

(19) **DANMARK**

(10) **DK/EP 3271633 T3**



Patent- og
Varemærkestyrelsen

(12) **Oversættelse af
europæisk patentskrift**

-
- (51) Int.Cl.: **F 16 L 27/12 (2006.01)** **F 28 D 20/00 (2006.01)**
- (45) Oversættelsen bekendtgjort den: **2020-11-09**
- (80) Dato for Den Europæiske Patentmyndigheds bekendtgørelse om meddelelse af patentet: **2020-08-26**
- (86) Europæisk ansøgning nr.: **16714779.2**
- (86) Europæisk indleveringsdag: **2016-03-17**
- (87) Den europæiske ansøgnings publiceringsdag: **2018-01-24**
- (86) International ansøgning nr.: **EP2016055760**
- (87) Internationalt publikationsnr.: **WO2016146724**
- (30) Prioritet: **2015-03-18 FR 1552234**
- (84) Designerede stater: **AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR**
- (73) Patenthaver: **Commissariat à l'Énergie Atomique et aux Énergies Alternatives, 25, Rue Leblanc , Bâtiment "Le Ponant D", 75015 Paris, Frankrig**
- (72) Opfinder: **MIRATON, Arnaud, 6 bis rue Mayen, 38000 Grenoble, Frankrig**
MATRINGE, Gilles, 3 rue des Artilleurs de Montagne, 38100 Grenoble, Frankrig
- (74) Fuldmægtig i Danmark: **Zacco Denmark A/S, Arne Jacobsens Allé 15, 2300 København S, Danmark**
- (54) Benævnelse: **Teleskopisk og flydende system til fordeling af varmeoverføringsfluid til en indretning til lagring af termisk energi**
- (56) Fremdragne publikationer:
EP-A1- 1 039 256
EP-A2- 2 418 449
WO-A1-00/63624
CZ-A3- 20 080 237
FR-A1- 2 364 411
FR-A1- 2 498 171
GB-A- 1 439 291
GB-A- 2 074 706
GB-A- 2 511 590

DESCRIPTION

TECHNICAL FIELD

The present invention relates to the general field of the thermal energy storage, in particular by sensible heat, particularly for home storage and/or storage for a heating network. It concerns more specifically the field of the systems for injecting and/or withdrawing heat transfer fluid within a thermal energy storage tank.

The invention thus proposes a system for distributing heat transfer fluid for a thermal energy storage device, a thermal energy storage device including such a distribution system and a thermal storage tank stratified by heat transfer fluid, as well as an associated method for distributing heat transfer fluid in a thermal energy storage device.

STATE OF THE PRIOR ART

Currently, thermal energy needs are certain, and in particular for its use for heating and production of domestic hot water (DHW).

However, such thermal energy needs vary considerably during a single day. Indeed, peaks in thermal energy consumption are observed during the day. Thus, within the context of the use of thermal energy for heating needs for example, these consumption peaks can reach up to four times the average load of a heating network, and the consumption peaks in the morning and in the evening, cumulated together, can alone represent nearly 30% of the daily thermal energy consumption. Likewise, over a full year, the thermal energy needs are also variable since in particular the heating needs are practically zero during the summer while they can reach very high values during the winter.

In order to be able to meet the thermal energy demand, the thermal energy supply is ensured by production units which encounter difficulties in complying with this fluctuating demand, indeed being generally either intended to be intermittent, for example in the case of thermal solar panels, or designed to operate with stable and regular operating regimes, such as, for example, wood-fired power stations.

Consequently, the use of the thermal energy storage, particularly by sensible heat, appears to be a suitable solution to allow reconciling both the thermal energy fluctuating demand and the thermal energy production constraints, by thus

absorbing by "buffer effect" the fluctuations specific to the demand and to the production.

In the sensible heat thermal storage, the energy is stored as a rise in temperature of the storage material. The amount of stored energy is then directly proportional to the volume, to the temperature rise and to the thermal capacity of the storage material. This type of storage is only limited by the difference in the available temperature and the temperature withstood by the material or its container, by the thermal losses of the storage and by the possible change of state that the material used for the storage may have to undergo.

A thermal energy storage device can operate on a daily basis, the charges and discharges then occurring at a day time scale with typically a charge during the day and a discharge when an energy need is requested, or even also in inter-seasonal pattern, the charges and discharges then occurring on a yearly basis with typically a charge during the summer and a discharge during the winter.

In addition, a thermal energy storage device can be designed in different sizes depending on its use. Particularly, the volume of stored heat transfer fluid can be variable. For example, home storage, for example for a home DHW balloon or an individual solar water heater, may require a volume of heat transfer fluid from a few hundred liters to a few cubic meters. On the other hand, the storage for a heating network may require a much larger volume of heat transfer fluid, and particularly from a few hundred cubic meters to several tens of thousands of cubic meters.

However, whatever the intended purpose of the thermal storage, there is a major problem which determines the performances of the thermal storage and which consists in the preservation of the thermal stratification within the tank of the thermal storage device, containing the heat transfer fluid.

Indeed, in order to obtain quality thermal storage, it is necessary to obtain a strong temperature gradient between the two ends of the storage, in particular between the top and the bottom of the thermal storage device considered in a vertical position.

Also, in order to preserve the storage quality and therefore this thermal gradient, it should be possible to distribute, namely to inject and/or withdraw, the heat transfer fluid without however inducing convective movements which are then responsible for the thermal destratification. In addition, since the injection

temperatures are not constant, it should also be possible to be able to inject the fluid at a given temperature within a suitable temperature stratum to avoid mixing of the fluid stored in the tank of the storage device. Likewise, in case of withdrawal, it should be possible to withdraw from any temperature stratum depending on the requested temperature need.

In the process of charging or discharging a thermal tank of a thermal storage device, the functions of distributing and diffusing heat transfer fluid can be distinguished from each other. Indeed, on the one hand, the heat transfer fluid distribution function consists as such in distributing the heat transfer fluid at a certain level or a certain height of the storage of the tank, while on the other hand the function of diffusing heat transfer fluid aims at limiting the impact of the injection/withdrawal of the heat transfer fluid in the storage stratum where distribution takes place.

Furthermore, it should be noted that the distribution of thermal energy in the tank of the storage device can be achieved directly, that is to say the storage fluid of the tank and the injected/withdrawn fluid are identical, or even indirectly, via the presence of a heat exchanger equipping the storage device. The indirect solution allows avoiding the problem of diffusion which can lead to destratification of the thermal tank by jet effect. However, it generally induces an exergy loss due to the actual heat exchange between the two separate fluids.

Thus, considering the distribution and diffusion functions described above for a thermal tank of a thermal storage device, solutions are already known in the prior art.

Regarding firstly the distribution of heat transfer fluid, several types of distributors are known.

There is thus in particular the principle of fixed injection, consisting in injecting the hot fluid in the upper part of the storage tank via a stationary pipe and in withdrawing the cold fluid in the lower part of the tank. Such an injection system is simple to implement and design, and it turns out to be interesting when the inlet temperatures are constant and the rate is low. However, it leads to poor quality stratification under complex conditions of fluid entry and exit, such as the presence of a variable temperature or a high rate.

