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⑤④ **Solid fuel burning stove and catalytic converter.**

⑤⑦ A stove for use in burning solid fuel such as coal or wood has a catalytic converter (24) which comprises a plurality of catalytic cells which may be located in the flue (20) of the stove. Each cell has a length oriented in the direction of the flow of the exhaust and a volume in cubic inches expressed as functions of the density (N) of the cells in a direction perpendicular to the exhaust flow. This function is at least:

$$\frac{6720.23}{\left(N\ \frac{\text{cells}^2}{\text{in}}\ 2\right)} + \frac{2554.85}{\left(N\ \frac{\text{cells}}{\text{in}}\ 2\right)} + 14.84$$

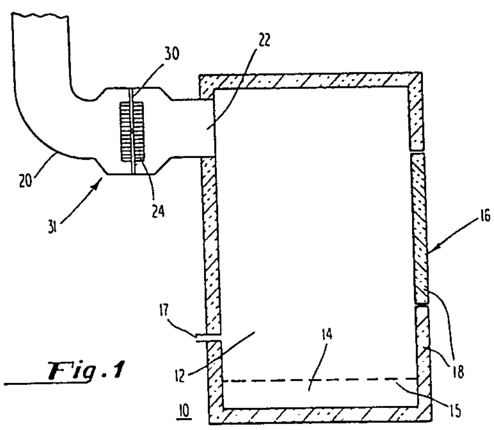

Fig. 1

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Title: Solid Fuel Burning Stove and Catalytic Converter

The invention relates to stoves which burn solid fuel, such as especially coal and wood stoves having improved efficiency and safety, and further relates to catalytic converters or combustors for use in such stoves.

Due to the relative scarcity and high cost of petroleum products, wood or coal burning stoves have been increasingly employed for home heating and other purposes. A reasonably air tight wood or coal burning stove is far more efficient than a home fireplace, which may result, in fact, in a net energy loss. Especially the stoves burning wood presently being utilized suffer from three significant drawbacks. First, wood burning stoves represent a severe fire hazard since the wood fuel therefore contains volatible substances which are normally not oxidized during combustion. These volatiles will burn if mixed with air at temperatures in excess of 590°C. However, the typical wood burning stove operates within a temperature range of between 230° and 370° C. At these temperatures, these volatible substances, known generally as creosote, remain unoxidized and tend to adhere to the flue pipes and are a cause of not infrequent chimney fires. Secondly, the incomplete combustion of the carbonaceous fuel in wood burning stoves leaves the unoxidized residue as a pollutant and an environmental hazard which is discharged to the atmosphere. Third, the unoxidized residue represents a loss of overall combustion efficiency. While claims have been made to efficiencies greater than 65% in some wood burning stoves, independent testing laboratories have determined that the combustion efficiency of typical wood burning stoves lies in the range of between 50 and 65%. One possible solution to the aforementioned problems is to increase the combustion temperature of the typical wood burning stove by providing additional air into the combustion chamber so as to create temperatures high enough to bring about complete combustion. Variations on this technique date back to the 18th century with the Franklin stove, wherein the volatiles are mixed with additional air in the combustion chamber in order that temperatures high enough to bring about complete combustion may be obtained. These efforts have only been partially successful.

It is an object of the present invention to provide solid fuel burning stoves and catalytic converters therefor, having increased safety and efficiency, in which the unoxidized carbonaceous pollutants are minimized and the fuel efficiency and utilization is increased.

These and other objects of the present invention are achieved by the modification of a stove to include a catalytic converter which reduces the reaction temperature sufficiently to remove volatile substances at the ordinary operating temperatures of the stove. In accordance with the present invention, the catalytic converter is located either in the combustion chamber of the stove or in the flue extending therefrom but in either case at a location wherein the temperature is sufficiently high to sustain the catalytic oxidation of the volatiles contained in wood fuels.

In the preferred embodiment of the present invention, the catalytic converter means is situated in the flue emanating from a wood burning stove either as close as possible to or even partially within the combustion chamber of the stove.

In another embodiment of the present invention, a wood burning stove is provided with a primary combustion chamber and a secondary heat exchange chamber and with a communicating passageway therebetween. A catalytic converter means is situated in the passageway.

In still another embodiment of the present invention, the catalytic converter means is integral with or applied directly to the walls of the combustion chamber of the wood burning stove.

Moreover, while various catalytic converter means might be acceptable in any of the foregoing embodiments for removing the aforementioned volatiles from the flue gas of a wood burning stove, it has been found that the nature and structure of the catalytic monolith, that is the cell density, length, inside cell dimension and volume, thereof, are critical. For example, in typical automotive applications, it has been found that catalytic converters having a cell density (in a plane perpendicular to the axial direction of cells) of 200 cells per square inch as desirable. However, in wood burning stoves, it has been found that catalytic cell densities of this magnitude may cause severe plugging and excessive back pressure, resulting in insufficient draft to operate the stove.

In wood or coal burning stoves, it has been found that the external volume of the catalytic converter means has a marked effect on catalytic performance. Specifically, it has been found that for optimum catalytic performance, the volume, V (in cubic inches), of the catalytic converter means, when expressed as a function of the cell density, N (in cells per square inch) thereof, should be at least: $2554.85/N - 6720.23/N^2 + 14.84$.

Additionally, it has been found that for optimum pressure drop in a wood burning stove, the catalytic converter means employed should have a predetermined ratio of its length, L (in inches) to its density, N (in cells per square inch), volume V (in cubic inches), and inside cell dimension, X (expressed in inches). Specifically, it has been found that:

$$\frac{L^2}{NVX^4} < 5$$

Still more specifically, it has been found that a catalytic converter means with a volume of 150 in.^{3}, a cell density of 16 cells/in^2, a length of 6 in. and an inside cell dimension of 0.21 in. is particularly preferred as to both its catalytic performance and the pressure drop thereacross.

A stove of the present invention advantageously includes an exhaust bypass for allowing at least a portion of the exhaust or combustion gases to bypass the porous catalytic structure of the converter means when such converter means causes excessive back pressure, e.g. upon plugging of the structure by creosote or upon opening the stove door. In such cases, the converter means is situated for the exhaust or combustion gases to normally pass through its porous catalytic structure to the flue.

Hence, according to a further embodiment, the stove includes exhaust bypass means for allowing at least a portion of the exhaust to bypass the catalytic structure of the converter. In a preferred embodiment, the converter means is moveable to permit at least some exhaust to bypass the converter.

The invention will now be described with reference to the accompanying drawings in which:

Figure 1 is a cross-sectional view of a wood burning stove employing a catalytic converter means in accordance with one embodiment of the present invention;

Figure 2 is a detailed view of the mounting arrangement of the catalytic converter means shown in Figure 1 in a first position;

Figure 3 is a detailed view of the catalytic converter means shown in Figure 2, but rotated 90°;

Figure 4A is an elevational view of a flue for a wood burning stove having alternative mounting arrangement for a catalytic converter means, than that shown in Figures 1 - 3;

Figure 4B is an elevational view of a catalytic converter means and mounting bracket therefor for use with the flue of Figure 4A;

Figure 4C is a top view of the converter means and mounting bracket shown in Figure 4B;

Figure 5 is a detailed view of an alternative embodiment of the mounting arrangement shown in Figures 2 - 3;

Figure 6 is a sectional view of a wood burning stove employing a catalytic converter means mounted in accordance with another embodiment of the present invention;

Figure 7 is a cross-sectional view of a wood burning stove employing a catalytic converter means mounted in accordance with a third embodiment of the present invention,

Figure 8 is a plan view of a stove made according to one embodiment of this invention, portions of the stove being cut away and shown in section for purposes of illustration;

Figure 9 is a front elevational view of this stove also with portions thereof cut away and shown in section for purposes of illustration;

Figure 10 is a side elevational view of this stove with portions again being cut away and shown in section;

Figure 11 is a slightly enlarged, fragmentary sectional view taken generally along the line 4-4 Figure 2 looking in the direction of the arrows, and illustrating one manner in which duel glass windows can be mounted in the front doors of the stove, and

Figure 12 is a view similar to Figure 11 and illustrating still another manner in which duel windows can be mounted in the stove doors.

Referring now to Figure 1 a cross-sectional view of a typical wood burning stove modified in accordance with one embodiment of the present invention will be described. A wood burning stove is shown generally at 10. The wood burning stove 10 includes a firebox or primary combustion chamber 12 situated above an ash pan 14 and separated therefrom by means of a grate 15. Access to the primary combustion chamber 12 is by means of an entrance door or hatch shown generally at 16. Suitable insulation 18 may surround the combustion chamber 12 including the interior surface of the hatch or door 16, although such insulation is not a requirement. A flue 20 communicates with the combustion chamber 12 by means of an exit port 22. A primary air inlet port 17 provides a source of oxygen for combustion within the primary combustion chamber 12. Wood fuel is combusted in the primary combustion chamber 12 and exhaust gases emanating therefrom pass through exit port 22 to the flue 20 and from there to the outside environment. In accordance with one aspect of the present invention, a catalytic converter means 24 is situated internal to the flue 20 immediately adjacent to the exit port 22 from the combustion chamber 12. In accordance with this aspect of the present invention, the catalytic converter means 24 is situated as close as possible to the combustion chamber 12, even extending in part into the combustion chamber 12 if the configuration of the exit port 22 permits such an installation. In any event, at most, the catalytic converter means 24 is situated at a position in the flue where converter inlet temperature are above 200°C. Generally, this position is no greater than 6 inches from the combustion chamber. The aforementioned insulation 18 is provided to ensure that at least some of the heat liberated from fuel being combusted in the combustion chamber 12 is utilized to heat the exhaust in the flue 20 sufficiently to cause light off of the converter 24 rather than being transferred through the walls of the wood burning stove 10.

