Feb. 23, 1965 G. E. KEEFER 3,170,678

REGENERATIVE FURNACE DRAFT REVERSAL APPARATUS

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FIG. 1

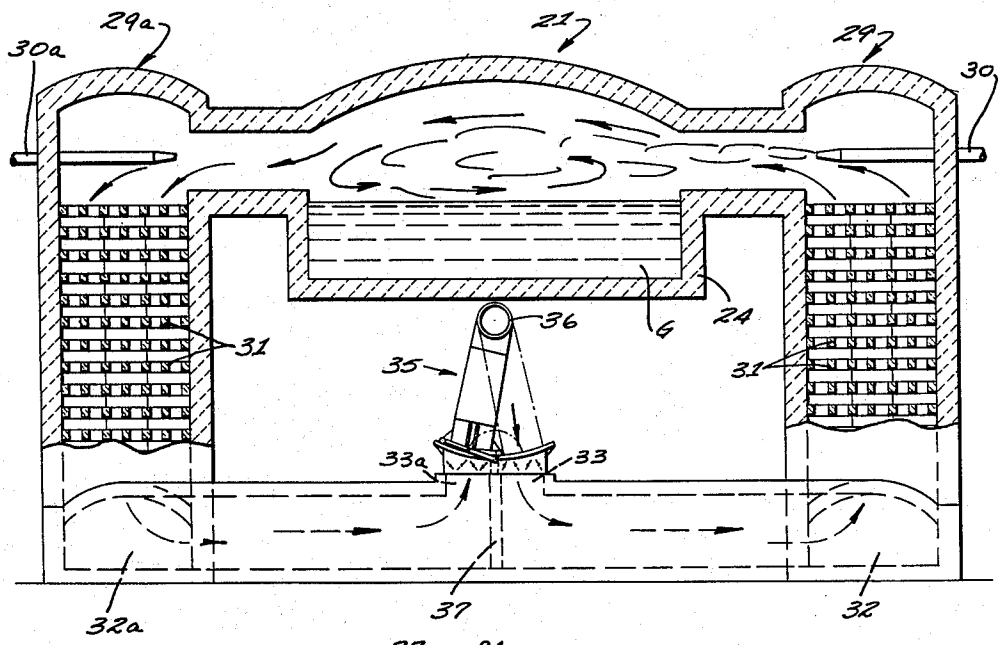
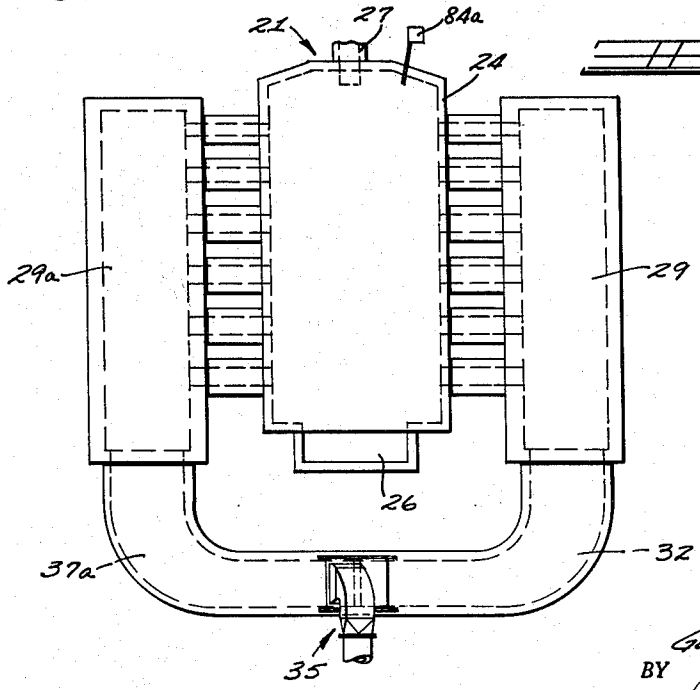


FIG. 2



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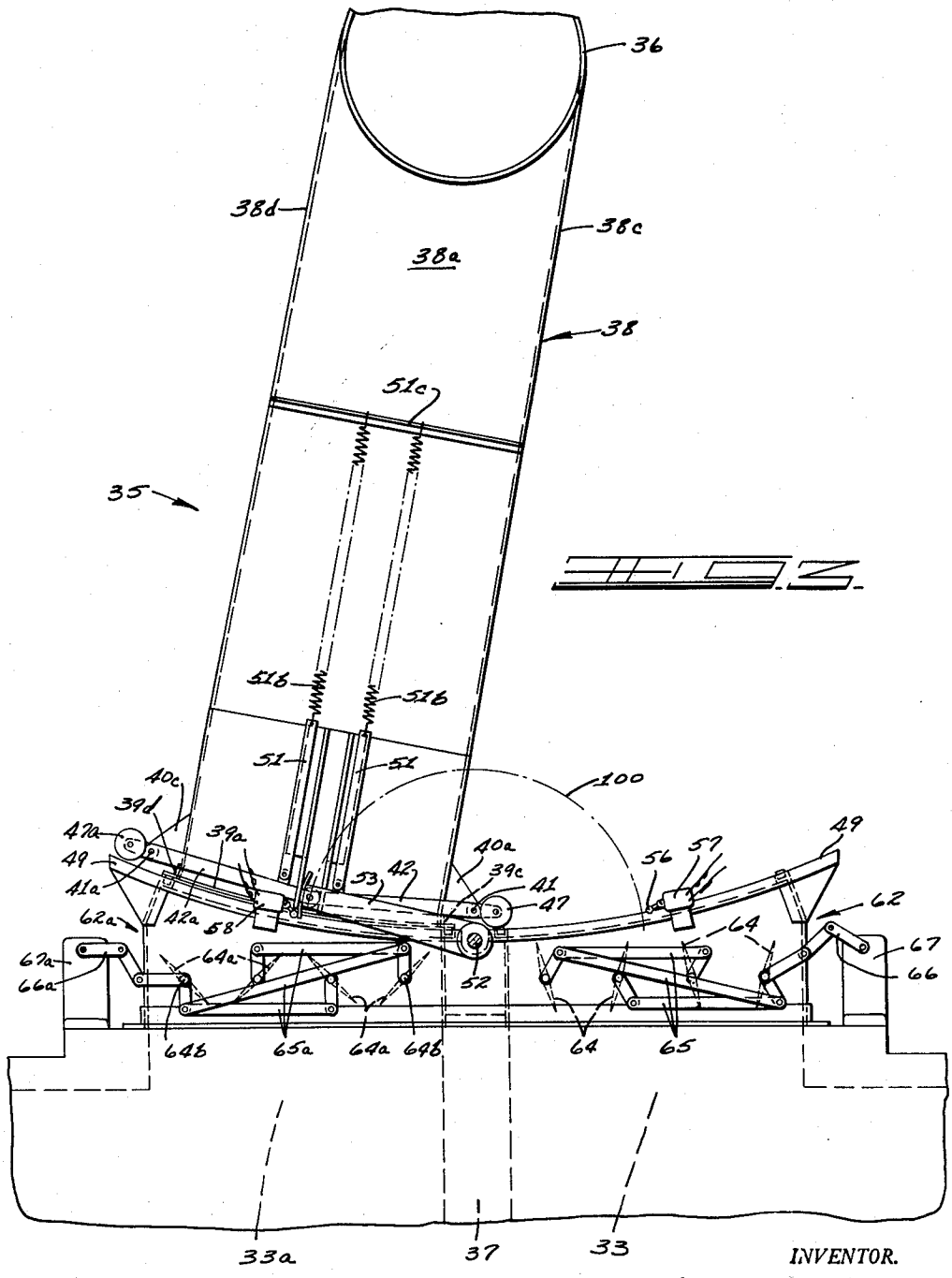


