35 and supports a live fuel bed extending from the upper surface of plate 30 to the plane of ignition within refractory surface 25. A bushing 42 is provided at the end of a fixed bracket 43 to assist in the journaling of shaft 44 which is keyed at its upper end to base plate 30 and at its lower end to a worm wheel 45. A worm gear 46 is driven either continuously or stepwise by appropriate control and driving mechanism (not shown) during the operation of the furnace system. Heat-absorbing fluid is supplied to jacket 10a through a pipe 47 and after circulation therethrough passes out through an outlet pipe 48. Gaseous combustion products including entrained material after passing through the fuel bed filling the lower end of the upper portion of combustion chamber 29 make an abrupt turn and pass laterally and then upwardly through the bed and into the proximate vertical flue pipes 14. Thence, they pass into flue chamber 15 and out through a duct 49 to a stack. The vertical surfaces of flue pipe 14 and the absence of horizontal ledges around the walls of combustion chamber 29 minimize any possibility of deposition of fly ash or soot.

Referring to Figure 3, furnace 1 is supplied with solid organic fuel such as an agglomerating bituminous coal through a conveyor or conduit or pipe 50, the upper end of which is connected to the outer end of pipe 22. A feed screw 22a having universally coupled sections turns in pipes 50 and 22 to feed the coal. A shaft 51 is connected to the lower end of feed screw 22a by a universal joint 52. A clutch assembly 53 is positioned at the outer end of shaft 51 and is adapted to be disengaged under proper conditions to stop the coal feed even though the conventional temperature demand thermostat control system (not shown) remains "on." By such disengagement, coal feed screw 22a stops, even though an electric driving motor 54 continues to run and operate a combustion air blower 55 during the continuance of such "on" period. A belt 56 connects motor 54 to clutch assembly 53.

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Clutch assembly 53 is in a control circuit 57 which is part of the control system of this invention. A schematic wiring diagram for such a circuit 57 is illustrated in Figure 3 but many other wiring arrangements are possible and within the skill of the electrical art. A differential pressure manometer 58 of the bell type is connected in circuit 57 and operates on the gaseous pressure differential across the fuel bed in furnace 1 which is substantially proportional to any change in the depth of the fuel bed.

In clutch assembly 53 a driven pulley 59 is turned by belt 56. Pulley 59 rotates freely about shaft 51 being mounted in an idling bearing 60. A clutch ring 61 is fastened to pulley 59 about the axis of shaft 51. Ring 61 has a conical driving clutch face 62 which cooperates with a clutch face 63 on an axially slidable driven clutch disc 64. A hub 65 forming a part of disc 64 is telescoped over the end of a stud shaft 66 which is fastened in the end of shaft 51. A spline 67 in a splineway in shaft 66 cooperates with a corresponding longitudinal recess in hub 65 to permit axial but not rotatable movement of disc 64 relative to shaft 66.

A thrust bearing 68 connects disc 64 with a solenoid link 69, preferably of a non-magnetic metal, so that disc 64 may rotate freely relative to link 69 but may not move endwise relative thereto. A pin 70 pivotally connects link 69 to a clevis 71 which is fastened to the end of a normally off-center (relative to the winding of a solenoid 74) ferrous solenoid core 72. Core 72 is provided with a threadably and rigidly engaged non-ferrous extension 72a, of a non-magnetic metal like brass, integral with clevis 71. Solenoid 74 includes a conventional winding 75 and yoke 76 for the longitudinal actuation of core 72 when winding 75 is energized. A tension spring 77 is fastened at one end through an eye bolt 73 in core 72 and at the other end about a pin 78 spanning the looped end of a stop 79. Stop 79 is immovably fastened relative to motor 54 and other fixed parts of the equipment and normally engages an enlarged end 80 of core 72 under the pull of spring 77. When clutch assembly 53 is in the position shown in Figure 5, so long as electric motor 54 turns, feed screw 22a operates to feed coal into furnace 1. However, when solenoid 74 is energized, core 72 is displaced to the left and surfaces 63 and 62 respectively are disengaged, stopping shaft 51 and feed screw 22a.

