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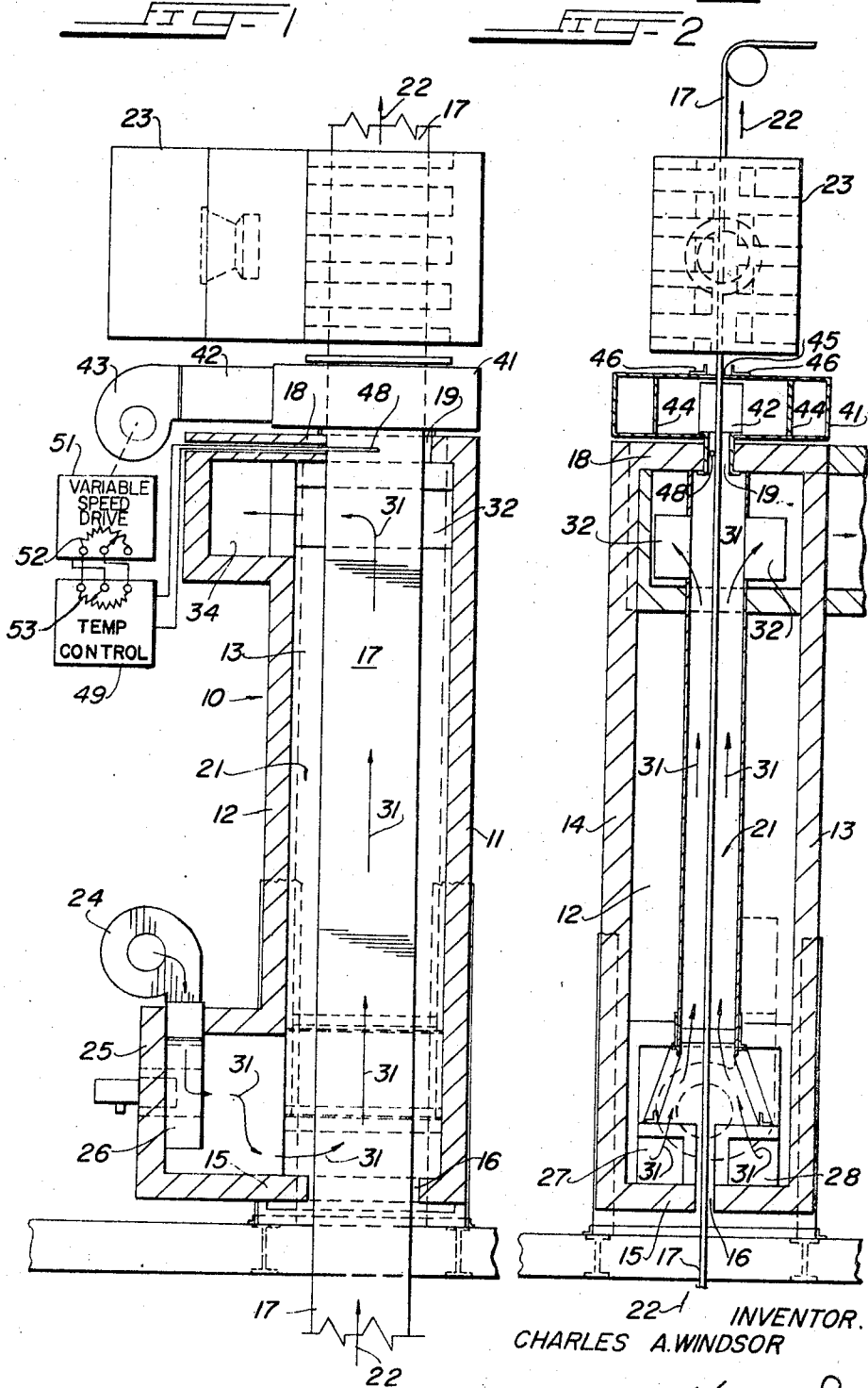
C. A. WINDSOR