The catalytic converter means 24 is preferably a ceramic honeycomb structure having a plurality of mutually parallel cells extending therethrough with a catalytic substance being applied to the walls thereof. Such catalytic converter means may be made by applying an unfired ceramic to a carrier means, corrugating the coated carrier, subsequently firing the ceramic and thereafter applying a catalyst thereto as set forth in U.S.A. Patent Specification No. 3,112,184 Hollenbach. Alternatively, the catalytic converter means may be formed by extrusion from a suitable die means as taught in U.S.A. Patent Specification No. 3,790,654 Bagely.

Since the catalytic converter means 24 may operate at temperatures of between 700° to 900°C. and since internal temperatures of the converter means 24 may at times reach 1100°C., it is desirable that the flue 20 have insulation (not shown) surrounding the same in the vicinity of the catalytic converter means 24.

Alternatively, as shown in Figure 5, it is desirable to provide a flue 20 with a shielding means comprising a first generally cylindrically shaped baffle 26 surrounding an internal cylindrical baffle 28. Cool air enters the space between the first baffle 26 and the second baffle 28 and passes in the vicinity of the catalytic converter means 24 and then exits in the space between the second baffle 28 and flue 20. Such an installation not only shields the high temperatures of the catalytic converter means 24 from persons in the vicinity thereof, but also provides an additional source of heat transfer to the space being heated by the wood burning stove 10, thus increasing the combustion efficiency of the stove.

The mounting of the catalytic converter 24 within the flue 20 may be accomplished by situating the catalytic converter means 24 in a metal ring 30 which preferably is formed from stainless steel. At the time the stove is loaded with new or additional fuel, and the door 16 is opened, increased air flow into its combustion chamber 12 occurs and the presence of catalytic converter means 24 may cause an excess back pressure causing smoke to improperly exhaust. In such an instance, it is necessary that the oxidation products bypass the catalytic converter means.

Accordingly, in the embodiment shown in Figure 1, it is desirable to mount the catalytic converter means 24 for rotation as shown specifically in Figures 2 and 3. There it will be seen that a handle 32 is provided which projects from the flue 20. The handle 32 is connected to the mounting plate 30 which supports the catalytic converter means 24. The mounting plate 30 is rotatably mounted within the flue by means of bushings 34 and 36, Rotation of the handle 32 causes rotation of the mounting plate 30 and ultimately of the catalytic converter means 24 so as to permit combustion gases to pass through the flue 20 without passing through the catalytic converter means 24 during those periods when excess back pressure may be encountered such as when the door 16 is open. As shown in Figures 1 - 3 in order to accomodate converters of different thickness or cell length, the area 31 in the flue 20 in which rotation occurs has a larger cross-sectional area than the remainder of the flue 20. Without such an arrangement, the converter means 24 would not have sufficient clearance for rotation within the flue 20 unless its cross-sectional area were less than that of the flue.

Referring now to Figures 4A - 4C, another mounting arrangement from that shown in Figures 2 and 3 will be described. Specifically, with respect to Figure 4A, a portion of a flue 20 is shown having an opening 62 therein. The opening 62 extends at least 180° about the periphery of the flue. Parallel tracks 64 on the internal surface of the flue 20 are provided.

As shown in Figure 4B, a catalytic converter means 24 is provided having annular mounting brackets 66 on the top and bottom surfaces thereof, the brackets 66 preferably being formed from stainless steel. The brackets 66 are spaced so as to mate with tracks 64 such that the catalytic converter means 24 may be slideably engaged within the flue 20. The brackets 66 are joined to a shielding means 68 having a suitable handle 70, such that the catalytic converter means 24 may be selectively placed in the flue 20, with the shield 68 providing a closure to the opening 62. The converter means 24 may also be at least partially removed from the flue 20 when new or additional fuel is added to the combustion chamber 12, thus eliminating excess back pressure. An additional shielding means similar to that shown at 68 may also be provided which is not associated with a catalytic converter means for closing opening 62 when new or additional fuel is added to the combustion chamber so that smoke does not exit from this opening.

Referring now to Figure 6, still another embodiment of the present invention is disclosed wherein like numerals are utilized to describe features common to the embodiment shown in Figures 1 - 3. In the embodiment shown in Figure 6, a wood burning stove 10 is shown having a primary combustion chamber 12 with an ash pan 14. A grate 15 provides a support for the location of wood fuel to be combusted within the primary combustion chamber 12. Wood fuel is introduced within the primary combustion chamber 12 by means of a door or hatch 16. Insulation 18 may be situated within the interior of the combustion chamber 12. Moreover, in accordance with the embodiment shown in Figure 6, a catalytic converter means 24 is provided which is located within the primary combustion chamber. The insulation 18 is provided to ensure that some of the heat liberated in the combustion chamber 12 is utilized for light off of the catalytic converter means 24. The catalytic converter means 24 is retained within a bracket 38, preferably made from stainless steel. Combustion products from the primary combustion chamber 12 exit therefrom by passing through the catalytic converter means 24 and thereafter exiting by means of the flue 20 to the external environment.

In the embodiment shown in Figure 6, a bypass passageway 40 is provided which communicates with the interior of the combustion chamber 12 of the wood burning stove 10. Access to the bypass passageway 40 is controlled by means of a bypass damper 42 which is rotatable about an axis 44 so as to allow combustion gases to bypass the catalytic converter means 24 during those periods in which an excess back pressure is expected such as when wood fuel is added to the combustion chamber 12.

Referring now to Figure 7, still another embodiment of the present invention is disclosed, again with like numerals referring to items common to those shown in the embodiments of Figures 1 and 5. Figure 7 discloses a wood burning stove 10 having a primary combustion chamber 12 wherein wood fuel is combusted. Wood fuel is placed in the primary combustion chamber 12 by means of a door or hatch (not shown). Communication between the primary combustion chamber 12 and the ash pan 14 is by way of a grate 15 as shown. Air for combustion enters the primary combustion chamber 12 by means of a primary air inlet 17 and by means of grate 15. The primary combustion chamber 12 is preferably insulated to provide sufficient heat for light off of the converter means 24. Unlike the embodiments shown in Figures 1 and 6, in addition to the provision of a primary combustion chamber 12, the embodiment shown in Figure 7 also includes a heat exchange chamber 46 interconnected by means of an opening 48 to the primary combustion chamber 12. Situated in or adjacent to the opening 48 is a catalytic converter means 24. Combustion gases from the combustion chamber 12 are directed by means of a flow director or vane 50 to the catalytic converter means and catalyzed combustion gases are then passed through the heat exchanger chamber 46 in the vicinity of a heat exchanger comprising a serpentine series of pipes or tubes 52. The combustion gases are then directed to the flue 20 by means of a communicating passageway 54. Entrance to the communicating passageway 54 is controlled by means of a damper 56 which is rotatable about an axis 58.

Like the embodiment shown in Figure 6, the wood burning stove 10 shown in Figure 7 also includes a bypass passageway 40 controlled by a bypass damper 42 rotatable about an axis 44 whereby combustion gases may be caused by bypass the catalytic converter means 24 when excess back pressure is expected such as during loading of additional fuel.

In the embodiment shown in Figure 7, a secondary air inlet 60 is provided such that additional oxygen may be provided to the vicinity of the catalytic converter means 24 for sufficient operation thereof. The secondary air inlet 60 preferably comprises a tube, one end of which contains apertures 61 in the vicinity of the converter means 24, and the other end terminating in the vicinity of the primary air inlet 17.

With respect to each of the embodiments shown in the foregoing figures, it has been determined that the nature and structure of the catalytic converter means 24 which is employed is important. The catalytic converter means 24 employed preferably includes a ceramic monolith having an alumina washcoat applied thereto and coated with precious metal catalysts such as palladium, platinum or alloys of the two in amounts ranging from, for example, 13 grams per cubic foot to 57 grams per cubic foot. However, regardless of the catalysts selected or the loading thereof, the length, volume, and wall thickness of the catalytic monolith selected as well as the density of the catalytic cells employed are critical for adequate creosote removal without excessive back pressure.