Furthermore, the principle of the multi-level injection by three-way valve is also known. This type of injection is the most common, and consists of the

introduction of the heat transfer fluid at three different temperature levels. The three-way valve(s) operate in all or nothing mode, and are regulated by the exit temperature of the fluid. Setting up a plurality of three-way valves allows increasing the number of injection strata in the thermal tank. This multilevel technology allows
5 obtaining at least two different temperature strata in the thermal tank, and is also robust and reliable. However, its cost proves to be significant and the all-or-nothing operation of the three-way valves limits the regulation.

There is also the injection principle called "stratification rod" injection principle which allows energy distribution by natural convection. More specifically,
10 the fluid rises inside a thermosyphon tube (stratification rod) pierced with holes for injecting fluid into the tank. By density difference, the fluid circulates in the stratification rod until reaching the height of the stratum having the same temperature. This operating principle therefore allows the establishment of strata throughout the storage tank, giving rise to a large thermocline, but with little mixing.
15 This principle is also more difficult to set up. Furthermore, installations can be set up to stop the rise of fluid in the stratification rod, such as for example check valves or inclined tubes. The injection can be achieved indirectly via the use of a heat exchanger.

The stratification rods can take different shapes depending on their
20 manufacturer. The active stratification balloon Stratos® from the company Solvis is thus known, which comprises a plurality of stratification rods, each covering different temperature stages. Balloons of the Conus® and Solus® type from the company Consolar are also known, which also operate with a stratification rod. More specifically, a thermal exchanger system designed on the thermosyphon
25 principle allows establishing a counter-current thermal transfer with very low losses within the balloon. Thus, the upper thermal exchanger heats the hot circulating fluid. The fluid of the balloon cools down and flows through the flow tube towards the lower part where it can be heated again. In case of low solar radiation, the thermal exchanger located in the middle part and connected to a boiler heats the upper third
30 of the balloon. Thanks to the conductive envelope of the supplementary heat exchanger, heat for a supplement ambient heating is extracted from the middle part. In bright sunlight, the heated heat transfer fluid is conducted through a copper tube in the lower part of the heat exchanger. In addition, there are also dynamic temperature stratification accumulators as designed by the company Ratiotherm,

particularly under the reference Oskar®. Thus, different pipes join the stratification rod in the shape of a spiral and pierced.

In addition, other technologies are currently under development, such as those relating to the use of manifolds (porous tubes), which technologies are promising to promote the elaboration of a stratification but using materials more adapted to small-scale storage. Thus, the manifolds are materials that can shrink or expand depending on the conditions, thus giving the possibility of releasing the fluid at the right pressure level. The use of manifolds in the shape of porous rigid or fabric tubes is thus known, the drawback of such materials coming especially from their low thickness that leads to strong thermal transfers through their wall.

Moreover, there are also solar balloons equipped with stratification sheets, which are intended to physically separate the hot part from the cold part of the balloon by the presence of obstacles.

With regard to the heat transfer fluid diffusion function, and in the case of direct injection distributors (therefore without heat exchanger), it may be interesting to add diffusers or jet-breakers having the function of attenuating the jet phenomenon which can lead to degradation of the stratification. Thus, various studies have been conducted around this problem revealing that, on the one hand for the diffusers, it is possible to reduce the kinetic energy and to allow good distribution of the heat transfer fluid although they do not allow by themselves solving the problem of setting up the stratification and its maintenance, while, on the other hand for the jet-breakers, it is possible to reduce the kinetic energy although these can cause the mixing of the injected heat transfer fluid.

In addition, various other solutions for designing distributors, using in particular the stratification rod principle, and fluid diffusers in a storage tank have also been described in the patent literature. As examples, mention can thus be made to the European patent application EP 2 065 666 A1 which describes the presence of a middle enclosed coil at the storage with two distribution rods connected to the enclosed space, the Korean patent application KR 2005-0064018 A which describes the production of a diffuser with a movable part allowing to modify the passage section of the diffuser, or the international application WO 2013/083911 A1 which describes a design of a jet-breaker disposed at the water inlet in a hot water storage tank.

EP 1 039 256 A shows a system for distributing heat transfer fluid for a thermal energy storage device including a thermal storage tank stratified by heat transfer fluid, the solid density of the solid part of the distribution system, being substantially equal to the fluid density of the fluid part of the distribution system, comprising the heat transfer fluid intended to be distributed within said target thermal stratum, to allow flotation of said diffuser element at the level of said target thermal stratum.

DISCLOSURE OF THE INVENTION

There is a need to propose an improved alternative solution to a system for distributing heat transfer fluid for a thermal energy storage device, in particular by sensible heat, including a thermally stratified heat transfer fluid storage tank, in order to carry out charges and/or discharges of heat transfer fluid while preventing, or at least greatly limiting, thermal destratification within the storage tank.

The aim of the invention is to at least partially addressing the needs mentioned above and the drawbacks relating to the embodiments of the prior art.

The invention thus relates, according to one of its aspects, to a system for distributing heat transfer fluid for a thermal energy storage device, according to claim 1.

In other words, the distribution system according to the invention has a mass volume density of this system, comprising the fluid density and the solid density of the distribution system, which varies with the temperature of the target thermal stratum.

Still advantageously, the distribution system according to the invention is thus configured to allow flotation of said diffuser element at the level of at least different target thermal strata, particularly having different temperatures.

By "stratified thermal storage tank" is meant that the volume of heat transfer fluid contained in the thermal storage tank has a temperature gradient between the two ends of the storage. In other words, the volume of heat transfer fluid of the thermal storage tank can be divided into a multitude of superimposed thermal layers of heat transfer fluid having different and gradual temperatures from one of the storage ends to the other of the storage ends, these superimposed layers thus forming successive thermal strata.

Thanks to the invention, it may be possible to distribute the heat transfer fluid during phases of charging and/or discharging the thermal storage tank of the thermal energy storage device while preventing, or at least minimizing, the disturbance of the thermal stratification within the tank during these operations.

5 In addition, the distribution system according to the invention has the advantage of being completely self-sufficient. Indeed, this system can retract and deploy without any external assistance, and its distal end can be placed continuously in the target thermal stratum having a suitable temperature. Advantageously, no instrumentation of the thermal storage tank, nor any
10 automation system, of mechanical system or of external energy source is thus necessary to allow movement of the distribution system. Indeed, only the floatability of the distribution system, in particular of the diffuser element, controls the displacement of the distribution system.

In this way, it may also be possible to considerably reduce any maintenance
15 need, or even to dispense with it, which represents a certain cost saving given the fact that the maintenance and shutdown of the facilities typically incur significant costs for the manufacturer.

Furthermore, the particular divergent shape of the distribution system that can be given by a gradual increase in the passage section of the heat transfer fluid
20 in the direction of flow of the heat transfer fluid can allow the distribution system to act as a diffuser upon entry of the heat transfer fluid into the distribution system. Indeed, the reduction in the speed of the heat transfer fluid can thus take place gradually over the entire length of the distribution system, and proves to be less severe than for some of the diffusers of the prior art.

25 The distribution system according to the invention may further include one or more of the following characteristics taken separately or in any possible technical combinations.

The heat transfer fluid intended to be distributed can be of any type, being typically water.