3,448,969

FLUID PRESSURE SEALING SYSTEM FOR PROCESSING OVEN

Filed Jan. 8, 1968

Sheet 1 of 2



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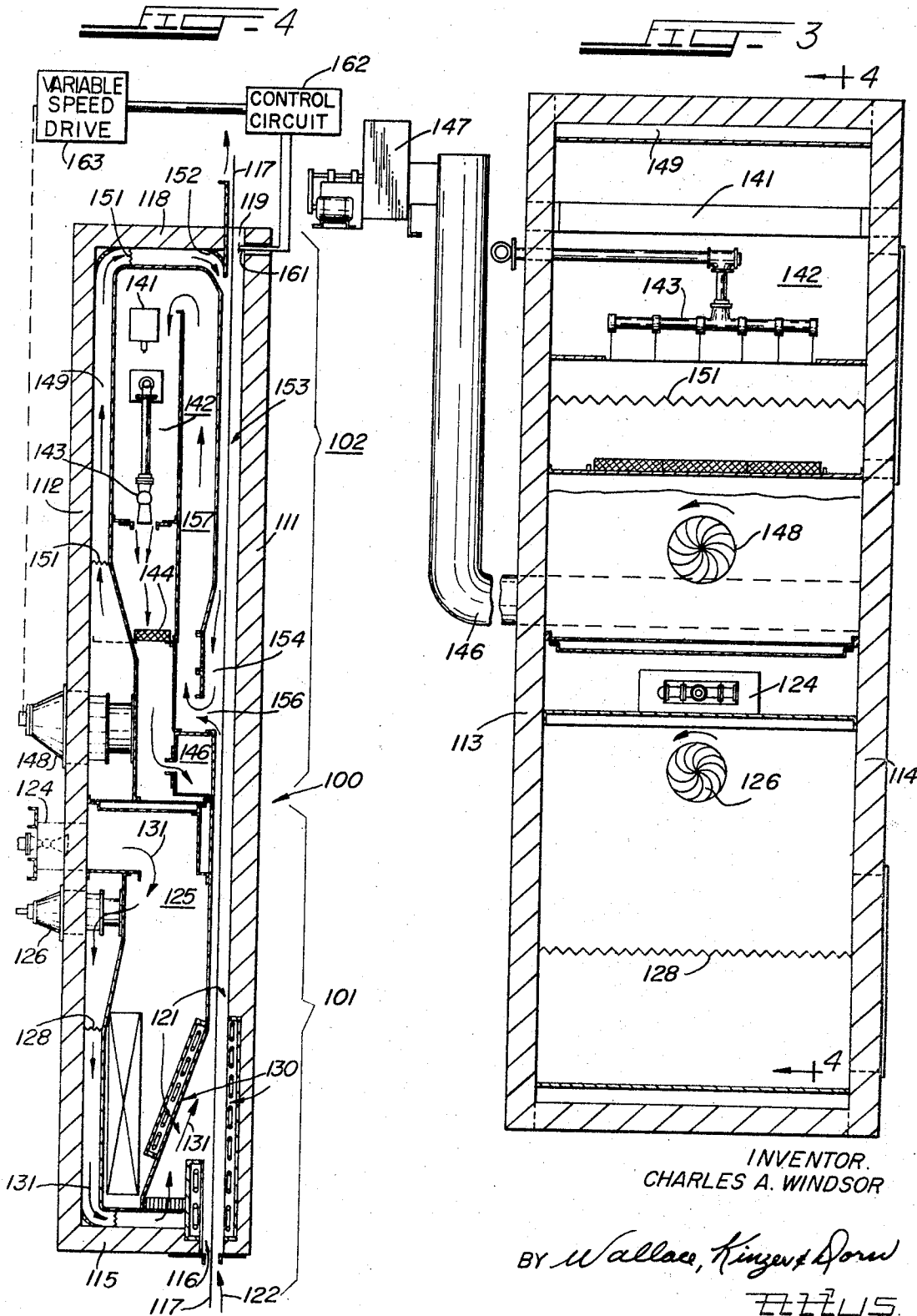
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Sheet 2 of 2



1

2

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FLUID PRESSURE SEALING SYSTEM FOR PROCESSING OVEN

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6 Claims

ABSTRACT OF THE DISCLOSURE

An automatic control for preventing excess leakage of gas inwardly or outwardly from the upper opening in a continuous-strand processing oven employing an air pressure seal. Two oven structures are described; one is a foil-coating oven using a pressure box seal and the other is a wire-enamelling oven using a venturi seal. In each, a thermocouple or other thermal sensor located in the upper opening controls the speed of a blower to maintain an effective seal and prevent excessive leakage.

