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(54) **Combustor device for a solid fuel heating appliance.**

(57) A combustor device (16) is provided for oxidizing oxidizable species in the exhaust from the combustion chamber (12) of a solid fuel heating appliance (10). The combustor device comprises a structure (16) having a plurality of axially extending cells (32) for passing oxidizable species therethrough and at least one leakage path for the oxidizable species through said structure (16) or around and adjacent said structure (16).

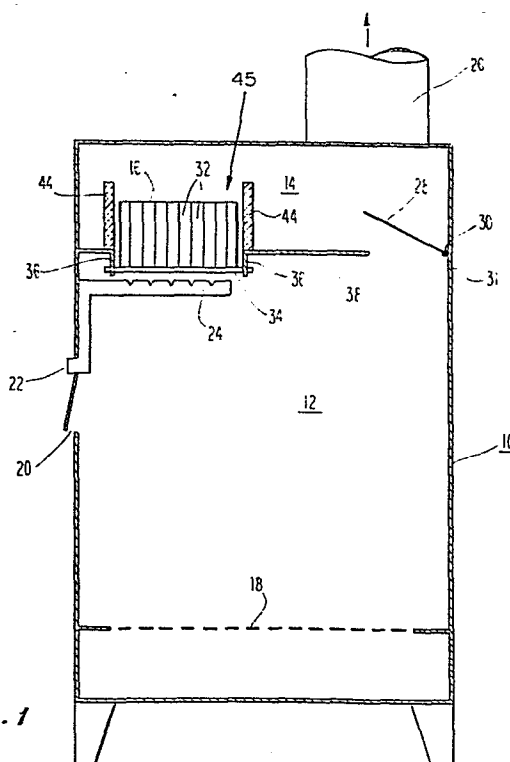


Fig. 1

COMBUSTOR DEVICE FOR A SOLID FUEL
HEATING APPLIANCE

This invention relates to solid fuel heating appliances, and more particularly, to appliances which burn wood, densified or compacted wood products, coal, charcoal, peat, compacted trash or similar solid fuels and utilize a combustor or catalytic converter.

US-A-4373452 discloses the use of a catalytic converter in a wood burning stove. The catalytic converter which serves as a combustor provides more complete burning or oxidation of the volatile and particulate organic substances present in gases arising from burning wood in a wood burning stove and especially those solid particles and resinous and oily droplets that cause the dense smoke which, upon deposition on the inside surface of the flue pipe or chimney, is generally known as creosote. More particularly, a catalytic converter which comprises noble-metal catalysts on a suitable substrate reduces the ignition temperatures of carbon monoxide and the lower boiling, more volatile hydrocarbons present in the exhaust issuing from the combustion of wood. As the hydrocarbons and carbon monoxide burn, the temperature of the catalyst and its substrate is raised which increases its catalytic activity. The elevated temperature pyrolyzes and cracks the higher molecular weight hydrocarbons occurring in the smoke as solid particles and oily droplets, converting them to volatile compounds which readily mix with oxygen present and thereby leading to their rapid oxidation. The temperature continues to rise until the system reaches a temperature at which there is equilibrium between the inlet gas temperature, flow rate and the amount of oxidizable material. This temperature is typically 600°C to 900°C for a properly sized catalyst system. At these temperatures, oxidation proceeds very rapidly to completion if the catalytic device

has the appropriate volume and internal surface area. As converter temperatures increase, the exhaust gas temperature rises above the ignition point of an increasing number of its constituents so that the catalytic combustion process is augmented by thermal combustion. The high temperatures also break the complex hydrocarbons and other combustibles (including solid particular entrained in the combustion gases) into compounds which will burn more easily.

10 As disclosed in the aforesaid US-A-4373452, the catalytic converter comprises a number of cells which extend axially through the substrate so as to permit the stove exhaust to pass therethrough. Since the cells may be relatively small, e.g. 16 cells per square inch (about
15 2.5 cells/cm.²), it is possible that some or many of the cells may become plugged with exhaust materials including creosote and other hydrocarbon compositions. This, in turn, may produce a safety hazard since the smoke from the stove which is unable to pass properly through the catalytic converter may enter any living space surrounding
20 the stove and create an asphyxiation hazard. It will be understood that such a hazard can occur when a combustor or catalytic converter is utilized in any solid fuel heating appliance which utilizes a solid fuel such as wood,
25 densified or compacted wood products, coal, charcoal, peat, compacted trash and/or garbage and the like which may give off, during burning, solid particles and vapour that may lead to some temporary plugging of the catalytic converter.

