OPIC
Office de la propriété intellectuelle du Canada

CIPO
Canadian Intellectual Property Office

(12) (19) (CA) **Brevet-Patent**

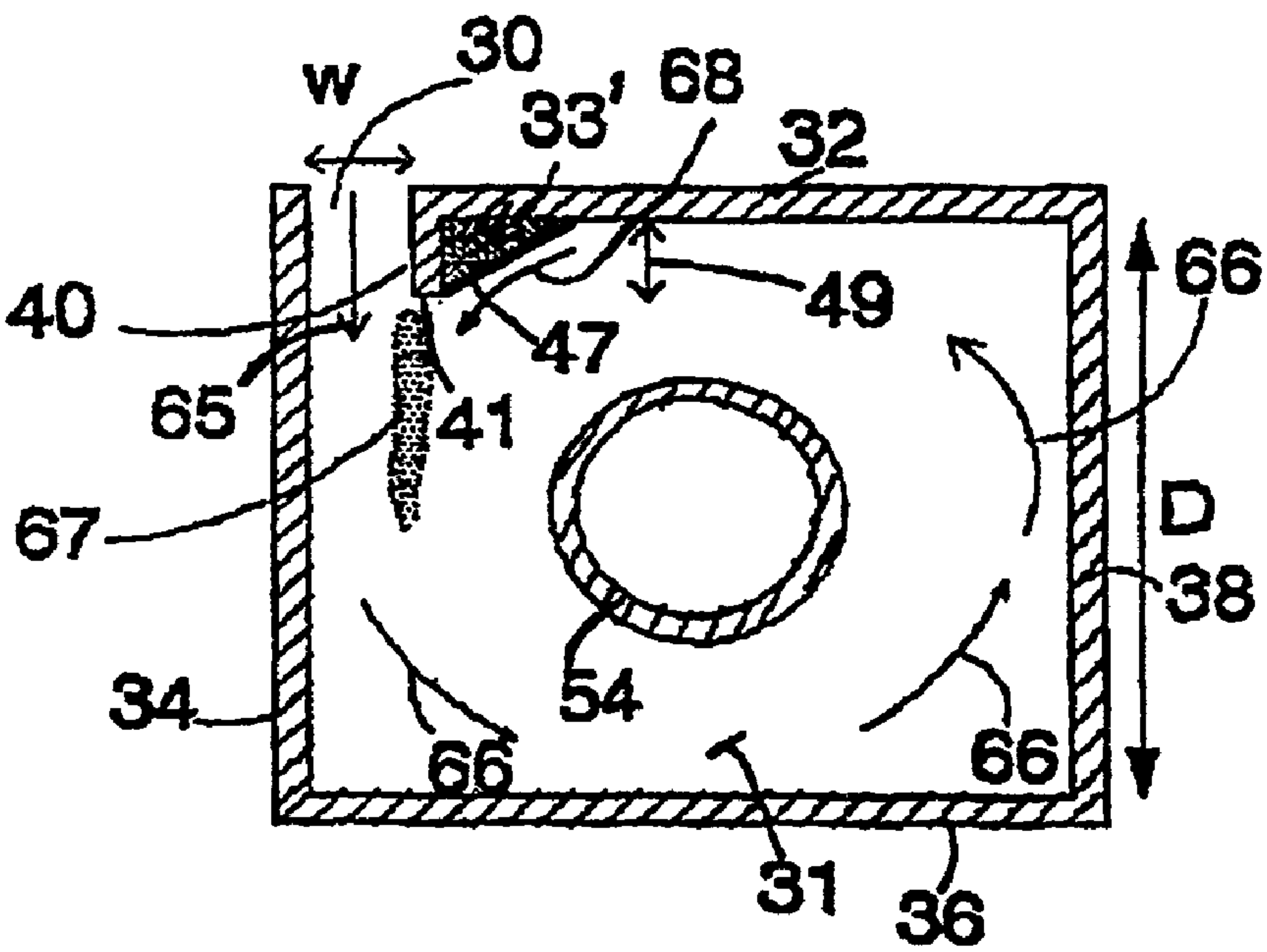
(11) (21) (C) **2,215,040**

(86) 1996/03/07
(87) 1996/09/19
(45) 2001/07/03

(72) HYPPÄNEN, Timo, FI
(73) FOSTER WHEELER ENERGIA OY, FI
(51) Int.Cl.^{6} B04C 5/081
(30) 1995/03/13 (08/402,170) US

(54) SEPARATEUR CENTRIFUGE ET METHODE DE SEPARATION DES PARTICULES ET DES GAZ CHAUDS

(54) CENTRIFUGAL SEPARATOR ASSEMBLY AND METHOD FOR SEPARATING PARTICLES FROM HOT GAS



(57) A centrifugal separator (11) has a plurality of substantially planar walls, including a first wall (32), defining a vortex chamber (12) having an interior gas volume (31) and for establishing at least one gas vortex in the gas volume, and the gas volume has a cross section that is distinctly non-circular. In addition to conventional outlets, the separator includes a gas inlet (30) having at least one elongated jet-defining wall (40) with a free end portion (41) extending into the gas volume (31) a first distance from the first wall (32), to define a gas jet that extends substantially tangentially to the gas vortex in the gas volume. An insert (33') extends between the jet-defining wall (40) free end portion (41) and the first wall and defines a gas flow direction changing surface (47). The insert may be substantially solid refractory material, or include a number of cooling fluids circulating tubes, and a gas flow direction changing surface may he substantially planar or curved.

CA 02215040 1997-09-09

PCT

WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 : **B01D 45/12, B04C 5/081 // F23C 9/00** — A1

(11) International Publication Number: **WO 96/28237**

(43) International Publication Date: 19 September 1996 (19.09.96)

(21) International Application Number: PCT/FI96/00139

(22) International Filing Date: 7 March 1996 (07.03.96)

(30) Priority Data:
08/402,170 13 March 1995 (13.03.95) US

(71) Applicant *(for all designated States except US)*: FOSTER WHEELER ENERGIA OY [FI/FI]; P.O. Box 66, FIN-48601 Karhula (FI).

(72) Inventor; and
(75) Inventor/Applicant *(for US only)*: HYPPÄNEN, Timo [FI/FI]; Siikakoskenpolku 10, FIN-48710 Karhula (FI).

(74) Agent: TURUN PATENTTITOIMISTO OY; P.O. Box 99, FIN-20521 Turku (FI).

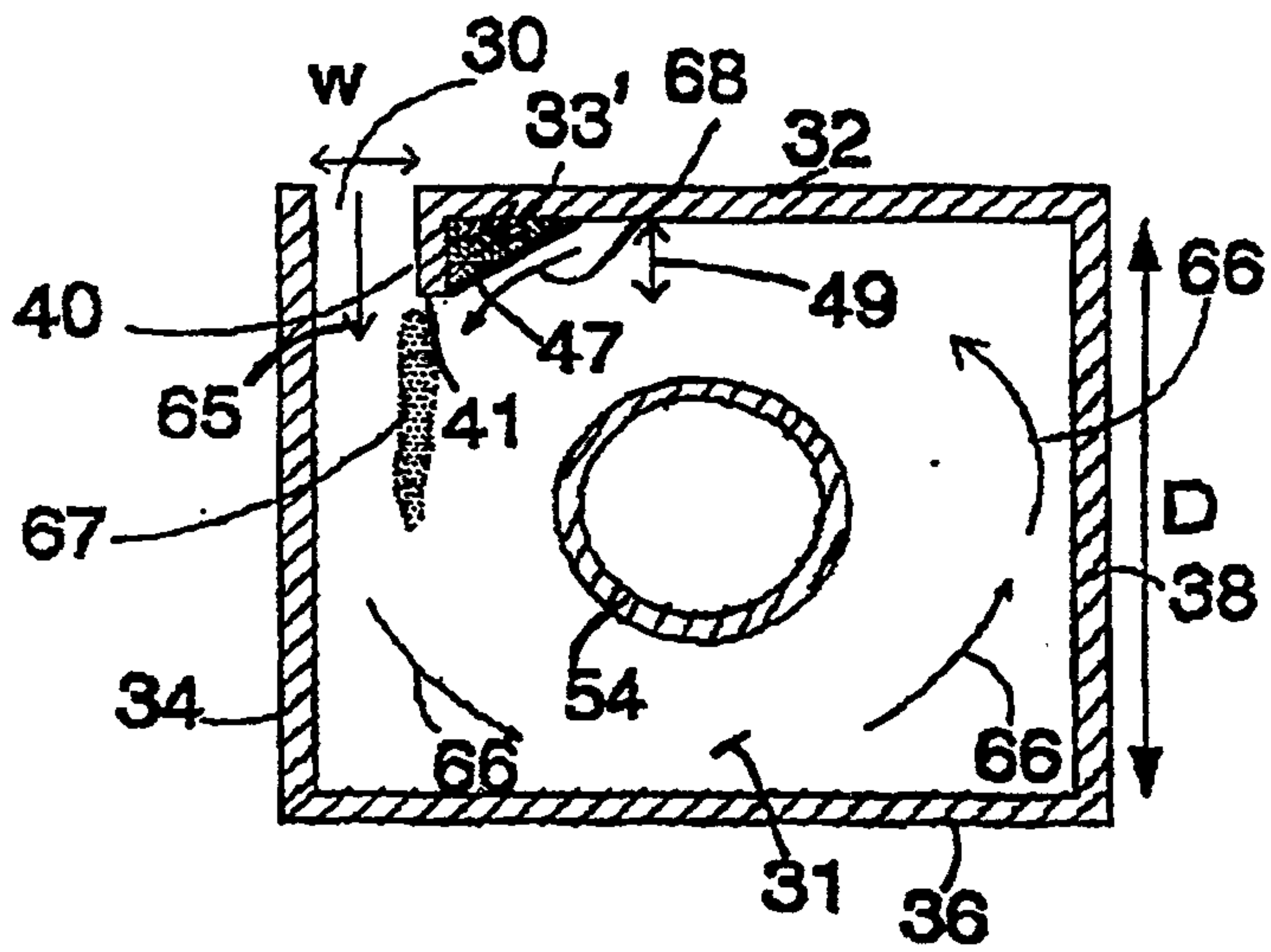
(81) Designated States: AU, CA, CN, FI, JP, KR, PL, RU, US, European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