30 Advantageously, the distribution system according to the invention is a direct-injection distribution system, the heat transfer fluid of the thermal storage tank being identical to the heat transfer fluid injected and/or withdrawn via the distribution system.

In addition, the distribution system according to the invention is advantageously rigid and can also be compact, so as to be able to prevent, or at least greatly limit, any mixing of heat transfer fluid in the thermal storage tank upon displacement of the distribution system.

5 As indicated previously, the injection of a heat transfer fluid into a target thermal stratum having a temperature substantially equal to the temperature of the injected heat transfer fluid, or the withdrawal of a heat transfer fluid from a target thermal stratum having a predetermined temperature, are made possible by a principle of flotation of the diffuser element, forming the fluid communication
10 interface between the thermal storage tank and the distribution system, at the level of the target thermal stratum.

According to the invention, in order to allow flotation of the diffuser element at the level of the target thermal stratum, the solid density of the distribution system is chosen to be substantially equal to the fluid density of the distribution system,
15 comprising the heat transfer fluid to be injected and/or withdrawn. In this way, the distribution system deploys and/or retracts, depending on the density variation, until allowing the diffuser element to be located at the level of the target thermal stratum.

In order to better explain how the density value of the distribution system affects the deployment and/or the retraction thereof, it should be understood that
20 the operations of injection and/or withdrawal of heat transfer fluid depend on two parts, namely: a solid part of the distribution system comprising the plurality of distribution elements; and a fluid, in particular liquid, part of the distribution system comprising the heat transfer fluid intended to be injected and/or withdrawn within the target thermal stratum having the same temperature.

25 Thus, the expression (a) of the density of the distribution system, weighted by the considered volumes, is as follows:

$$(a): \rho_{sd} = (\rho_s \times V_s + \rho_l \times V_l) / (V_s + V_l),$$

Where:

ρ_{sd} represents the density of the distribution system,

30 ρ_s and ρ_l represent respectively the solid and fluid densities of the solid and fluid parts presented above, and

V_s and V_l represent respectively the volumes of the solid and fluid parts presented above.

As indicated above and according to the invention, the solid density ρ_s is substantially equal to the fluid density ρ_l .

In addition, advantageously, the solid volume V_s of the solid part of the distribution system is sufficiently low, and therefore negligible, compared to the liquid volume V_l of the fluid part of the distribution system.

Under these conditions, if the expression (a) mentioned above is reconsidered, the density ρ_{sd} of the distribution system then tends towards the fluid density ρ_l of the fluid part of the distribution system. In other words, the density ρ_{sd} of the distribution system is substantially equal to the density ρ_l of the heat transfer fluid intended to be injected into the target thermal stratum and/or to be withdrawn from the target thermal stratum. Consequently, the density ρ_{sd} of the distribution system being comparable to the density ρ_l of the heat transfer fluid to be distributed, the distribution system is then able to float inside the thermal storage tank at the level of the target thermal stratum.

In order to be able to obtain a value of the solid density of the solid part of the distribution system substantially equal to the value of the fluid density of the fluid part of the distribution system, various solutions can be provided.

Particularly, the plurality of distribution elements can be made of one or more material(s) with a density substantially equal to the density of the heat transfer fluid intended to be distributed.

Preferably, this/these materials is/are provided to withstand high temperatures, in particular up to 100 °C.

According to the invention, all or part of the distribution elements may include at least one flotation element, in particular an air float, configured to give the plurality of distribution elements of the distribution system a density substantially equal to the density of the heat transfer fluid intended to be distributed.

The presence of one or more flotation element(s) in one or more distribution element(s) may in particular be desirable when the material(s) constituting the distribution elements has/have a high density, that is to say much greater than the density of the heat transfer fluid intended to be distributed.

Advantageously, the flotation element(s) is/are thus defined such that the total density of the flotation elements is substantially equal to the density of the heat transfer fluid intended to be distributed.

According to the invention, said at least one flotation element can be integrated inside a side wall of at least one distribution element.

In this way, it may be possible to achieve a substantially uniform distribution of the flotation element and also to improve balancing of the distribution element.

5 In addition, said at least one flotation element may extend over the entire length of said at least one distribution element, or even in part.

In order to simplify the manufacture of the distribution elements, it can particularly be envisaged to provide the following configurations for integrating a flotation element into a distribution element.

10 Thus, each distribution element may include a flotation element, the flotation elements being identical and with a fixed volume. The desired density of the plurality of distribution elements can then be obtained by ballasting the distribution elements of a mass selected to reach the desired density. This solution can allow easily controlling the density by gradually adding weight, which can allow a certain
15 inaccuracy in the production of the distribution system. Particularly, any density error can be rectified.

Furthermore, since the integration of a flotation element inside a side wall of a distribution element can be complicated, said at least one flotation element can also be incorporated externally to any wall of said at least one distribution element,
20 in at least one additional cavity located at least at one end of said at least one distribution element. Said at least one additional cavity can then accommodate the entire volume of said flotation element. This solution may be simpler to implement but has the drawback of a non-uniform distribution of the weight within said at least one distribution element, which can interfere with the movement of the distribution
25 system.

Furthermore, in order to obtain a value of the solid density of the solid part of the distribution system substantially equal to the value of the fluid density of the fluid part of the distribution system, it is also possible to envisage the integration of a variable density material at the level of a distribution element, the fluctuations of
30 which would be close to those of the heat transfer fluid intended to be distributed. Particularly, all or part of the distribution elements can include at least one variable density material integrated into a flexible envelope allowing its expansion and/or its shrinkage depending on the temperature of the heat transfer fluid intended to be distributed so as to modify the total density of the distribution elements.

Preferably, said at least one variable density material is integrated between a rigid wall with a low thermal conductivity and a flexible wall with a high thermal conductivity, the assembly forming in particular a side wall of at least one distribution element. Indeed, for the distribution system with the same density as the distributed heat transfer fluid to be able to float continuously at the level of the target thermal stratum, it is desirable that the thermal transfer is instantaneous between the heat transfer fluid and the variable density material, which requires having a flexible internal wall with a high thermal conductivity, and that the thermal transfer is almost zero between the variable density material and the different thermal strata of the thermal storage tank, which requires having an external rigid wall with a low thermal conductivity, in other words an insulating wall.

Furthermore, the distribution system may include a proximal distribution element provided with a means for securing to the thermal energy storage device, a distal distribution element provided with a heat transfer fluid diffuser element, and one or more intermediate distribution element(s), the distribution elements being successively fitted inside one another from the proximal distribution element to the distal distribution element.

The securing means of the proximal distribution element may for example include a plurality of orifices for fixing, for example by screws, to the thermal energy storage device, these orifices being in particular evenly distributed all around the proximal distribution element.

In addition, the passage section of the heat transfer fluid of the distribution elements can advantageously increase gradually from the proximal distribution element to the distal distribution element of the distribution system.

Particularly, this gradual increase in the passage section of the heat transfer fluid from the proximal distribution element to the distal distribution element can be obtained via an increasing variation in the diameters of the distribution elements. This increasing variation in section or in diameter, in addition to facilitating and allowing fitting of the distribution elements together, can also allow reducing beforehand the speed of the heat transfer fluid before its entry in a diffuser element and its diffusion into the thermal storage tank. Thus, the reduction in the speed of the heat transfer fluid is more gradual and less abrupt than for a simple diffuser as known from the prior art.