Adjustable and closable bypasses have recently
30 been utilized or proposed between a combustion chamber and an exhaust flue or chamber of a wood burning stove as disclosed in European patent specification 0037281A, GB-A-2081886 and GB-A-2081887. The main purpose of these bypasses is to minimize back pressure within the stove
35 having a combustor or catalytic converter when the door of

the stove is open which can result in the introduction of smoke into the living space around the stove. Such a bypass is spaced a substantial distance from the catalytic converter.

5 It is an object of this invention, and preferred embodiment thereof, to provide a combustor or catalytic converter for a solid fuel heating appliance, for example a wood burning stove wherein the plugging of the cells in the catalytic converter will not result in the leakage of
10 smoke into the living space adjacent the appliance, the risk of asphyxiation is reduced without adversely affecting the efficiency of the stove, and indeed in which oxidation of carbon monoxide, hydrocarbons and other combustibles (including solid particles entrained in the
15 combustion gases) is optimized.

 According to the invention there is provided a combustor device for oxidizing oxidizable species in the exhaust from the combustion chamber of a solid fuel heating appliance, comprising a structure having a plurality of
20 axially extending cells for passing oxidizable species therethrough and at least one leakage path for the oxidizable species through said structure, or around and adjacent said structure.

 A preferred embodiment of the invention comprises a solid fuel heating appliance in the form of a wood
25 burning stove of the type including a combustion chamber, a flue for removing exhaust from the combustion chamber and a combustor or catalytic converter means having a plurality of cells extending therethrough for oxidizing
30 oxidizable species in the exhaust. Other solid fuel heating appliances which may embody the invention include boilers, incinerators and the like.

 At least one leakage path, as a passive bypass, is provided around the cells and is located immediately
35 adjacent the combustor or catalytic converter. In several embodiments of the invention, the leakage path is located

at the periphery of the catalytic converter. In one of the several embodiments, the leakage path may be provided a spaced distance from the catalytic converter but nevertheless in the vicinity immediately adjacent the catalytic converter. In another of these several embodiments of the invention, a leakage path may be provided between a container for the catalytic converter and the periphery of the catalytic converter. In still another of these several embodiments, the catalytic converter is movably mounted within an opening and provided with the leakage path adjacent to the periphery, which may also permit a variation in the size of the leakage path. In yet another embodiment of the invention, the leakage path may be provided by one or more axially extending and enlarged openings within the interior of the catalytic converter itself.

In order to provide sufficient leakage, the overall transverse cross-sectional area of the leakage path must be substantially greater than the transverse cross-sectional area of any of the individual cells. Preferably, the transverse cross-sectional area of the leakage path is substantially greater than the average cell transverse cross-sectional area of substantially all of the cells. For example, it is desirable to have a transverse cross-sectional area of the leakage path which is at least two and preferably four times as great as the average cell transverse cross-sectional area. In any event, the leakage path should provide for at least 10% and preferably 10% to 40% of the overall flow of exhaust through the converter itself and the leakage path.

In the accompanying drawings:

FIG. 1 is a sectional view of a solid fuel heating appliance comprising a wood burning stove representing a preferred embodiment of the invention including a combustor in the form of a catalytic converter mounted in accordance with this invention;

FIG. 2 is an enlarged fragmentary view of the catalytic converter and mounting shown in FIG. 1;

FIG. 3 is a bottom view of a catalytic converter and mounting taken along line 3-3 of FIG.2;

5 FIG. 4 is a sectional view of a catalytic converter and mounting in yet another embodiment of the invention;

FIG. 5 is a bottom view of the catalytic converter and mounting taken along line 5-5 of FIG.4;

10 FIG. 6 is a sectional view of a catalytic converter and mounting comprising yet another embodiment of the invention;

FIG. 7 is a bottom view of the catalytic converter and its mounting taken along line 7-7 of FIG. 6;

15 FIG. 8 is a sectional view of a catalytic converter and mounting in still another embodiment of the invention; and

FIG. 9 is a bottom view of the catalytic converter and mounting taken along line 9-9 of FIG.8.