Specifically, it has been determined that for adequate performance, i.e. prevention of creosote accumulation as well as for improvement of combustion efficiency, the volume of the converter means as well as the cell density thereof must be controlled. Catalytic performance may be considered optimum if no creosote accumulation is detected and if no detectable unoxidized residue is discharged in the flue. Catalytic performance may, however, still be acceptable if no creosote is formed even through a small quantity of unoxidized residue may be detected. Finally, performance may be considered marginal if most but not all creosote is eliminated from the flue even if considerable unburned material passes through the flue. Specifically, it has been determined that optimum performance may be attained with a catalytic converter means having a volume of 150 cu. in. and a density of 16 cells per sq. in. Catalytic performance of a number of cells may be determined from Table I:

Table I

Performance	Volume $V(in^3)$	Diameter D(in)	Length L (in)	Density N $(cells/in^2)$
Optimum	150	5.66	6	16
Acceptable	150	5.66	6	9
Acceptable	75	5.66	3	25
Marginal	75	5.66	3	16
Marginal	50	5.66	2	25
Unacceptable	75	5.66	3	9

From the foregoing data it has been hypothesized that catalytic performance is related to volume and density by the following relationships:

For optimum performance, Volume, V in cubic inches, of the converter, expressed as a function of cell density, N expressed in terms of cells per square inch, should be at least:

$$V = -6720.23/N^2 + 2554.85/N + 14.84$$

For acceptable performance, Volume, V, of the converter, expressed as a function of cell density, N, should be at least:

$$V = -4458.33/N^2 + 1957.5/N + 3.83$$

For marginal performance, Volume, V, of the converter, expressed as a function of cell density, N, should be at least:

$$V = -3333.33/N^2 + 1537.50/N - 14.17$$

Moreover, even if a particular catalytic converter means has optimum, acceptable or marginal performance as defined above, it has been determined that the converter means must additionally exhibit a suitable pressure drop across it for adequate stove operation, since, as cell density is increased to improve catalytic performance, the pressure drop across the converter may be too great to sustain combustion in the stove.

The pressure drop through a square cell catalytic converter is defined as:

$$\Delta P = \dot{m}\frac{\mu}{\rho}28.4L\frac{4}{\pi D^2}\frac{(X+T)^2}{X^4}$$

where:

Δp = pressure drop

$\dot{m}$ = mass flow rate of gases

μ = gas viscosity

ρ = gas density

L = converter length

D = converter diameter

X = inside cell dimension

T = wall thickness

This form can be modified to give:

$$\Delta P = \dot{m}\frac{\mu}{\rho}56.8\frac{L^2}{NVX^4}$$

where:

L = converter length

N = cell density

V = converter volume

X = inside cell dimension

All the terms which are constant can be moved to the left side of the equation and accordingly:

$$\frac{\Delta P \rho}{56.8\ m\mu} = \frac{L^2}{NVX^4} = K \text{ (constant)}$$

It has been determined that pressure drop may be considered optimum where K is less than 5. In such a situation, the pressure drop across the catalytic converter means is generally not noticeable. An acceptable pressure drop may still be had where K is greater than or equal to five but less than seven. In such a situation, pressure drop is noticeable, however, there are generally no adverse effects. In the situation where K is greater than or equal to seven but less than 10, a significant pressure drop occurs across the catalytic converter means and the usefulness of a particular catalytic converter means will depend on the particular wood burning stove with which it is utilized. Finally, it is believed that when K is greater than or equal to 10 excessive pressure drop across the converter occurs, such that combustion may not be sustained. As may be seen from the data set forth in Table II, the following catalytic converter means were tested for pressure drop thereacross:

Table II

K	L (in)	N(cells/in^2)	V (in^3)	X (in)
2.40	3	9	75	0.273
4.80	6	9	150	0.273
3.86	3	16	75	0.210
7.71	6	16	150	0.210
4.32	2	25	50	0.165
6.48	3	25	75	0.165

Also, while to the use of cellular monolithic type catalytic converters have been described above, those skilled in the art will appreciate that beds of catalytic pellets might also be employed, the pellets being situated in a metal mesh or other perforated container. However, it should be understood that the use of a ceramic monolith catalytic converter means is preferred.

Referring now to the drawings by numerals of reference, 110 denotes generally a stove's fire box, comprising of a plane, vertical front wall 113, a pair of spaced, parallel side walls 114 and 115, which project at right angles rearwardly from the front wall 113, and a vertically disposed back wall 116, which extends transversely between the rear edges of the side walls 114 and 115, and parallel to the front wall 113. The rectangular firebox 110 is secured centrally on the upper surface of a plane, horizontally disposed bottom plate 117 and is closed at its upper end by a similar plate 118, which is secured adjacent its marginal edges on the fire box adjacent each of its corners on the upper ends of four, similarly shaped metal feet or legs 119, which are designed to support the bottom 117 of the fire box horizontally on the floor of a room or the like.

The fire box 110 has in the center of its front wall 113 a large rectangular opening 121 (Figs 9 and 10), which is surrounded by a narrow flange 122 that projects laterally from the outer surface of wall 113. The opening 121 is adapted to be closed by two, rectangular, similarly-shaped doors 124 and 125, which are hingedly connected as at 126 and 127 to the left and right hand side edges, respectively, of the front wall 113 as shown in Fig. 9. These hinge connections 126 and 127, which are conventional and are therefore not described in detail herein, support the doors 124 and 125 so that the inner edges thereof meet and nearly engage along a vertical seam 128 (Fig. 9), when the doors are closed over the opening 121.

Doors 124 and 125 are manipulated by a pair of knobbed handles 130 and 131 (Figs. 8 and 9), the former of which is a dummy handle that is fixed at its inner end to the lower, right hand corner of door 124 as shown in Fig. 9. Handle 131 is rotatably journaled intermediate its ends in an opening 132 formed in the lower left hand corner of door 125 (Fig. 9), and projects at its inner end into the fire box 110 when the doors 124 and 125 are closed. Secured at one end to the inner end of handle 131 to project radially therefrom is a small, rectangular plate 134. A screw 135 is adjustably threaded into the outer end of plate 134 (Fig. 10) so as to have its head disposed in closely spaced, confronting relation to the stationary fire box wall 113, when the doors 124 and 125 are latched closed as shown in the drawings.

When the plate 134 and adjustable screw 135 are swung by handle 131 into their latching positions (Fig. 10), plate 134 extends downwardly in front of a horizontal plate 138, that is positioned just above and parallel to the bottom plate 117 of the fire box to form part of a liner therefor. Plate 138 is fastened adjacent its forward edge to the front wall 113; and adjacent its rear edge it has thereon a downwardly projecting flange portion 139 (Fig. 10) which is supported on plate 117 just forwardly of wall 116. The fire box liner also includes a back plate or wall 141 (Fig 10), which is secured along its lower edge to the rear edge of the liner plate 138, and the lower portion of which projects upwardly and parallel to the rear wall 116 of the fire box. Intermediate its ends plate 141 is bent slightly as at 142 so that its upper portion is inclined slightly to the vertical, and away from the rear wall 116 of the fire box. This inclined, upper portion of the liner plate 141 has therein a large, rectangular bypass opening 143 which registers with an exhaust opening 144 that is formed in the upper end of the rear fire box wall 116 for a purpose noted hereinafter.

Opening 143 is adapted to be closed by a large, rectangular damper plate 146, which has its lower edge mounted for pivotal movement in an angle bracket 147, that is secured to the inside surface of plate 141 adjacent to the lower edge of opening 143. Plate 146 is pivotal between the legs of a generally U-shaped bracket 148, the marginal side of which are fastened to the inside surface of the liner plate 141 adjacent opposite sides of opening 143. The back or inside surface of damper plate 146 rests upon the inner end of a push rod 150, which slides adjacent its inner end in an opening in a support plate 151, which is fastened to, and projects upwardly from, bracket 148. Adjacent its outer end rod 150 projects slidably through an opening in a stationary baffle 152 on the upper edge of wall 113, and into engagement with the inside of the door 125 when the latter is closed. With this construction, whenever the door 125 is swung to its open position, the weight of the inclined damper plate 146 urges the push rod 150 toward the left in Fig. 10 until the plate 146 is swung from its closed, full line position to its open or broken line position as shown in Fig. 10, wherein the upper edge of plate 146 comes to rest against the support plate 151. Obviously whenever the door 125 is closed, it re-engages the push rod 150 and forces it and plate 146 back to their full line positions as shown in Fig. 10, thus once again closing the bypass opening 143.

Secured on top of the fire box cover plate 118 substantially centrally thereof is a rectangular housing 155, the upper end of which is sealed by a large flat cover plate 157 which is similar in configuration to, but slightly smaller than, plate 118. The interior of housing

155 defines an exhaust chamber 158, which communicates through a large, rectangular opening 159 (Fig. 10), in plate 118 with the space formed in the upper end of the fire box between the bypass opening 143 and the exhaust opening 144 in wall 116.

Secured along one edge of the inside of the vertical portion of the liner plate 141, and projecting horizontally therefrom into the center of the fire box above and in spaced, parallel relation to the bottom plate 138 of the liner, is a rigid plate or shelf 161, which can be used to support thereon burning embers for banking a fire in the box 110 as noted hereinafter. Secured in opposite ends in the opposed side walls of the fire box, and extending transversely therebetween in a plane containing the shelf 161, is a plurality of spaced, parallel metal bars 162, which form supports for a conventional grate (not illustrated), which may be removably placed in a fire box 110 for holding kindling, fire wood, etc. in a known manner.