Published
With international search report.

(54) Title: CENTRIFUGAL SEPARATOR ASSEMBLY AND METHOD FOR SEPARATING PARTICLES FROM HOT GAS

(57) Abstract

A centrifugal separator (11) has a plurality of substantially planar walls, including a first wall (32), defining a vortex chamber (12) having an interior gas volume (31) and for establishing at least one gas vortex in the gas volume, and the gas volume has a cross section that is distinctly non-circular. In addition to conventional outlets, the separator includes a gas inlet (30) having at least one elongated jet-defining wall (40) with a free end portion (41) extending into the gas volume (31) a first distance from the first wall (32), to define a gas jet that extends substantially tangentially to the gas vortex in the gas volume. An insert (33') extends between the jet-defining wall (40) free end portion (41) and the first wall and defines a gas flow direction changing surface (47). The insert may be substantially solid refractory material, or include a number of cooling fluids circulating tubes, and a gas flow direction changing surface may be substantially planar or curved.



CENTRIFUGAL SEPARATOR ASSEMBLY AND METHOD FOR SEPARATING PARTICLES FROM HOT GAS

The present invention refers to a centrifugal separator assembly and to a method of separating particles from a stream of gas.

The present invention refers more particularly to centrifugal separators comprising:

- a vortex chamber formed of a plurality of substantially planar walls and thus defining a multilateral cross-section, the chamber, including a first wall, the vortex chamber having an interior gas volume having a cross-section that is distinctly non-circular,
- at least one gas inlet formed in the first wall for introducing gas with entrained particles into the gas volume and at least one gas outlet for cleaned gas extending from the vortex chamber and being in communication with the gas volume, for establishing at least one gas vortex in said gas volume, and
- at least one separated particles outlet from the gas volume.

U.S. Patent 5,281,398 discloses such a centrifugal separator. Particles entrained in hot gases are separated in a vortex chamber defined by a plurality of substantially planar plates or panels, preferably in a quadrate cross-section, or of another polygonal shape. Such a separator has numerous advantages over conventional centrifugal separators, particularly in ease of construction, cost, and the like. The gas is introduced into the vortex chamber through one or more gas inlets in the side wall so as to guide the gas tangentially into the vortex chamber to maximize the swirling or spinning of the gas as it is introduced. Such centrifugal separators are ideally utilized in connection with circulating fluidized bed reactors, but also -- as described in an article entitled "Pyroflow Contact: A Second Generation CFB Boiler by Ahlstrom Pyropower", Gamble et al, Fluidized Bed Combustion, vol. 2, ASME, 1993, pages 751-760 -- can be utilized on a commercial scale with boilers.

While such planar wall separators, US 5,281,398, are highly advantageous, according to the present invention it has been recognized that there is a quirk in the efficiency of operation of such separators because of the planar geometry at the gas inlet or inlets. At the area of the inlet particles which are on the periphery of the gas vortex tend to separate out from the gas as they flow along the front wall of the vortex chamber, containing the gas inlet and interfere with the proper introduction of the gas into the vortex chamber, interfering with the desired intensity of swirling or spinning action of the gas in the vortex.

The object of the present invention is thus to provide an improved centrifugal separator assembly and method of operation thereof.

It is a primary object of the present invention to provide an improved centrifugal separator with planar walls, and a method of operation thereof, which maximizes the swirling action of gas and particles and prevents premature separation of particles from the vortex flow within the vortex chamber .

It is a further object of the present invention to provide an improved centrifugal separator and method of operation thereof which minimizes disturbances or disruption at the gas inlet caused by gas within the vortex chamber.

It is also an object of the present invention to provide an improved centrifugal separator and method of operation thereof which minimizes the interfering effect of gas and particles swirling within the vortex chamber on gas being introduced into the vortex chamber.

AMENDED SHEET

The above objects are according to the present invention achieved by a centrifugal separator and a method of operation thereof being characterizing by features included in claim 1 and claim 19.

According to the present invention thereby an apparatus and method are provided which overcomes earlier mentioned drawbacks, such as disruption of the gas flow in the gas inlet that can occur in the otherwise advantageous centrifugal separators as disclosed in U.S. Patent 5,281,398. The area of the front wall, close to the gas inlet, is configured in such a way that particles swirling within the gas vortex but tending to separate are smoothly redirected from movement along the front wall to movement in the direction of gas introduction, i.e. parallel or close to parallel with the gas flow being introduced into the vortex chamber. In this way, the swirling action of the gas during tangential introduction into the vortex chamber may be truly maximized.

According to one aspect of the present invention a centrifugal separator assembly is provided that includes the following components which are common to the separator disclosed in patent 5,281,398:

- A plurality of substantially planar walls defining a multilateral cross-section, including a first wall, said walls defining a vortex chamber having an interior gas volume, and for establishing at least one gas vortex in the gas volume, the gas volume having a cross-section that is distinctly non-circular (that is having a circularity of greater than 1.1, preferably greater than 1.3, and most preferably substantially quadrate).
- At least one gas outlet for cleaned gas extending from the gas volume.
- At least one gas inlet formed in the first wall for introducing gas with entrained particles into the gas volume, the gas inlet comprising at least one elongated jet-defining wall having a free end portion extending into the gas volume a first distance from the first wall, to

define a gas jet extending substantially tangentially to a gas vortex in the gas volume.

- At least one separated particles outlet from the gas volume.

According to one aspect of the present invention there is provided a flow guiding means within the vortex chamber to prevent disturbances in the gas flow at introduction into the vortex chamber. The guiding means provided comprise means for guiding the gas vortex between the first wall and the jet-defining wall so that the flow direction of particles separating from gas in the gas vortex is smoothly changed from the first wall to substantially in line with the gas jet (e.g. substantially perpendicular to the first wall at the gas inlet, and substantially tangentially to the gas vortex).

The guiding means preferably comprises an insert extending between the jet-defining wall free end portion and the first wall, and defining a gas flow direction changing surface. The surface may be substantially planar, or curved. The insert may be substantially solid refractory material (e.g. ceramic) or may have a plurality of cooling fluid circulating tubes which cool the gas direction changing surface. Alternatively, the jet-defining wall and portions of the first wall adjacent the insert may have a plurality of cooling fluid circulating tubes which cool the insert.

The plurality of substantially planar walls typically includes a second wall substantially perpendicular to and intersecting the first wall. The at least one jet-defining wall may comprise a single jet-defining wall, substantially parallel to the second wall and spaced from the second wall a distance W, defining the width of the gas inlet, and the gas inlet typically has a height H which is greater than 2W (preferably greater than 4W). The second wall typically has a length D interior of the gas volume, and the first

AMENDED SHEET

distance is at least 50 mm but less than 25% of that length D.

Alternatively, the planar walls may include at least second and third walls connected to the first wall, and the at least one jet-defining wall comprises two walls spaced from each other a distance W which defines the width of the inlet openings. The jet-defining walls each have a free end portion which extends into the gas line the first distance, and has an insert with gas direction changing surface, and the walls are disposed in a central section of the first wall remote from the second and third walls. Each of the jet defining walls makes an angle α with respect to its associated gas flow direction changing surface, the angle α typically being between 20 - 80°, preferably between about 40 - 60°.

Alternatively, the first and second jet-defining walls may define two different gas inlets, the first jet-defining wall adjacent but spaced from and substantially parallel to the second wall, and a second jet-defining wall adjacent but spaced from and substantially parallel to the third wall, each of the jet defining walls in the first wall having a guiding means associated therewith. The first distance is typically between 0.2 - 5 times the width (W) of the gas inlet.