The diffuser element of the distal distribution element can be in various shapes. However, preferably, the diffuser element of the distal distribution element can include radial diffusion means of the heat transfer fluid.

5 These radial diffusion means of the heat transfer fluid can be preferably evenly distributed around the periphery of the distal distribution element. They can be in the shape of orifices for injecting and/or withdrawing heat transfer fluid.

Advantageously, the radial injection allowed by the diffuser element of the distal distribution element allows reducing the speed of entry of the heat transfer fluid into the thermal storage tank.

10 For example, the diffuser element can be in the shape of a disc pierced around its periphery with heat transfer fluid injection and/or withdrawal orifices. If necessary, the diffuser element can be coupled to bent or T-shaped heat transfer fluid inlets.

In addition, the distribution elements can be in the shape of cylindrical tubes
15 with different diameters.

The lengths of the distribution elements may be different, but are preferably identical. In addition, the main shapes of the distribution elements are preferably similar. Likewise, the material(s) constituting the distribution elements are preferably identical for all the distribution elements.

20 Furthermore, the fitting of a first distribution element into a second distribution element can be achieved by the cooperation between a distal cylindro-conical portion of the first distribution element and a proximal frusto-conical portion of the second distribution element, the proximal frusto-conical portion of the second distribution element covering the distal cylindro-conical portion of the first
25 distribution element so as to abut against one another when the first and second distribution elements slide away from each other.

Advantageously, the frusto-conical shape of the proximal portion of the second distribution element cooperating with the cylindro-conical shape of the distal portion of the first distribution element can allow preventing dislocation of the
30 first and second distribution elements relative to each other, and also preserving the overall cohesion of the distribution system.

Furthermore, advantageously, the distribution elements are not secured to each other.

Particularly, there may be a small clearance between two successive distribution elements. The presence of such a clearance can indeed allow preventing any friction which could interfere with the displacement of each distribution element. Also, advantageously, the only instant of contact between two successive distribution elements is constituted by the abutment-to-abutment contact of a proximal frusto-conical portion of one of the two distribution elements and of a distal frusto-conical portion of the other of the two distribution elements, as described above.

In addition, it should be noted that even though the presence of such a clearance between two successive distribution elements could lead to a leakage of heat transfer fluid at the level of the junctions between distribution elements, such a leak would be small and therefore admitted and tolerated.

The distribution elements can preferably be made from one or more polymer material(s), in particular selected from: polycarbonate (PC), polyamide (PA), polyoxymethylene (POM), polyphenylether (PPE), polytetrafluoroethene (PTFE), polyetheretherketone (PEEK), polyethersulfone (PES), polysulfone (PSU), polyethyleneimine (PEI), phenylene polysulfide (PPS) and/or polyvinylidene fluoride (PVDF).

Alternatively, the distribution elements can also be made from one or more metal(s), for example from aluminum or steel, among others.

Nevertheless, the choice of polymer materials is favored mainly because of their low thermal conductivity, their availability, their ease of shaping and their low cost. In addition, the materials used must be preferably able to withstand a temperature resistance stress at around 100 °C.

In addition, the invention also relates, according to another of its aspects, to a thermal energy storage device, characterized in that it includes:

- a stratified thermal storage tank including a heat transfer fluid for storing thermal energy, and
- a heat transfer fluid distribution system as described above, extending inside the thermal storage tank for injecting and/or withdrawing heat transfer fluid.

Preferably, the thermal energy storage device according to the invention is a thermal energy storage device by sensible heat.

In addition, the distribution system can be secured at one of its ends to an inner wall of the thermal storage tank, in particular the upper inner wall, the other of its ends including in particular said heat transfer fluid diffuser element.

5 In addition, the thermal energy storage device according to the invention may include a guide element passing through the interior of the distribution elements of the distribution system over its entire length, being in particular secured to the upper inner wall of the thermal storage tank and to the lower inner wall of the thermal storage tank.

10 Particularly, this guide element may be in the shape of a guide pin extending from one end to the other of the thermal storage tank, namely from top to bottom. Such a guide element can advantageously allow the distribution system to remain stable, and in particular in a very vertical position, and also to facilitate the movement of the distribution elements relative to each other.

15 Furthermore, the thermal energy storage device according to the invention may include, inside the thermal storage tank, a first device for injecting and/or withdrawing heat transfer fluid fixed to the upper inner wall of the thermal storage tank and a second device for injecting and/or withdrawing heat transfer fluid fixed to the lower inner wall of the thermal storage tank to respectively allow injection and/or withdrawal of the heat transfer fluid within the upper thermal stratum of the thermal storage tank, adjacent to the upper inner wall, and within the lower thermal stratum of the thermal storage tank, adjacent to the lower inner wall, the distribution system then allowing injection and/or withdrawal of the heat transfer fluid within the intermediate thermal stratum/strata of the thermal storage tank.

25 Advantageously, the presence of such first and second injection and/or withdrawal devices inside the thermal storage tank can allow increasing the accuracy of the heat transfer fluid distribution. Thus, within the thermal storage tank, the heat transfer fluids having extreme temperatures can be permanently injected and/or withdrawn by the upper and lower parts of the thermal storage tank, the heat transfer fluids having intermediate temperatures can then be injected and/or withdrawn by the distribution system.

In this way, it may be possible to reduce the range of displacement of the distribution system and thus further reduce a possible positioning error.

The operation of the system for distribution and the first and second devices for injecting and/or withdrawing heat transfer fluid can be controlled in temperature

via at least one three-way valve, able to distribute the heat transfer fluid either in the distribution system, or in the first injection and/or withdrawal device, or in the second injection and/or withdrawal device depending on the temperature of the heat transfer fluid to be distributed.

5 In addition, the presence of such first and second injection and/or withdrawal devices inside the thermal storage tank can allow carrying out operations of injecting and withdrawing heat transfer fluid simultaneously.

 Furthermore, the invention also relates, according to another of its aspects, to a method for distributing heat transfer fluid in a thermal energy storage device, 10 in particular by sensible heat, including a thermal storage tank stratified by heat transfer fluid, for injecting and/or withdrawing heat transfer fluid within the thermal storage tank, characterized in that it is implemented by means of a distribution system as defined above.

 The distribution method according to the invention advantageously includes 15 the step of injecting a heat transfer fluid into a thermal stratum of the thermal storage tank having the same temperature as the heat transfer fluid via the distribution system, in particular via the heat transfer fluid diffuser element.

 In addition, the distribution method according to the invention advantageously includes the step of withdrawing a heat transfer fluid having a 20 predetermined temperature from a thermal stratum of the thermal storage tank having the same temperature as the heat transfer fluid via the distribution system, in particular via the heat transfer fluid diffuser element.

 In addition, the distribution method according to the invention may include the step of determining the solid density of the solid part of the distribution system, 25 comprising the plurality of distribution elements, so as to be substantially equal to the fluid density of the fluid part of the distribution system, comprising the heat transfer fluid intended to be distributed, by injection and/or withdrawal.