20 FIG. 1 shows a solid fuel heating appliance comprising a wood burning stove 10 including a primary wood combustion chamber 12 in the lower portion of the stove and an exhaust or secondary combustion chamber 14 in the upper portion of the stove. A combustor in the
25 form of a catalytic converter 16 is located between the primary combustion chamber 12 and the exhaust or secondary combustion chamber 14 to promote more complete burning or oxidation of the carbon monoxide, hydrocarbons and other combustibles (including solid particles entrained
30 in combustion gases) exiting from the primary combustion chamber 12.

The stove 10 includes a grate 18 within the primary combustion chamber for supporting the wood to be burned therein. Air to the primary combustion chamber 12 is
35 supplied through a primary combustion air inlet 20. A secondary combustion air inlet 22 is coupled to a manifold 24 which provides air or oxygen to the inlet face of the

catalytic converter 16 so as to optimize the oxidation or burning with the catalytic converter. The manifold 24 is positioned and designed in the appliance so as to provide adequate premixing of the secondary air from the manifold 24 with the combustion gases and fumes before they enter the converter 16. Additional combustion or oxidation and/or heat exchange to a living space occurs within the chamber 14 before the exhaust gases leave through a flue 26.

10 An adjustable or closable bypass to the flue 26 is preferably provided by a damper 28 which is attached at a pivot or hinge position 30 to a wall 31 of the stove 10 (similar to European patent specification 0037281A, although it may optionally be like the damper in GB-A-
15 2081886.

 The catalytic converter 16 is mounted between the primary combustion chamber 12 and the chamber 14 so as to provide the leakage path around the axially extended cells of the catalytic converter 16 as best shown in FIGS. 2 and 3. More specifically, the catalytic converter 16 comprises an open-ended honeycomb structure with a plurality of axially extending cells 32 supported on rods 34 which extends transversely across a cylindrical structure 36 extending downwardly from a wall 38 separating the
25 primary combustion chamber 12 from the chamber 14. Since the catalytic converter 16 is of lesser diameter than the opening through the tubular or cylindrical structure 36, exhaust from the primary combustion chamber is permitted to flow around the periphery of the catalytic converter 16 as depicted by arrows 40. This flow of exhaust gases as depicted by arrows 40 ensures that, even if the axially extending cells 32 of the catalytic converter 16 should become plugged preventing the flow of exhaust gases through the axially extending cells 32 as depicted by arrows 42,
30 exhaust gases will still be permitted to pass from the primary combustion chamber 12 to the chamber 14 and hence

to the flue 26 without backing up and entering the living space surrounding the stove 10.

Also, as shown in FIGS. 1 and 2, the mounting of the catalytic converter 16 includes a cylindrical insulating member 44 having a central opening 45 substantially
5 corresponding in diameter with the opening of the cylindrical structure 36. The insulating material 44 in conjunction with the cylindrical member 36 provides a container for the catalytic converter which permits the establishment
10 of a leakage path 40 between the catalytic converter and the container. By utilizing the insulation material 44, the exhaust gases which pass through the leakage path are maintained in close proximity to the catalytic converter 16 and heat generated at the catalytic converter 16 is
15 retained so as to create an elevated temperature at the outlet of the catalytic converter 16 to ensure at least some oxidation or combustion of the carbon monoxide, hydrocarbons and other combustibles (including solid particles entrained in the combustion gases) flowing
20 through the leakage path even though that exhaust does not pass through the small cells of the catalytic converter 16 itself.

In order to fabricate the structure shown in FIGS. 1 to 3, a refractory insulating material 44 such as
25 FIBERFRAX (Registered Trade Mark) refractory fibre products, may be secured to the wall 38 by means of a refractory of cement, such as QF 180 cement made and sold by the Carborundum Company. The rods 34 pass through openings in the metallic cylindrical structure 36. Alth-
30 ough the rods 34 need not be fastened in place within those openings, it may be desirable to provide fasteners at the end of the rod 34, e.g. nuts received by threaded portions of the rods 34.

Another embodiment of the catalytic converter
35 mounted in a wood burning stove with a leakage path for exhaust gases is shown in FIGS. 4 and 5. In this

embodiment, a cylindrical structure 136 is provided having an interior opening which substantially corresponds with the dimension of the catalytic converter 16 so that there is no leakage path between the catalytic converter and the container 136 for the catalytic converter. The leakage path around the catalytic converter 16 is provided by a vent structure 138 located immediately adjacent the catalytic converter 16. The vent structure 138 includes an elbow 140 which directs the leaked exhaust gas back to the high temperature area above the catalytic converter 16 so as to ensure to the degree possible, combustion and oxidation of the carbon monoxide, various hydrocarbons and other combustibles (including solid particles entrained in the combustion gases) which are leaked around the catalytic converter 16. In order to mount the catalytic converter 16 within the cylindrical structure 136, the structure 136 includes small flange segments 142 which are of insufficient length or depth to substantially block the cells 32 while at the same time having sufficient length and depth to ensure that the catalytic converter 16 is retained within the cylindrical structure 136.