Background of the invention

There are a number of heating processes in which the best configuration for the oven or furnace is a vertical tower having openings at the top and at the bottom through which the work enters and leaves the oven. This is particularly true with respect to processes involving a continuous web, strip, filament or wire, referred to generically throughout this specification as a "strand." There are also a number of processes of similar nature in which the work is passed through a vertical oven, either on a continuous conveyor or by gravity, which require a similar oven construction.

In a vertical oven with openings at the top and the bottom there is a natural draft effect tending to pull cold air into the bottom of the oven and to discharge hot air out of the top of the oven. This natural draft effect wastes heat and makes it difficult or impossible to maintain adequate control over the operating temperatures in the oven. Moreover, the discharge of hot air from the top of the oven heats the area above the oven excessively unless some effective means of sealing the top opening in the oven is provided. Since the continuous strand or other work must pass through the opening at the top of the oven the seal at that opening must be achieved by air pressure or air current.

The most commonly used means for sealing the top opening in a vertical pass-through oven entail the use of either a pressure box or a venturi nozzle. For a pressure box seal, an enclosure is built around the top opening of the oven, this enclosure having a top opening of its own through which the work passes. The pressure enclosure or box is connected to a blower and air is blown into the box on either side of the work in a carefully distributed manner. This air escapes from the top of the pressure box through the opening that passes the work. The opening at the top of the pressure box and the volume of air blown into the box are adjusted in relation to each other so that the pressure drop of the air leaving the top opening in the box is essentially equal to the stack or draft effect within the oven. Thus, when the pressures below and above the top opening in the oven are equal there is no appreciable flow of air either into or out of the top opening in the oven. Pressure box seals of this general kind are shown in Patent No. 3,183,605 of Argue et al. and in Patent No. 3,186,698 to Thome.

In a venturi seal, the recirculating air in the top portion of the oven is blown downwardly into the oven through a wide nozzle constructed to produce a low pressure ef-

fect above the point where the recirculating gases enter the oven. The combination of the downward velocity of the recirculating gases and the venturi effect of the nozzle tends to overcome the draft effect within the oven. Under certain conditions, in fact, the venturi nozzle may actually pull cold air in through the top opening of the oven. This may also happen in a pressure box seal if the pressure within the box becomes excessive in relation to the pressure within the oven. Generally speaking, venturi seals are used primarily in convection heating ovens whereas pressure box seals are used on both radiant heating ovens and convection ovens.

Either the pressure box seal or the venturi seal can be adjusted manually to afford a good working seal at any specific operating temperature and air flow conditions within the oven. But if the operating temperature is changed, as may frequently be required, the seal is no longer fully effective. Thus, when operating conditions within the oven are modified, there may be a substantial loss of heated air through the top opening of the oven or an excessive amount of cold air may be pulled into the oven through that opening. In either instance the efficiency and effectiveness of oven operation are materially reduced.

Summary of the invention

It is an object of the present invention, therefore, to provide a new and improved fluid pressure seal means, which may include either a pressure box seal or a venturi seal, that automatically compensates for changes in operating temperature, within a processing oven of the kind having a top opening through which the work passes either entering or leaving the oven.

It is an additional object of the invention to provide a new and improved self-compensating fluid pressure seal system for the top opening of a processing oven that is inexpensive in construction yet effective and durable in operation, and which requires a minimum of additional apparatus incorporated into the oven structure.

Accordingly, the invention is directed to a fluid pressure sealing system for a processing oven of the kind comprising a housing, means in the oven housing defining an elongated vertical treating chamber having upper and lower openings permitting passage of a strand of material of indefinite length through the chamber, and heating means for heating the chamber, the normal operating temperature of the oven being sufficient to produce an appreciable draft or stack effect tending to impel heated air or other gas outwardly through the upper opening of the chamber. The fluid pressure sealing system comprises fluid pressure seal means, including a blower, for maintaining a minimal pressure differential across the upper opening, thus preventing substantial movement of gas through that opening. A thermal sensor is located within the upper opening of the oven housing and detects temperature changes within that opening. Control means comprising a variable speed drive for the blower is coupled to the thermal sensor and operates to vary the speed of the blower in response to changes of temperature within the upper opening of the oven housing, maintaining the aforesaid pressure differential within a limited range and preventing excessive movement of gas through the upper opening, either into or out of the oven chamber.