FIG. 2

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REGENERATIVE FURNACE DRAFT REVERSAL APPARATUS

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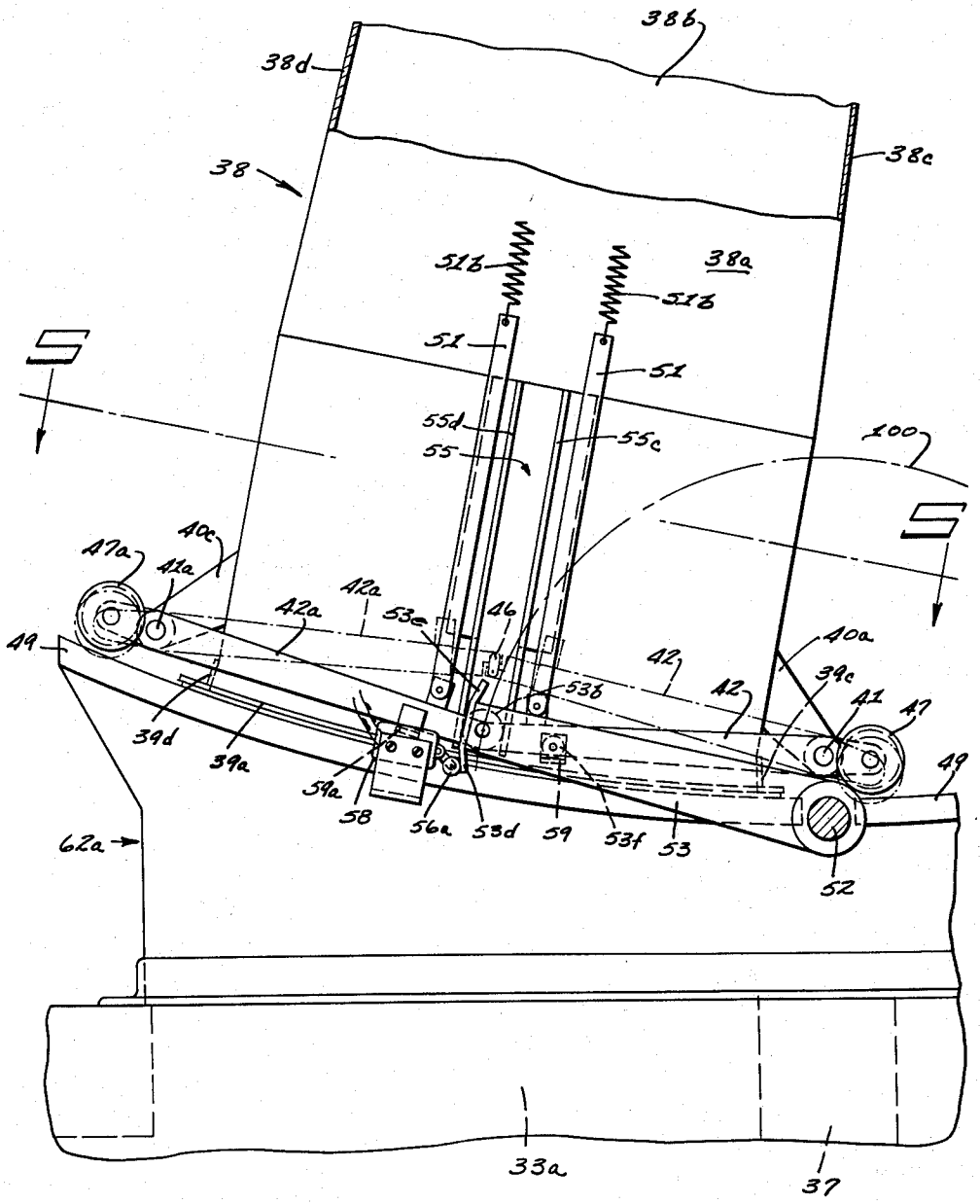


FIG. 4

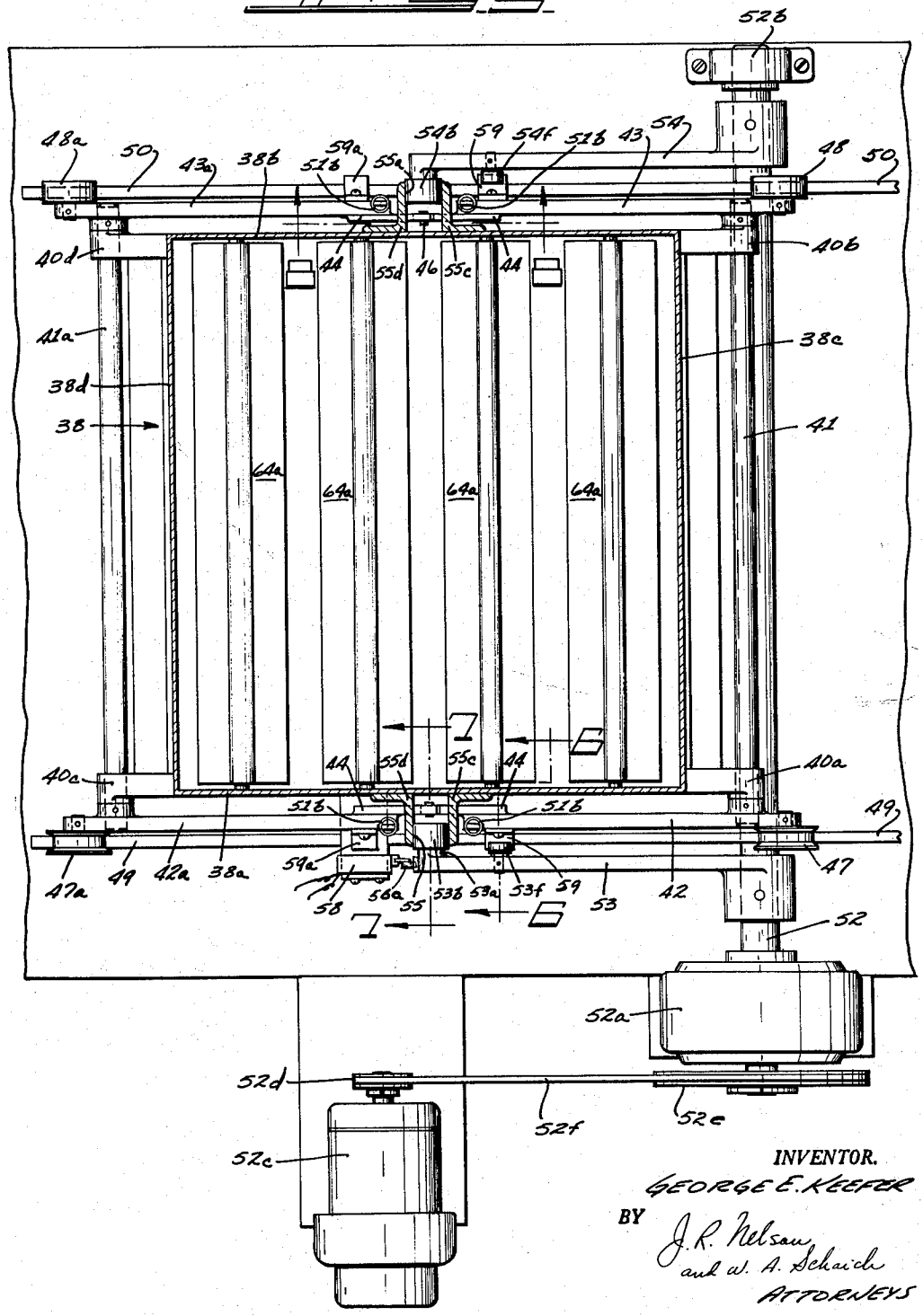
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REGENERATIVE FURNACE DRAFT REVERSAL APPARATUS

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FIG. 5



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REGENERATIVE FURNACE DRAFT REVERSAL APPARATUS

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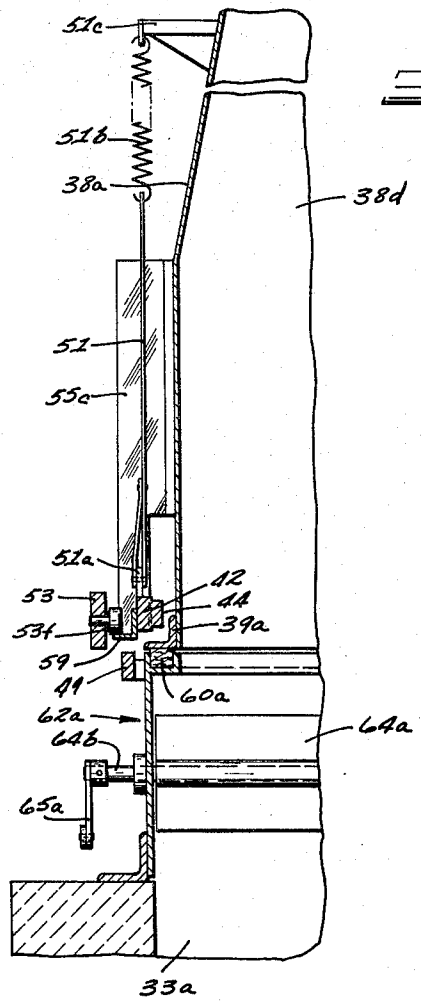


