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(54) **Wood burning stove.**

(57) A combustor (16) having a plurality of cells is coupled to the primary combustion chamber (12) in a wood burning stove (10). An insulated hot zone (14) is coupled to the output (56) of the combustor (16) for combusting the exhaust from the combustor (16).

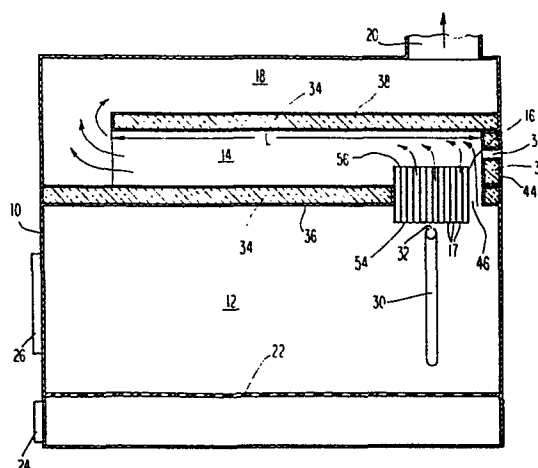


Fig. 1

WOOD BURNING STOVE

This invention relates to wood burning stoves which 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. 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.

It is important that the catalytic converter or combustor be of the appropriate volume and internal geometry to provide both satisfactory catalytic performance and a minimal pressure drop so as not to adversely

affect the stove operation. Typically, the converter comprises a plurality of cells extending through and along the length of the converter. In this connection, it has been found that catalytic combustion within the converter of the various exhaust gases passing through the converter in a wood stove is carried further to completion as the converter length is increased. In other words, the reactions required to break down and burn complex hydrocarbons is more nearly completed in catalytic converters of increased length. In contrast, materials exiting from a catalytic converter in a wood burning stove which is relatively short are still reacting and these reactions are quickly quenched by the relatively cold conditions outside the converter, i.e., the shorter the catalytic converter the sooner the quenching takes place. A longer catalytic converter may enhance these reactions to ensure that the complex hydrocarbons are fully broken down and burned, but such catalytic converters are expensive and undesirably add to the pressure drop which can adversely effect stove operation.

It is an object of this invention to provide for more complete combustion of the exhaust gases within a wood burning stove.

According to the present invention there is provided a wood burning stove comprising: a primary combustion chamber; a combustor having a plurality of cells, an input and an output, said input being in communication with said primary combustion chamber; and an insulated hot zone coupled to said output for combusting the exhaust from said combustor.

In a preferred embodiment of the invention the combustor comprises a catalytic converter.

The insulated hot zone preferably functions in such a way as not to adversely affect the pressure drop within the stove. In one embodiment of the invention, the hot zone extends horizontally. In another embodiment of

the invention, the hot zone extends vertically.

In accordance with one preferred embodiment of the invention, the insulated hot zone comprises insulation having a thermal conductivity less than 0.0017 watts/cm. °C. (0.10 BTU/hr. ft. °F.). Preferably, the insulated hot zone comprises insulation having a thermal conductivity of 0.0014 watts/cm. °C. or less (0.08 BTU/hr. ft. °F. or less).

The hot zone preferably has an overall length along the path of travel of the exhaust gases which is greater than 76.2 mm. (3 inches). Preferably, the overall length is less than 762 mm. (30 inches).

Preferably, the thickness of the insulation is at least 3.8 mm. (0.15 inches). The thickness of the insulation in the hot zone is preferably at least 0.05 units per unit of length.

In the accompanying drawings:

FIG. 1 is an elevational view of a wood burning stove representing a preferred embodiment of the invention;

FIG. 2 is a side elevational view of the wood burning stove of FIG. 1; and

FIG. 3 is an elevational view of a wood burning stove representing another embodiment of the invention.

Referring to FIGS. 1 and 2, a wood burning stove 10 is shown comprising a primary wood combustion chamber 12 in the lower portion of the stove. In accordance with this invention, the stove 10 includes a secondary combustion chamber or hot zone 14 located immediately above the primary combustion chamber 12.

A catalytic converter or combustor 16 includes an input 54 coupled to and in communication with the primary combustion chamber 12 and an output 56 coupled to and in communication with the combustion chamber 14 through a plurality of axially extending cells or passageways 17. The converter 16 is located physically between the primary combustion chamber 12 and the secondary combustion chamber 14. A heat exchanger 18 is located immediately above and in communication with the hot zone 14.