Brief description of the drawings

FIG. 1 is a front elevation view, partly in cross-section, of a vertical processing oven including a pressure box seal with an automatic control constructed in accordance with one embodiment of the present invention;

FIG. 2 is a side elevation view, in partial cross-section, of the oven and pressure seal of FIG. 1;

FIG. 3 is a front elevation view, partly in cross-section, of a vertical processing oven, incorporating another embodiment of the present invention; and

FIG. 4 is a side elevation view, partly in cross-section, of the oven of FIG. 3.

Description of the preferred embodiments

FIGS. 1 and 2 illustrate a vertical processing oven 10 comprising an insulated housing including side walls 11 and 12 and front and back walls 13 and 14. The bottom wall 15 of the oven housing includes an opening 16 through which a continuous strand workpiece 17 enters the oven. The top wall 18 of the oven housing includes a similar opening 19 through which the continuous strand 17 leaves the oven. In the particular construction illustrated in FIGS. 1 and 2, strand 17 is a continuous strip of foil bearing a coating that requires heating for the purpose of drying and curing the coating. However, a continuous web or strip of any other material requiring oven processing could be treated in a process oven of similar configuration.

In oven 10, the direction or movement of the foil strip 17 through the central heating chamber 21 of the oven is generally indicated by the arrows 22. That is, the strip enters the oven chamber through the bottom opening 16 and passes directly up through the oven and out the top opening 19. A cooler 23 is shown mounted above oven 10 and is used to cool the coated foil 17 after it leaves the oven. It should be noted, however, that the foil could equally well move downwardly through the oven entering at the upper opening 19 and exiting at the lower opening 16 in the oven housing, in which case cooler 23 would be located below the oven. Where a two-stage oven is employed, it is known practice to pass the strip or other work strand through the oven moving in an upward direction through one section of the oven and in a downward direction through the other; both types of construction present the draft effect problem to which the present invention is directed.

Oven 10 (FIGS. 1 and 2) is a convection oven. An input blower 24 is connected to an entrance chamber 25 containing a burner 26 that blows heated air through appropriate ducts 27 and 28 into the bottom of the vertical treating chamber 21 in the oven housing. The heated air moves upwardly through chamber 21 as indicated by the arrows 31 and is exhausted from the upper part of the treating chamber 21 through a pair of suitable exhaust ducts 32. An appropriate blower (not shown) may be employed to exhaust the heated air from the oven chamber and to impel the heated air to a suitable exhaust stack. On the other hand, if a two stage oven is employed, the heated air exhausted from oven 10 may be used as the input to a second stage in the oven system.

A pressure enclosure or box 41 is mounted on the top of oven 10 intermediate the top wall 18 of the oven and the bottom of cooler 23. Pressure box 41 is disposed in encompassing relation to the upper opening 18 in the oven housing and is itself provided with upper and lower openings through which the continuous strand 17 passes as it moves from the oven to the cooler. Pressure box 41 is connected by a duct 42 to a blower 43. The pressure box is provided with appropriate internal baffles 44 for balanced distribution of air entering the pressure box from duct 42, maintaining the air pressure on both sides of strand 17 approximately equal. Pressure box 41 may be provided with adjustable members 46 for adjusting the effective width of the upper opening 45.

A thermal sensor 48, which may be a conventional thermocouple or mercury-expansion element, is mounted within the upper opening 18 of the housing of oven 10. Thermal sensor 48 is electrically connected to an adjustable control circuit 49 that is in turn electrically connected to a variable speed drive 51 that constitutes the drive for blower 43. Control circuit 49 and variable speed drive 51 thus comprise a control means for varying the speed of

blower 43 in response to changes of temperature within the upper opening 18 of the oven housing.

The particular forms of thermal sensor, control circuit, and variable speed drive selected for units 48, 49 and 51 in oven 10 are not critical. As a typical example, the variable speed drive may comprise an electrically motor, using a transistor amplifier, of the kind manufactured by Dynamatic Division, Eaton, Yale & Towne, Inc., Kenosha, Wis., in which the amplitude of a D.C. current supplied to a clutch coil is varied to regulate the torque transmitted from the motor to the blower, thereby regulating the blower speed. Variable speed drives of this type are usually provided with some means, such as the potentiometer 52, for adjusting the normal operating speed of the drive. The thermal control unit 49 may comprise a temperature control such as the Model LFP of The Partlow Corporation, Utica, N.Y., a modulating control that includes a potentiometer 53, in this instance connected to the potentiometer 52 in the amplifier circuit of the eddy current clutch control. But it will be recognized that many other specific forms of speed control apparatus suitable for controlling blower 43 in accordance with the temperature of sensor 48 are available and can be utilized.