FIG. 6

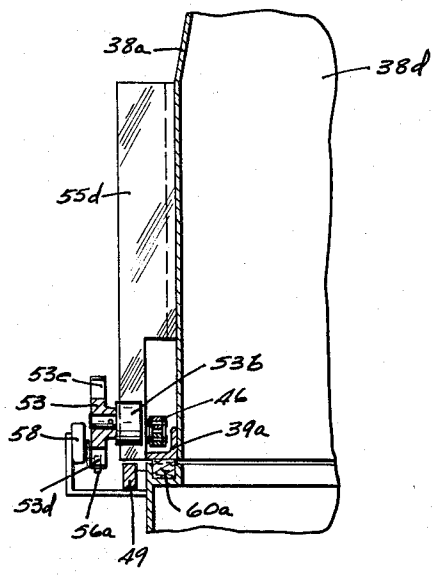


FIG. 7

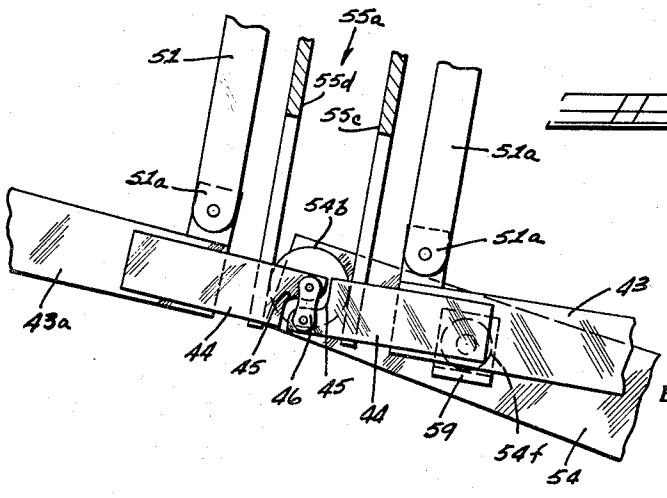


FIG. 10

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REGENERATIVE FURNACE DRAFT REVERSAL APPARATUS

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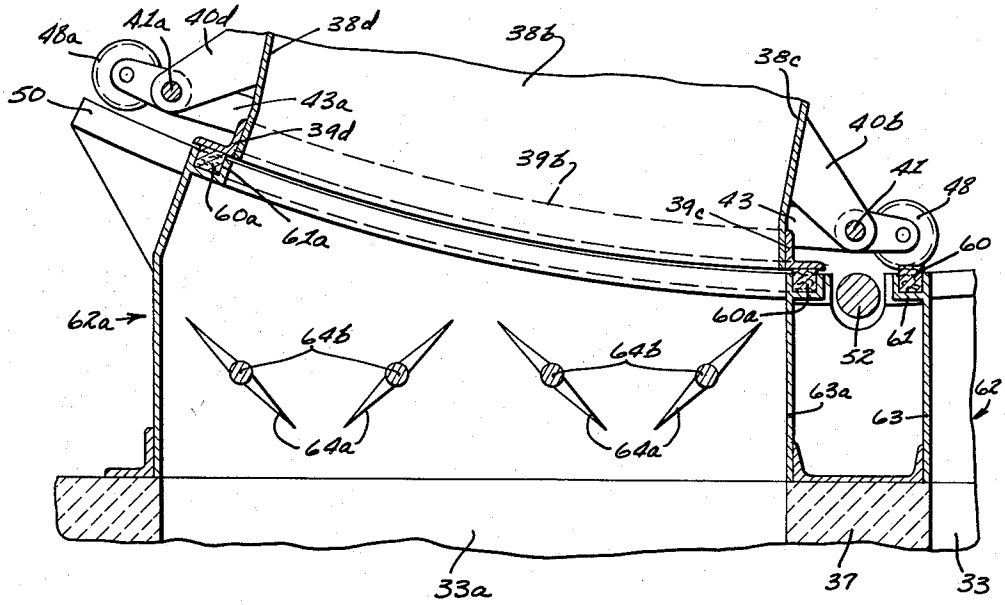


FIG. 9

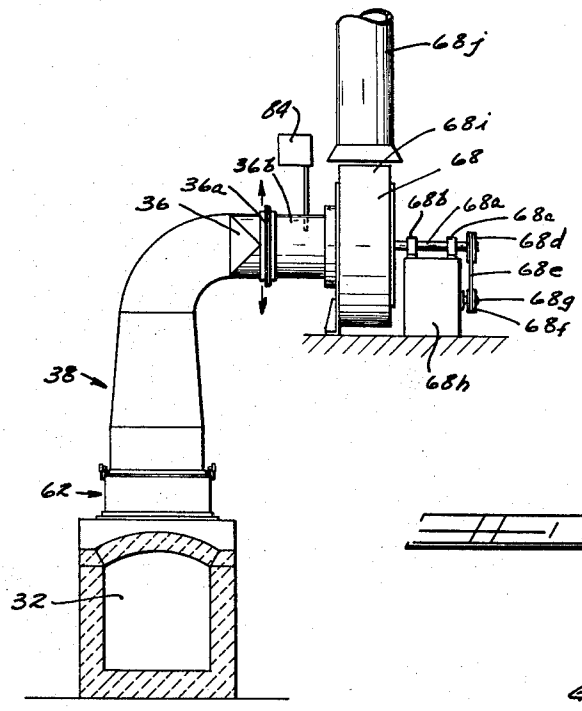


FIG. 10

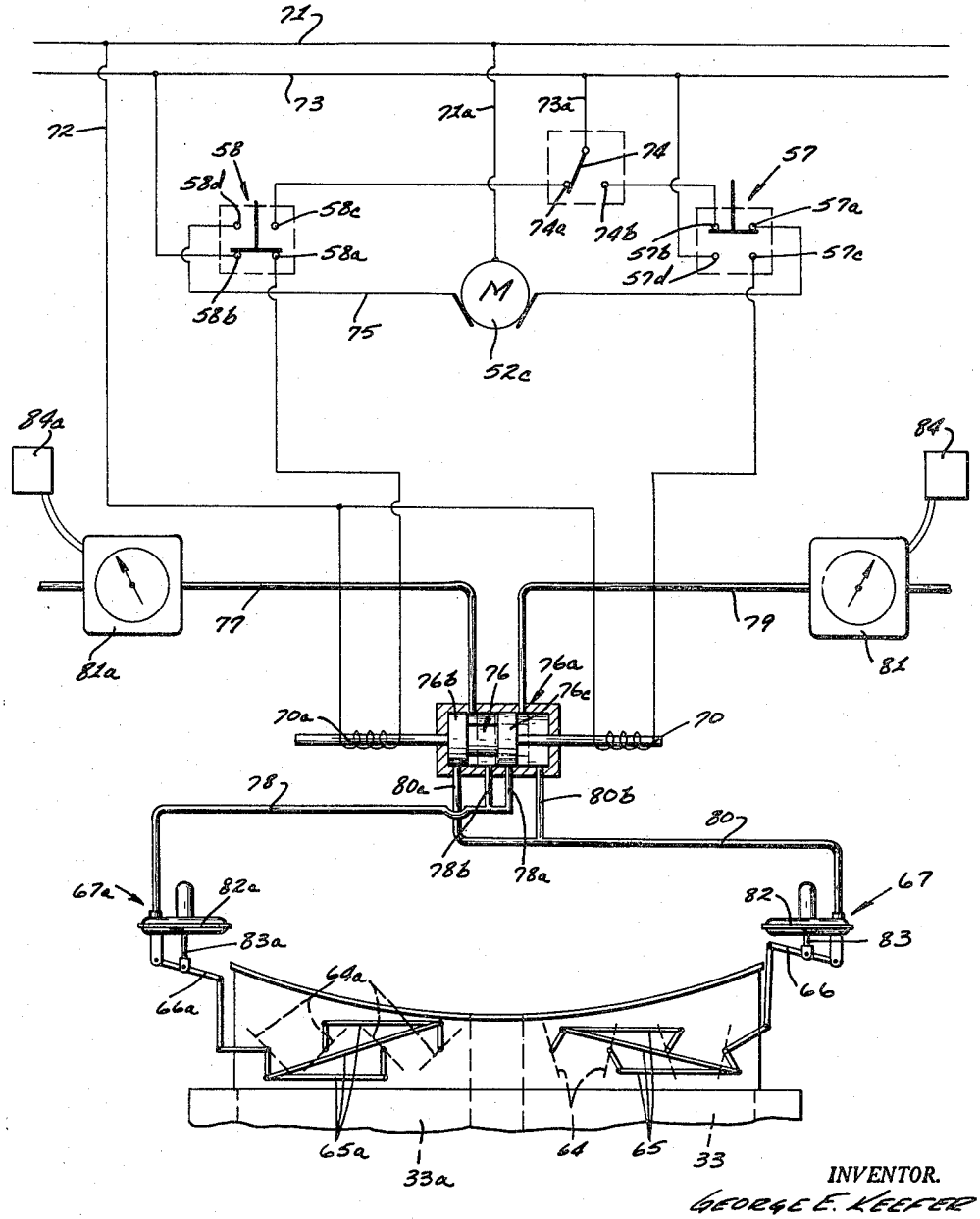
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REGENERATIVE FURNACE DRAFT REVERSAL APPARATUS

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FIG 11



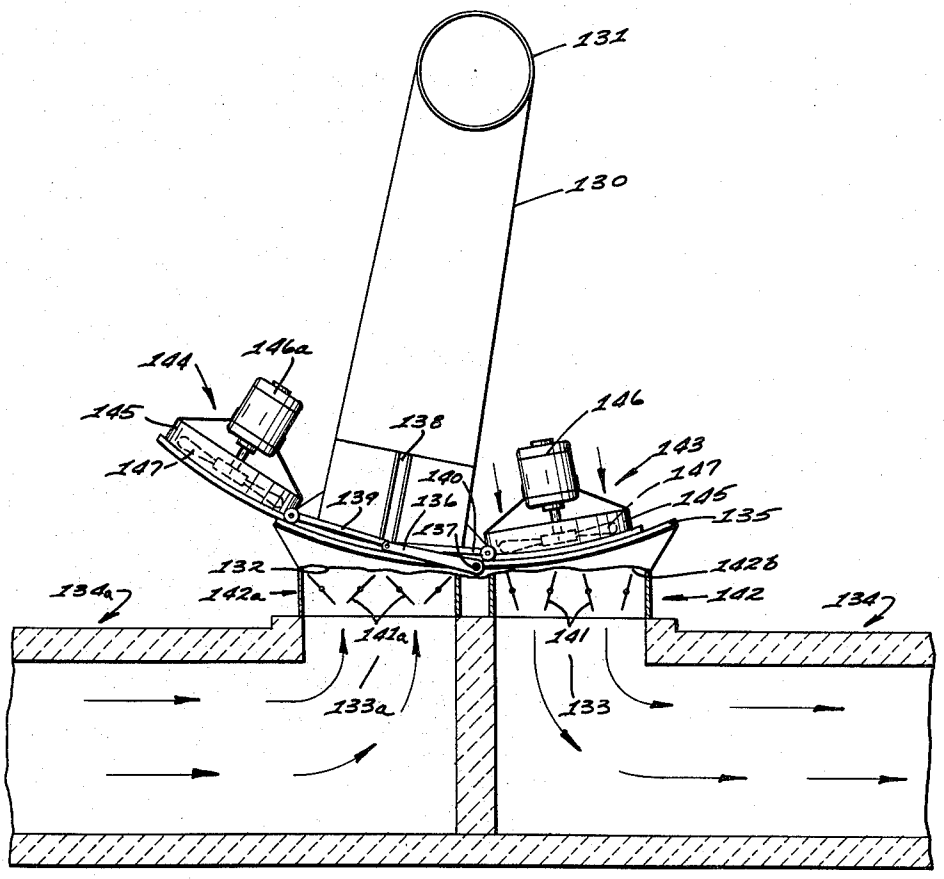
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REGENERATIVE FURNACE DRAFT REVERSAL APPARATUS

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FIG 12



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United States Patent Office 3,170,678 Patented Feb. 23, 1965

3,170,678

REGENERATIVE FURNACE DRAFT REVERSAL APPARATUS

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Filed June 20, 1962, Ser. No. 204,004
24 Claims. (Cl. 263—15)

The present invention relates generally to the art of combustion furnaces.