Manometer 58 comprises a liquid and gas tight casing 81 having a suitable manometer liquid 82 therein. A bell 83 is inverted over the end of a high-pressure pressure tube 84. A low-pressure pressure tube 85 is connected to the manometer at the top thereof. A vertically adjustable pressure plate 86 is fastened to the inside of casing 81 adjacent the top thereof for engagement by a pressure pin 87. Pressure pin 87 is a part of a normally closed microswitch 88 pivotally supported at 89 inside the manometer to casing 81. An arm 90 rigidly attached to switch 88 is pivoted at 91 to a floating link 92. One end of floating link 92 is hingedly connected to a bracket 93 attached to the interior of casing 81. The other end of link 92 is fastened to the top of bell 83. Insulated liquidproof leads 94 are connected to the terminals of switch 88 which may be of any suitable conventional nature, and pass out through suitable seals 95 in casing 81.

Higher pressure pressure tube 84 extends into the upper portion of combustion chamber 29

preferably adjacent the plane of ignition so that the static pressure of the incoming combustion air from port 23 will be communicated through pressure tube 24 to manometer 58. Lower pressure pressure tube 25, on the other hand, is connected on the other side of the fuel bed so as to communicate the static pressure of the combustion gases leaving the fuel bed. The location and conventional character of the furnace connections to register these static pressures adjacent the admission and outlet surfaces of the bed are matters within the skill of pneumatic engineering and are schematically shown in one possible location for each in Figure 1. Hence, manometer 58 may be set for a maximum predetermined depth of the fuel bed by the vertical adjustment of pressure plate 65.

As a consequence, after the requisite adjustment is made, upon any potentially troublesome deepening of the fuel bed the differential pressure within manometer 58 on the two sides of bell 63 will increase. Such an increase will cause bell 63 to rise within casing 81, moving pin 87 into contact with pressure plate 86 and opening switch 88. Switch 88 will remain open only so long as such pressure differential exceeds the predetermined maximum amount corresponding to the predetermined maximum depth of fuel bed desired.

When switch 88 is broken, control circuit 57 causes solenoid 74 to be energized moving ferrous core 72 to the left from the position shown in Figure 5, thereby disengaging clutch disc 64 from clutch ring 61 and stopping shaft 51. Thereby, no additional fresh, raw, relatively cool coal is fed to furnace 1 where it would become heated and aggravate the bed-deepening tendency. Of course, when the temperature demand thermostat control system is "off," motor 54 will stop and no coal will be fed to furnace 1 irrespective of the connections within control circuit 57.

In circuit 57, a push-button switch 96 is normally closed and remains closed until manually opened to disconnect the control system of this invention from the furnace system with which it is employed. An alternating current power source is provided across lines 97 and 98. Line 98 continues through switch 88, a line 99, a relay coil 100, switch 96 and return to line 97. An armature 101 cooperates with a switch point 102, the circuit through which is connected by a spring 103 whenever relay coil 100 is deenergized as by the opening of switch 88. Switch point 102 is connected by line 104 to power line 98. A line 105 extends from armature 101 through solenoid winding 75, a line 106, a fuse 107 and a line 108 to line 97 on the other side of switch 96.

In operation, therefore, when the pressure differential across the fuel bed in furnace 1 increases beyond the predetermined maximum signalling a proportionate increase in bed depth, manometer 58 opens switch 88, thereby closing the circuit in lines 104 and 105 through switch 101-102. This in turn energizes solenoid 74 and stops the coal feed. Conversely, during normal operations with the fuel bed remaining relatively constant in depth with equilibrium burning, solenoid 74 is not energized and hence spring 77 maintains driving engagement between shaft 51 and motor 54 through clutch assembly 53. Further, since any particles of clinker which may tend to be formed are broken up and crushed between grooves 34, edge 32, the outer periphery of plate 30 and the cast or milled vertical grooves 28 in liner 27, no material distortion of the

accuracy of the differential pressure control system of this invention can result because of any presence of such particles in the fuel bed.

In the preferred embodiment illustrated in Figure 3, the control system of this invention is effective in the event of deepening of the fuel bed in furnace 1 beyond the prescribed limit. In some types of operation, it may be desirable to have positive control by a control system embodying the principles of this invention, operative also in the event of an undue decrease in the depth of the fuel bed. In such event, as shown in Figure 6, a differential pressure manometer 110 may be provided.