In the embodiment of the invention shown in FIGS. 6 and 7, the leakage around the cells of the catalytic converter 16 occurs as a result of enlarged openings extending through the interior of (and thereby being adjacent to) the converter itself. For this purpose, the catalytic converter 16 includes a plurality of openings 200 having substantially larger transverse cross-sectional areas than the cell transverse cross-sectional area of the average or even the largest of the cells 32 through the catalytic converter 16. If so desired, the converter 16 may include only one opening 200 where such a single opening will provide adequate leakage. The converter 16 is mounted within a cylindrical structure 236 as shown in FIGS. 6 and 7 using a refractory cement such as Super 3000

cement made and sold by Combustion Engineering, Inc.

FIGS. 8 and 9 disclose yet another embodiment of the invention wherein the catalytic converter 16 is mounted within a metallic ring 300 which is pivotally supported on a cylindrical structure 336 by means of pins 338 which extend through openings in the cylindrical structure 336. In the embodiments of FIGS. 8 and 9, the leakage flow 340 is provided by the annular opening between the ring 300 and the structure 336 and may be adjusted by change in the angle of rotation of the ring 300 about pins 338. As the catalytic structure 16 and the supporting metallic ring 300 is pivoted out of the horizontal plane, the size of the leakage path 340 increases.

In the embodiment of FIGS. 8 and 9, it will be appreciated that the ceramic structure 16 may be mounted within the ring 300 by suitable means including a refractory cement such as Combustion Engineering Super 3000 cement. It will also be appreciated that it may be desirable to displace the manifold 24 (FIG. 1) for the secondary combustion air so as to permit substantial and free rotation of the catalytic converter 16 within the ring 300.

It will be appreciated that it is important that the leakage path around the cells 32 of the converter 16 be in the vicinity of the converter such that the elevated temperatures in the vicinity of the converter can assist as much as possible in oxidizing or burning the carbon monoxide, hydrocarbons and other combustibles (including solid particles) within the exhaust gases which flow through the leakage path. It is also important that the volume of flow through the leakage path be consistent with the objective that most of the exhaust gases flow through the catalytic converter while at the same time providing sufficient flow through the leakage path to avoid the backing up of smoke if the cells of the

catalytic converter should become blocked. In this regard, it is desirable that the transverse cross-sectional area of the leakage path(s) be such that at least 10% and preferably 10% to 40% of the overall flow of exhaust gases goes through the leakage path(s) instead of the axially extending cells. Where the leakage paths are provided by enlarged openings of square transverse cross-section in the catalytic converter 16 having square transverse cross-sectional cells 32 as shown in FIGS. 6 and 7, the amount of leakage for any given cell distribution can be calculated from the following equation for the total flow through the combustor:

$$Q = \frac{2 \Delta P}{56.8 \mu L} [N_1 X_1^4 + N_2 X_2^4 + \dots + N_n X_n^4]$$

where Q = total volume flow through the combustor;
 ΔP = pressure drop across combustor;
 μ = gas viscosity;
 L = combustor length;
 N_1 = number of holes of inside dimension X_1 ;
 N_2 = number of holes of inside dimension X_2 ;
 N_n = number of holes of inside dimension X_n ;

It will be appreciated that

$$A = \text{combustor frontal area} = N_1 (T_1 + X_1)^2 + N_2 (T_2 + X_2)^2 + \dots + N_n (T_n + X_n)^2$$

where T_1, T_2, T_n are wall thicknesses.

From the foregoing equation for Q , the percentage flow through the leakage path of a given size opening may be expressed as:

$$[N_n X_n^4 / (N_1 X_1^4 + N_2 X_2^4 + \dots + N_n X_n^4)] \times 100\%$$

Assuming, for example, a catalytic converter of 14.38 cm.