 The distribution system, the thermal energy storage device and the distribution method according to the invention may include any one of the 30 characteristics set out in the description, taken separately or in any technically possible combinations with other characteristics.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention could be better understood upon reading the following detailed description of non-limiting examples of implementation thereof, as well as upon examining the schematic and partial figures of the appended drawing, on which:

- 5 – Figure 1 represents, in perspective, an example of a distribution system according to the invention in a configuration where it is fully deployed,
- Figure 2 represents, in perspective, an example of a thermal energy storage device according to the invention including the distribution system of Figure 1, the thermal energy storage device being partially represented in cross-section
- 10 to view the distribution system positioned thereinside,
- Figures 3A, 3B and 3C respectively represent, in perspective, the proximal distribution element, an intermediate distribution element and the distal distribution element of the distribution system of Figure 1,
- Figures 4A and 4B respectively represent, in perspective, the distribution
- 15 system of Figure 1 in a configuration where it is fully retracted and in a partially retracted and partially deployed intermediate configuration,
- Figure 5 represents, in cross-section, the configuration allowing fitting between two distribution elements of the distribution system of Figure 1,
- Figure 6 represents, in cross-section and in perspective, an alternative
- 20 embodiment of an intermediate distribution element of a distribution system according to the invention, integrating a flotation element,
- Figure 7 represents, in cross-section and in perspective, another alternative embodiment integrating a guide element through a distribution system according to the invention,
- 25 – Figure 8 represents yet, in cross-section, another alternative embodiment of a distribution element of a distribution system according to the invention, integrating a variable density material,
- Figure 9 represents, in schematic cross-section, an alternative embodiment of a thermal energy storage device according to the invention,
- 30 – Figure 10 represents, in cross-section, an enlarged detail of the configuration allowing fitting between two distribution elements of a distribution system according to the invention, and

– Figure 11 represents, in cross–section and in perspective, an example of an intermediate distribution element of a distribution system according to the invention, integrating a flotation element over part of its length.

In all of these figures, identical references can designate identical or similar elements.

In addition, the different parts represented in the figures are not necessarily represented on a uniform scale in order to make the figures more readable.

DETAILED DISCLOSURE OF PARTICULAR EMBODIMENTS

It should be noted that in all the exemplary embodiments described below with reference to Figures 1 to 11, the distribution system 1 according to the invention has the general shape of a flotation rod 1 provided with a plurality of distribution elements 2a–2e, also called rod elements 2a–2e, in the shape of cylindrical tubes fitted inside one another, without securing together so as to allow overall movement in vertical translation of the rod elements 2a–2e relative to each other. Thus, the flotation rod 1 is retractable.

Furthermore, it should also be noted that, advantageously, the flotation rod 1 according to the invention can allow ensuring both the function of injecting heat transfer fluid into the storage, namely from the exterior to the interior of the storage, but also the function of withdrawing or collecting heat transfer fluid from the storage, namely from the interior to the exterior of the storage.

In terms of injection of heat transfer fluid into the storage, the invention aims at allowing injection of the heat transfer fluid having a given temperature within a target thermal stratum having the same temperature. In addition, in terms of withdrawal of heat transfer fluid from the storage, the invention aims at allowing collection at the desired temperature while maintaining the highest temperature in the storage in order to limit the exergy losses and to subsequently recover this energy at a higher temperature level. Also, the invention proposes, among other things, to allow correct positioning of the flotation rod 1 relative to a previously targeted thermal stratum of the thermal storage tank.

Furthermore, in all the examples described below, it is considered that the heat transfer fluid corresponds to water and that the thermal energy storage corresponds to the thermal energy storage by sensible heat.

It will first be described, with reference to Figure 1, an example of a flotation rod 1 according to the invention and, with reference to Figure 2, an example of a thermal energy storage device 50 according to the invention including such a flotation rod 1.

5 As can be seen in Figure 1, the flotation rod 1 is in a telescopic shape allowing its deployment and retraction depending on the heat transfer fluid to be distributed. It thus includes a set of five rod elements 2a, 2b, 2c, 2d and 2e fitted inside one another and translating vertically relative to each other.

Moreover, as can be seen in Figure 2, the thermal energy storage device
10 50 includes a stratified thermal storage tank 51, comprising an upper inner wall 51a, a lower inner wall 51b, opposite to the upper inner wall 51a, and a side inner wall 51c, the thermal storage tank 51 containing a volume V of heat transfer fluid.

The number of rod elements 2a–2e of the flotation rod 1 can be variable, but should be preferably sufficient to allow the flotation rod 1 to deploy over the
15 entire height of the thermal storage tank 51. In addition, the lengths of the rod elements 2a–2e may be different, but are preferably identical.

The flotation rod 1 more specifically includes a proximal rod element 2a provided with a securing means 4 allowing fixing the proximal rod element 2a to the upper inner wall 51a of the thermal storage tank 51, for example by insertion of
20 screws in a plurality of fixing orifices 4a of the securing means 4, evenly distributed around the periphery of a disc forming the securing means 4.

In addition, the flotation rod 1 includes a distal rod element 2e provided with a heat transfer fluid diffuser element 3. This diffuser element 3 is for example in the shape of a disc pierced around its periphery with a plurality of distribution orifices
25 3a, for injecting and/or withdrawing heat transfer fluid. Thus, these distribution orifices 3a constitute radial diffusion means of the heat transfer fluid, evenly distributed around the periphery of the distal rod element 2e. In this way, when the diffuser element 3 allows radial injection of the heat transfer fluid, it may be possible to reduce the speed of entry of the heat transfer fluid into the thermal storage tank
30 51. If necessary, the diffuser element 3 can be coupled to bent or T-shaped heat transfer fluid inlets. It should also be noted that, in Figure 2, the arrows F symbolize the radial injection of the heat transfer fluid into the thermal storage tank 51 from the element diffuser 3 of the flotation rod 1.

Furthermore, three intermediate rod elements 2b, 2c and 2d are located between the proximal rod element 2a and the distal rod element 2e of the flotation rod 1. These three intermediate rod elements 2b, 2c and 2d are successively fitted inside one another from the proximal rod element 2a to the distal rod element 2e.

5 Figures 3A, 3B and 3C respectively represent, in perspective, the proximal rod element 2a, an intermediate rod element 2b, by way of example, among the three intermediate rod elements 2b, 2c and 2d, and the distal rod element 2e of the flotation rod 1.

Further, the five rod elements 2a–2e of the flotation rod 1 have different
10 diameters. Particularly, as can be seen in Figure 1, the passage section Sa, Sb, Sc, Sd and Se of the heat transfer fluid of each rod element 2a–2e gradually increases from the proximal rod element 2a to the distal rod element 2e of the flotation rod 1. The gradual increase in the passage section of the heat transfer fluid in the flotation rod 1 is therefore obtained via an increasing variation in the
15 diameters of the rod elements 2a–2e, which variation, in addition to facilitating and allowing fitting of the rod elements 2a–2e therebetween, also allows reducing beforehand the speed of the heat transfer fluid before it enters the diffuser element 3 and its diffusion into the thermal storage tank 51.