Manometer 110 has a liquid and gas tight casing 111 which is horizontally partitioned by a diaphragm 112 forming a lower chamber 113 and an upper chamber 114. A higher pressure pressure tube 115 is connected to chamber 113 and a lower pressure pressure tube 116 is connected to chamber 114. A post 117 is fastened to diaphragm 112 and passes through a flexible sealing member 118 whence it terminates in a double electrical switch contact respectively numbered 119 and 120. An adjustable electric switch contact 121 is adapted to cooperate with contact 119 and an adjustable electric switch contact 122 is adapted to cooperate with an electrical contact 122a. Appropriate leads respectively numbered 120a, 121a and 122a and an appropriate electrical circuit (not shown) may be provided in a circuit controlling a conventional magnetic clutch and in turn respectively controlled by the vertical movements of rod 117. Thus, in the event of excessive deepening of the fuel bed, diaphragm 112 would bow upwardly, closing switch 119-121 and stopping the fuel feed by disengagement of such a clutch. On the other hand, if the fuel bed should tend to thin beyond another predetermined setting corresponding to a predetermined minimum pressure differential across the fuel bed as determined by the adjustment of switch contact 120, diaphragm 112 would move to the other side of its electrically open circuit position, closing switch 120-122, engaging such clutch and feeding coal to a furnace such as furnace 1. With the use of the control system of this invention employing such a double-acting differential pressure control device as manometer 110, the feeding of coal to the furnace system may if desired be made independent of the "on" periods of the overall heat demand and hold-fire thermostat control system employed, by having an independent drive motor for the coal feed.

Either of the modifications of the control system of this invention disclosed herein, may have the clutch assembly thereof so positioned relative to the power source that when ever the coal feed is stopped the combustion air blower and any grate rotating mechanism and ash discharge mechanism may also be stopped. In the further embodiment shown in the aforesaid application Serial No. 93,562, this result would be obtained by placing any such clutch assembly between the coal feed driving motor and the transmission gear box. On the other hand, by interposing such clutch assembly between the gear box and coal feed screw, only the coal feed itself would be affected.

Although I have illustrated and described a preferred and a modified control system in this invention for the maintenance of a substantially constant depth of fuel bed, it is to be understood that various changes in the circuits and in the arrangement and character of parts may be made

within the spirit of the invention and the scope of the appended claims.

I claim:

1. In a control system for a residential stoker-fed furnace for bituminous coal or the like, apparatus comprising in combination, a combustion chamber in said furnace adapted to contain a fuel bed, said combustion chamber having an upper restricted frusto-conical portion and a lower unrestricted portion, said fuel bed being adapted to extend upwardly into said frusto-conical portion and be confined thereby, a stoker for feeding such coal generally downwardly into said frusto-conical portion, driving means for said stoker, a blower for supplying combustion air generally downwardly into said frusto-conical portion, means responsive to the static pressure of said combustion air adjacent its area of entrance into said fuel bed, means responsive to the pressure of the gaseous combustion products emanating from said fuel bed adjacent the area of said emanation, means responsive to the differential pressure registered between said both-mentioned pressure responsive means and adapted to control said driving means, whereby when said differential pressure exceeds a predetermined amount, said driving means is disconnected from said stoker at least for the period during which such differential pressure exceeds said predetermined amount.

2. In a control system for a residential stoker-fed furnace for bituminous coal or the like, apparatus comprising in combination, a combustion chamber in said furnace adapted to contain a fuel bed, said combustion chamber having an upper restricted frusto-conical portion and a lower unrestricted portion, said fuel bed being adapted to extend upwardly into said frusto-conical portion and be confined thereby, a stoker

for feeding such coal generally downwardly into said frusto-conical portion, driving means for said stoker, a blower for supplying combustion air generally downwardly into said frusto-conical portion, means responsive to the static pressure of said combustion air adjacent its inlet into said combustion chamber, means responsive to the pressure of the gaseous combustion products emanating from said fuel bed adjacent the outlet from said combustion chamber, means having two-way movement responsive to the differential pressure registered between said both-mentioned pressure responsive means and adapted to control said driving means, whereby when said differential pressure exceeds a predetermined amount said driving means is disconnected from said stoker at least for the period during which said differential pressure exceeds said predetermined amount, and when said differential pressure falls below a second predetermined amount, said driving means is reconnected to said stoker.

WILLARD J. HATTON.

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