(5.66 inches) in diameter with 4 square transverse cross-sectioned cells per square cm. (16 square transverse cross-sectioned cells per square inch), the percent of flow through the leakage path using various sized holes of square transverse cross-section in various numbers may be calculated:

	Large Hole Size Xn	Number of Large Holes	% Flow Through Large Holes
10	2.54 cm. (1.0 inch)	1	60%
	1.91 cm. (0.75 inch)	1	29%
	1.52 cm. (0.60 inch)	2	25%
	1.27 cm. (0.50 inch)	3	20%

As noted in the foregoing, it is preferred that the percentage of leakage flow be 10% to 40% and the hole sizes of 1.91 cm., 1.52 cm. and 1.27 cm. with the number of holes indicated falling within this range. A hole size of 2.54 cm. (1.0 inches) in this particular catalytic converter structure produces a percentage of flow which is somewhat higher than the preferred range. On the other hand, the smaller size holes and the numbers indicated provide sufficient flow without any substantial risk of hole plugging. In general, it is desirable to provide leakage paths having transverse cross-sectional areas which are at least two and preferably four times as large as the average cell transverse cross-sectional area of the cells.

It will be appreciated by skilled persons in this field of technology that the converter structure may optionally be formed with cells of transverse cross-section other than square. Thus, the configuration of transverse cross-section for converter cells may be circular, oval, any polygon, etc. Such persons can reasonably formulate a suitable formula for percentage flow through large holes with respect to any selection of any other transverse cell

cross-sectional configuration, based on analogy and guidance of the preceding formula for square cells.

5 In the catalytic converters, 16, it is, of course, extremely important to ensure proper combustion for oxidation of the carbon monoxide, hydrocarbons and other combustibles (including solid particles entrained in the combustion gases) exiting the primary combustion chamber 12. Details concerning the catalytic converter 16 are set forth in the aforesaid US-A-4373452.

10 In all of the various embodiments of the invention, it will be appreciated that the leakage path(s) around the axially extending cells of the catalytic converter is (are) located in the immediate vicinity of the catalytic converter. This is, of course, important,
15 as described above, in order to subject the leaked exhaust gases to high temperatures, thereby ensuring, to the degree possible, combustion or oxidation of carbon monoxide, hydrocarbons and other combustibles (including solid particles) within the leakage exhaust gases themselves. As shown in FIG. 1, a leakage path within the
20 vicinity of the catalytic converter 16 is to be distinguished from any leakage resulting from a bypass of exhaust gases provided at a position more remote from the catalytic converter. The function served by the bypass opened and
25 closed by the damper 28 is entirely different from the function served by the leakage path in the immediate vicinity of the catalytic converter 16 (see the aforesaid European patent specification 0037281A).

Although a wood burning stove has been shown and
30 described in detail, it will be appreciated that the invention may be embodied in other solid fuel heating appliances which can utilize various solid fuels including densified or compacted wood products, coal, charcoal, peat and compacted trash and/or garbage and the like which may
35 give off during burning, solid particles and vapours that

may lead to some temporary plugging of the catalytic converter. Such appliances make take the form of stoves as well as boilers, incinerators and the like, especially those well-suited for residential use.

Claims:

1. A combustor device for oxidizing oxidizable species in the exhaust from the combustion chamber of a solid fuel heating appliance, comprising a structure having a plurality of axially extending cells for passing oxidizable species therethrough and at least one leakage path for the oxidizable species through said structure, or around and adjacent said structure.
2. A device according to claim 1, wherein said structure comprises a honeycomb arrangement of cells.
3. A device according to claim 1 or 2, wherein said at least one leakage path has a substantially larger cross-sectional area than the average cell cross-sectional area of the cells.
4. A device according to claim 1 or 2, wherein said leakage path is located at the periphery of said structure.
5. A device according to claim 1 or 2, further comprising a container surrounding the periphery of said structure, said leakage path extending between said container and said structure.
6. A device according to claim 5, wherein said container comprises a tubular member and a support member extending transversely relative to the tubular member for supporting said structure.
7. A device according to claims 5 or 6, wherein the cross-sectional area of the leakage path is adjustable.
8. A device according to claim 7, wherein said structure is movably mounted within an opening forming said leakage flow path.

9. A device according to any preceding claim, wherein the volume flow through the leakage path comprises at least 10% of the overall exhaust.

10. A device according to any preceding claim, wherein the volume flow through the leakage path comprises 10% to 40% of the overall exhaust.