Removably mounted on the liner plate 138, and extending at its rear and beneath the support rods 162 and the shelf 161, is a relatively shallow, rectangular ash pan 164. The forward, vertically disposed wall 165 of the pan 164 is spaced horizontally from the front wall 113 of the fire box, and has thereon a forwardly projecting lip or flange 116 which overlies the door latching plate 134, and which provides a handle portion for moving the pan 164 into and out of the fire box through its front doors 124 and 125. When these doors are closed (Fig. 10), the forward edge of the flange 166 is spaced slightly rearwardly from the inside surfaces of the doors to allow air for combustion to enter the combustion chamber above pan 164 from the space between plates 117 and 138, as noted hereinafter. Air from this latter space is also permitted to enter the combustion chamber through a plurality of spaced openings 167 which are formed in the front wall 165 of the pan.

The primary source of air for supporting combustion in the fire box 110 is a rectangular opening 171 (Fig. 10), which is formed in the base plate 117 adjacent to its rear edge, and inwardly from the flange 139 on the liner plate 138. The quantity of air admitted through this opening is controlled by a damper plate 172, which is supported by a bracket 173 for sliding movement against the underside of plate 117. A pair of lugs 174, which project from the bottom of plate 172 adjacent to its forward end, are adjustably attached to the threaded end of a horizontal operating rod 175, which is slidably supported intermediate its ends by bracket 176 which projects from the underside plate 117. A knob 177 on the outer end of rod 175 can be used manually to shift the damper 172 back and forth to cover or uncover the opening 171 to varying degrees, thereby to control the amount of primary combustion air that is admitted to the fire box.

Secured intermediate its ends in a circular opening, which is formed in the fire box cover plate 118 medially of its sides and slightly to the left (Fig. 10), or forwardly of its centerline, is a steel ring or sleeve 181. Removably mounted in the bore sleeve 181 is the cylindrically-shaped catalytic converter element 182. The outside diameter of element 182 is slightly less than the inside diameter of sleeve 181 so that the element can be readily inserted into, and withdrawn from the bore of the sleeve. Element 182 is seated at its lower end on an elongate supporting pin 184, opposite ends which are removably seated in registering openings formed in the annular wall of sleeve 181 adjacent to its lower end, so that the pin 184 extends substantially diametrally across the center of the sleeve. As shown more clearly in Fig. 10, the sleeve 181 and the enclosed converter element extend at their upper ends part way into the exhaust chamber 158 in the housing 155, and at their lower ends extend into the upper end of the combustion chamber in the fire box 110.

Welded or otherwise secured to the inside surface of the exhaust chamber cover plate 157 to overlie the upper ends of sleeve 181 and its converter element 182 is a stainless steel plate 185. A circular opening 186 in the center of plate 185 registers coaxially with the sleeve 181 and element 182, and also with a circular opening 187 in the plate 157. A transparent, disc-shaped window or sight glass 188 is secured in the opening 187 to register with the center of the converter element 182, and to provide means for observing the element during operation of the stove.

When the damper plate 146 is in its closed position over the bypass opening 143 (Fig. 10), all combustion gases and the like rising from the interior of the fire box 110 must pass upwardly through the converter element 182 before entering the exhaust chamber 158. From there the gases pass beneath a plate baffle 190, which extends downwardly from the cover plate 157 and transversely between the side walls of housing 155 so to be positioned between the sleeve 181 and the exhaust opening 159. Consequently, after the gases have passed through element 181 and beneath baffle 190, they pass downwardly through the opening 159 to the opening 144 in the back 116 of the opening box. This opening communicates through an exhaust duct or flue 191 with the fire box chimney (not illustrated). As shown more clearly in Fig. 10, this duct 191 is secured at its inner end around the opening 144 in plate 116, and extends intermediate its ends through a registering opening formed in the back 193 of a generally U-shaped radiation shield which surrounds the rear portion of the fire box 110 between plates 117 and 118.

This shield includes two, spaced, parallel side portions or arms 194 and 195, which project from section 193 forwardly to be disposed in spaced, parallel, overlapping relation to slightly more than the rear halves of the side walls 114 and 115 of the fire box. A conventional electric blower 196, which is mounted at the exterior of the radiation shield (Fig. 10), has its discharge end secured by a plate 197 over opening 198, which is formed in the back portion 193 of the shield in communication with the narrow space which is formed between the shield and the rear portion of the fire box. When the stove is in operation, the shield 193, 194, 195 and the associated blower 196 perform the functions of preventing the fire box side walls 114 and 115 from over heating, thereby obviating the need to employ a fire brick lining in the fire box, and also serving to direct heated air from the space between the shield and the fire box out of the vertical openings formed between the forward edges of the shield and the fire box, when the stove and fan 196 are in use. Even when the fan is not in use the shield blocks direct radiation from the back and side walls of fire box 110 allowing the stove to be safely positioned closer to combustible walls.

As shown more clearly in Figs 9 and 11, the doors 124 and 125 have therein large, central, rectangular openings 201 and 202 respectively. Each of the openings 201 and 202 is closed by a pair of spaced, parallel, vertically disposed panes 203 and 204 of medium and high temperature glass, respectively. Two of these panes are shown by way of example in Fig. 11. Since the manner in which the way the two panes are mounted in each door 124 and 125 is similar, only the construction of door 124 will be described in detail herein.

Referring now to Fig. 11, 206 denotes generally a rectangular frame which is fastened to the inside of the door 124 around its opening 201. This frame also has therethrough a rectangular opening 207 which registers with, and is similar in configuration to, the opening 201 in the door. The panes 203 and 204 are secured in frame 206 to extend transversely between the opening 201 and 207 in spaced, parallel relation to each other. The outer pane 203 is sealingly secured by conventional gasket material along three of its edges, namely its upper edge (as at 208) and along its two side edges, against the inside of door 124 around its opening 201. Deliberately, however, the gasket material is not incorporated between the lower edge of pane 203 and the confronting surface of the frame 206, whereby an elongate, narrow opening or gap 209 is formed between the frame of 206 and the lower edge of pane 203. Pane 204, on the other hand, has its two vertical side edges and its lower edge secured, as at 211, by gasket material against the inside surface of the frame 206 around its opening 207, so that its upper edge is spaced as at 212 slightly beneath the confronting surface of frame 206.

As a result of the manner in which panes 203 and 204 are mounted in each door 124 and 125, when the stove is in operation a secondary supply of air for combustion enters the interior of the fire box through its doors 124 and 125 by passing through the gap 209 along the bottom of the outer pane 203, as indicated by the arrows in Fig. 11, then upwardly between the panes 203 and 204, and then through the gap 212 and out of the opening 207 in frame 206 to the combustion chamber adjacent its upper end. Assuming that the stove is in operation, primary air will also be entering the interior of the fire box at this time from beneath the liner plate 138, passing upwardly as shown by the arrows in Fig. 11 between the lip 166 on the ash pan 164 and into the combustion chamber. Also as indicated by the arrows in this figure, a portion of this primary air is free to pass to the interior of the fire box through the openings 167 in the front wall of pan 164.

The inner pane operates at a higher temperature due to reflected radiation from the outer pane. The higher temperature reduces condensation. The secondary air flow draws any flow of smoke away from the upper portion of the window. As a result of the design of the pane mountings in the doors 124 and 125, and also because of the manner in which the primary air is fed into the fire box over the forward edge 166 of the ash pan, the windows or panes 203 and 204, are in essence, self-cleaning. For example, with incoming secondary air entering the fire box along the upper edges of doors 124 and 125, and with the primary combustion-supporting air being directed by the ash pan lip 166 vertically upwardly along the inside of the window panes 204, accumulation of ash and other foreign matter on the panes 203 and 204 is minimized. Moreover, with the secondary air entering the upper end of the combustion chamber, it supplies the necessary oxygen for supporting complete combustion of gaseous fuels in the catalytic converter which might overwise by only partially burned because of an inadquate supply of oxygen from the primary air supply from the bottom of the fire box.

Figure 12 which is similar to Fig. 11, illustrates a modified manner of mounting the two panes 203 and 204 in doors 124 and 125 to permit a secondary supply of air therethrough. In this modified embodiment each of the panes 203 and 204 has its vertical side edges and its lower edge secured by gasket material as in 215 against the inside frame 206, thereby forming a gap 216 in the frame 206 over the upper edges of the two panes 203 and 204 in each door so that the secondary air supply enters through the doors 124 and 125 over the upper edges of the panes. Also as in the preceding embodiment, the primary air still enters the fire box over the forward edge of the lip 166 on the ash pan 164, so that the incoming primary air tends to wash or clean the inside surfaces to the inner panes 204.

In use, handle 131 may be manupilated by rotating it counterclockwise from its position as shown in Fig. 9, thereby swinging its latching screw 135 out of registry with the bottom of wall 113, and thus permitting both doors 124 and 125 to be swung open about their respective hinges 126 and 127. A conventional grate (not illustrated) can then be placed on top of supporting rods 162, together with a supply of fuel (for example wood). The damper 172 is then opened at least partially; and assuming that the converter element 182 is already in the holder 181, the fire can be started and the doors 124 and 125 once again may be closed. As previously noted, whenever door 125 is open, the damper plate 146 swings downwardly to its broken line position in Fig. 10, thereby opening the bypass 143 so that any flame or gases in the fire box will be drawn rearwardly and outwardly through the openings 143 and 144 and the exhaust duct 191 to the associated chimney (not illustrated). This prevents any undesirable rush of flame and/or gas out of the front of the fire box, when its doors are opened during its operation.