According to the invention, the displacement of the rod elements 2a–2e
20 relative to each other allows deployment or retraction of the flotation rod 1 according to a predetermined configuration for distributing heat transfer fluid within a target thermal stratum of the thermal storage tank 51 having a temperature substantially equal to the temperature of the heat transfer fluid intended to be distributed.

In order to allow the diffuser element 3 to be properly located in floatation in
25 the target thermal stratum where the heat transfer fluid is at the same temperature as that of the heat transfer fluid to be distributed, that is to say to be injected and/or withdrawn, the solid density ρ_s , also called mass volume density, of the solid part of the flotation rod 1, which comprises the rod elements 2a–2e, is substantially equal to the liquid density ρ_l of the liquid part of the flotation rod 1, which comprises
30 the heat transfer fluid intended to be distributed within the target thermal stratum.

Indeed, the injection of the heat transfer fluid into a target thermal stratum having a temperature substantially equal to the temperature of the injected heat transfer fluid, or the withdrawal of the heat transfer fluid from a target thermal stratum having a predetermined temperature, are made possible by this principle

of flotation of the diffuser element 3, forming the fluid communication interface between the thermal storage tank 51 and the flotation rod 1, at the level of the target thermal stratum. Thus, to allow flotation of the diffuser element 3 at the level of the target thermal stratum, the solid density ρ_s of the flotation rod 1 is chosen to be substantially equal to the liquid density ρ_l of the flotation rod 1. In this way, the flotation rod 1 deploys and/or retracts, depending on the density variation, until allowing the diffuser element 3 to be located at the level of the target thermal stratum.

Figures 4A and 4B also respectively represent, in perspective, the flotation rod 1 of Figure 1 in a configuration where it is fully retracted and in any partially retracted and partially deployed intermediate configuration. It is thus possible to vary the position of the diffuser element 3 of the distal rod element 2e depending on the targeted thermal stratum in the thermal storage tank 51.

In addition, Figure 5 represents in cross-section, the configuration allowing fitting between two rod elements of the flotation rod 1 of Figure 1, namely here the intermediate rod element 2b and the intermediate rod element 2c.

As can be seen in this figure 5, the fitting of the intermediate rod element 2b into the intermediate rod element 2c is achieved by the cooperation between a distal cylindro-conical portion 5b of the intermediate rod element 2b and a proximal frusto-conical portion 6c of the intermediate rod element 2c. Particularly, the proximal frusto-conical portion 6c of the intermediate rod element 2c covers the distal cylindro-conical portion 5b of the intermediate rod element 2b so as to abut against one another when the intermediate rod elements 2b and 2c slide away from each other.

It should also be noted that Figure 3A represents the distal cylindro-conical portion 5a of the proximal rod element 2a, that Figure 3B represents the proximal frusto-conical portion 6b and the distal cylindro-conical portion 5b of the intermediate rod element 2b, and that Figure 3C represents the proximal frusto-conical portion 6e of the distal rod element 2e of the flotation rod 1.

Advantageously, the proximal frusto-conical portions of the rod elements 2a-2e cooperating with the distal cylindro-conical portions of the rod elements 2a-2e can allow preventing dislocation of the rod elements 2a-2e relative to each other, and also preserving the overall cohesion of the flotation rod 1.

In addition, as can be seen in Figure 5, the rod elements 2a–2e are not secured to each other. Particularly, a small clearance exists between two successive rod elements to prevent any friction that could interfere with the displacement of each rod element.

5 Furthermore, each rod element 2a–2e can be preferably made from one or more polymer material(s), in particular selected from: polycarbonate (PC), polyamide (PA), polyoxymethylene (POM), polyphenylether (PPE), polytetrafluoroethene (PTFE), polyetheretherketone (PEEK), polyethersulfone (PES), polysulfone (PSU), polyethyleneimine (PEI), phenylene polysulfide (PPS)
10 and/or polyvinylidene fluoride (PVDF), among others.

In addition, as indicated above and according to the invention, in order to be able to obtain a value of the solid density ρ_s of the solid part of the flotation rod 1 substantially equal to the value of the liquid density ρ_l of the liquid part of the flotation rod 1, various solutions can be provided.

15 First, the rod elements 2a–2e can be made of one or more material(s) with a density ρ_s substantially equal to the density ρ_l of the heat transfer fluid intended to be distributed. In addition, such materials are advantageously provided to withstand high temperatures, in particular ranging up to 100 °C.

Moreover, all or part of the rod elements 2a–2e may also include at least
20 one flotation element 7, in particular an air float 7, configured to give the plurality of rod elements 2a–2e of the flotation rod 1 a density ρ_s substantially equal to the density ρ_l of the heat transfer fluid intended to be distributed.

Thus, Figure 6 represents, in cross–section and in perspective, an alternative embodiment of the intermediate rod element 2b of a flotation rod 1
25 according to the invention, which integrates such an air float 7.

More specifically, the air float 7 is integrated inside the side wall 8 of the intermediate rod element 2b, in particular over the entire length of the intermediate rod element 2b.

The presence of such an air float 7 is in particular required when the
30 material(s) constituting the rod elements 2a–2e has/have a high density, that is to say much greater than the density of the heat transfer fluid intended to be distributed. In addition, the presence of the air float 7 within the side wall 8 of the intermediate rod element 2b allows obtaining a substantially uniform distribution of the air float 7 and also improving the balancing of the intermediate rod element 2b.

There is also represented in Figure 7, in cross-section and in perspective, another alternative embodiment integrating a guide element 12 through a flotation rod 1 according to the invention.

Indeed, in order to allow the flotation rod 1 to remain stable in a vertical position inside the thermal storage tank 51, and also to facilitate the movement of the rod elements 2a–2e relative to each other, the thermal energy storage device 50 may include such a guide element 12, which passes through the interior of the rod elements 2a–2e over the entire length of the flotation rod 1.

This guide element 12 is preferably fixed to the upper inner wall 51a of the thermal storage tank 51 and to the lower inner wall 51b of the thermal storage tank 51. It is particularly in the shape of a guide pin 12, thus extending from one end to the other of the thermal storage tank 51, namely from top to bottom.

It should also be noted that the vertical displacements of the rod elements 2a–2e are very slow because they depend on the speed of increase of the thermal stratum which is very low. Also, the disturbances in the stratification of the thermal storage tank 51 are little affected by the displacement of the flotation rod 1.

Furthermore, in order to obtain a value of the solid density ρ_s of the solid part of the flotation rod 1 substantially equal to the value of the liquid density ρ_l of the liquid part of the flotation rod 1, it is also possible to envisage the integration of a variable density material at the level of the rod elements 2a–2e, whose fluctuations would be close to those of the heat transfer fluid intended to be distributed.

Thus, Figure 8 represents, in cross-section, an alternative embodiment of the intermediate rod element 2b of a flotation rod 1 according to the invention, integrating a variable density material 9.

More specifically, the variable density material 9 is integrated into a flexible envelope allowing its expansion and/or its shrinkage depending on the temperature of the heat transfer fluid intended to be distributed so as to modify the total density of the rod elements 2a–2e.

Particularly, this variable density material 9 is integrated between a rigid outer wall with a low thermal conductivity 10 and a flexible inner wall with a high thermal conductivity 11, the assembly thus forming a side wall of the intermediate rod element 2b.