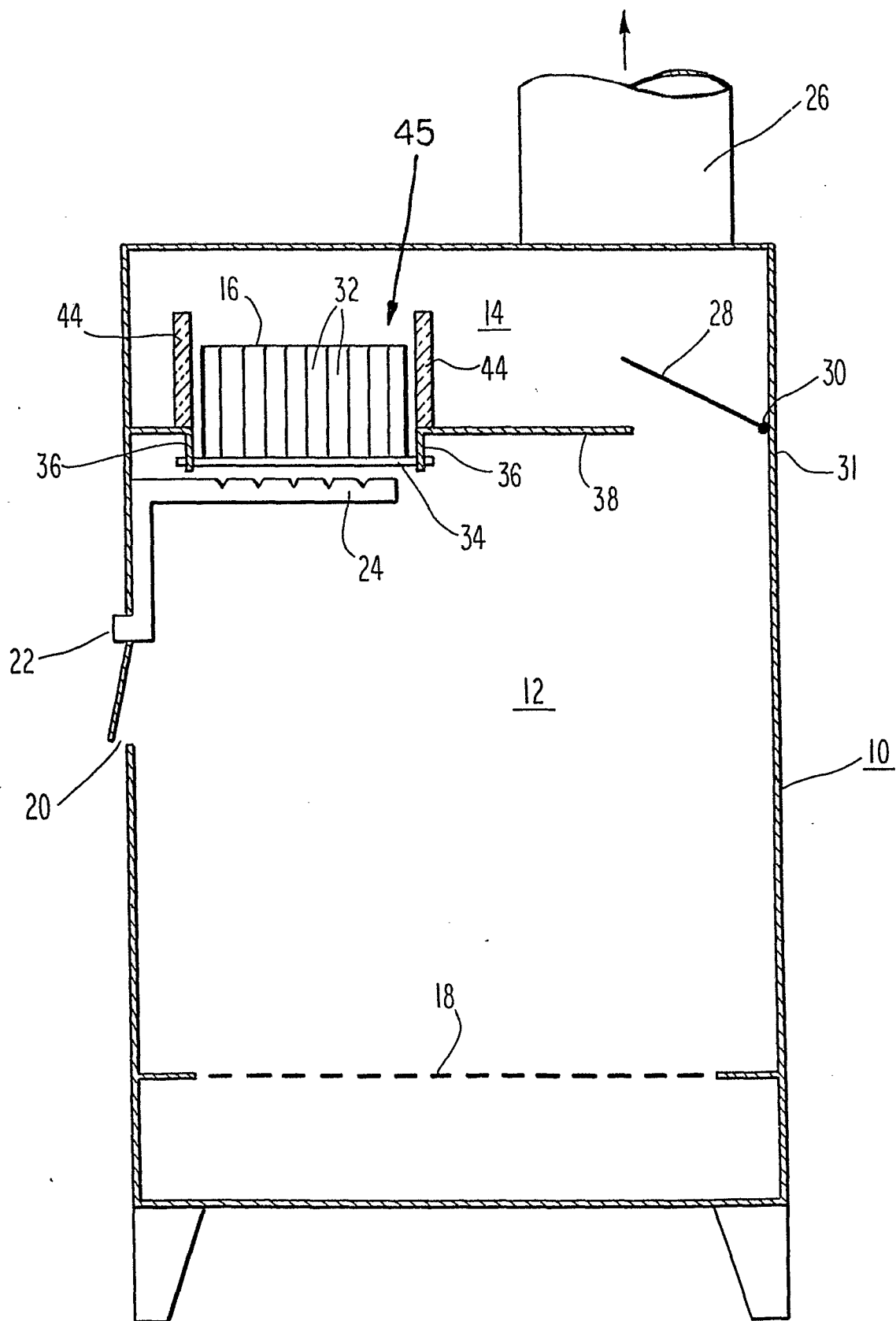
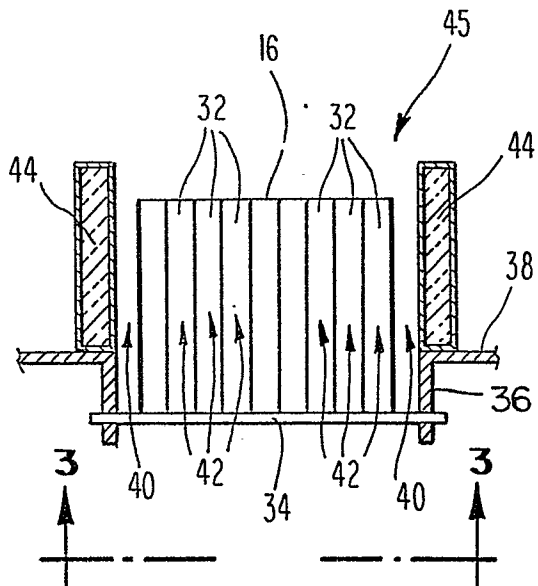
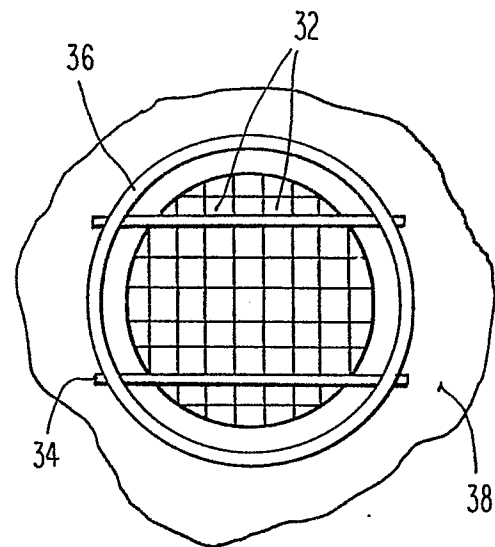
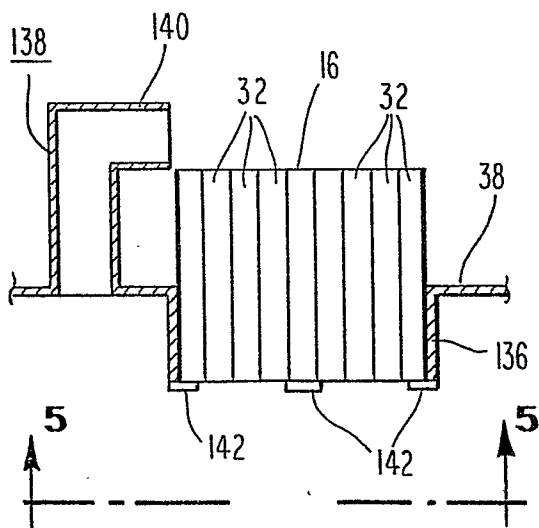
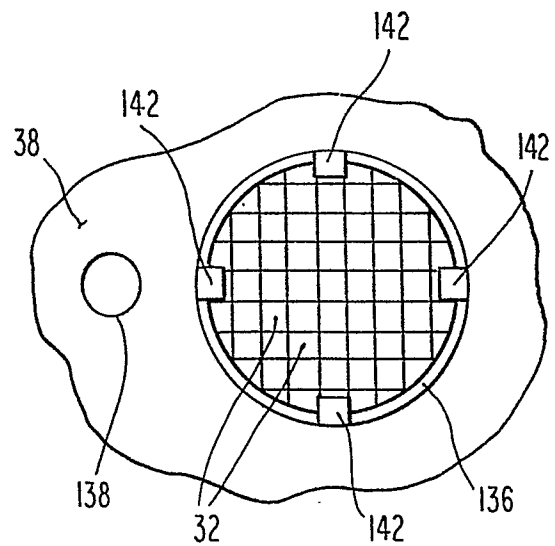