After the fire has been started and the fire box doors have been closed, door 125 strikes the rod 150 which pushes the damper plate 146 closed over the bypass opening 143, so all carbon and gases generated in the combustion chamber will thereafter have to pass upwardly through the converter element 182 before entering the exhaust chamber 158. Especially in the spring and the fall, when the heating requirements of a stove of the type described are not as high, the combustion air fed to the fire box is usually quite restricted. At this point much of the combustion in the fire box is accompanied by pyrolysis, which is an incomplete combustion of fuel resulting from oxidizing without sufficient air. As a result, smoke is produced because the hot combustible gases, tars, and carbon particles are not mixing well enough with available oxygen, and the temperature in the combustion chamber of the fire box is not high enough, under this type of operation, to effect complete combustion.

However, it has been found that when a converter 182 of the type disclosed herein is employed, additional and more complete combustion occurs in and around the converter itself. The effectiveness of the converter element 182 can be monitored by observing its colour through the sight glass 188. When the element is working properly, it tends to glow bright red or orange in colour, indicating that secondary combustion is taking place in and around the element, thereby completely burning up combustible gases, tars and carbon particles which might otherwise be discharged as undesirable emissions to the associated stack or chimney. The relative position of the sight glass with respect to the catalytic converter is such that the catalytic converter, when, operative will clean the glass of any deposits through high intensity radiant heat.

From the foregoing it will be apparent that the present invention provides a relatively simple and inexpensive means for effecting substantially complete and thorough combustion of all combustible by-products of the fuel which is burned in the main combustion chamber of applicant's novel stove. By supplying combustion air from two different sources, (i.e. both from the bottom and from the top of the fire box) it is possible better to maintain the quantity of oxygen necessary to support combustion both in the main combustion chamber of the fire box, and in the vicinity of the converter element 182.

The automatically operating damper control rod 150 provides a simple means for eliminating any undesirable flashback or discharge of flame and gas out of the front of the stove whenever its doors 124 and 125 are open.

While this invention has been described in connection with the use of the fire wood, it will be apparent that it can be used to burn any type of bio-mass fuels, including coal provided the usual cautions are taken to prevent the escape of noxious fumes.

CLAIMS:

1. A catalytic converter means for use in solid fuel burning stoves, which comprises a plurality of catalytic cells each having a length oriented in the direction of the flow of said exhaust and a volume in cubic inches expressed as function of the density (N) of said cells in a direction perpendicular to said flow, said function being at least:

$$-\frac{6720.23}{\left(N\ \frac{cells^2}{in^2}\right)} + \frac{2554.85}{\left(N\ \frac{cells}{in^2}\right)} + 14.84$$

2. A converter as claimed in claim 1 wherein said volume is equal to about 150 in^3 and said density is equal to about 16 cells per in^2.

3. A converter as claimed in claim 1, which comprises a plurality of catalytic cells each having a length oriented in the direction of the flow of said exhaust and a volume in cubic inches expressed as a function of the density of said cells in a direction perpendicular to said flow being at least:

$$-\frac{4458.33}{\left(N\ \frac{cells^2}{in^2}\right)} + \frac{1957.5}{\left(N\ \frac{cells}{in^2}\right)} +3.83$$

4. A converter as claimed in claim 1, which comprises a plurality of catalytic cells each having a length oriented in the direction of the flow of said exhaust and a volume in cubic inches expressed as a function of the density of said cells in a direction perpendicular to said flow being at least:

$$- \frac{3333.33}{\left(N_{\text{cells}/\text{in}^2}\right)^2} + \frac{1537.5}{\left(N_{\text{cells}/\text{in}^2}\right)} - 14.17$$

5. A converter as claimed in claim 4, wherein said volume is equal to about 150 in^3 and said density is equal to about 9 cells per in^2.

6. A converter as claimed in claim 3 or 4, wherein said volume is equal to about 75 in^3 and said density is equal to about 9 or 16 cells per in^2.

7. A converter as claimed in claim 4, wherein said volume is equal to about 50 in^3 and said density is equal to about 25 cells per in^2.

8. A converter as claimed in any one of claims 1, 3 or 4, wherein the square of the length of said cells divided by the product of the cell density times the converter volume times the fourth power of the inside dimension of one of said cells is less than 5.

9. A converter as claimed in claims 1 - 3, wherein the square of the length of said cells divided by the product of the cell density times the converter volume times the fourth power of the inside dimension of one of said cells is less than 7.

10. A converter as claimed in claims 1 - 3, wherein the square of the length of said cells divided by the product of the cell density times the converter volume times the fourth power of the inside dimension of one of said cells is less than 10.

11. A solid fuel burning stove, which comprises a combustion chamber, a flue for removing exhaust from said chamber, and a catalytic converter for oxidizing oxidizable species in said exhaust.

12. A stove as claimed in claim 11, wherein said catalytic converter is situated in said flue immediately adjacent said chamber.

13. A stove as claimed in claim 11, wherein said flue communicates with said combustion chamber at an exit port and wherein said catalytic converter means is situated in said chamber at said exit port.

14. A stove as claimed in claim 11, wherein said catalytic converter is situated in said combustion chamber.

15. A stove as claimed in claim 14, further comprising: a heat exchange chamber in communication with said flue; and an opening interconnecting said combustion and heat exchange chambers, said catalytic converter being situated adjacent said opening.

16. A stove as claimed in claim 11, wherein said oxidizable species is creosote.

17. A stove as claimed in claim 11, wherein the catalytic converter means has a porous catalytic structure situated for the exhaust to normally pass through it to the flue and the stove includes an exhaust bypass means for allowing at least a portion of the exhaust to bypass the porous catalytic structure.

18. A stove as claimed in claim 17, wherein the catalytic converter means is mounted in a moveable structure comprising the exhaust bypass means whereby

the converter means is moveable to permit at least some of the exhaust to bypass the converter means.

19. A stove as claimed in claims 11, 17 or 18, which comprises means for admitting air for combustion to said chamber, including a door on said combustion chamber moveable between open and closed positions relative to a first opening in said chamber and a second opening in said combustion chamber adjacent the bottom thereof, the combustion chamber having therein two further openings for exhausting combustion gases from said chamber to the exterior thereof, and means for selectively closing the other of said two further openings, said converter being positioned so that, when said other opening is closed, all said gases from said combustion chamber are caused to pass through said converter.

20. A stove as claimed in claim 19, wherein said closing means includes means automatically closing said other opening when said door is closed, and opening said other opening, when said door is opened.

21. A stove as claimed in claim 19, wherein said door has therein at least one pane of glass secured across an opening in said door, and said means for admitting air to said box further includes means for directing at least a portion of said air across the inside surface of said pane to help keep said surface clean.

22. A stove as claimed in claim 21, wherein there are two panes of glass secured across said opening in said door in spaced, parallel relation, and at least a portion of the peripheral edge of each of said panes is spaced from the periphery of the opening in said door, thereby to admit additional air to said chamber through said opening in the door.

23. A stove as claimed in claim 22, wherein said portions of said edges of said panes are located adjacent diametrally opposite edges of the opening in said door, whereby said additional air passes through the space between said panes during passage thereof into said combustion chamber.

24. A stove as claimed in claim 19, including a heat shield surrounding a portion of said chamber in spaced, confronting relation to said portion, and means for directing air under pressure into the space between the said shield and said chamber.

25. A stove as claimed in claim 19, including a secondary chamber mounted on said combustion chamber and communicating through said converter with the interior of said combustion chamber, and a transparent sight member mounted in the wall of said secondary chamber and registering with said converter to permit viewing of the converter from the exterior of said combustion chamber and said secondary chamber.

26. A stove as claimed in claim 19, wherein said other of said two openings is in a portion of a wall of said combustion chamber which is inclined to the vertical, said closing means comprises a damper mounted for movement by gravity from a closed position over said other opening to an open position relative thereto, and said damper is connected to said door to be moved thereby from its open to its closed position each time said door is closed.

27. A stove as claimed in claim 26, wherein said door is mounted on the front wall of said fire box, and said other of said two openings is formed in an inclined

portion of the rear wall of said combustion chamber, a plate projects horizontally from the rear wall of said combustion chamber adjacent the lower edge thereof, and part way into said combustion chamber in spaced, parallel relation to the bottom thereof, and an ash pan is removably mounted on the bottom of combustion chamber and projects adjacent its inner end beneath said plate.