The plurality of substantially planar walls may comprise a fourth wall, opposite the gas inlet and the first wall, and the fourth wall may include a refractory surface opposite the gas inlet which has enhanced erosion resistant properties compared to the rest of the interior surfaces of the substantially planar walls (whether or not they are also covered with a refractory material).

According to another aspect of the present invention, a centrifugal separator assembly is provided comprising the following elements: A plurality of substantially planar walls, including a first wall, defining a vortex chamber having an interior gas volume, and for establishing at least one gas vortex in the gas volume, the gas volume having a cross-section that is distinctly non-circular and substantially quadrate. At least one gas outlet for cleaned gas extending from the gas volume. At least one gas inlet formed in the first wall for introducing gas with entrained particles into the gas volume. At least one separated particles outlet from the gas volume. The gas inlet comprising at least one elongated jet-defining wall having a free end portion extending into the gas volume a first distance from the first wall, to define a gas jet extending substantially tangentially to a gas vortex in the gas volume. And an insert extending between the jet-defining wall free end portion and the first wall, and defining a smooth flow (gas and particles) direction changing surface.

The centrifugal separator as described above preferably is in combination with a circulating fluidized bed reactor having a reaction chamber, including a fluidized bed at a bottom portion thereof and a gas discharge at a top portion thereof and connected to the gas inlet of the centrifugal separator. The gas inlet extends substantially vertically and the gas outlets lead clean gas from the separator gas volume upwardly out of the gas volume, and a return duct leads particles from the bottom of the separator to the bottom portion of the reaction chamber.

According to another aspect of the present invention, a method of separating particles from a stream of gas having particles entrained therein at a temperature higher than 500°C (typically a temperatures of a circulating fluidized bed reactor, e.g. 900° or above) utilizing a centrifugal separator substantially as described above, is provided. A method comprises the following steps: (a) Introducing a stream of gas with entrained particles and at a temperature of higher than 500°C into the gas volume as a jet in a direction tangential to a vertical axis swirling gas vortex formed in the gas volume, the jet and vortex intersecting at an intersection point. (b) Removing cleaned gas from the top of the gas vortex. (c) Removing separated particles from the bottom of the gas vortex. And (d) smoothly changing the direction of any particles separated from the vortex in the vicinity of the first wall from substantially along the first wall to substantially in the direction of the jet.

Step (d) is typically practiced to prevent settling of particles within the range of 270 - 315° from the intersection point. Step (a) is practiced by introducing gas with entrained particles in a flow configuration having a height at least twice as great as its width W, and step (a) is further practiced so that the jet is introduced into the gas volume a distance from the first wall that is between 0.2 - 5 times W. Step (a) is typically also practiced so that the jet is introduced into the gas volume a distance from the first wall that is greater than 50 mm but less than 25% of the width dimension of the cross-section of the gas volume.

The invention is discussed in more detail in the following with reference to the enclosed drawings in which

FIG.1 is a side schematic view, partly in cross section and partly in elevation, of a circulating fluid bed reactor with a centrifugal separator according to the present invention;

FIG. 2 is a cross sectional view of the centrifugal separator of FIG. 1 taken along lines 2-2 thereof;

FIG. 3 is a cross sectional view of the separator of FIG. 2 taken along lines 3-3 thereof; and

FIGS. 4 through 7 are views like that of FIG. 3 for alternative embodiments of centrifugal separators according to the present invention.

FIG. 1 illustrates a circulating fluidized bed reactor comprising a reaction chamber 10, a centrifugal particle separator (cyclone) 11 and a return duct 14 for returning separated particles back to the chamber 10. The cross section of the reaction chamber 10 is rectangular, and the reaction chamber 10 is composed of water tube walls, only the long walls 16 and 18 of which are shown in Fig. 1. The water tube walls are preferably formed of joined vertical water tubes.

The upper part of wall 18 is bent to form the ceiling 20 of the reaction chamber 10. The walls of the lower section of the reaction chamber 10 are protected with refractory material 22. The reactor has an inlet 23 for solid material. The bottom of the reaction chamber 10 is formed of a distribution plate 24, which is equipped with nozzles or openings 26 for introducing fluidizing gas from an air plenum chamber 28 into the reaction chamber 10 for maintaining a fluidized bed in the chamber 10. Fluidizing gas or fluidizing air is introduced into the reaction chamber at such a high rate that it causes a substantial portion of the fluidizing bed material to continuously flow together with the gas into the upper portion of chamber 10 through an opening or slot 30, disposed in the upper section of the chamber 10, into the particle separator 11. The slot forms a gas inlet 30 into the separator.

The centrifugal separator 11 according to the FIG. 1 embodiment is a multivortex centrifugal separator, in which two parallel, vertical gas vortices separating particles from gas exhausted from the reactor chamber 10 by means of the centrifugal force are formed in the gas volume 31 of the separator 11. A vortex chamber 12 defines the separator 11, and preferably comprises planar, primarily rectangular water tube walls 32, 34, 36 and 38 (see also FIG. 3). Preferably, the walls 32, 34, 36, 38 are also made of joined, vertical water tubes 37 connected to each other by fins 39 (see FIG. 2). The vortex chamber 12 of separator 11 according to the FIG. 1 has one long wall, adjacent to the reaction chamber 10, in common with the reaction chamber 10, i.e., part of the wall 16 of the reaction chamber 10 constitutes the wall 32 of the vortex chamber 12. In some cases distinct walls for both the reactor 10 and the separator 11 may also be provided.

At the slot or gas inlet 30, the water tube wall 32 is bent towards the inside of the vortex chamber 12 so that parallel jet-defining walls 40 are formed, defining (see FIG. 2 and 3) an inlet duct 42 leading the gas flow into the vortex chamber 12 gas volume 31. The slot or gas inlet 30 is high and narrow, higher and narrower than in conventional vertical cyclones, preferably as high as the upper section 43 (see FIG. 1) of the vortex chamber 12. Preferably the ratio of the height to the width of slot 30 is > 2, more preferably > 4.

Each of the jet-defining walls 40 extends inwardly from the first wall 32 into the gas volume 31 a first distance to a free end portion 41, best seen in FIG.3. Also, guiding means are provided, shown generally by reference numeral 33, for guiding the gas vortex between the first wall 32 and the jet-defining wall 40 so that the flow direction of particles separating from gas in the gas vortex is smoothly changed from generally along the interior of the first wall 32 to substantially perpendicular to the first wall 32 at the gas inlet 30 (i.e. substantially tangential to the gas vortex in the gas volume 31 thereat, and along the jet introduced through slot 30).

The guiding means 33 may comprise fluid introducing jets at the intersection between the walls 40 and the wall 32 for redirecting the flow, or may comprise electrical or magnetic generating devices which repel the particles at the corners between the wall 40 and the wall 32 if the particles are electrostatically or magnetically charged, or a wide variety of other structures may be provided. However, in the preferred embodiment the guiding means 33 comprises an insert 33' which has a solid gas flow direction changing surface 47. The surface 47 may be substantially planar -- as illustrated in FIGS. 3 and 4 -- or may be curved -- as illustrated in FIGS. 5 through 7. In the embodiment illustrated in FIGS. 1 through 5, the insert 33' comprises an insert of substantially solid refractory material, such as a ceramic, crushed refractory held together by a binder, or other conventional refractory materials. The insert 33' -- as seen in FIG. 2 -- has a height comparable to the height H of the slot 30. The slot 30 has a width W (e.g. see FIG. 4) and in the preferred construction according to the invention the height H is at least twice as great as the width W, and preferably at least four times as great.

In the embodiment illustrated in FIGS. 2 and 3 in which two jet-defining walls 40 are provided in a central portion of the first (front) wall 32 of the separator 11, each of the walls 40 makes an angle α with the wall 47 (or if the wall 47 is curved, the end points of the surface 47 at the free end 41 of the wall 40 and where the surface 47 intersects the first wall 32). The angle α is preferably 20 - 80°, most desirably between about 40 - 60°. Also, the first distance -- the distance between the wall 32 and the free end 41 along the jet-defining wall 40 -- is between 0.2 - 5 times the width W of the slot 30.

As seen in the FIG. 4 embodiment, the first distance (the length of the jet-defining wall 40 between the first wall 32 and the free end 41 thereof) is indicated by reference numeral 49, which typically is at least 50 mm. If the length of the walls 34, 38 from the first wall 32 is D (where a quadrate cross section is provided for the gas volume 31, as illustrated in FIG. 4), then the maximum dimension 49 is less than 25% of D.