In the operation of oven 10, room air or other appropriate processing gas is blown into the oven by means of blower 24, and is heated to required temperature by burner 26. The heated air enters the oven at the bottom at ducts 27 and 28. The heated air passes upwardly through the oven (arrows 31) and is exhausted from the oven by ducts 32 and exhaust plenum 34. Blower 43, on the other hand, forces air under pressure through duct 42 and into pressure box 41. The drive for blower 43 and the opening 45 in the top of the pressure box are adjusted relative to each other to establish operating conditions such that the pressure at the top opening 45 of the pressure box is equal to the pressure at the bottom opening of the pressure box, which is directly connected to the top opening 19 in the oven. With these conditions established, the normal draft or stack effect within the treating chamber 21 in oven 10 is balanced out and none of the heated air from the oven escapes through opening 19 in the top of the oven. Furthermore, with accurate balancing, none of the relatively cold air from pressure box 41 is forced downwardly into the oven.

With the operating temperature and pressures reasonably stabilized, the coated foil or other strand 17 is passed through the oven to effect the desired drying, curing, or other processing for the foil.

Subsequently, it may prove necessary or desirable to modify the temperature within the heating chamber 21 or to change the volume of heated air or other gas flowing through the treating chamber of the oven. A change of this sort may be made deliberately or may result from a variation in operating conditions elsewhere in the overall system of the process of which the oven 10 forms a part. A substantial change of this nature creates an unbalanced condition insofar as the pressure at the oven top opening 19 in relation to the pressure at the pressure box top opening 45 is concerned.

A temperature drop within the treating chamber 21 of oven 10 reduces the draft effect in the oven and produces a lowering of the pressure at the upper opening 19 of the oven. If this occurs, there is a tendency for cold air to be drawn into the oven through top opening 19. Any substantial movement of cold air in this direction, however, produces a temperature change that is detected by thermal sensor 48. The change in temperature is signalled to control circuit 49 which in turn actuates the variable speed drive 51 and reduces the speed of blower 43. By reducing the speed of blower 43, the flow of air through duct 42 is reduced and a corresponding reduction is effected in the air pressure within pressure box 41. A balanced condition is achieved when the pressure at openings 19 and 45 is again equalized and

5

the system continues in stable operation until there is a subsequent change in temperature or air flow, of a substantial nature, within the oven.

Of course, the reverse operation occurs if the oven temperature is materially increased. An increase in the oven temperature produces a corresponding increase in the draft effect within treating chamber 21 and produces a higher pressure at the oven opening 19 than at the pressure box opening 45. The resulting outward flow of heated air or other gas from the furnace, through opening 19, produces a temperature change that is detected by thermal sensor 48. This temperature change produces an electrical signal that is supplied to control circuit 49 and causes the control circuit to increase the speed of variable speed drive 51. The flow of air through duct 42 from blower 43 is increased until a balanced pressure condition is again achieved, affording continuing stable operation.

It is thus seen that the control means comprising circuit 49 and variable speed drive 51, actuated by thermal sensor 48, varies the speed of blower 43 in response to any change of temperature within the upper opening 19 of the oven. In this manner, the pressure differential across the upper opening 19 of the oven is maintained at a minimum, being held in balanced condition with respect to the pressure at the top opening 45 of the pressure box. By maintaining the pressure differential across opening 19 within a limited range, excessive movement of air or other gas through upper opening 19, either into or out of treating chamber 21, is prevented.

FIGS. 3 and 4 illustrate a processing oven 100 that is different in construction from oven 10 (FIGS. 1 and 2) and that incorporates a fluid pressure sealing system constructed in accordance with the invention and modified to meet the requirements of the different oven construction. Oven 100 is a two-zone oven employed for drying and curing the insulator coating on insulated wire, the first or bottom zone being designated by reference numeral 101 and the upper zone being indicated by reference numeral 102. Oven 100 includes a housing comprising front and rear walls 111 and 112 and side walls 113 and 114. The bottom wall 115 of the oven housing is provided with an opening 116 for admitting the insulator-coated wire 117 into the oven. The top wall 118 of the oven housing is provided with an opening 119 through which wire 117 leaves the oven. In processing, wire 117 moves continuously through the oven from the bottom to the top in the direction indicated by the arrows 122.