28. A converter as claimed in any one of claims 1 - 10, which comprises a catalytic coating of palladium or platinum.

29. A stove as claimed in any one of claims 11 - 27, wherein said converter is coaxially mounted in a metal sleeve.

30. A stove as claimed in claim 29, wherein said converter comprises a catalytic coating of palladium or platinum.

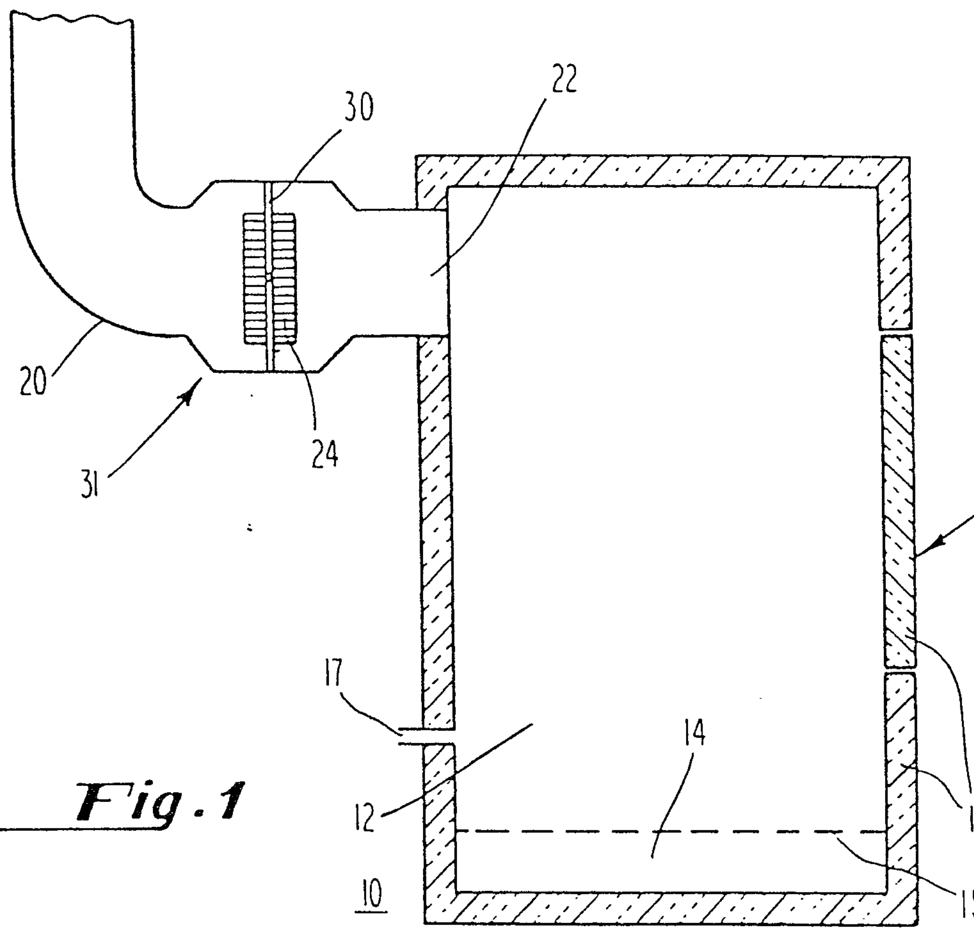

Fig. 1

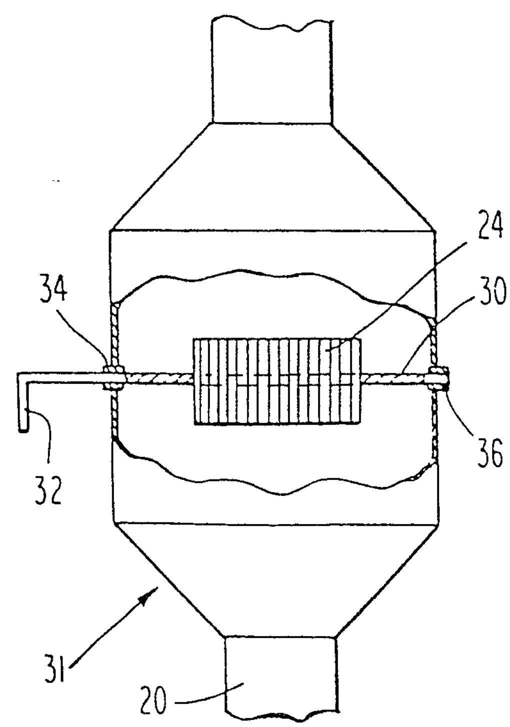

Fig. 2

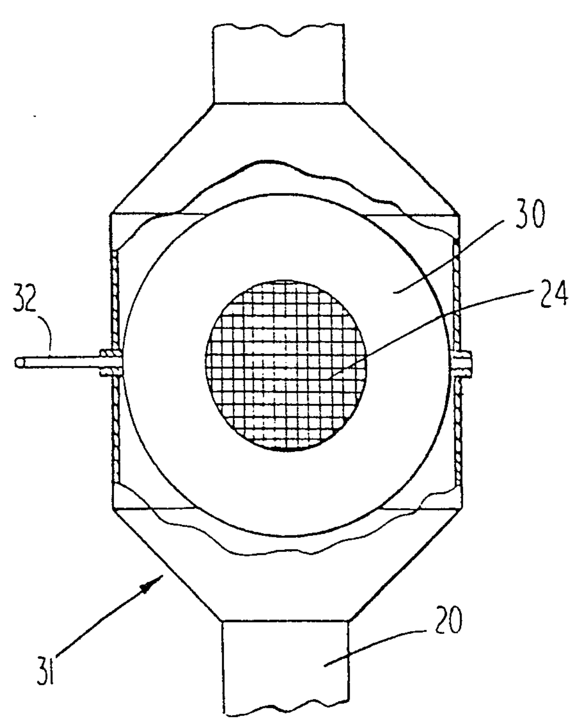

Fig. 3