Indeed, for the flotation rod 1 with the same density as the distributed heat transfer fluid to float continuously at the level of the target thermal stratum, it is desirable that the thermal transfer is instantaneous between the heat transfer fluid and the variable density material 9, which requires having a flexible internal wall with a high thermal conductivity 11, and that the thermal transfer is almost zero between the variable density material 9 and the different thermal strata of the thermal storage tank 51, which requires having a rigid external wall with a low thermal conductivity 10, in other words insulating conductivity.

Figure 9 also represents, in schematic cross-section, an alternative embodiment of a thermal energy storage device 50 according to the invention.

In this Figure 9, the thermal energy storage device 50 includes a stratified thermal storage tank 51 comprising three thermal strata, namely an upper thermal stratum S1, an intermediate thermal stratum S2 and a lower thermal stratum S3, respectively containing heat transfer fluids at temperatures of about 100 °C, 60 °C and 20 °C.

As represented, this thermal energy storage device 50 includes, inside the thermal storage tank 51, a first device 13 for injecting and/or withdrawing heat transfer fluid fixed to the upper inner wall 51a of the thermal storage tank 51 and a second device 14 for injecting and/or withdrawing heat transfer fluid fixed to the lower inner wall 51b of the thermal storage tank 51 to respectively allow injection and/or withdrawal of heat transfer fluid within the upper thermal stratum S1 of the thermal storage tank 51, adjacent to the upper inner wall 51a, and within the lower thermal stratum S3 of the thermal storage tank 51, adjacent to the lower inner wall 51b, the flotation rod 1 then allowing the injection and/or withdrawal of heat transfer fluid within the intermediate thermal stratum S2 of the thermal storage tank 51.

Thus, advantageously, the presence of such first 13 and second 14 injection and/or withdrawal devices inside the thermal storage tank 51 allows increasing the accuracy of the heat transfer fluid distribution.

Indeed, within the thermal storage tank 51, the heat transfer fluids having extreme temperatures 100 °C and 20 °C can be permanently injected and/or withdrawn from the top and the bottom of the thermal storage tank 51, the heat transfer fluid having an intermediate temperature 60 °C can then be injected and/or withdrawn by the flotation rod 1.

In this way, it may be possible to reduce the displacement range of the flotation rod 1 and thus further reduce a possible positioning error.

It should also be noted that instead of a single intermediate thermal stratum S2, there could be a plurality of intermediate thermal strata at the level of which the flotation rod 1 moves, having heat transfer fluid temperatures comprised between about 30 and 80 °C.

In addition, the operation of the flotation rod 1 and of the first 13 and second 14 devices for injecting and/or withdrawing heat-transfer fluid can be controlled in temperature via at least one three-way valve, able to distribute the heat transfer fluid either in the flotation rod 1 or in the first injection and/or withdrawal device 13 or in the second injection and/or withdrawal device 14 depending on the temperature of the heat transfer fluid to be distributed. Thanks to these first 13 and second 14 injection and/or withdrawal devices, simultaneous operations of injecting and withdrawing heat transfer fluid can also be carried out.

Two examples of dimensioning of a flotation rod 1 and of a thermal energy storage device 50 according to the invention will now be described below.

Particularly, these two examples are differentiated by the presence or absence of air floats 7 at the level of each rod element of the flotation rod 1.

However, for each example, it is considered that the thermal energy storage device 50 includes a cylindrical thermal storage tank 51 with a height of about 10 m and a diameter of about 20 m. In addition, the effective storage volume is of about 3,142 m³, the heat transfer fluid distribution rate, by injection/withdrawal, is of about 86.4 m³/h (or 24 kg/s), the flow speed of the heat transfer fluid within the flotation rod 1 is of about 1 m/s and the injection/withdrawal speed of the heat transfer fluid in/from the thermal storage tank 51 is of about 0.1 m/s.

It is further considered, for each example, that the flotation rod 1 includes six rod elements 2a–2f, the distal rod element 2f comprising the diffuser element 3. The six rod elements 2a–2f all have the same length, of about 1.5 m, which allows the diffuser element 3 to reach all the positions located between 1.5 m (fully retracted floatation rod 1) and 9 m depth (fully deployed floatation rod 1), so as to sweep most of the height of the thermal storage tank 51.

The dimensioning principle relates in particular to the determination of the diameters of the rod elements 2a–2f, as well as the length of the air float to be

integrated into the flotation rod 1, in particular at the level of the rod elements 2a–2f.

Example 1: presence of air floats

5 In this first example, it is considered that the six rod elements 2a–2f integrate air floats 7, as described above. The plurality of the air floats 7 forms the overall air float of the flotation rod 1.

The flow rates and speeds of the heat transfer fluid determine the diameters of the six rod elements 2a–2f.

10 In the table below, the flow speeds of the heat transfer fluid and the internal diameters of the six rod elements 2a–2f have been calculated, assuming that the rod element 2a corresponds to the proximal rod element, that the rod element 2f corresponds to the distal rod element and that the rod elements 2b, 2c, 2d, 2e correspond to the intermediate rod elements.

15

	Element 2a	Element 2b	Element 2c	Element 2d	Element 2e	Element 2f
Internal diameter of the element (mm)	176	256	336	416	496	576
Flow speed of the heat transfer fluid (m/s)	1	0.47	0.27	0.18	0.13	0.09

More specifically, the diameter of the first proximal rod element 2a was calculated to meet the constraints in flow rates and speeds. The other diameters of the other rod elements 2b–2f were calculated from the diameter of the first proximal rod element 2a by adding for each rod element a distance corresponding to the sum of the thickness E_c of the rod element and of the additional thickness E_b generated by the cylindro–conical shape at the distal end of the rod element to allow the abutment.

Figure 10 represents, in cross–section, an enlarged detail of the configuration allowing fitting between, for example, the intermediate rod element 2b and the intermediate rod element 2c. In this figure 10, the thickness E_c of the intermediate rod element 2b and the thickness E_b due to the presence of the distal cylindro–conical portion 5b of the intermediate rod element 2b can be viewed.

Thus, each rod element diameter can be determined by the following relation: $D_i = D_{i-1} + 2 \times (E_b + E_c)$.

In the example considered, it is estimated that the thickness E_b is equal to the thickness E_c , equal to about 20 mm.

Furthermore, in order to adjust the density of each rod element 2a–2f to the density of the heat transfer fluid, namely the density of water at a given temperature, several possibilities can be envisaged.

Preferably, the air float 7 is fully integrated into the side wall of a rod element with a fixed thickness, and the length L of the air float 7 is changed to adjust the volume thereof.

Figure 11 thus represents, in cross–section and in perspective, the intermediate rod element 2b, integrating an air float 7 with a length L over part of its total length H .

It is considered, in this example, that the total side wall thickness e_{tot} of the intermediate rod element 2b is of about 20 mm, and that the thickness e_f of the air float 7 is of about 10 mm.

Furthermore, the material selected for making the rod elements 2a–2f is polyvinylidene fluoride (PVDF) with a softening temperature of about 132 °C and a density of about 1,780 kg/m³.