The upper parts of the walls of the vortex chamber 12 defining volume 31 are preferably vertical and planar and form the upper section 43. The lower part of the long wall 36 is bent towards the opposite long wall 32 forming the lower section 45 of the vortex chamber 12. By this structure, an asymmetric, long, funnel-shaped volume 44 (see FIG. 1) is formed, the bottom part of the volume 44 forming a solids outlet 46.

The outlet 46 also serves as an inlet into the return duct 14. The long walls of the return duct are formed by the extensions of the walls 32 and 36 of the particle separator 11. The end walls of the return duct 14 are correspondingly formed by the extensions of the walls 34 and 38. Only a portion having the width of the return duct 14, of the end walls 34 and 38 continues downwardly, thereby forming a return duct. The remaining portions of the end walls only extend to the upper part of the return duct 14, as disclosed in FIG. 1 for a part of wall 34. The lower part of the return duct 14 is in communication with the lower section of the reaction chamber 10 via an L-bend 48, for returning the solids separated in the separator 11 into the fluidized bed in the bottom of chamber 10; other types of solid flow seals may alternatively be used.

In the upper section 43 of the vortex chamber 12, two successive gas outlets are formed of ducts 54 and 56 disposed in openings 50 and 52 (see FIG. 2), for the discharge of purified gas from the gas volume 31 of the vortex chamber 12. The gas outlet ducts 54, 56 in the separator 11 may be either ceramic or cooled ducts in order to resist hot conditions in the separator 11. The gases are conducted from the separator 11 into a duct 60 disposed on top thereof, the duct 60 being provided with heat recovery surfaces 62, and further into a vertical convection section disposed next to the reaction chamber 10, the convection section being also provided with heat recovery surfaces. Instead of using the multivortex concept it may sometimes be preferred to use several separators 11, e.g. two separators with single vortices as shown in Fig. 4, combined together.

Preferably, the heat and abrasion resistant refractory material may be attached directly to at least some portions of the walls 32, 34, 36, and 38 of the vortex chamber 12 . Places which are exposed to heavy abrasion require a thicker layer of refractory, or a more abrasion resistant refractory may be used. Thus, for example, the wall 36, opposite to the gas inlet 30, may be provided with a thick refractory lining 57 (see FIGS, 1 and 3) the length of which corresponds to the height of the inlet 30, 42 (see FIG. 1) At least a portion of the particles entrained in the inlet gas jet flowing into the vortex chamber 12 then hit this refractory area 57 on the wall 36.

The particles entrained with the gas entering the separator 11 tend to flow along a straighter path than the gas. For example, when the gas flows into the vortex chamber 12 and changes its direction of movement in order to form a vortex, some of the particles mainly continue along their straight path eventually hitting the opposite wall 36. Due to the slowness of the change in the movement of the particles, the edge areas of the vortex chamber 12 are susceptible to abrasion and preferably they have to be protected with a thicker layer of refractory or with a more resistant refractory, as seen at 57 in FIGS. 1 and 3.

FIG. 5 discloses an illustration of an embodiment, wherein a multivortex of two vortices is formed. Both vortices have their own inlet 30 at the corners of the chamber. Vortex guiding means with inserts 33' are also provided in proximity of the slots 30.

FIG. 6 discloses an assembly for arranging the cooling tubes according to the present invention. The partition wall 632 is formed of refractory lined tubes 610 connected with each other by fins 612 to form a substantially gas tight wall structure. At a location of the inlet opening

30, the tubes 610' are bent away so that they protrude out of the wall (32) into the vortex chamber and form a part of the guiding member 33 to form the jet-defining wall 40. In this embodiment bent away tubes 610'' are near the first surface of the guiding member 33. Tubes 610 and 610'' are lined with a refractory material, which forms a refractory insert 33', having the guiding surface 47.

FIG. 7 discloses another assembly for arranging the cooling tubes according to the present invention. The partition wall 732 is also formed of refractory lined tubes 710 connected with each other by fins 712 to form a substantially gas tight wall structure. At a location of the inlet opening 30, the tubes 710' are bent away so that they protrude out of the wall (32) into the vortex chamber and form a part of the guiding member 33, having the surface 47 formed by a refractory coating on member 33. In this embodiment the bent away tubes 710'' are spaced substantially equally inside the guiding member 33.

The tubes 610, 610', 610'', 710, 710' and 710'' illustrated in FIG. 5 and 6 circulate cooling fluid (e.g. water or steam) therethrough to cool the gas flow direction changing surface 47.

Other configurations for the separator 11 are disclosed in U.S. Patent 5,281,398, and may be readily modified to incorporate the invention.

In an exemplary method of separating particles from the stream gas having particles entrained therein and at a temperature of higher than 500°C (typically about 900°C or more once associated with a circulating fluidized bed reactor), a stream of gas with entrained particles is introduced into the high, narrow vertical inlet 30 into the gas volume 31 as a jet in a direction -- shown by reference numeral 65 in FIG. 4 -- into a vertical axis swirling gas vortex -- shown generally by arrows 66 in FIG. 4 -- formed in the gas volume 31. The jet and the vortex intersect at an intersection point shown schematically by reference numeral 67 in FIGURE 4. Clean gas is removed from the top of the gas vortex 66 through the outlet conduit 54, while separated particles are removed from the bottom of the gas vortex 66, as indicated at reference numeral 44 in FIG. 1. The surface 47 smoothly changes the direction of any particles separating from gas in the vortex 66 in the vicinity of the first wall 32 from substantially along the first wall 32 to substantially in the direction of the jet 65, as indicated by arrow 68 in FIG. 4. The combination of the jet-defining wall 40 extending into the volume 31, and the smooth gas direction change provided by the surface 47, minimize interference with the jet 65 tangentially being introduced into the volume 31, and therefore maximize the swirling action of the gas vortex 66. The arrangement prevents settling of particles within the range of 270 - 315° from the intersection point 67 (in the general curvature of the gas vortex 66).

It will thus be seen that according to the present invention an effective centrifugal separator and method of centrifugally separating particles have been provided which overcome the drawbacks associated with disturbances at the gas inlet in substantially quadrate cross-section gas volume formed by planar walls as disclosed in U.S. Patent 5,281,398. While the invention has been herein shown and described in what is presently conceived to be the most practical preferred embodiment thereof, it will be apparent to those of ordinary skill in the art that many modifications may be made thereof within the scope of the invention, which scope is to be interpreted broadly so as to encompass all equivalent structures and methods.

CLAIMS

1. A centrifugal separator assembly comprising:

- a vortex chamber formed of a plurality of substantially planar walls, including a first wall, the vortex chamber having a multilateral cross-section;
- at least one gas inlet formed in the first wall for introducing gas with entrained particles into the gas volume, the gas inlet comprising at least one elongated jet-defining wall having a free end portion extending into the gas volume a first distance from the first wall, to define a gas jet extending substantially tangentially to a gas vortex in the gas volume;
- at least one gas outlet for cleaned gas extending from the vortex chamber and being in communication with the gas volume, for establishing at least one gas vortex in said gas volume, and
- at least one separated particles outlet from the gas volume,

characterized in that

the vortex chamber further includes guiding means including

- an insert of solid refractory material, said insert extending between the jet-defining wall free end portion and the first wall and having a curved gas flow direction changing surface,

for guiding the gas vortex between the first wall and the jet-defining wall so that the flow direction of particles separating from gas in the gas vortex is smoothly changed from generally along said first wall to substantially in line with said gas jet at said gas inlet.

2. A centrifugal separator as recited in claim 1 wherein the cross-section of the gas volume is substantially quadrate.

3. A centrifugal separator as recited in claim 2 wherein the plurality of substantially planar walls comprises a second wall, substantially perpendicular to and intersecting the first wall; and wherein the at least one jet-defining wall comprises a single jet defining wall, substantially parallel to the second wall and spaced from the second wall a distance W, defining the width of the gas inlet, and wherein the gas inlet has a height H which is greater than 2W.

4. A centrifugal separator as recited in claim 2 or 3 wherein the plurality of substantially planar walls comprises a second wall, substantially perpendicular to and intersecting the first wall; and wherein the at least one jet-defining wall comprises a single jet defining wall, substantially parallel to the second wall and spaced from the second wall; and wherein the second wall has a length D interior the gas volume, and wherein the first distance is at least 50 mm, but less than 25% of D.

5. A centrifugal separator as recited in claim 1 wherein the insert includes a plurality of cooling fluid circulating tubes which cool the gas flow direction changing surface.

6. A centrifugal separator as recited in claim 1 wherein the jet-defining wall, and portions of the first wall adjacent the insert, have a plurality of cooling fluid circulating tubes which cool the insert.

7. A centrifugal separator as recited in claim 1 wherein the plurality of substantially planar walls comprises at least second and third walls connected to the first wall; and wherein the at least one jet defining wall comprises two jet defining walls spaced from each other a distance W which defines the width of said gas inlet opening, the gas inlet having a height H which is greater than 2W; and wherein the jet defining walls each have a free end portion which extends into the gas volume the first distance, and have an insert with gas flow direction changing surface, and are disposed in a central section of the first wall, remote from the second and third walls.