More particularly, the present invention relates to a glass furnace having opposed regenerative chambers for the temporary storage of heat removed from the combustion zone by the draft system. Even more particularly, the invention relates to an apparatus which is useful in effecting reversal of the flow of the gaseous products of combustion and the combustion air within the furnace and particularly the regenerative system whereby the thermal efficiency of the operation is improved.

A regenerative type furnace of the type with which the invention is concerned has heat storage chambers on opposite sides of the combustion zone proper where the combustion is taking place. These opposed regenerative chambers have an interior constituted of a plurality of bricks, frequently called "checkers," which are so stacked that the air or exhaust gases can pass through them, providing a large surface area for the hot gases to contact. The regenerative chambers each have canals leading therefrom, terminating in openings (referred to as ports hereinafter) which are alternately connected to a stack which may have draft induced therein by a centrifugal blower or other type of fan arrangement. In the operation of such furnaces, wherein one regenerative chamber has had the combustion gases passed therethrough and thence to the stack for a given period, the flow in the system is reversed so that the inlet air is directed through the same regenerative chamber and into the combustion zone while the combustion gases are drawn out the other regenerative chamber to give up heat to the "checkers" therein, as described hereinabove. In such fashion the inlet air proceeding through the "checker" system absorbs heat which has been, as indicated, extracted from the exhaust gases and temporarily stored in the bricks constituting the "checker" system.

As indicated, there are presently reversal apparatus, such as butterfly valves, which serve the purpose of changing the flow of gases within a regenerative system. The butterfly-valve-type of reversal apparatus has been found to leave much desired, primarily because butterfly valves do not make an effective seal and, consequently, the thermal efficiency is not at an optimum. Furthermore, it can be appreciated that with fairly large furnaces that considerable amounts of gases, both of inlet air and of outgoing combustion gases, are involved. As a consequence, the canals, ductwork and ports for handling such volumes have to be quite large. As a consequence, the butterfly type valve must be quite massive in order to span the distances between the walls of the port, etc. Being so large and massive, the considerable heat involved causes considerable warpage of the valve elements, further reducing the sealing efficiency. Operation of these valves is also found to be quite expensive, due to their size and also due to the involved bearing structure necessary to support the shaft thereof. Resource has also been had to a shifting type of ductwork but, unfortunately, it has been accompanied by excessive leakage and also requires considerable cooling, otherwise warpage occurs leading to mechanical jamming in operation. Reversal valves known heretofore have also been found to require a considerable amount of maintenance. Most importantly, none of the reversal valves or reversal type apparatus known heretofore has provided a really effective seal permitting an approach to the theoretical thermal efficiency possible.

Accordingly, it is a principal object of the present invention to provide a reversal apparatus for regenerative type furnaces, which apparatus embodies features providing an extremely tight seal whereby thermal efficiency of the entire system approaches an optimum.

It is another object of the present invention to provide such a reversal apparatus which embodies features permitting quick reversal from a draft or outlet position over one regenerative chamber canal outlet to the other regenerative furnace chamber canal outlet.

It is still another object of the present invention to provide such a reversal apparatus for regenerative type furnace which is easily accessible in terms of the moving parts thereof whereby maintenance which, although at a minimum, can be performed with a minimum of ease.

It is yet another object of the present invention to provide an apparatus of the type described which includes eminently desirable features permitting integral and automatic control of the proportioning of the waste gases or products of combustion in accordance to efficient combustion principles and, at the same time, provide, correspondingly, control of the flow and amount of inlet air in accordance with sound combustion practice.

It is still another object of the present invention to provide an apparatus of the type concerned in which features are embodied permitting reversal of the apparatus utilizing a minimum of power.

The above enumerated objects, as well as others, will become apparent to those skilled in the art from the following detailed description taken in conjunction with the annexed sheets of drawings on which there is presented, for purposes of illustration only, several embodiments of the apparatus of the present invention.

In the drawings:

FIG. 1 is an end elevation view, partly in section and with other portions broken away, of a glass furnace, of the crown top type, having opposed regenerative chambers.

FIG. 2 is a plan view of the furnace shown in FIG. 1 and includes, as does FIG. 1, a disclosure of a draft reversal apparatus of the present invention illustrated in schematic form.

FIG. 3 is an end elevational view of a draft reversing apparatus in accordance with the present invention and illustrated situated over the upwardly facing side by side openings or ports of opposed regenerative chamber canals.

FIG. 4 is a somewhat enlarged view of the draft reversal apparatus showing in more detail certain mechanical features of its construction and a means for effecting movement thereof.

FIG. 5 is a sectional view taken on the line 5—5 in FIG. 4.

FIG. 6 is a sectional view taken on the line 6—6 in FIG. 5.

FIG. 7 is a sectional view somewhat enlarged taken on the line 7—7 in FIG. 5.

FIG. 8 is a sectional view somewhat enlarged taken on the line 8—8 in FIG. 5.

FIG. 9 is a sectional view of the lower portion of the plenum chamber element of the draft reversal apparatus and showing its relationship with other components thereof, and particularly showing the sealing arrangement with one regenerative chamber canal port.

FIG. 10 is a side elevation view showing the relationship of the plenum chamber, the regenerative furnace canal and the draft induced stack.

FIG. 11 is a schematic illustration of the electrical circuitry and the pneumatic controls providing for automatic operation of the draft reversal apparatus in accord-

ance with a preferred embodiment of the present invention.

FIG. 12 is an end elevation view, presented schematically, of another embodiment of the present invention in the form of a reversal apparatus somewhat similar to that illustrated in FIG. 3, but including several other features providing desirable operation under certain conditions.

As will become more apparent from a reading of the description to follow, it may be seen that the apparatus of the present invention is designed particularly for a regenerative system of a furnace wherein side by side ports in canals leading respectively to the opposed regenerative chambers are alternately connected to an induced draft stack. For such a furnace arrangement the apparatus of the present invention comprises arcuate track means extending coextensive with the ports leading respectively to opposed regenerative chambers and a plenum chamber having an upward outlet end and a lower inlet end, said outlet end being sealingly connectible to an induced draft stack, said plenum chamber being pivotable about said outlet, said inlet end including support means adapted to follow said track means for shifting said inlet end on said track means for alternate connection with said ports. As a further embodiment of the present invention, the apparatus includes a manifold ductwork for improving the connection between the ports leading to the respectively opposed regenerative chambers and the lower inlet end of the plenum chamber. In still a further embodiment providing desirable control of the flow of gases through the ports and plenum chamber, the manifold ductwork is provided with a plurality of louvers, blades or vanes of controllable angular attitude providing a control of the free cross-sectional area of the ductwork at a given location and of the flow rate of inlet combustion air or outlet gases.

Referring now more specifically to the drawings, there is disclosed in FIGS. 1 and 2 a crown topped glass furnace **21** containing a pool of glass G in the furnace receptacle **24**. A dog house **26** (FIG. 2) at one end permits introduction of glass forming ingredients while the throat **27** at the opposite end allows drawing off of the molten glass for further processing into finished glass goods. The furnace is provided with opposed regenerative chambers **29** (on the right) and **29***a* (on the left). A plurality of nozzles **30** on the right and like nozzles **30***a* on the left serve to issue a combustible gas, such as natural gas, providing melting conditions for the glass forming ingredients. A stacked network of bricks **31** is contained in each of the regenerative chambers **29** and **29***a* and permits a flow of gases therethrough, as indicated schematically by the arrows. As shown in FIGS. 1 and 2, the gases are proceeding from right to left and only the right hand fuel nozzle **30** is operating while the left hand nozzle **30***a* is in the off position. After combustion, the gases pass down the network of checkers in the left hand regenerative chamber **29***a* and through the left canal **32***a* which terminates in an upwardly facing port **33***a*. As shown in FIG. 2, the left hand outlet port **32***a* is connected to the apparatus **35** of the present invention which directs the gases upward therethrough and out the horizontal pipe **36**. The apparatus pivots about the outlet **36** and can be rotated to the right (as shown in dotted outline in FIG. 1) so that it will be situated over the right hand port **33**, which is in side by side relationship to the port **33***a*. Right hand port **33** is connected to a canal **32**, which is like the canal **32***a* except that it connects with the right hand regenerative chamber **29**. A center wall **37** separates the two canals and aids in defining the upwardly facing ports **33** and **33***a*.