The heat exchanger 18 also communicates with a flue 20 so as to exhaust the combustion products from the wood burning stove therethrough.

5 The primary combustion chamber 12 includes a grate 22. An ash door 24 is located immediately below the grate 22 and a wood loading door 26 is located above the grate 22.

10 In order to supply oxygen for combustion in the primary combustion chamber, a primary combustion air opening 28 is provided at the rear of the chamber 12. A secondary combustion air manifold 30 is provided including a plurality of openings 32 located immediately below the catalytic converter 16. Tertiary combustion air is provided through an opening 33 in the rear of the hot zone
15 14.

In accordance with this invention, the secondary combustion chamber or hot zone 14 is heavily insulated with high temperature insulation materials so as to permit the retention of the high temperatures in the exhaust from
20 the catalytic converter 16 and the primary combustion chamber 12. In this connection, insulation 34 is provided along a lower horizontal wall 36 separating the primary combustion chamber 12 from the secondary combustion chamber 14, an upper horizontal wall 38 separating the secondary
25 combustion chamber 14 from the heat exchanger 18, side walls 40 and 42 and an end wall 44.

In the preferred embodiment of the invention, the insulation is characterized by a thermal conductivity less than 0.0017 watts/cm. °C. (0.10 BTUs/hr. ft. °F.) and preferably, a thermal conductivity of 0.0014 watts/cm °C.
30 (0.08 BTUs/hr. ft. °F) or less. Such high temperature insulation material ensures that the temperatures within the secondary chamber or hot zone 14 are sufficiently high to carry to completion the combustion reactions required
35 to break down and burn complex hydrocarbons.

In accordance with the invention of copending European patent application No. which claims priority from U.S.S.N. 351168 filed 22nd February, 1982 and which is in the name of the present applicants, a
5 leakage path 46 is provided adjacent or alongside the catalytic converter 16 at the rear wall 44 of the secondary combustion chamber 14. Further details concerning the nature and function of the leakage path 46 are described in the aforesaid copending application.

10 As shown in FIG. 2, the stove 10 also includes a bypass adjacent the secondary combustion chamber 14. The bypass includes a damper 48 which is adapted to pivot about a point 50 so as to open and close a passageway 52 directly beneath the flue 20. The bypass is intended to
15 minimize back pressure during loading of the stove when the loading door is opened as disclosed in European patent specification No. 0037281 A. The damper 48 is therefore adapted to open and close the passageway 52 as a door 26 is opened and closed.

20 In the embodiment of the invention shown in FIG. 1, the length L of the hot zone 14 extends horizontally. The length L as used herein is intended to indicate the overall dimension of the hot zone which is parallel to the path the exhaust gases travel.

25 Referring to the embodiment of the invention shown in FIG. 3, a stove 100 comprises a primary combustion chamber 112 in the lower portion of the stove 100 and a vertically extending secondary combustion chamber or hot zone 114 located above. A catalytic converter or
30 combustor 116 having an input coupled to and communicating with the combustion chamber 112 and an output coupled to and communicating with the hot zone 114 is located generally between the chamber 112 and the hot zone 114. The catalytic converter 116 is mounted in a stainless steel
35 ring 118 having an axis 120 of rotation in a direction as indicated by arrows 122. An area 124 of leakage

between the cylindrical wall of insulation 126 and the chamber 114 is provided in accordance with the aforesaid copending European patent application. The size of the area 124 is a function of the rotational position of the ring 118.

As shown in FIG. 3, the primary combustion chamber 112 includes an opening 128 for supplying combustion air to the chamber 112. The secondary combustion chamber air is supplied to the catalytic converter 116 as well as the secondary combustion chamber 114 through a manifold 130.

The insulated walls 126 of the hot zone 114 ensure that high temperatures can be attained and maintained within the hot zone 114 so as to complete the oxidation of complex hydrocarbons and carbon monoxide. In this connection, the insulation 126 preferably has a thermal conductivity less than 0.0017 watts/cm. °C. (0.10 BTUs/hr. ft. °F.), with a thermal conductivity of 0.0014 watts/cm. °C. (0.08 BTUs/hr. ft. °F.) or less being more preferred. Suitable insulation materials for the hot zone 114 include various alumina silicate fibres. These materials are refractories which are sold under the trade names "Kaowool" by Babcock and Wilcox Co. and the trade name "Fiberfrax" by Carborundum Co. These refractories are available in blanket form and may be cut and enclosed within metal housings as shown or directly cemented in place. These refractories are also available in round or rectangular shapes which may be suitably mounted in place.