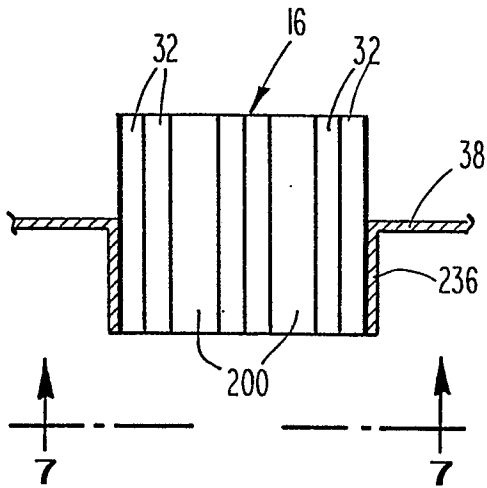
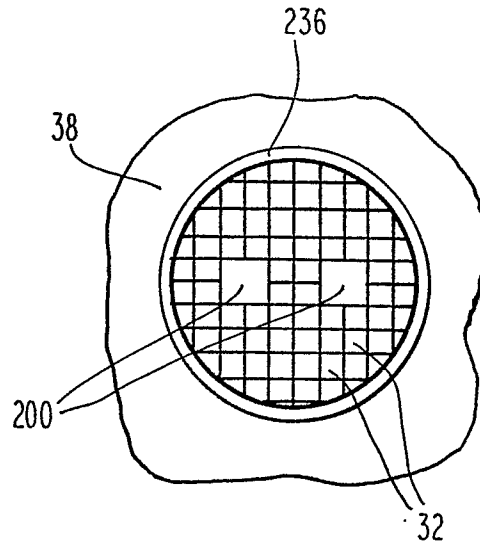
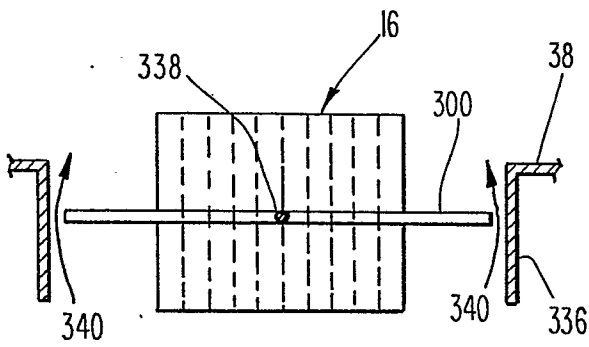
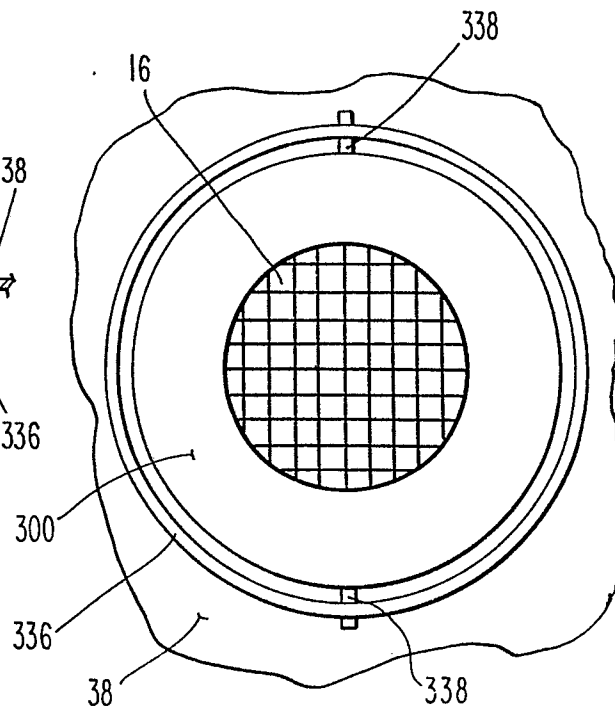