The draft reversal apparatus **35** is shown in more detail in FIGS. 3 through 9. The apparatus includes an upstanding plenum chamber **38** formed of sheet metal and which is connected to the outlet **36** and is open at the bottom. The chamber **38** is a hollow rectangular ductwork that is defined by spaced side walls **38***a*, **38***b* and like spaced walls **38***c* and **38***d* all connected together. Flanges **39***a*, **39***b*, **39***c* and **39***d* are secured respectively to the lowermost edge of each of these walls. Brackets **40***a*, **40***b*, **40***c* and **40***d* are secured to the lower corners of the plenum (FIG. 5). Brackets **40***a* and **40***b* extend outwardly perpendicular to side wall **38***c*, while brackets **40***c* and **40***d* extend perpendicular to the other side wall **38***d*. Shafts **41** and **41***a* in spaced relationship are mounted in rotatable fashion in the brackets **40***a*–**40***b* and **40***c*–**40***d*, as shown most clearly in FIG. 5. Terminal ends of shaft **41** are also rotatably mounted in a pair of spaced parallel right hand lift arms **42** and **43**, which extend along and beneath walls **38***a* and **38***b* from a point beyond the shaft **41** to about half way across walls **38***a* and **38***b*. Shaft **41***a* has its terminal ends similarly rotatably mounted in spaced parallel relationship on opposite sides of the plesimilarly located on the left hand side extending from beyond shaft **41***a* to the right to meet right hand lift arms **42** and **43**. The lift arm pairs **42**–**42***a* and **43**–**43***a* are in spaced parallel relationship on opposite sides of the plenum chamber. Lift arms **42** and **42***a* are generally aligned as are arms **43** and **43***a*. The inner ends of the lift arms include an offset piece **44** which is notched as at **45** in either the upper or lower corner permitting the terminal ends to overlap, as shown best in FIG. 8. These ends of the aligned lift arms are fastened together by a pivotable link connection **46**, see also FIG. 5. Lift arms **42** and **42***a* have rotatably mounted on their outboard extremities flanged wheels **47** and **47***a* respectively, while lift arms **43** and **43***a* have rotatably mounted on their outboard extremities wheels **48** and **48***a*. These wheels ride on spaced arcuate track members **49** (forward side) and **50** (rear side) when the lift arms are in their operating position, as shown in dotted outline in FIG. 4. Flanged wheels **47** and **47***a* function as guides. Tracks **49** and **50** are in spaced relationship and constitute arcs of a circle. The inner ends of the four lift arms, e.g. the ends proximate their link connection **46**, have upwardly extending straps **51** secured thereto as at **51***a*. The straps are in turn secured to a spring **51***b*, which connects with horizontal bracket **51***c* extending laterally outwardly from the plenum chamber wall **38***a* and, likewise but not shown, the opposite wall **38***b*. The spring **51***b*, of which there are four (one on each of the straps **51**) connected to each inner end of the four lift arms, normally urge the inner ends of the lift arms including the link **46** connection in an upward direction, whereby the pivot of the lift arm pairs **42** and **43** about the axle **41** and the pivot of lift arm pairs **42***a* and **43***a* about axle **41***a* maintain the wheels (**47**, **47***a*, **48** and **48***a*) in contact with the track **49** on the forward side and the track **50** on the rearward side. The normal position of the lift arms as urged upward by springs **51***b* is shown in dotted outline in FIG. 4. The position of the lift arms, shown in full line in FIG. 4, raises the wheels off the track and seals the plenum as will be described more fully hereinafter.

Referring to FIGS. 1 and 3, there will now be described the manner by which the plenum chamber is shifted from its position over the port **33***a* to a position over to the right to the port **33**, it being appreciated that port **33***a* leads to the left regenerative chamber **29***a*, while port **33** leads to the right regenerative chamber **29** of furnace **21**. Shifting is accomplished in the following way. Referring to FIG. 5, it can be seen that the plenum chamber **38** is situated over the left hand port **33***a*. Horizontal drive shaft **52** situated over wall **37** between ports **33***a* and **33** is journaled on the forward side in a gear reduction box **52***a* and on the far side in a journaled mounting **52***b*. A motor **52***c* delivers power to the shaft **52** via spaced pulleys **52***d* (on the motor shaft) and **52***e* (on the gear box shaft) carrying belt **52***f*. A forward crank arm **53** and a rear crank arm **54** are secured on the principal shaft **52**, spaced just inward respectively from the gear box **52***a* and the journal mounting **52***b*. The crank arms move upon rotation of the shaft **52**, controlled by gear box **52***a* through the arc (broken line) identified by the reference numeral **100** in FIGS. 3 and 4. The arc of travel of the crank arm

extremities is not quite 180 degrees. The crank arms 53 and 54 move in unison and in parallel relationship upon rotation of the shaft 52. Each crank arm has a boss 53*a* and 54*a* facing inwardly on its extremity upon each of which is mounted in rotatable fashion cylindrical rollers 53*b* and 54*b*. The rollers are adapted to roll in vertical roller guideways 55 (fore) and 55*a* (aft), each being defined by like spaced flange members 55*c* and 55*d*, mounted on forward wall 38*a* and also on rear wall 38*b*. The crank arm 53 only has mounted at its outer extremity finger elements 53*d* and 53*e*. Finger 53*d* is adapted to engage contact 56*a* of left limit switch 58 when the crank arm 53 is in its extreme position over to the left, while finger 53*e* engages contact 56 of right limit switch 57 when the crank arm is at its extreme position over to the right. The limit switches 57 and 58 energize other control features and elements of the present invention and these will be described in more detail hereinafter. For the purpose of urging the inner ends of the four lift arms down pivotably to sealingly seat the plenum, the crank arms 53 and 54 are provided with cam rollers 53*f* and 54*f*. Cam stops 59 are secured to each of the four lift arms in such position as to be contacted by the cam rollers. As the crank or trunnion arm 53 and its companion arm 54 move in the arc of travel, as described, with rollers 53*b* and 54*b* in their guideways 55 and 55*a* respectively, the plenum chamber, supported on the lift arms 42, 42*a*, 43 and 43*a* and turn on the wheels 47, 47*a*, 48, 48*a* resting on tracks 49 and 50, is moved from one position to the other, e.g. from a position over one port 33*a* to a position over the other port 33. The movement of the plenum chamber 38, as described, is controlled by actuation of the motor, such that rotation of the crank arm shaft from its extreme left to the extreme right position takes about 3 seconds. Looking at FIG. 4 and FIG. 6, the trunnion arm 53 is in its extreme counter clockwise position with the plenum chamber 38 situated over the left hand port 33*a*. The springs 51*b* connected to the straps 51 and thence to the lift arms 42 and 42*a*, as shown in full lines, are in extended position. The lift arms have moved from the dotted line position to the latter by the action of the cam rollers 53*f* and 54*f* on the cam stops 59 on lift arms 42 and 43. The link connection between the inner extremities of the lift arms forces the lift arms 42*a* and 43*a* down also, causing a pivoting of all lift arms about their pivot axles 41 and 41*a*, whereby the wheels 47, 47*a*, 48 and 48*a* are lifted up off of the tracks 49 and 50, and the lower flanges 39*a*, 39*b*, 39*c* and 39*d* constituting the lower edge of the plenum 38 are pushed firmly down into compressing contact with asbestos sealing ring 60*a*, which is mounted about the periphery of manifold ductwork 62*a*, as shown in FIG. 9. The asbestos 60*a* is mounted in the peripheral canal 61*a* (FIG. 9), formed in the upper edge of a manifold duct member 62*a* which is also situated over both ports 33*a* and 33. The right hand side over port 33 is similarly constructed and reference to FIG. 3 reveals the right ductwork 62 having asbestos sealing ring 60 mounted in canal way 61 in its upper edge. Walls 63 and 63*a* separate the adapter ductwork 62 from the adapter ductwork 62*a*, creating independent passageways communicating with the openings. Midway between the walls 63 and 63*a* is situated the principal axle 52 to which the trunnion or crank arm 53 is connected for its movement as described, causing the roller bearing end and the limit-switch-shoe bearing end to travel in the path described by the dotted line indicated by the reference numeral 100.

A desirable aspect of the present invention lies in a unique arrangement of louvers or vanes, including controls, which serve to automatically regulate the passage of and the amount of gas flow through the outlet and the inlet ports leading to the regenerating chambers. Referring to FIGS. 3 and 9, there is situated in the ductwork 62*a*, located over port 33*a* and serving to communicate the port with the plenum chamber 38, a series of four spaced blades or louvers 64*a* which extend transversely as shown in FIG. 5. These louvers or vanes 64*a* are controlled as to their angular relationship or attitude by a plurality of levers 65*a* pivotably connected together so that the movement of arm 66*a* will control the attitude of all. The arm 66*a* is controlled by the pressure inside an air diaphragm 67*a*. The louvers 64*a* are shown in dotted lines in FIG. 3. It can be seen that they are individually pivotable on shafts 64*b*.

An air motor 67*a* is shown in block outline form in this FIG. 3 for ease of illustration but is shown in a somewhat simplified schematic illustration in FIG. 11 and will be discussed in more detail in connection with FIG. 11 hereinafter. The louvers or vanes 64*a* situated over the port 33*a* are shown in operative attitude for the control of the passage of waste gases upwardly therethrough and out the plenum 38. That is they are serving to throttle somewhat the free flow of exit gases proceeding upwardly through the plenum 38 and out the outlet 36. The louvers may be adjusted in either of two known manners, one being the opposed blade action which I prefer and disclose on the drawings, and the other being the parallel blade action, which may be likened to the motion of the elements or blades of a common "Venetian blind." The opposed blade action provides a more accurate adjustment and control of the amount of gases proceeding therethrough.