A heat exchanger 132 is located above the secondary combustion chamber 114. The heat exchanger 132 may include water-filled coils located in area 136 which are heated by the hot exhaust gases passing through the coils. A flue 134 is coupled to the hot zone 114 through the heat exchanger 132.

In general, it has been found desirable to provide a thickness of insulation of at least 3.8 mm (0.15 inches) in the walls of the hot zones 14 and 114. In addition, it has been found that the thickness of the walls in the secondary combustion chambers 14 and 114 and should be at least 0.05 units per unit length, e.g. 3.8 mm (0.15 inches) thick for each 76.2 mm (3 inches) of length. It has also been found that the hot zone should be greater than 76.2 mm (3 inches) in length with 762 mm (30 inches) representing a maximum.

In order to provide a better understanding of the details concerning the secondary combustion chamber 14 and 114, the following analysis is presented.

The heat content of the gas stream exiting the combustor is given by:

$$\dot{m} C_p T_o$$

where:

$\dot{m}$ = mass flow rate - kg./min. (lbm/min.)

C_p = gas specific heat - cal./kg.°C (BTU/lbm°F.)

T_o = gas temperature leaving combustor - °C (°F.)

If the gas stream loses no more than 20% of its heat content in the insulated hot zone, temperatures will remain high enough to maintain combustion under most stove conditions.

Assuming that the gas temperature in the insulated zone remains relatively constant and that conduction through the insulation is the dominant mode of heat transfer, the heat loss downstream of the combustor is given by:

$$Q = \frac{kA (T_o - T)}{t}$$

where:

Q = heat flux - watts/min. (BTU/min.)

k = thermal conductivity of the insulation - watts/cm.°C. (BTU/hr. ft. °F.)

T = room temperature - °C. (°F.)

t = insulation thickness - cm. (ft.)

A = area of insulation exposed to hot gases -
cm.² (ft.²)

5 From the criterion that no more than 20% of the heat content of the gas be lost in the insulated zone, the following formulae are applicable:

$$10 \quad \frac{\dot{m} C_p T_o}{5} \geq Q = \frac{kA (T_o - T)}{t}$$

This equation can be solved for the insulation thickness required for various lengths of insulated zones using typical stove operating conditions, where

15 T = 21.1°C. (70°F.),

T_o = 760°C. (1400°F.),

k = 0.0014 watts/cm.°C. (0.08 BTU/hr. ft. °F.,
typical for high temperature insulations),

$\dot{m}$ = 19.27 kg./hr. (42.5 lbm/hr.),

20 $C_p = 0.326$ watt hr./kg.°C. (0.28 BTU/lbm °F.),
 $3332 \geq 106.4 \frac{A}{t}$,

A = cm.² [ft.²], and

t = cm. [ft.].

25 $\frac{A}{t} \geq 31.3$

Also,

A = pL

where:

30 p = perimeter of an axial section of the insulated zone, and

L = length of the insulated zone.

For an insulated zone which has the same perimeter as the 15.24 cm. (6 inch) inside diameter of the can
35 around the combustor,

p = 47.85 cm. (1.57ft.).

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If this value is put into equation (2), the following equation results,

$$t \geq 0.050L$$

In this equation, t and L can be in either inches or feet or cm. The following table for t can be generated for various values of L.

	L (cm.)	t (cm.)	L (in.)	t (in.)
	7.62	0.38	3	.15
	15.24	0.76	6	.30
10	22.86	1.14	9	.45
	30.48	1.52	12	.60
	38.10	1.91	15	.75
	50.80	2.54	20	1.00

These thicknesses are the minimum required to maintain the combustor exhaust stream above the burning temperature of the gases. In other words, the longer the insulated zone is, the thicker the insulation which is required to maintain temperatures in the region where continued thermal combustion will take place. The practical limits on the length of the insulated zone are from 7.62 cm (3 inches) to 76.2 cm (30 inches).

As shown herein, the hot zones 14 and 114 extend horizontally and vertically. It will however be appreciated that the hot zones may extend circuitously, i.e. extend vertically and horizontally. One such hot zone could be U-shaped. However, regardless of the hot zone configuration, the overall length of the hot zone as measured along the path of the exhaust through the chamber should conform with the foregoing consideration.