8. A centrifugal separator as recited in claim 7 wherein each of the jet defining walls makes an angle α with respect to its associated gas flow direction changing surface, said angle α being from about 20° to 80°.

9. A centrifugal separator as recited in claim 8 wherein the angle α is from about 40° to 60°.

10. A centrifugal separator as recited in claim 7 wherein the first distance is between 0.2 - 5 times W.

11. A centrifugal separator as recited in claim 1 wherein the plurality of substantially planar walls comprises at least second and third walls connected to the first wall, extending substantially perpendicular thereto; and wherein the at least one jet defining wall comprises first and second jet defining walls defining two different gas inlets, the first jet defining wall adjacent but spaced from and substantially parallel to the second wall, and the second jet defining wall adjacent but spaced from and substantially parallel to the third wall, each of the jet defining walls and the first wall having the guiding means.

12. A centrifugal separator as recited in claim 1 wherein the plurality of planar walls each have an interior surface thereof, defining the gas volume, covered with a refractory material.

13. A centrifugal separator as recited in claim 12 wherein the plurality of substantially planar walls comprises a fourth wall, opposite the gas inlet in the first wall; and wherein the fourth wall opposite the gas inlet includes a refractory surface having enhanced erosion resistance properties compared to the refractory material covering the rest of the interior surfaces of the substantially planar walls.

14. A centrifugal separator as recited in claim 1 characterized by the separator being combined to a circulating fluidized bed reactor having a reaction chamber, including

- a fluidized bed at a bottom portion of the reaction chamber, and
- a gas discharge portion at a top portion of the reaction chamber and connected to the gas inlet of the centrifugal separator,

the gas inlet of the centrifugal separator extending substantially vertically, and the gas outlets leading cleaned gas from the separator gas volume upwardly out of the gas volume;

and the reactor further having a return duct for particles leading from the bottom of the separator to the bottom portion of the reaction chamber.

15. A method of separating particles from a stream of gas having particles entrained therein and at a temperature of higher than 500°C, utilizing a centrifugal separator comprising

- a plurality of substantially planar walls, including a first wall, defining a vortex chamber having an interior gas volume, the vortex chamber having a multilateral cross-section; and
- at least one gas outlet for cleaned gas extending from the vortex chamber and in communication with the gas volume, and at least one gas inlet formed in the first wall for introducing gas with entrained particles into the gas volume, for establishing at least one gas vortex in the gas volume; the method of separating particles including

(a) introducing a stream of gas with entrained particles and at a temperature of higher than 500°C into the gas volume as a jet in a direction tangential to a vertical axis swirling gas vortex formed in the gas volume, the jet and vortex intersecting at an intersection point;

(b) removing cleaned gas from the top of the gas vortex, and

(c) removing separated particles from the bottom of the gas vortex;

the method further being characterized by

(d) smoothly changing with an insert of solid refractory material having a curved surface the direction of any particles separated from the vortex in the vicinity of the first wall from along the first wall to the direction of the jet.

16. A method as recited in claim 15 wherein step (d) is practiced to prevent settling of particles within the range of 270-315° from the intersection point.

17. A method as recited in claim 15 wherein step (a) is practiced by introducing gas with entrained particles in a flow configuration having a height at least twice as great as its width.

18. A method as recited in claim 15 wherein the gas inlet has a width W, and wherein step (a) is practiced so that the jet is introduced into the gas volume a distance from the first wall that is between 0.2-5 times W.

19. A method as recited in claim 15 wherein the gas volume is substantially quadrate in cross section, and has a width dimension extending from the gas inlet; and wherein step (a) is practiced so that the jet is introduced into the gas volume a distance from the first wall that is greater than 50 mm but less than 25% of the width dimension.

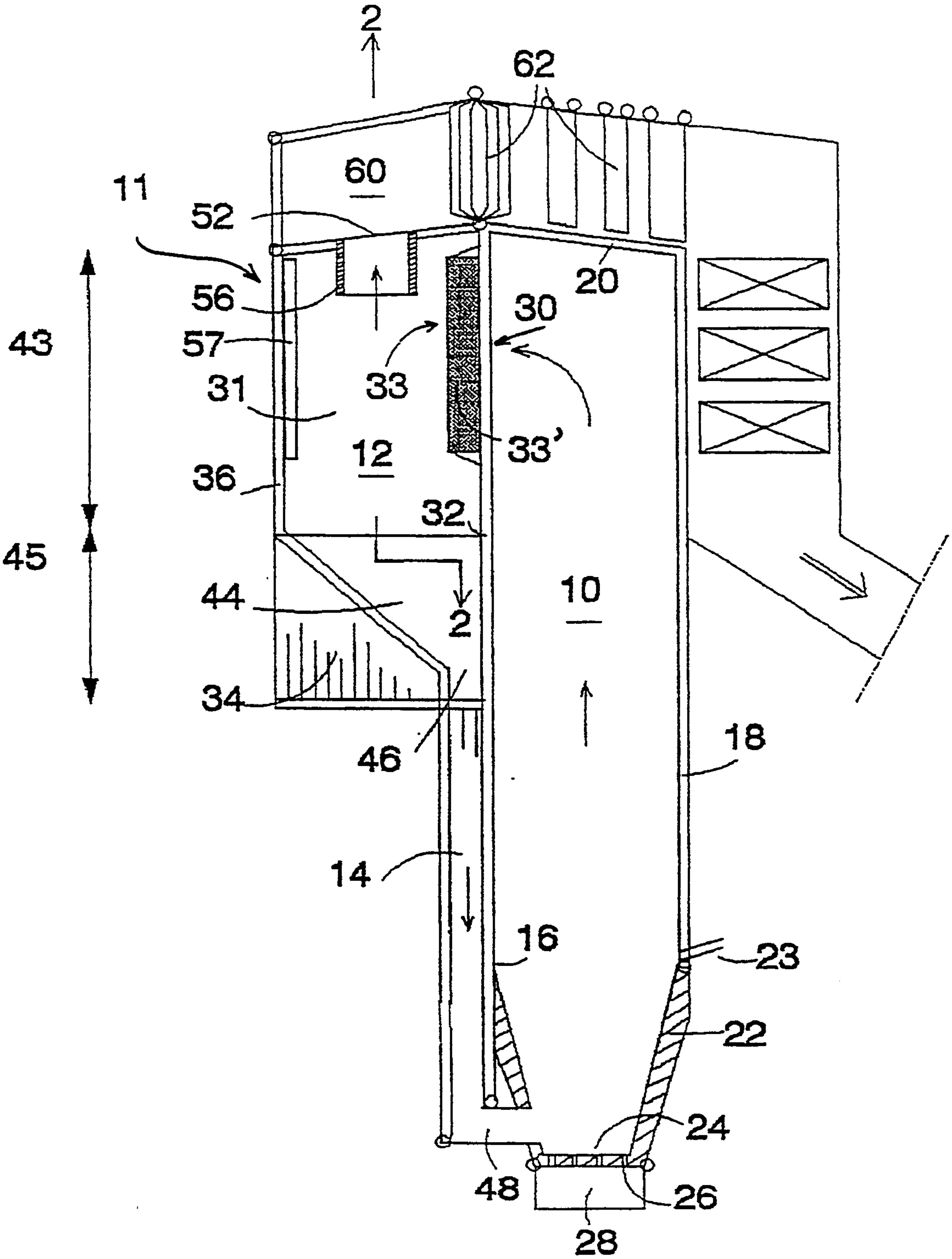

2
62
60
11
52
20
56
30
43
57
33
31
33'
12
36
32
45
44
10
2
34
46
18
14
16
23
22
24
48
26
28