A similar arrangement of louvers 64 are located in ductwork 62, situated over right port 33 which as shown in FIG. 3 is serving as an inlet for combustion air since the plenum 38 is situated in exiting relationship over left hand port 33*a*. The louvers 64 are controlled similarly to the louvers 64*a* in ductwork 62*a*, that is by a plurality of levers 65 pivotably connected together so that movement of arm 66 will control the attitude of the four louvers. The arm 66 is in turn controlled by the air pressure inside air diaphragm motor 67, shown in block form in FIG. 3 but in more detail in FIG. 11. The louvers 64 are illustrated in operative attitude for best controlling the rate of introduction of combustion air to the furnace through the right hand regenerative chamber 29 (FIG. 1). As can be seen in this figure, the louvers are arranged to permit substantial free entry of air and every other louver is in substantial parallel relationship as preferred.

As discussed previously, the plenum chamber 38, depending on its location over one port or the other, serves as a conduit directing the exhaust gases or products of combustion through upper outlet 36. The connection of the latter to the draft system is illustrated in FIG. 10. As can be seen, the outlet 36 has a flanged connection 36*a* to horizontal conduit 36*b*. The flanged connection permits some vertical (indicated by the arrows) movement of the plenum chamber, as necessitated by the downward seating of the plenum caused by the movement of lift arms responsive to engagement of cam rollers 53*f* and 54*f* with cam stops 59. Conduit 36*b* connects to the center inlet of a centrifugal blower 68 having a central shaft 68*a*, mounted in journals 68*b* and 68*c*, terminating therebeyond in a connected pulley 68*d*. The pulley 68*d* is connected by belt 68*c* to pulley 68*f*, mounted on shaft 68*g* which is driven by motor 68*h*. Blower 68 has a peripherally located outlet 68*i* which connects to the hooded stack 68*j*, extending vertically up into the air.

Reference may now be had to FIG. 11, wherein there is illustrated the circuitry for sequential energization of the principal drive motor 52*c* which controls the movement of the crank arm 53 via the limit switches 57 (on the right) and 58 (on the left). Included in the circuitry, which will be described more in detail just following this introductory remark, are two solenoid coils 70 and 70*a*. These coils on energization provide for a shifting control of the air diaphragm 67 and 67*a* for respective ad-

justment of the attitude of the left hand louvers 64*a* and right hand louvers 64, depending on whether they are to control the flow of the inlet combustion air or the outlet waste gases.

Line current, as indicated, enters the circuitry on line 71 and may pass via line 72 through one or the other of the solenoid coils 70 or 70*a*, depending upon the position of the terminal contacts of limit switches 57 and 58 returning thence to line 73. As shown, right solenoid 70*a* would be energized while left solenoid 70 would not. Line current from line 71 can also pass through line 71*a* to motor 52*c*, depending upon the contact of the poles of the limit switches referred to and also depending upon the connection of the main reversal switch 74 which is connected to the other main current line 73. The main reversal switch 74 contacts either with contact 74*a* or contact 74*b*. This main reversal switch is controlled either manually or by a timer. Since timers are well known in the art, they will not be discussed further. In this operation the time is usually adjusted to cause contact with 74*a* and then contact 74*b* on twenty or thirty minute cycles. Left limit switch 58 is shown in a depressed position. It is connecting contacts 58*a* and 58*b*, thus putting the solenoid coil 70*a* in series connection with the main current lines 71 and 73. The limit switch 58 in its normally closed (or released) position would be connecting contact 58*c* and 58*d* and thus putting the line current 71 in series connection with the motor 52*c* via line 75, the contacts 58*c* and 58*d*, the main reversal switch contact 74*a* to line 73*a* and to line 73. Limit switch 57, as shown, is in its normally closed position connecting contacts 57*a* and 57*b*. In this position the motor 52*c* is disconnected because the main reversal switch contact 74*b* is not connected to line 73. In its open position limit switch 57 will connect contacts 57*c* and 57*d*, energizing the right hand solenoid coil 70, since it will be in series with line current 71, through line 72, through the limit switch, and thence to line 73. Sequential energization of solenoid coils 70*a* and 70 causes piston 76 within barrel 76*a* to move from an extreme left hand position, shown in full line, to an extreme right hand position, shown in dotted line. The piston 76 includes two spaced land elements 76*b* and 76*c* which are separated by a central portion of lesser diameter leaving an inner annular chamber. The land elements, depending on their position, serve to allow connection of two inlet lines on one side of the piston to two of the four outlet lines on the other side while blocking the other two lines in the following manner. The position of the piston 76, as shown in full line, connects line 77 with line 78 (leading to left hand air diaphragm motor 67*a*) and line 79 with line 80 (leading to right hand air diaphragm motor 67) since outlets 80*a* and 78*a* are blocked by the lands 76*c* and 76*b*. Now when piston 76 is shifted to the right (shown in dotted line) the previously blocked outlets 80*a* and 78*a* will be in communication respectively with inlet lines 77 and 79 while the previously open outlets 80*b* and 78*b* will be blocked, whereby inlet 77 is in direct line connection with line 80 (leading to the right hand air diaphragm motor 67) while inlet 79 connects with line 78 (leading to the left hand air diaphragm motor 67*a*). There has thus been described in extremely simplified fashion a four-way reversal valve, permitting control air from a furnace pressure controller 81*a* and control air from a combustion air controller 81 to be reversed from one air diaphragm motor 67*a* to the other 67, and vice versa. A commercial four-way valve controlled by dual solenoids, suitable for use in the reversal of controls as described herein, is manufactured by the Automatic Switch Company of Florham Park, New Jersey.

With the elements connected, as shown in FIG. 11, control air from furnace pressure controller 81*a* is connected directly to air diaphragm motor 67*a*. The amount of air pressure exerted on the diaphragm 82*a* will determine the vertical travel of stem 83*a* thus controlling, through the control arm lever 66*a* and the connected series of levers 65*a*, the position or attitude of the louvers 64*a*. Similarly, the right hand combustion-air controller 81 will be connected to the right hand air diaphragm motor 67 and, depending on the air pressure in the line 79, will exert pressure on the diaphragm 82, thus determining the vertical extension of stem 83 which is connected to control arm lever 66 and thence to the connected series of levers 65, thereby adjusting the spatial attitude of the right hand louvers 64. The furnace presser controller 81*a* is connected to and receives an impulse from a pressure responsive element 84*a* located within the combustion zone of the furnace (see FIG. 2). The furnace pressure controller 81*a* is well known in the art and need not be described in detail. One such suitable device is manufactured by Bailey Meter Company of Cleveland, Ohio. The pressure controller 81*a* is supplied with high pressure air (15–25 lbs., for example) which is reduced in response to furnace chamber pressure changes and delivered through the line 77 and thence to either the air diaphragm motor 67*a* or the air diaphragm motor 67. It is normally so adjusted that pressures between 0.05 to 0.2 inch of water pressure in the furnace will be reflected in an appropriate air pressure in line 77 sufficient to control the extent of the travel of stem 83*a*, thereby controlling the spatial attitude of the louvers 64*a* anywhere from a substantially full open to a substantially full closed position.

Combustion air controller 81 (on the right in FIG. 11) is adapted to receive an impulse from an oxygen measuring device 84 located in the stack 68*j* (FIG. 10). This oxygen measuring element 84 is adapted to analyze the exhaust gases in the stack 68*j* for oxygen content and need not be described in detail since it is well known. In place of the combustion air controller 81 measuring the oxygen content of the waste gases, I may use an air flow meter or a fuel/air ratio control meter. These devices are known and their normal function in furnace operation is understood by those skilled in the industry. These latter devices are manufactured by Bailey Meter Company of Cleveland, Ohio. The controller 81 receives an impulse from the oxygen measuring element 84 and, depending on the oxygen content, it adjusts line air pressure to a lower value. The pressure via line 79 and line 80 acts on the air motor 67. Depending on the pressure, the motor controls the extent of stem 83 in a vertical direction thereby controlling the spatial attitude of the louvers 64 via the control arm levers 66 and the connected levers 65.

It should be understood that the foregoing presents a description of an automatic control means for adjusting the louvers; however, they may be properly adjusted by hand or means other than the example described.

It is a feature of the present invention that the utilization of the schematically shown four-way valving arrangement illustrated by the cylinder 76 and the piston arrangement 76*a* permits the system to be reversed. That is, the furnace pressure controller 81*a*, instead of controlling the left hand louvers 64*a*, may through the valving arrangement and the appropriate lines be connected to the right hand air motor 67 controlling the right hand louvers 64. Conversely, the combustion air controller 81, which is responsive to the oxygen content of the exhaust furnace gases, can exert its air control, through the solenoid valving arrangement, to the left hand air diaphragm motor 67*a* controlling the left louvers 64*a*.