The combustor or catalytic converters 16 and 116 are, of course, extremely important to ensure proper combustion of the hydrocarbons in the exhaust gas exiting the primary combustion chambers 12 and 112. Details concerning the catalytic converters 16 and 116 are set forth

in US-A-4373452 referred to above. It will be appreciated that uncatalyzed combustors identical to the converters 16 and 116 but without a catalyst may be advantageously utilized in connection with this invention.

CLAIMS:

1. A wood burning stove comprising: a primary combustion chamber; a combustor having a plurality of cells, an input and an output, said input being in communication with said primary combustion chamber; and an insulated hot zone coupled to said output for combusting the exhaust from said combustor.
2. A wood burning stove according to claim 1, further comprising a flue coupled to said insulated hot zone.
3. A wood burning stove according to claim 1 or 2, wherein said hot zone extends horizontally.
4. A wood burning stove according to claim 1 or 2, wherein said hot zone extends vertically.
5. A wood burning stove according to any preceding claim, wherein said insulated hot zone comprises insulation having a thermal conductivity of less than 0.0017 watts/cm. °C., preferably substantially 0.0014 watts/cm. °C.
6. A wood burning stove according to any preceding claim, wherein the length of the hot zone is greater than 76.2 mm, but less than 762 mm.
7. A wood burning stove according to any preceding claim, wherein the insulated hot zone comprises insulated walls having a thickness of at least 3.8 mm.
8. A wood burning stove according to any preceding claim, wherein the thickness of the insulated walls is at least 0.05 units per unit of length.

9. A wood burning stove according to any preceding claim, wherein the insulated hot zone comprises insulated walls having a thickness t greater than

$$\frac{5kA (T_o - T)}{\dot{m} C_p T_o}$$

where

k = thermal conductivity of the insulation material;

A = area of the insulation exposed to hot gases;

T_o = temperature of the hot gases;