Fig. 1

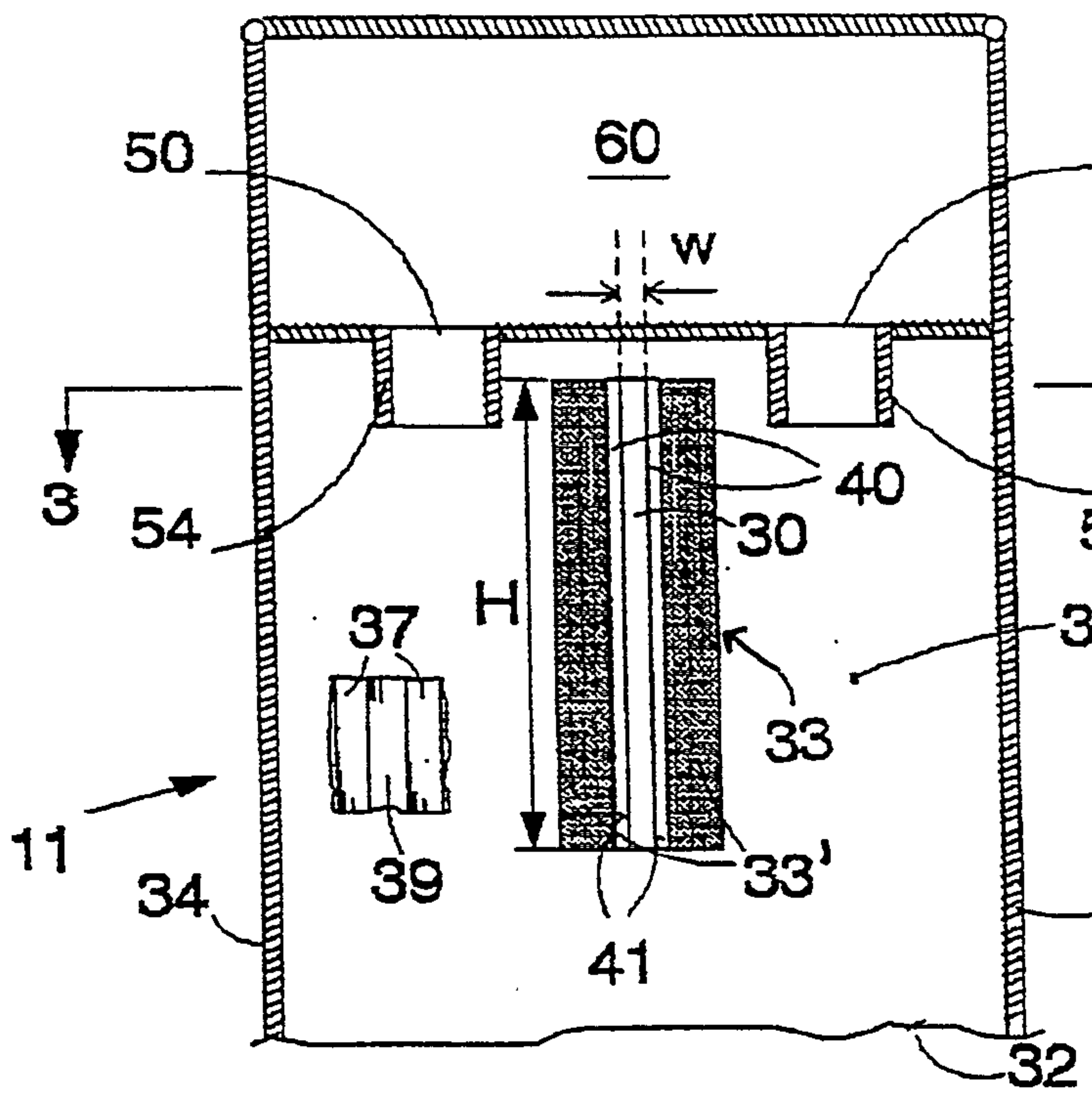

60
50
52
W
3
3
54
56
40
30
H
31
37
33
11
39
33'
34
38
41
32

Fig. 2

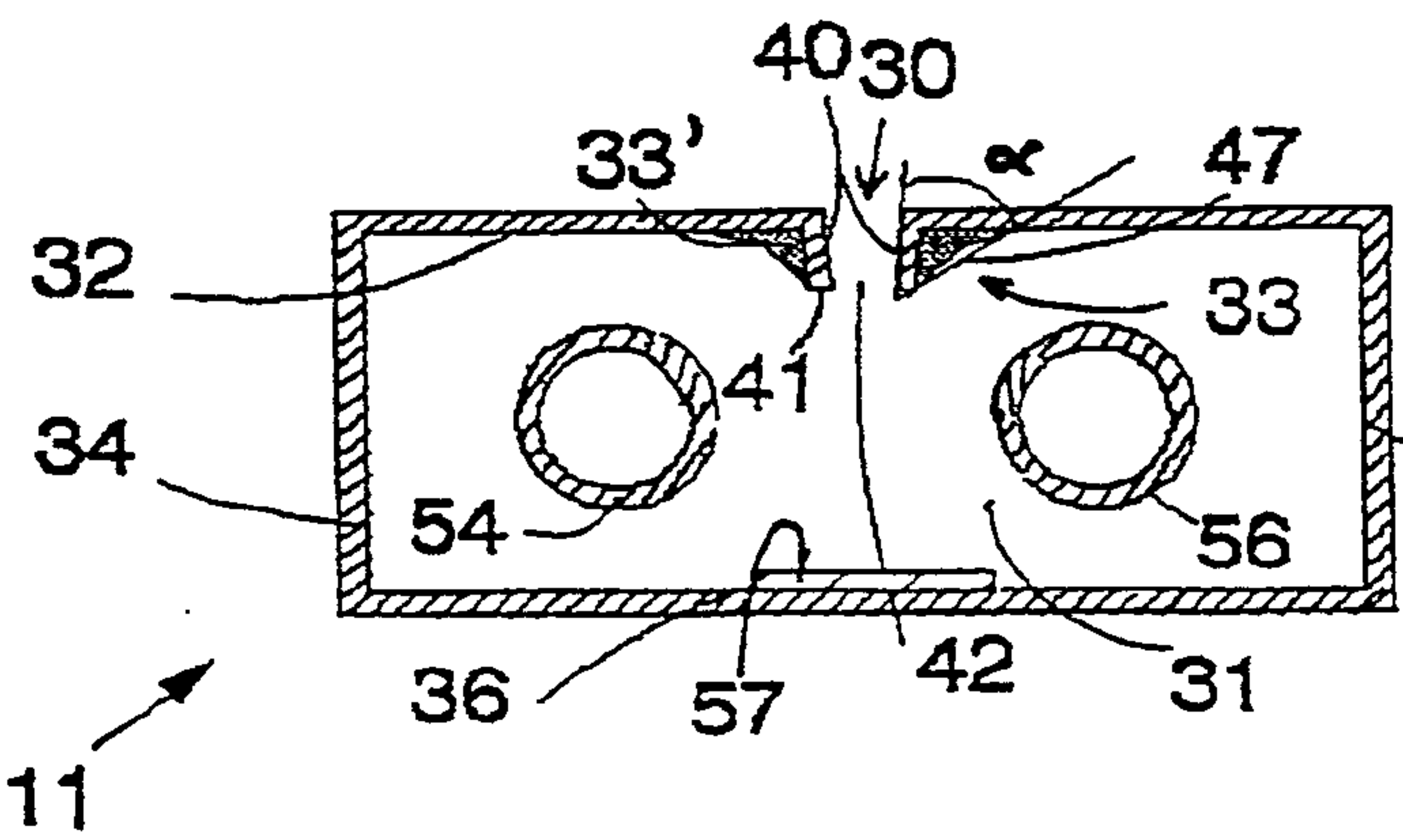

40
30
33'
α
47
32
33
41
38
34
54
56
36
57
42
31
11

Fig. 3

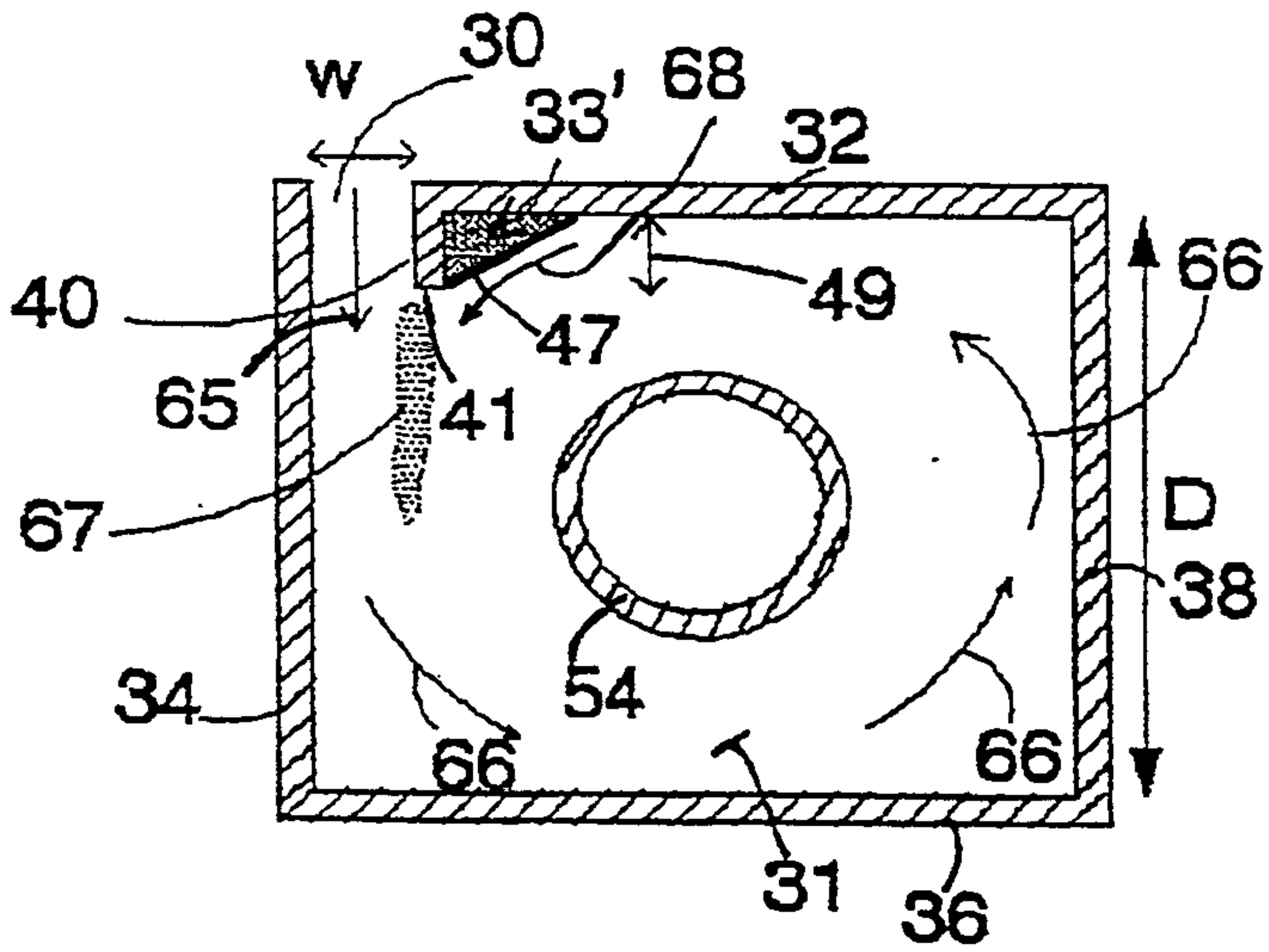