The elements, switches, solenoids, diaphragm motors, louvers, as now illustrated in FIG. 11, are so connected and set up that the plenum chamber (though not shown in this figure) is situated over the left hand canal port 33*a* and the louvers 64*a* are in exhaust attitude, while the right louvers 64 over the port 33 are in the proper spatial attitude for allowing combustion air into the right

hand canal 32, up the right regenerator chamber 29 and into the furnace. The piston 76 of the four-way control valve 76*a* is in its left-most position with the furnace pressure controller 81*a* supplying air to the diaphragm motor 67*a*, thereby controlling the left louvers 64*a* via the connected linkages 66*a* and 65*a*. At the same time, the crank or trunnion arms 53 and 54 are in their left-most or counterclockwise position with the shoe 53*d* on arm 53 engaging contact element 56*a* (FIG. 4) of limit switch 58, thereby connecting contacts 58*a* and 58*b*, as shown (see FIG. 11). In this position contacts 58*c* and 58*d* are not connected and no current flows in motor 52*c* which is therefore off. At the same time, contacts 58*a* and 58*b* are connected and the current is flowing in line 72 from the main current line 71 to main current line 73, whereby the coil 70*a* is energized, keeping the piston 76 in its left-most position in the barrel 76*a*, whereby the air pressure from the controllers 81*a* and 81, responsive to furnace pressure and stack gases oxygen content respectively, travels to the proper air diaphragm motors 67*a* and 67 to control the louver sets 64*a* and 64, as indicated hereinabove. To shift the plenum chamber 38 and reverse the other auxiliary components, one need simply throw contact switch 74 to the right to contact pole 74*b*, disconnecting 74*a*. This switch 74 is simply a two-position switch and, as indicated, can be controlled by an automatic timer adjusted to reverse the switch from one contact point 74*a* to the other contact point 74*b* at preselected desired time intervals, such as every 15 to 20 minutes. With switch 74 contacting pole 74*b* line current is supplied across limit switch contact 57*a* and 57*b*, energizing the motor 52*c* whereby it rotates in a clockwise direction, indicated by the arrow. As the motor turns, the trunnion or crank arms 53 and 54 mounted on shaft 52 and acting through the gear reducer 52*a* rotate clockwise to the right, immediately disengaging limit switch 58 (since finger 53*d* will no longer be in contact at 56*a*), whereby contacts 58*a* and 58*b* are disconnected and contacts 58*c* and 58*d* are connected by the return of the switch to its normal closed position. The disconnection of contacts 58*a* and 58*b* de-energizes solenoid coil 70*a*. The continued clockwise movement of the crank arms 53 and 54, of course, releases the pressure of cam rollers 53*f* and 54*f* on the cam stops 59 located on lift arms 42 and 43 and thereby releases pressure on lift arms 42*a* and 43*a* exerted by linkage 46. As a consequence, the stretched springs 51*b* retract, urging the inner ends of all four lift arms upwards, causing a pivoting thereof about the spaced axles 41 and 41*a* whereby the four wheels 47, 47*a*, 48 and 48*a* engage the tracks 49 and 50. All this foregoing is practically instantaneous and continued clockwise movement of the trunnion arms 53 and 54 causes the rollers 53*b* and 54*b* to pass up the guideways 55 and 55*a* contacting spaced flange members 55*c* and 55*d*, causing the plenum chamber 38 to shift to the right. It will be appreciated that the action of the springs lifting the plenum chamber 38 also lift the flanges 39*a*, 39*b*, 39*c* and 39*d* at the lower edges of the plenum 38 off of the peripheral asbestos sealing ring 60*a*. The plenum chamber thus supported on the lift arms 42, 42*a*, 43 and 43*a* and in turn on wheels 47, 47*a*, 48 and 48*a* passes to a position over the right port 33 and as the trunnion arms 53 and 54 passes downward to the right, the cam rollers 53*f* and 54*f* will engage the cam stops 59*g* (FIG. 4) on the left lift arms 42*a* and 43*a*. The latter are linked, as at 46, to right lift arms 42 and 43 and the inner ends of all of the lift arms are forced downward against the upward urging of springs 51*b*, causing a pivoting of the arms about the shafts 41 and 41*a*, lifting the wheels 47, 47*a*, 48 and 48*a* off the tracks 49 and 50 and bringing the flange 39*c* about the bottom edge of the plenum 38 into contact with the asbestos sealing ring 61 about the upper edge of ductwork 62. The plenum will now be in position over right hand port 33 and ready for exhaust of gasses through the right hand regenerator chamber of the furnace while the port 33*a* will be unobstructed (except by the spatial attitude of louvers 64*a*) to receive inlet air.

As the trunnion arms 53 and 54 reaches the right-most position, the finger 53*e* will engage contact 56 (FIG. 3) of right hand limit switch 57, which is mounted proximate the track 49. This opens contacts 57*a* and 57*b* interrupting current flow, thus de-energizing the motor 52*c*. At the same time, it connects contacts 57*c* and 57*d*, energizing coil 70 and causing the piston 76 within the barrel 76*a* to move to the right position, shown generally in dotted line. In this position the four-way valve connections are such that the combustion air controller 81 is supplying air through line 79, through the valve 76*a*, to line 78 and thence to the left hand air diaphragm motor 67*a*, controlling in turn levers 66*a* and 65*a* and left louvers 64*a*. This is desirable, of course, since the plenum chamber 38 is no longer thereabove but is now situated for exhaust over the right hand port 33. At the same time, the furnace pressure controller 81*a*, is supplying air through line 77, through the valve arrangement 76*a* and thence to the right hand air diaphragm 67, controlling in turn levers 66 and 65 and the exhaust attitude right hand louvers 64. Reversal of the entire operation, that is, the reversal of the plenum chamber from the right hand position to the left hand position, as well as reversal of controls, etc., is accomplished simply by either manually throwing the reversal switch 74 or having it controlled by a timer at the appropriate time sequence, as indicated hereinabove.

As hereinabove indicated, the reversal apparatus in accordance with the present invention provides an extremely efficient valving control of the flow of combustion air introduced to the regenerative furnace system and the existing of waste gases from the system. The change over in direction of flow in the regenerative chambers can be accomplished simply and speedily. Furthermore, the automatic cycling and automatic adjustment of the rate of flow of the inlet air and waste gases, as permitted by the control features of this invention operating in combination with the shiftable reversal apparatus, provides essentially operator-free operation.

A further embodiment of the apparatus of the present invention is illustrated in FIG. 12, wherein there is disclosed a shiftable plenum chamber 130 having an upper outlet 131 and a lower inlet 132. The mechanism for shifting the plenum from a left hand position over port 133*a* to a position over the right hand port 133 is shown schematically. The general purpose of the apparatus, in accordance with this embodiment, is the same as the previous embodiment. The canals 134*a* and 134 are separate and are connected respectively to a left hand regenerative and a right hand regenerative chamber (not shown) of a regenerative furnace of the type described hereinabove. The plenum chamber is shifted on tracks 135 which are the same as described earlier and is caused to move by action of a crank arm 136, provided about a driven power shaft 137, driven by a motor and gear reducer connection, not shown, but similar to that described in connection with FIGS. 1–11. The terminal end of the crank arm 136 contains a roller which moves in a track way 138 to shift the plenum chamber 130 from a left hand position to a right hand position. Furthermore, the plenum chamber is supported on the lift arms 139 and 140. The corresponding rear left arms are not shown in this view for ease of illustration. Louvers 141 and 141*a* independently controlled are located beneath the plenum in an adapter ductwork, indicated by the reference numeral 142. In accordance with this embodiment the plenum chamber carries, secured thereto on the right and left, a pair of units 143 and 144, respectively. The units are identical and are composed of a ductwork 145 adapted to sealingly engage the upper opening 142*b* in the ductwork 142. A motor 146 is mounted in the ductwork 145 which drives a

fan 147 for the purpose of positively driving fresh combustion air in the direction indicated by the arrows. Unit 144 is like unit 143, but sealingly engages the upper opening of left ductwork 142*a*.

With the arrangement as shown in FIG. 12, no matter which canal 134 or 134*a* is being exhausted by the plenum connection, the opposite port will have situated thereover a unit capable of instantaneously supplying forced combustion air. The motors 146 and 146*a* in the units 143 and 144 can be connected to run all of the time or they can easily be controlled by the same limit switches, discussed hereinabove, or different limit switches. Thus, deenergization of the principal drive motor 52*c* could at the same time, by a suitable switch, energize either the motor 146 or 146*a*. Thus, while the drive motor is at rest, either the motor 146 or 146*a* would be in operation.

The reversal apparatus described hereinabove is composed of easily accessible components for purpose of maintenance. Experience indicates that maintenance is minimal since the apparatus does not include any components particularly vulnerable to the operating conditions encountered. The apparatus is uniquely conservative of power requirements since gravity itself aids in the shifting of the bottom of the plenum in its path from up on one side of the circular tracks to the other side. All of the components of the apparatus, including controls and circuitry, are uniquely combined to yield an optimum in trouble free performance providing at the same time enhanced thermal efficiency through improved sealing arrangements.

From the foregoing description it can be seen that I have provided a new and novel furnace reversible exhaust apparatus and controls therefor, which apparatus controls provide advantageous features not known heretofore. Modifications may be resorted to without departing from the spirit and scope of the invention.

I claim:

1. A reversal valving apparatus for a regenerative type combustion furnace, said apparatus being adapted for alternate communication with first one and then the other of canal ports leading from opposed regenerative chambers of said furnace, said ports being located in proximate relationship, said apparatus comprising vertically arcuate track means, said track means being adapted to extend coextensively with said ports, plenum chamber means having an upper outlet and a lower inlet end, said upper outlet being adapted for pivotable connection to an exhaust stack, rollable support means carried on said lower inlet end, said rollable support means being adapted for rolling engagement with said track means and means for shifting said lower inlet end, via said support means, in an arcuate path along said track means from a position adapted for communication with one of said ports to a position adapted for communication with the other of said ports.