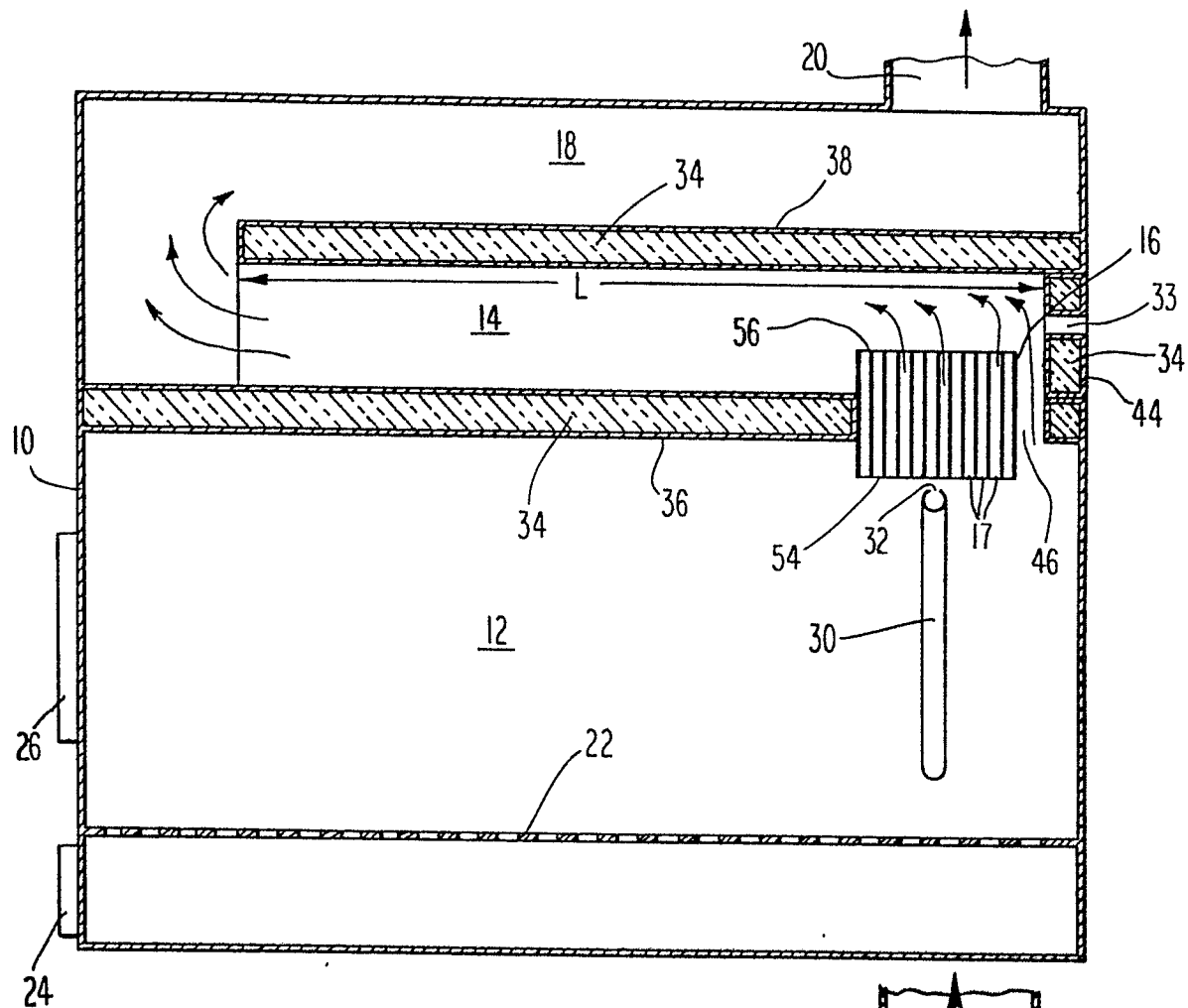
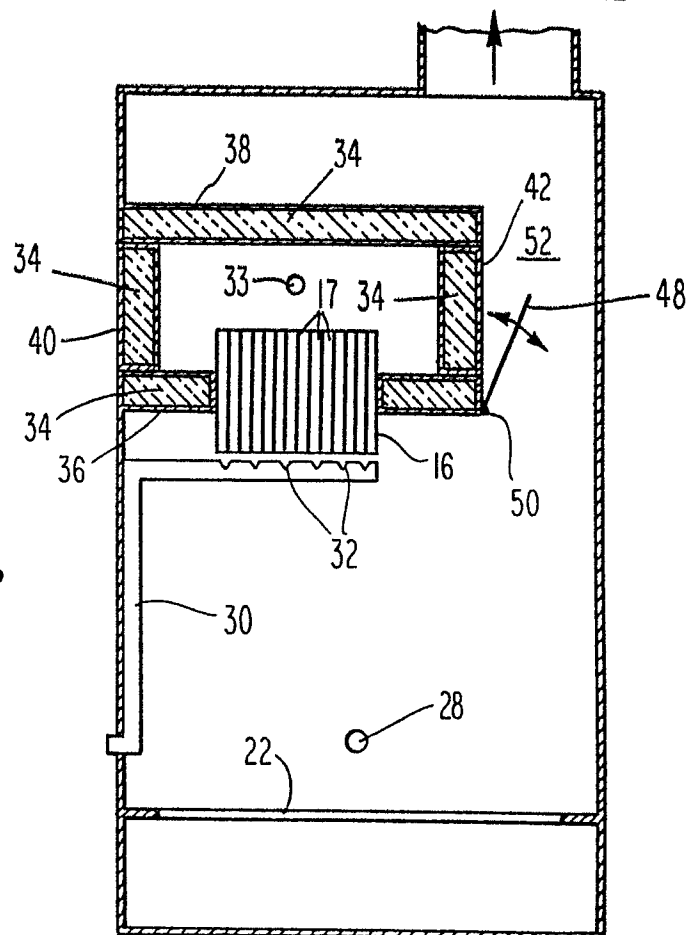
T = room temperature;

$\dot{m}$ = mass flow rate; and

C_p = gas specific heat.