The lower section or zone 101 of oven 100 includes a heat source and fresh air inlet 124 that feeds into supply plenum 125. A bottom zone circulating fan or blower 126 draws heated air from plenum 125 and blows the heated air into a duct 127. A series of pressure drop baffles 128 may be mounted within duct 127. Duct 127 terminates in an outlet 129 that feeds into a lower treating chamber 121 through which the coated wire or other strand workpiece 117 moves. Additional heat may be provided in the lower treating chamber 121 by radiant panels 130 mounted upon the interior walls of the treating chamber.

The upper zone 102 of oven 100 includes a fresh air inlet 141 located within an interior portion 142 of the oven above an upper zone heat source 143. A catalytic combustion element 144 is located below heat source 143 between the heat source and an exhaust plenum 145. Exhaust plenum 145 is provided with an exhaust duct 146 that is connected to an exhaust blower 147.

Exhaust plenum 145 takes its air or other gas from the same opening in zone 102 as does an upper zone recirculating fan or blower 148 which leads to a distribution duct 149. A series of pressure drop baffles 151 may be located within duct 149. Duct 149 extends up the back wall 112 in the upper zone of the oven and across the top of the oven, terminating in a venturi nozzle section 152 that discharges into an upper treating chamber 153 through which strand 117 moves during operation of the oven. Chamber

6

153 extends downwardly through the front of the oven and into a widened portion 154 that is in direct communication with the upper end 155 of the lower treating chamber 12. The two treating chambers are thus connected to an opening 156 that leads into a duct 157 that extends back to the oven section 142 containing the fresh air supply inlet 141 and heater 143.

A thermal sensor 161 is located within an upper opening 119 of oven 100 and is electrically connected to a control circuit 162. Control circuit 162, in turn, is electrically connected to a variable speed blower drive 163 that constitutes the drive for blower 148 in the upper zone of oven 100.

In operation of furnace 100, heated fresh air is drawn into the lower zone of the oven from supply and heater 124 into plenum 125 and then into duct 127 by means of blower 126. The movement of the heated air within the lower zone of the oven is indicated by arrows 131. From duct 127, the heated air flows outwardly of opening 129 into the bottom portion of the lower treating chamber 121. The heated air impinges upon strand 117 as the strand is passed through treating chamber 121 and is drawn off through opening 156 in the upper zone of the furnace into duct 157.

Air from duct 157, and additional fresh air from duct 141 as required, passes through the portion 142 in the upper zone of the oven and is heated by the catalytic preheater 143. The heated air, which contains substantial quantities of solvent and other volatile materials from the insulator coating on strand 117, then passes through the catalytic element 144, combustion within the catalytic element increasing the available heat in the furnace. A part of this air may be drawn off through exhaust duct 146 by blower 147. But most of the heated air is exhausted from plenum 145 by blower 148 and blown into duct 149.

In duct 149, the movement of the air, as indicated by the arrows 171, is in an upward direction, the heated air subsequently being diverted across the top of the oven and outwardly of duct 149 through venturi nozzle 152. The heated air moves downwardly through treating chamber 153, in contact with the upwardly moving strand 117, and is exhausted back into duct 157 through opening 156.

In oven 100, it is the venturi nozzle 152 that is employed to provide an effective seal for the upper opening 119 at the top of the furnace. That is, the recirculating air for the top zone of the oven is blown downwardly into the treating chamber 153 in the top zone of the oven and produces a low pressure effect above the outlet of the nozzle 152. The combination of the downward velocity of the recirculating gases and the venturi effect of the nozzle overcome the stack or draft effect in the oven. When the temperature and rate of flow of the gases are properly adjusted, there is little or no flow of air into or out of the oven through opening 119.

But oven 100, like oven 10, may require adjustment of the temperature of those gases in order to maintain effective processing with respect to the coating on strand 117. When any substantial adjustment is made, in this regard, the balance of the venturi pressure drop with respect to the stack effect of the oven is disturbed. For example, if the temperature within either zone of the oven is increased materially, the resulting increase in draft or stack effect may produce a substantial outflow of heated air and other gases from the opening 119. By the same token, a material reduction in temperature in either zone of the oven may cause cold fresh air to be drawn in through opening 119. In either case, effective processing within the oven may be prevented.