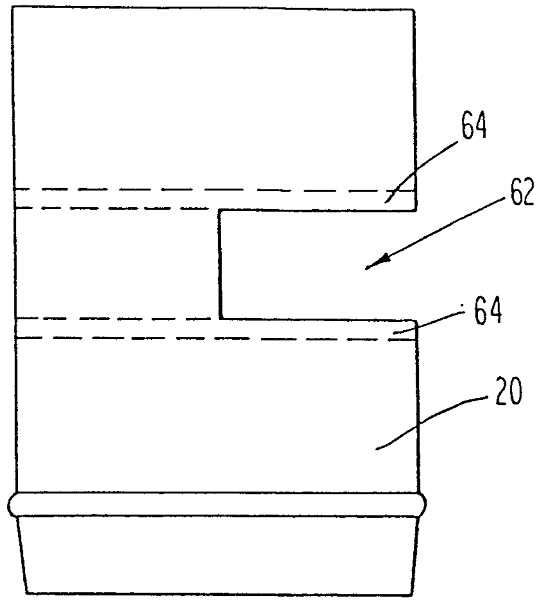

Fig. 4A

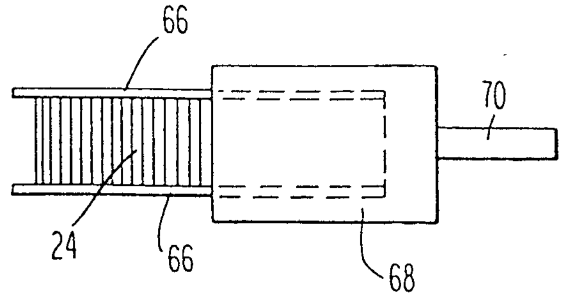

Fig. 4B

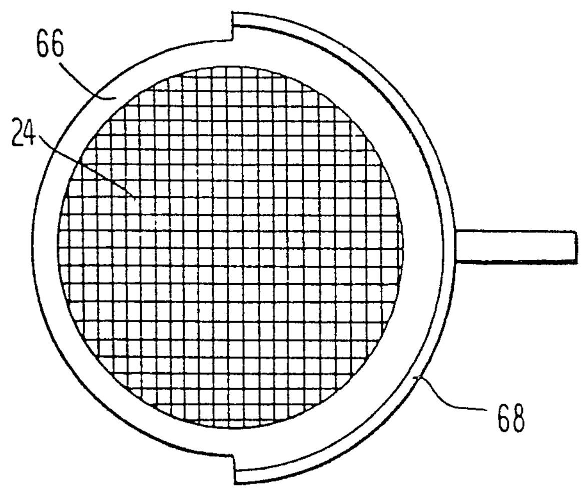

Fig. 4C

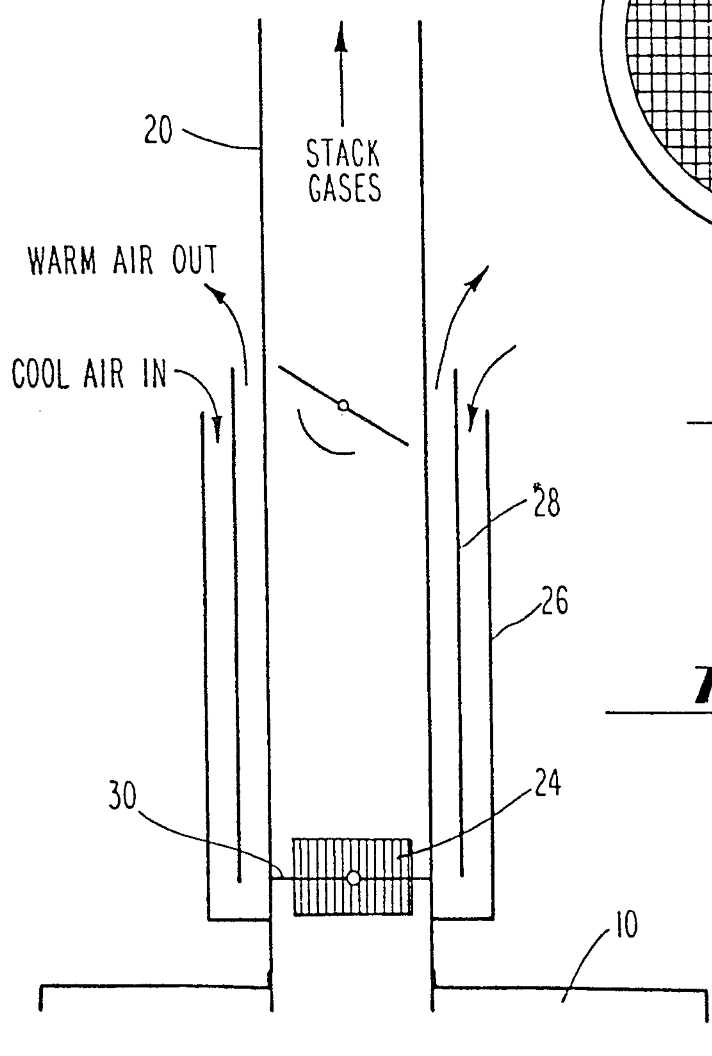

Fig. 5

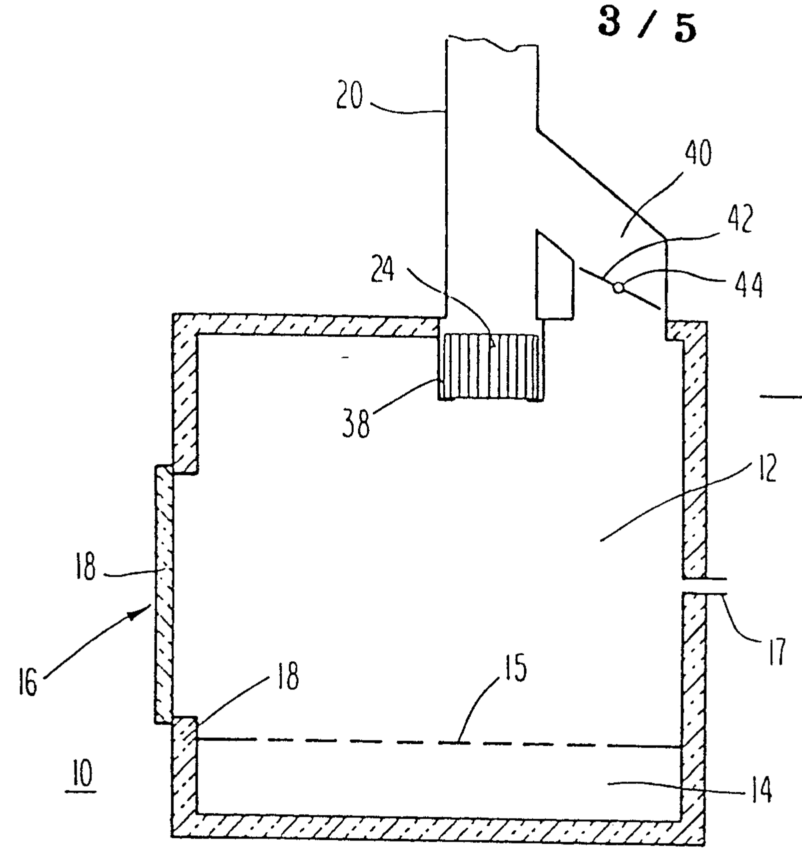
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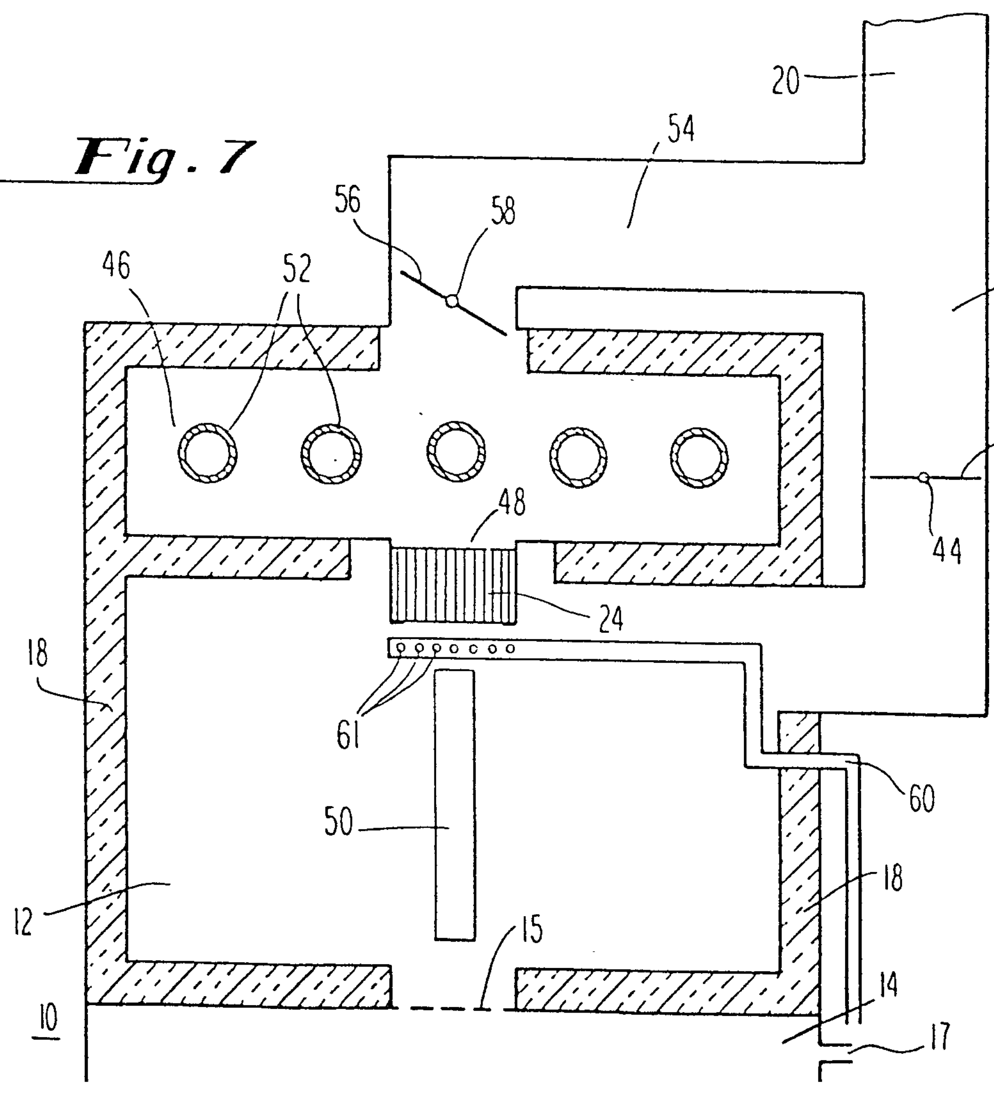
Fig. 6

Fig. 7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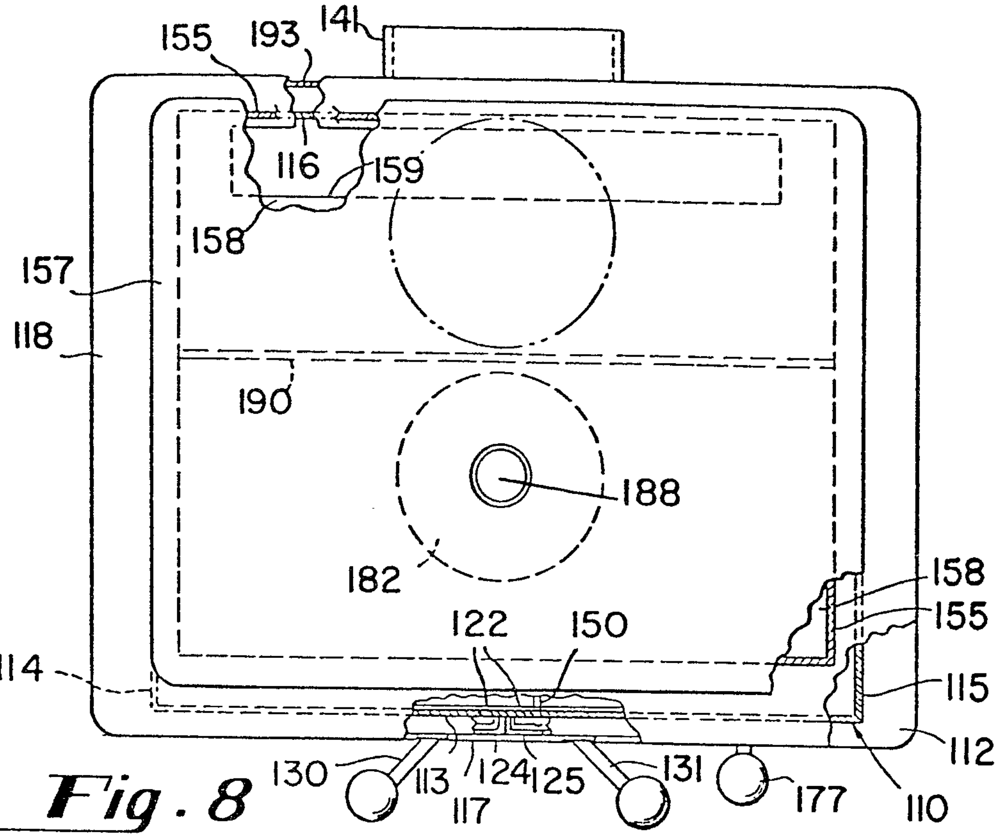
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Fig. 8