Fig. 1

**Fig. 2****Fig. 3****Fig. 4****Fig. 5**

**Fig. 6****Fig. 7****Fig. 8****Fig. 9**



DOCUMENTS CONSIDERED TO BE RELEVANT															
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl. 3)												
A,D	EP-A-0 037 281 (CORNING GLASS WORKS) * Page 4, lines 7-21; page 6, line 33 - page 7, line 1; page 8, line 2 - page 12, line 2; claims 17,18; figures 1-3,4a,b,c,6,7 * -----	1,2,8	F 23 G 7/06												
			TECHNICAL FIELDS SEARCHED (Int. Cl. 3)												
			F 23 G F 23 J F 23 B B 01 J F 24 B												
The present search report has been drawn up for all claims															
Place of search THE HAGUE		Date of completion of the search 31-05-1983	Examiner SARRE K.J.K.TH.												
<table><tr><td>CATEGORY OF CITED DOCUMENTS</td><td>T : theory or principle underlying the invention</td></tr><tr><td>X : particularly relevant if taken alone</td><td>E : earlier patent document, but published on, or after the filing date</td></tr><tr><td>Y : particularly relevant if combined with another document of the same category</td><td>D : document cited in the application</td></tr><tr><td>A : technological background</td><td>L : document cited for other reasons</td></tr><tr><td>O : non-written disclosure</td><td>& : member of the same patent family, corresponding document</td></tr><tr><td>P : intermediate document</td><td></td></tr></table>				CATEGORY OF CITED DOCUMENTS	T : theory or principle underlying the invention	X : particularly relevant if taken alone	E : earlier patent document, but published on, or after the filing date	Y : particularly relevant if combined with another document of the same category	D : document cited in the application	A : technological background	L : document cited for other reasons	O : non-written disclosure	& : member of the same patent family, corresponding document	P : intermediate document	
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