W
30
33'
68
32
40
49
66
47
65
41
67
D
38
54
34
66
66
31
36

Fig. 4

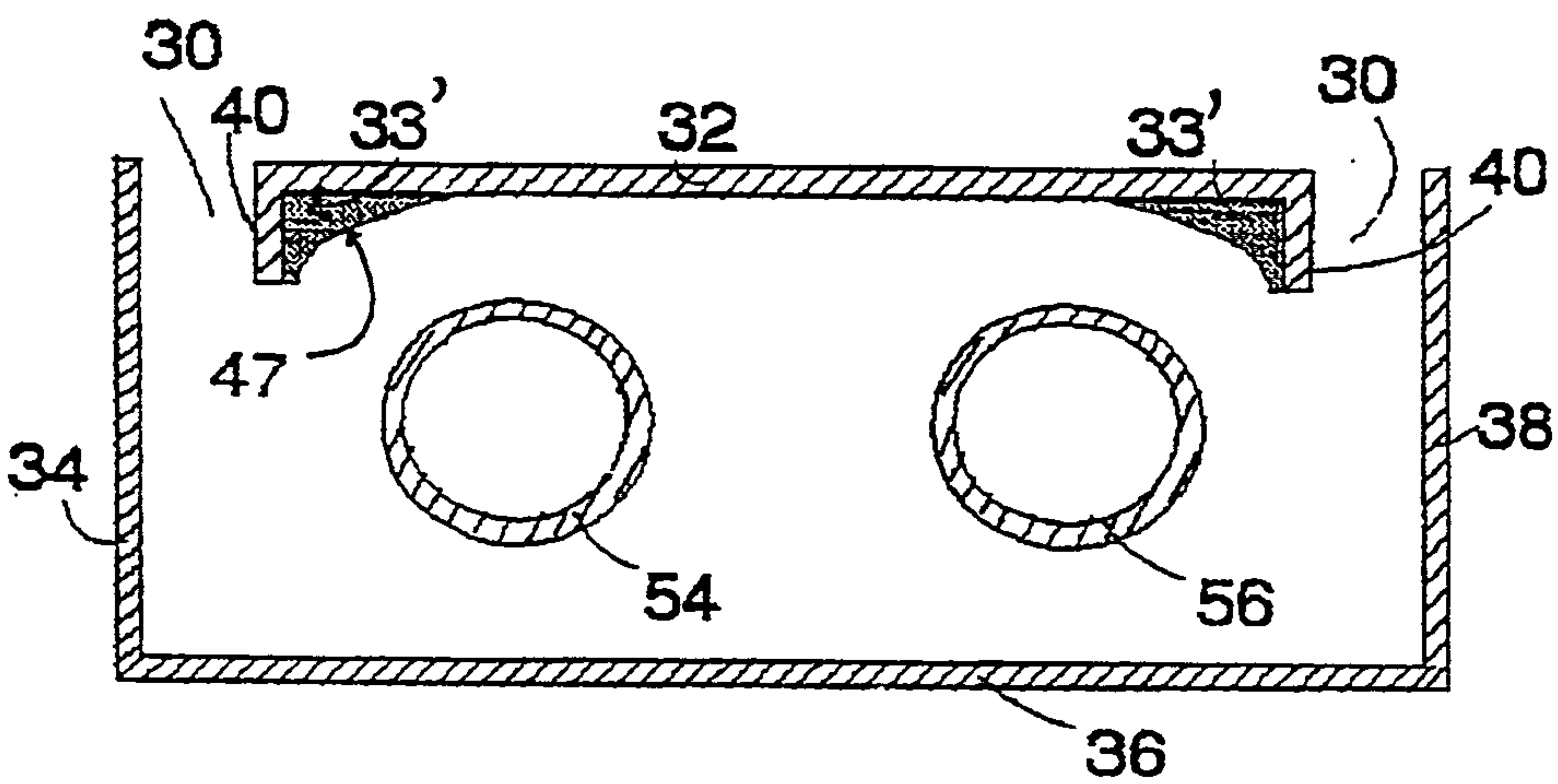

30
40
33'
32
33'
30
40
47
38
34
54
56
36

Fig. 5

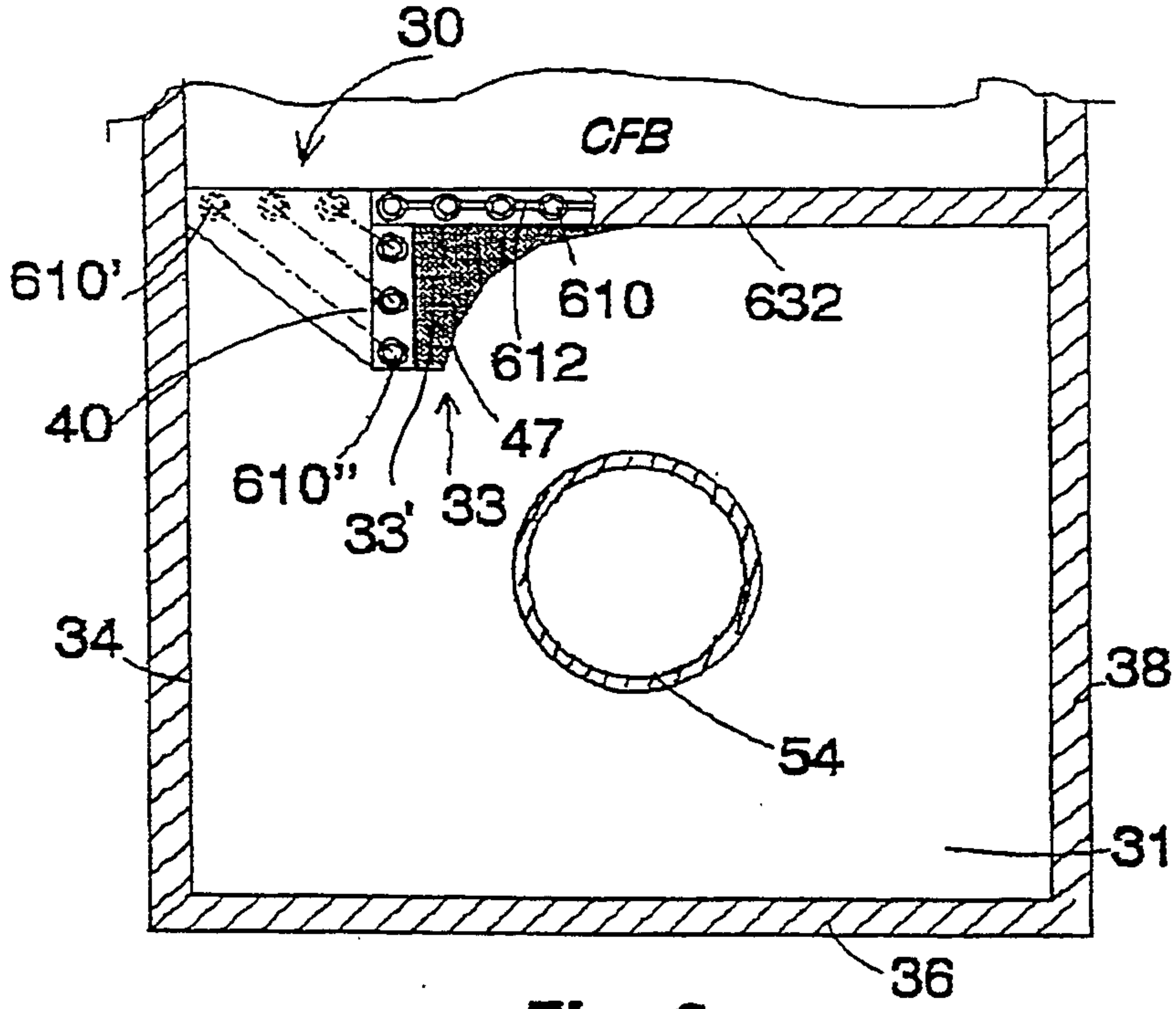

30
CFB
610'
610
632
612