Variations in the draft effect within oven 100 are balanced and compensated by the operation of thermal sensor 161 in conjunction with the control means comprising control circuit 162 and variable speed drive 163. Thus, if temperature conditions within oven 100 change

to reduce the draft effect within the oven, the resulting inrush of air through opening 119 produces an appreciable drop in the temperature within that opening and this temperature change is detected by thermal sensor 161. The thermal change is signalled to control circuit 162 which actuates variable speed drive 163 to decrease the speed of blower 148 and thus reduce the pressure drop effected by venturi nozzle 152. Restoration of a balanced condition is established when the temperature in opening 119 returns to its normal level.

The reverse action occurs when thermal conditions within oven 100 produce an increased stack effect, forcing hot gases from the oven out through opening 119 and thus increasing the temperature to which thermal sensor 161 is subjected. Under these circumstances, the thermal sensor actuates control means 162 and 163 to increase the speed of blower 148, increasing the pressure drop effect of venturi nozzle 152 and again establishing equilibrium in the oven system with respect to top opening 119. It is thus seen that the fluid pressure sealing system of FIGS. 3 and 4 operates in the same basic manner as that of FIGS. 1 and 2 to maintain any pressure differential at the top opening of the oven at a minimum and thus maintain an effective seal at that top opening despite substantial changes in thermal conditions within the oven.

In the control means of either embodiment of the invention, as described above, it is not desirable to employ an overly-sensitive control circuit. That is, if the normal temperature at the top opening of the oven is 500° F. it is not desirable to have the lower speed changed in response to small incremental temperature differences, such as differences of 5 to 10°. Rather, there should be considerable inertia in the control system, with respect to temperature changes, in order to avoid excessive hunting in the operation of the control. Preferably, upper and lower threshold temperatures are established, in the control circuit, with the blower speed being maintained at a set constant speed for any temperature between the two thresholds. A deviation from the range intermediate the two thresholds then causes a change in blower speed as described above. This arrangement has the advantage of avoiding excessive hunting and also tends to prevent changes in operation of the blower due to short-term thermal variations.

Hence, while preferred embodiments of the invention have been described and illustrated, it is to be understood that they are capable of variation and modification.

I claim:

1. In a processing oven of the kind comprising a housing, means in the oven housing defining an elongated vertical treating chamber having upper and lower openings permitting passage of a strand of material of indefinite length through the chamber, and heating means for heating the chamber, the normal operating temperature of the oven being sufficient to produce an appreciable draft effect tending to impel gas outwardly of the chamber through its upper opening, a fluid pressure sealing system for that upper opening comprising:

fluid pressure seal means, including a blower, for maintaining a minimal pressure differential across said upper opening to prevent substantial movement of gas therethrough;

a thermal sensor located within said upper opening to detect temperature changes therein;

and control means, comprising a variable speed drive for said blower, coupled to said thermal sensor, for varying the speed of the blower in response to changes of temperature within said upper opening and thereby maintain said pressure differential within a limited range and prevent excessive movement of gas, through said upper opening, either into or out of said chamber.

2. A fluid pressure sealing system for a processing oven, according to claim 1, in which said fluid pressure seal means comprises a pressure box disposed in encompassing relation to said upper opening of said oven, and said blower is a separate blower employed to blow air into said pressure box.

3. A fluid pressure sealing system for a processing oven, according to claim 2, in which said control means increases the speed of said separate blower above a given normal speed only in response to detection by said thermal sensor of a temperature above an upper threshold level and decreases the speed of said separate blower below said normal speed only in response to detection by said thermal sensor of a temperature below a lower threshold level, said upper and lower threshold levels being appreciably different from each other.

4. A fluid pressure sealing system for a processing oven, according to claim 1, in which said oven is a convection oven in which heated gases are introduced into the upper portion of said treating chamber through a venturi nozzle located adjacent said upper opening and are supplied to said venturi nozzle by said blower and in which said control means decreases the speed of said blower whenever said thermal sensor detects a substantial drop in temperature below a lower threshold level and increases the speed of said blower whenever said thermal sensor detects a temperature above an upper threshold level.

5. A fluid pressure sealing system for a processing oven, according to claim 4, in which said blower is an integral part of said oven and constitutes a recirculation blower for continuously recirculating heated gases within said oven.

6. A fluid pressure sealing system for a processing oven, according to claim 4, in which said control means increases the speed of said blower above a given normal speed only in response to detection by said thermal sensor of a temperature above an upper threshold level and decreases the speed of said blower below said normal speed only in response to detection by said thermal sensor of a temperature below a lower threshold level, said upper and lower threshold levels being appreciably different from each other.

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