10. A wood burning stove according to any preceding claim, wherein said combustor comprises a catalytic converter.

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**Fig. 1****Fig. 2**

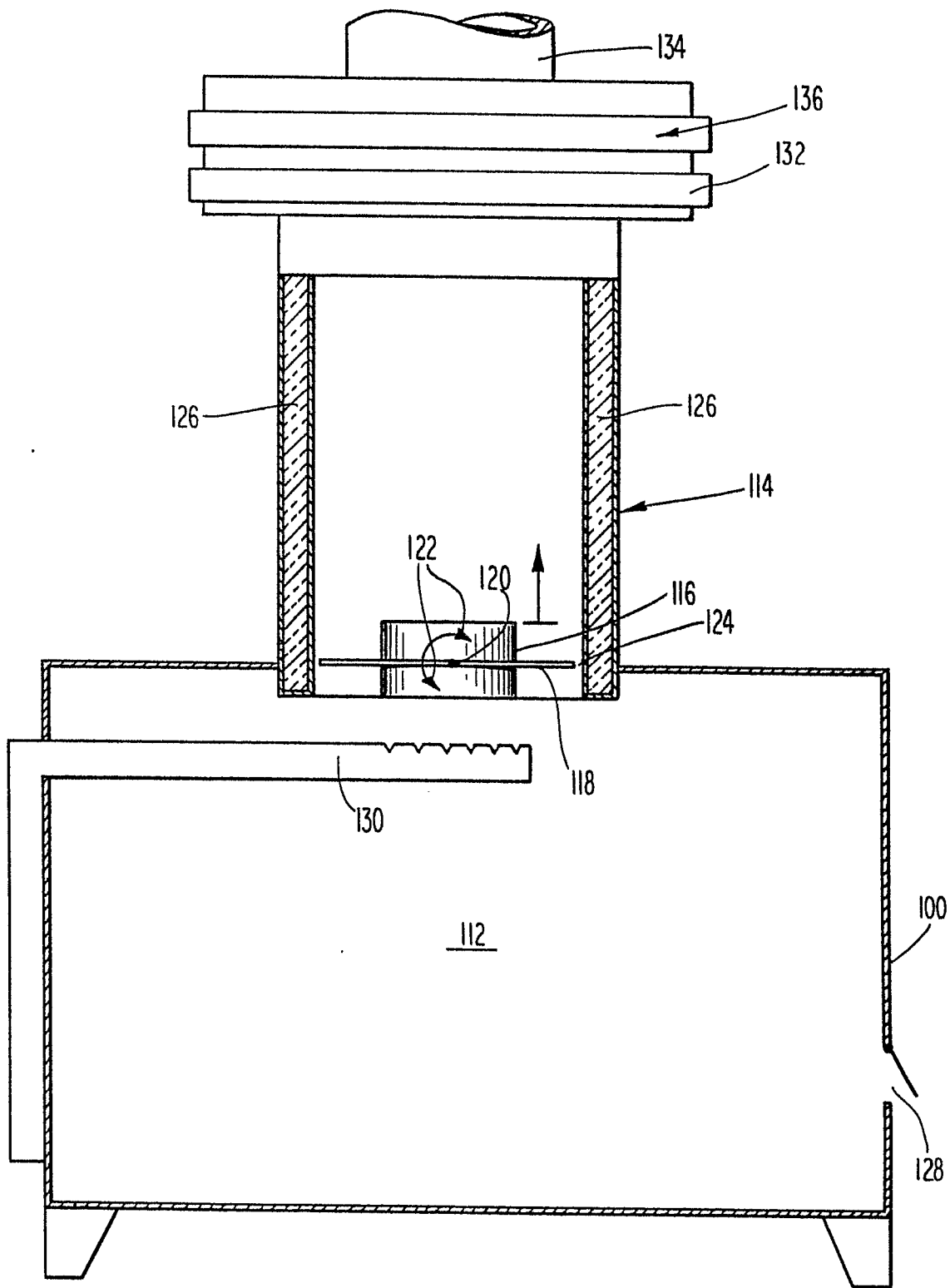


Fig. 3



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)
X	EP-A-0 037 281 (CORNING GLASS WORKS) * Page 10, line 15 - page 11, line 11 *	1-3	F 24 B 13/00 F 24 B 1/00
A	FR-A-2 486 214 (PERENNEC) * Claims 1, 3 *	1	
E, X	EP-A-0 072 391 (ATLANTA STOVE WORKS) * Claims 1, 10, 11 *	1, 2, 10	
			TECHNICAL FIELDS SEARCHED (Int. Cl. 3)
			F 23 M 5/00 F 23 M 13/00 F 24 B 1/00 F 24 B 5/00 F 24 B 13/00
The present search report has been drawn up for all claims			
Place of search BERLIN		Date of completion of the search 19-05-1983	Examiner PIEPER C
CATEGORY OF CITED DOCUMENTS			
X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	