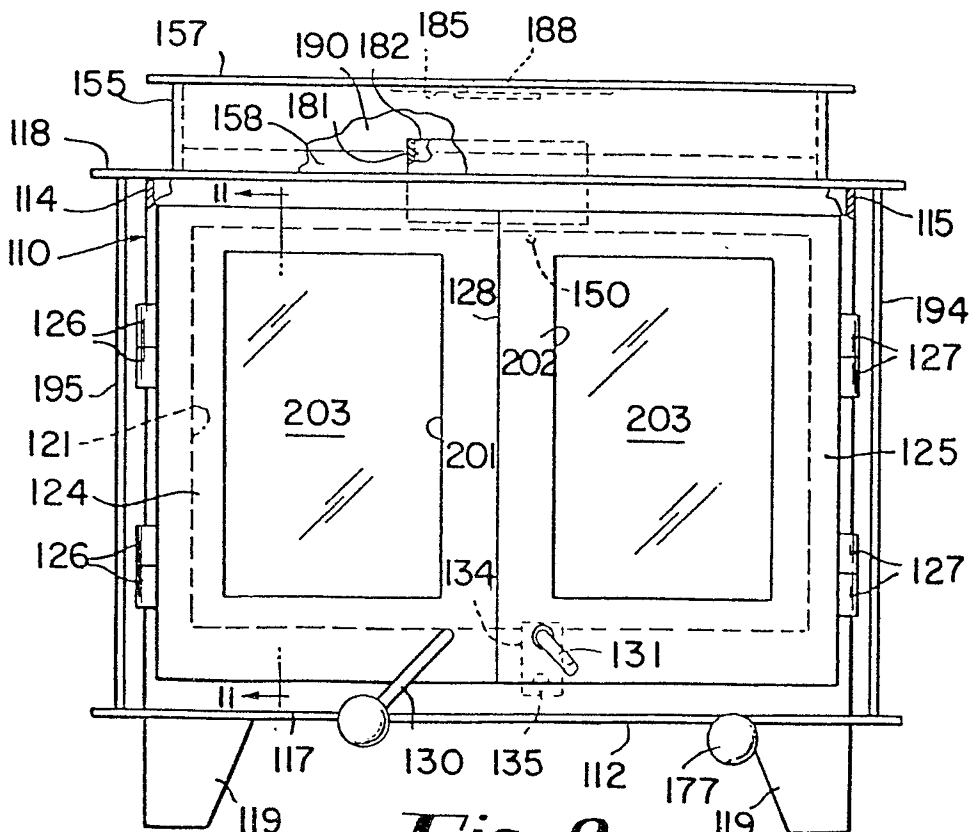
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Fig. 9

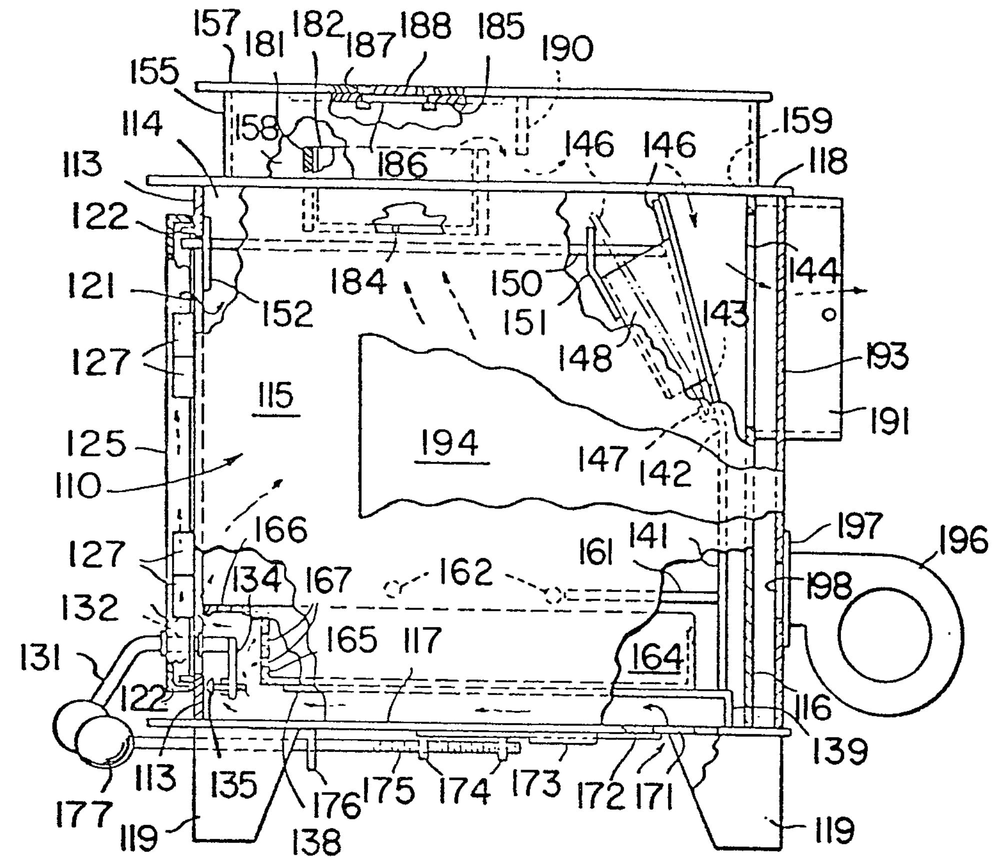

Fig. 10

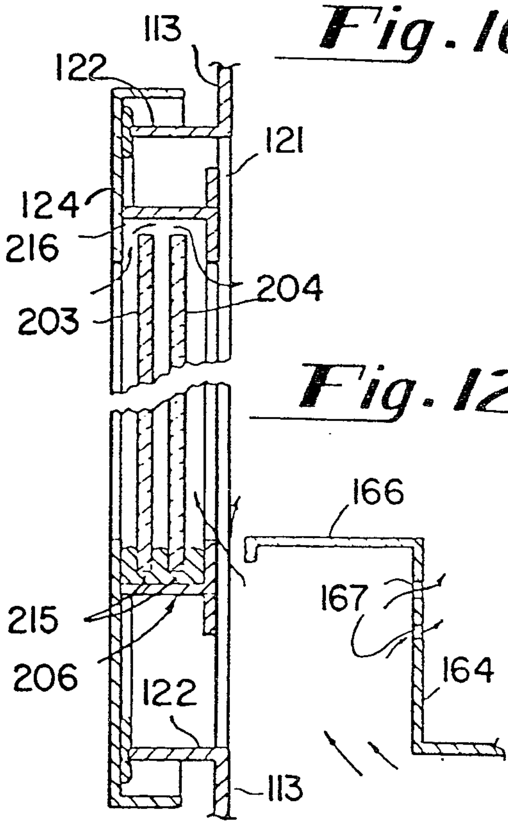

Fig. 12

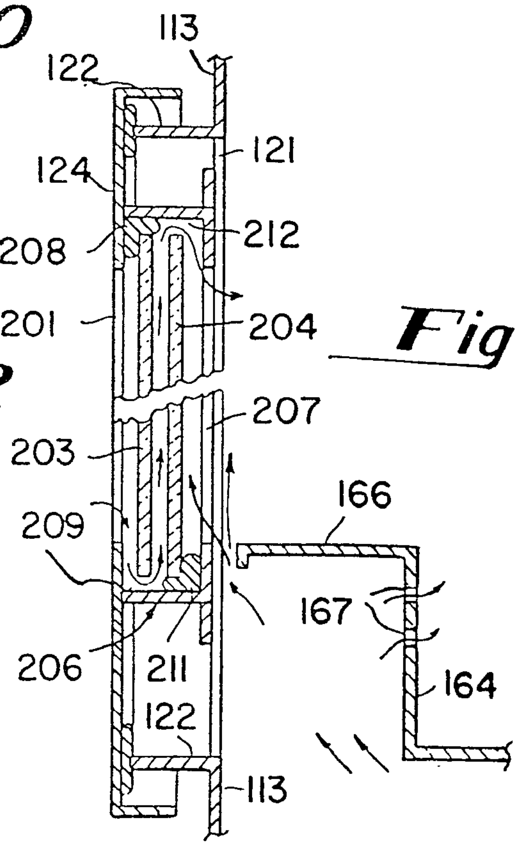

Fig. 11