2. A reversal apparatus for a regenerative type combustion furnace, said apparatus being adapted to sealingly connect with first one and then the other of canal ports leading from opposed regenerative chambers of said furnace, said ports being located in proximate side by side relationship, said apparatus comprising vertically arcuate track means having symmetrical upwardly curving extremities, said track means being adapted to extend coextensively with said ports, chamber means having an upper outlet end and a lower inlet end, said upper outlet being adapted for connection to a draft induced stack in such fashion that said chamber may pivot about said connection, said lower inlet end being adapted for sealing connection to either of said ports, means for shifting said lower inlet end in an arcuate path on said track means from a position adapted for communication with one of said ports to a position adapted for communication with the other of said ports and means for raising and lowering said chamber means in sequential relationship with said shifting.

3. A reversal apparatus for a regenerative type combustion furnace, said apparatus being adapted to sealingly connect with first one and then the other of canal ports leading from opposed regenerative chambers of said furnace, said ports being located in proximate relationship, said apparatus comprising chamber means having an upper outlet and a lower inlet end, said upper outlet being adapted for pivotal connection, to a draft induced stack, said lower inlet end structure being adapted for sealing connection to either of said ports, means for shifting said lower inlet end in an arcuate path from a position adapted for communication with one of said ports to a position adapted for communication with the other of said ports and means for raising and lowering said chamber means in sequential relationship with said shifting.

4. Apparatus for cyclically shifting an upright duct from communication with a first port to communication with a second port, said ports lying in side by side relationship, said apparatus comprising vertically curvilinear track means adapted to extend coextensively with said ports, follower means engaging said track means, means supporting said upright duct on said follower means, a drive shaft driven to reversibly rotate through an arc of not more than 180°, a crank arm means secured to said shaft, a member projecting normal to said crank arm and a guide track means vertically and centrally mounted on said upright duct with said member movably located in the bottom end of said guide track means when the shaft is at one extremity of its rotation with said duct in a position adapted for communication with said first port, whereby rotation of said drive shaft will move said crank arm means causing said member to contact said guide track moving said duct on said follower means along said curvilinear track means to a position adapted for communication with said second port as said member slides upwardly and downwardly in said guide track means.

5. Cyclical valving apparatus for first and second ports leading respectively to a central zone desirably subjected to reverse fluid flow, said apparatus comprising arcuate track means adapted to extend coextensively alongside said first and second ports, a plenum chamber means including an inlet end and an outlet end, rollable support means carried on said inlet end and supportingly riding on said track means and means for shifting said inlet end along said track means thereby being adapted for alternate communication with said ports, said outlet end being adapted for connection with an induced draft stack, whereby said ports are adapted to serve alternately as inlet and outlet ports for said zone.

6. Valving apparatus for regenerative furnace canals provided with side by side ports, said apparatus comprising a base duct member adapted to enclose said ports, said duct member having a center wall dividing said duct member into two adjacent passageways adapted for substantially sealing registry with said ports, a plenum duct member located adjacent said base duct member and having an inlet end and an outlet end, said outlet end being adapted for connection with a draft induced stack, said inlet end having an edge adapted to sealingly contact and edge defining an opening of either of said passageways in said base duct member, and means for shifting said inlet end of said plenum member from a position adapted for communication with one of said passageways to a position adapted for communication with the other of said passageways.

7. Valving apparatus as claimed in claim 6, which includes in each of said base duct passageways an independent array of adjustable blade louvers for regulating the flow of gases therethrough.

8. Valving apparatus as claimed in claim 7, wherein said blade louvers are horizontally disposed in side by side relationship and are pivotable about a central horizontal axis.

9. Valving apparatus as claimed in claim 8, wherein said blades in each of said arrays are linked together with

every other blade maintained in parallel relationship to provide an opposed blade action.

10. Valving apparatus as claimed in claim 7, wherein one array of louvers is shiftable in spatial attitude responsive to a preselected stimuli, and the other array of louvers is shiftable in spatial attitude responsive to a different preselected stimuli.

11. Valving apparatus as claimed in claim 10, which includes means for reversing the response stimuli from one array to the other array.

12. Valving apparatus as claimed in claim 10, wherein said first mentioned stimuli is the pressure in said furnace proper and said different stimuli is the oxygen content of the gaseous products of combustion of said furnace.

13. A valving apparatus as claimed in claim 12, wherein said different stimuli is the volume of air passing through the inlet port.

14. A valving apparatus as claimed in claim 12, wherein said different stimuli is the ratio of fuel supplied to the furnace and air fed to the furnace.

15. Valving apparatus as claimed in claim 6, which includes track means adapted to extend coextensively with said ports and follower means on said inlet end engaging said track means and supporting said plenum duct member for accomplishing said shifting movement of said inlet end.

16. Valving apparatus as claimed in claim 15, wherein said track means is curvilinear and symmetrical.

17. Valving apparatus as claimed in claim 15, wherein said track means is curvilinear, has symmetrical upwardly curving extremities and has a mid point centrally located between said ports.

18. Valving apparatus as claimed in claim 1, wherein said last mentioned means include a reversible drive motor operatively linked to shift said plenum, a first switch means, a second switch means, a third actuation switch means, control circuitry connecting said switches and a trip finger moving with said chamber, said first switch being located adjacent one port and said second switch being located adjacent said other port, both lying in the path of said finger, said third switch being controlled to actuate said motor to shift said lower inlet end in any preselected time sequence, said motor being de-energized by contact of said finger with either said first or second switch and remaining de-energized until actuated by said third switch upon which said motor will operate in a direction reverse from that of its previous actuation, thereby shifting said plenum in its arcuate path.

19. A valving apparatus as claimed in claim 7, which includes first sensing means responsive to a first stimuli, first control means for adjusting the attitude of one array of blade louvers responsive to said first sensing means, second sensing means responsive to a second stimuli, and second control means for adjusting the spatial attitude of the other array of blade louvers responsive to said second sensing means.

20. A valving apparatus as claimed in claim 19, which includes a third control means responsive to the position of said lower inlet end, and wherein said first and second control means are responsive to said third control means to thereby reverse their responsiveness to said first and second sensing means.

21. A reversal valving apparatus for adjacent ports each independently communicating with a central firing zone desirably subjected to reverse flow therein, said apparatus comprising a principal upstanding exhaust plenum chamber having an upper outlet adapted for connection to an induced draft stack and a lower open inlet end, said chamber pivoting about a horizontal axis such that said inlet end moves in an arcuate path, means for shifting said inlet end from a first position to a second position in repeating sequence, means adapted to effect a sealing connection of said inlet end with said ports proximate said position in sequence, support means on both sides of said inlet end, and a pair of forced air units carried on said supports, said units thereby shifting with said inlet end and being so positioned that each is adapted for registering relationship with one of said ports when the inlet end is in sealing exhaust connection with the other port.

22. In a furnace composed of a (1) principal firing zone, (2) opposed regenerative chambers connecting with said zone for alternate contact with (*a*) exhaust products of combustion and (*b*) introduced combustion air, said chambers extending independently to a location remote from said zone and each terminating in an upwardly opening port situated in side by said relationship with the other port; an improved valving manifold apparatus for effecting alternate flow in said regenerative chambers, said apparatus comprising (1) a vertically upstanding hollow plenum chamber having an open base, said plenum chamber having an opening in its upper portion and including means for sealingly connecting said opening to an induced draft stack discharging to the outside atmosphere, and (2) means for shifting said plenum chamber base through an arcuate path from a position where said open base sealingly communicates with one of said ports to a position where it sealingly communicates with the other of said ports, whereby exhaust is alternately induced in the opposed regenerative chambers while combustion air is alternately drawn in through the opposite port and through the opposite regenerating chamber to be heated up and introduced with combustible gas into said zone.

23. In the method of reversing gaseous flow in a combustion furnace having opposed regenerator chambers, said chambers each having canals terminating in independent proximately located ports, and wherein use is made of an upstanding plenum conduit chamber connected to an induced draft stack, the steps of arranging said ports so that the normal axis of each describe essentially radii of a common circle and said axis are on opposite side of vertical, supporting said chamber so that it is pivotable about a horizontal axis in its upper end while in communication with said stack periodically urging the lower end of said plenum to move in a circular arc congruent with said first mentioned circle, and sequentially connecting said lower end of said plenum chamber with first one of said ports and then the other of said ports.

24. A valving apparatus adapted for selective sequential communication with port openings in each of two canals connected to opposed regenerator chambers of a regenerative furnace, said apparatus being adapted for connection with induced draft means whereby said openings are subjected to exhaust conditions in sequence, said apparatus comprising a plenum chamber, rollable support means on said chamber, track means adapted to extend coextensively with said port openings, said support means riding on said track means in reciprocating fashion, and sealing means adapted to establish sealing connection of said chamber with first one and then the other of said port openings, as said plenum shifts in reciprocating fashion.

References Cited in the file of this patent

UNITED STATES PATENTS

83,176	Laird et al.	Oct. 20, 1868
1,476,534	Meyer	Dec. 4, 1923
1,825,815	Nye	Oct. 6, 1931
2,118,799	Willets	May 24, 1938
2,780,983	De Roo	Feb. 12, 1957
3,017,899	Goldsmith et al.	Jan. 23, 1962