40
47
610"
33'
33
34
38
54
31
36

Fig. 6

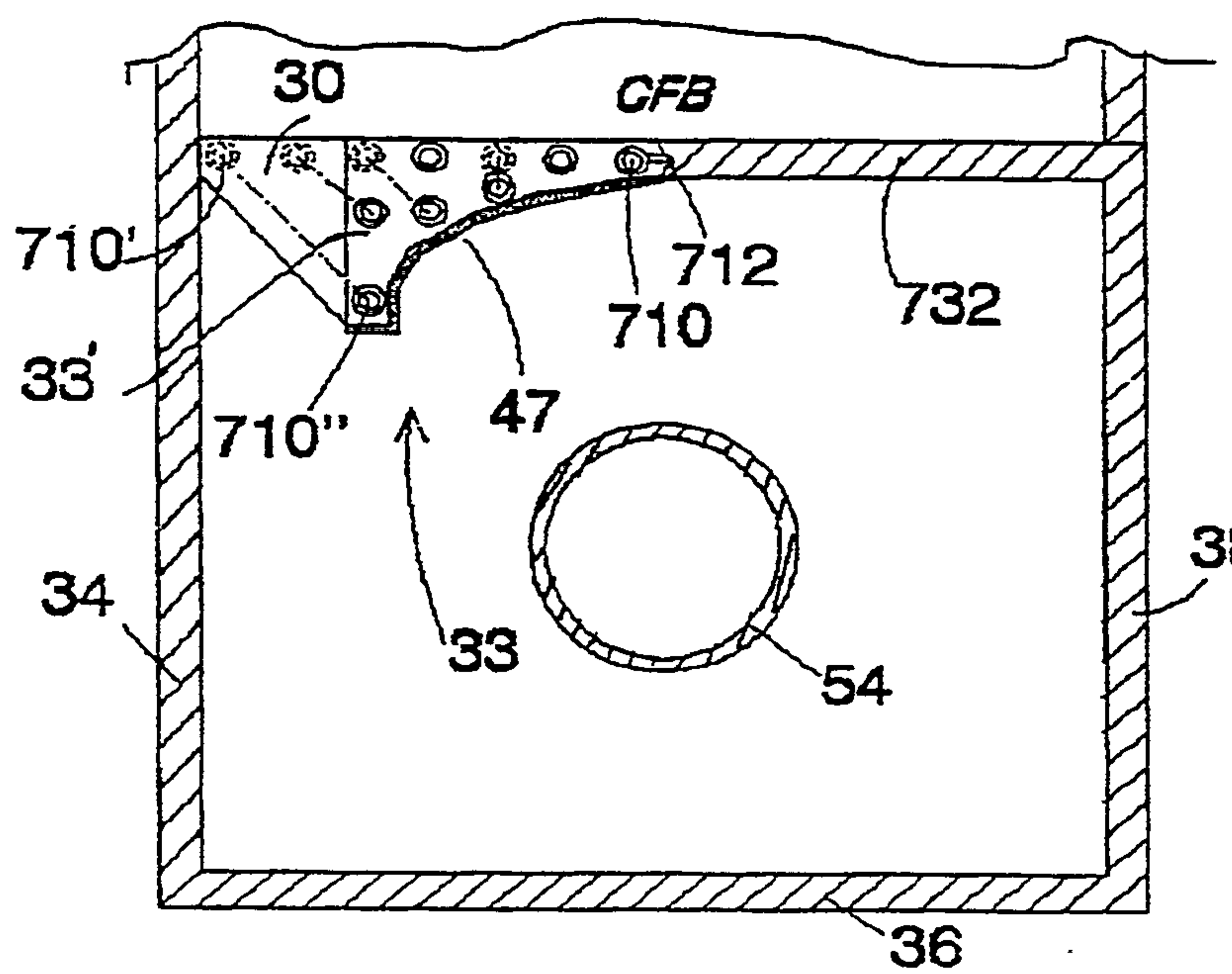
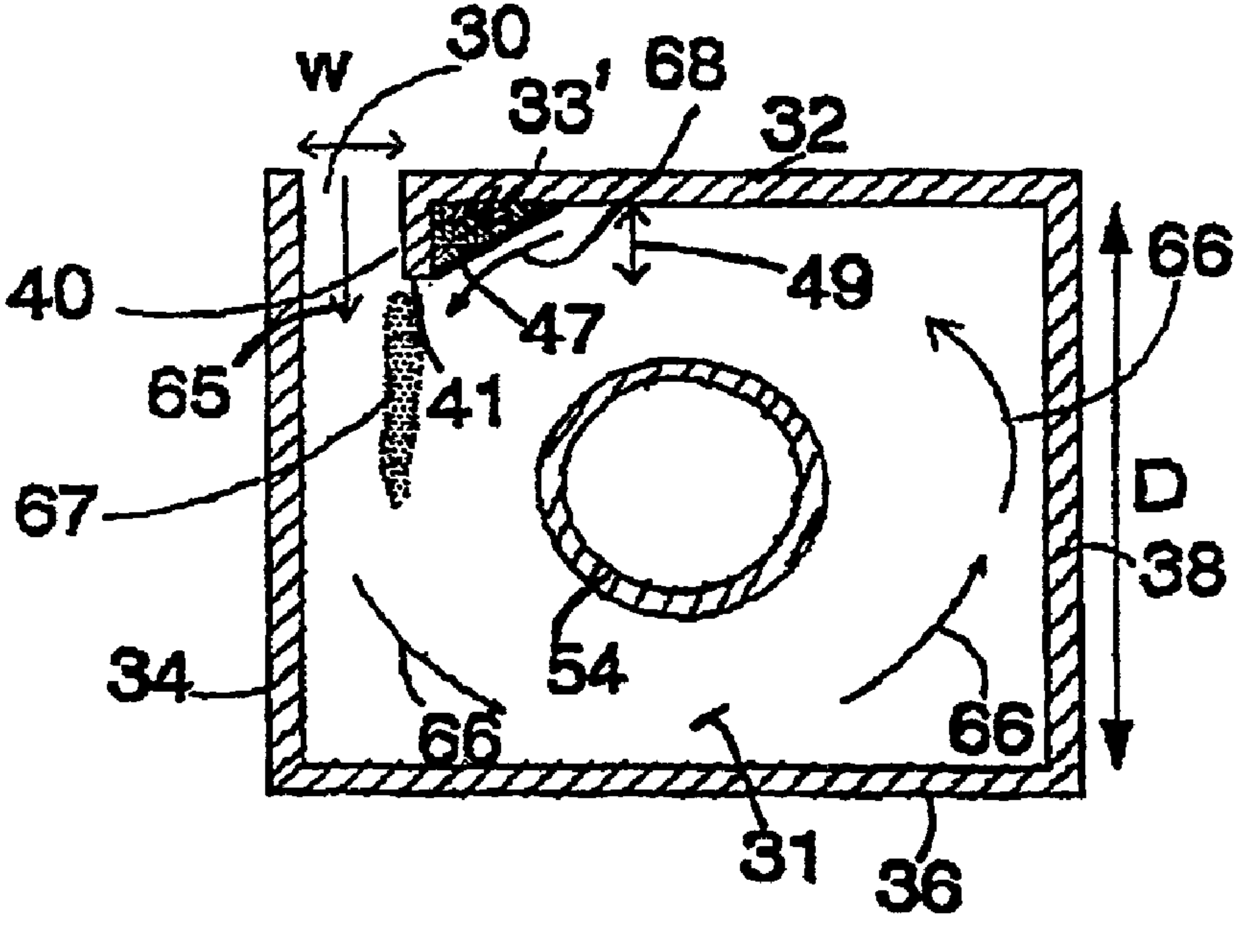

30
CFB
710'
712
710
732
33'
710"
47
33
34
38
54
36

Fig. 7



W
30
33'
68
32
66
40
49
47
65
41
67
D
38
54
34
66
66
31
36