The length of the air float 7 to be integrated can be determined by calculating the balance between the weight of the rod element 2b and the buoyancy, thus obtaining the following relation:

$$L = [H \times e_{tot} \times (\rho_{PVDF} - \rho_{waterX^{\circ}C})] / (e_f \times \rho_{waterX^{\circ}C}),$$

where:

- ρ_{PVDF} represents the density of polyvinylidene fluoride (PVDF), and
- $\rho_{waterX^{\circ}C}$ represents the density of water at X °C, X being a number.

In this way, the table below is obtained, giving the length L of the air float 7 integrated in a rod element with a total length H, when heat transfer fluid (water) temperatures are considered at 40 °C, 60 °C and 80 °C.

H	L at 40 °C	L at 60 °C	L at 80 °C
1.5 m	1.191 m	1.216 m	1.247 m

Furthermore, the diffuser element 3 may for its part be in the shape of a disc with a diameter of about 800 mm, and be pierced with 8 holes of about 200 mm in diameter, spaced by about 300 mm allowing water injection/withdrawal at a speed of about 0.1 m/s.

Example 2: absence of air floats

In this second example, it is considered that the six rod elements 2a–2f are devoid of air floats 7, as described above.

In this case, the densities of the rod elements 2a–2f must be specifically determined to allow desired flotation of the diffuser element 3 at the level of a target thermal stratum.

The table below gives the densities of the rod elements 2a–2f, and the total gives the density of the flotation rod 1, when it is composed of:

- a solid part comprising the rod elements 2a–2f of the flotation rod 1 made of a material with a density close to that of water, in particular Rilsan® from the

company Arkema with a density equal to 1,030 kg/m³; in addition, the wall thickness e_{tot} of the rod elements 2a–2f is considered equal to about 2 mm ;

- a liquid part comprising the water contained in the flotation rod 1; it is particularly considered that the water is injected at 60 °C and has a density of about 5 983.2 kg/m³.

In other words, the calculation parameters are such as: $\rho_s = 1,030 \text{ kg/m}^3$, $\rho_l = 983.2 \text{ kg/m}^3$ and also $H = 1.5 \text{ m}$.

rod element	internal diameter(m)	external diameter (m)	internal surface (m ²)	external surface (m ²)	solid volume (m ³)	liquid volume (m ³)	solid density (kg/m ³)
2a	0.176	0.18	0.0243	0.0254	0.0017	0.0365	985.3
2b	0.256	0.26	0.0515	0.0531	0.0024	0.0772	984.6
2c	0.336	0.34	0.0887	0.0908	0.0032	0.1330	984.3
2d	0.416	0.42	0.1359	0.1385	0.0039	0.2039	984.1
2e	0.496	0.5	0.1932	0.1964	0.0047	0.2898	983.9
2f	0.576	0.58	0.2606	0.2642	0.0054	0.3909	983.8
Total					0.0214	1.1313	984.1

- 10 The results show that, under these conditions, the density of the flotation rod 1, equal to 984.1 kg/m³, is very close to the density of the injected water, equal to 983.2 kg/m³.

Actually, the density deviation, equal to 0.9 kg/m³, corresponds to a temperature deviation of 1.5 °C, which therefore remains a small error.

- 15 However, this previous calculation is carried out by considering a flotation rod 1 completely unfolded for a configuration where the target thermal stratum, having a temperature equal to 60 °C and a density equal to 983.2 kg/m³, is located at the bottom of the thermal storage tank 51.

- 20 However, the flotation rod 1 must be able to distribute water in the target thermal stratum whatever its position in the thermal storage tank 51.

However, when the flotation rod 1 is folded, then it contains less heat transfer fluid, that is to say, less liquid. The influence of the solid part on the density of the assembly therefore becomes more significant.

For example, in the extreme case where the flotation rod 1 is fully folded, then the flowing part of the flotation rod 1 is reduced to the proximal rod element 2a. However, the solid volume is that of the flotation rod 1 in its entirety and therefore corresponds to the sum of the solid volumes of each rod element 2a–2f.

5 Based on this example, the table below allows obtaining the density of the flotation rod 1.

rod element	internal diameter (m)	internal surface (m ²)	solid volume (m ³)	liquid volume (m ³)	solid density (kg/m ³)
2a	0.176	0.0243	0.0214	0.0365	1000.5

10 Also, it is important to note that the density of the flotation rod 1 depends on the amount of water to be distributed contained therein, and consequently on its state of deployment.

The table below highlights the differences between the density of the liquid to be distributed and the density of the flotation rod 1 when the latter is fully unfolded and fully retracted. Five different solid densities ρ_s and four different liquid densities

15 ρ_l are also used as parameters.

solid density ρ_s (kg/m ³)	liquid density ρ_l (kg/m ³)	Unfolded floatation rod		Retracted floatation rod	
		Unfolded rod density ρ_{sd} (kg/m ³)	difference $\rho_{sd} - \rho_l$ (kg/m ³)	Retracted rod density (kg/m ³)	Difference $\rho_{sd} - \rho_l$ (kg/m ³)
1030	983.2	984.1	0.9	1000.5	17.3
1030	977.9	978.9	1	997.1	19.2
1030	972	973.1	1.1	993.4	21.4
1030	965	966.2	1.2	989	24
983.2	983.2	983.2	0	983.2	0
983.2	977.9	978	0.1	979.9	2
983.2	972	972.2	0.2	976.1	4.1
983.2	965	965.3	0.3	971.7	6.7

977.9	983.1	983.1	-0.1	981.2	-2
977.9	977.9	977.9	0	977.9	0
977.9	972.1	972.1	0.1	974.2	2.2
977.9	965.2	965.2	0.2	969.8	4.8
972	983	983	-0.2	979.1	-4.1
972	977.8	977.8	-0.1	975.7	-2.2
972	972	972	0	972	0
972	965.1	965.1	0.1	967.6	2.6
965	982.9	982.9	-0.3	976.5	-6.7
965	977.7	977.7	-0.2	973.1	-4.8
965	971.9	971.9	-0.1	969.4	2.6
965	965	965	0	965	0

Thus, the density deviations between the liquid and the flotation rod 1 are negligible in the unfolded position while they are greater in the retracted position. These deviations are moreover negative for the low solid densities and positive for the high solid densities. This feature can thus offer a wide possibility of optimizing the operation of the flotation rod 1.

Thus, the choice of the density of the solid part of the flotation rod 1 is strategic for adjusting the operation of the flotation rod 1 whatever its state of deployment. The optimization of this adjustment can in particular be done by experimentation.

Of course, the invention is not limited to the exemplary embodiments that have just been described. Various modifications can be made by those skilled in the art.

Patentkrav

- 5 1. System til fordeling (1) af varmeoverføringsfluid til en indretning til lagring af termisk energi (50), der omfatter en lagdelt, termisk lagringstank (51) til varmeoverføringsfluid, til indsprøjtning og/eller aftapning af varmeoverføringsfluid i en termisk lagringstank (51),
- 10 hvor fordelingsystemet (1) er i en teleskopisk form, som omfatter en flerhed af fordelingselementer (2a-2e), der er indpasset i hinanden og glider i forhold til hinanden for at muliggøre udrulning og/eller tilbagetrækning af fordelingsystemet (1) ifølge en forudbestemt konfiguration til fordeling af varmeoverføringsfluid inden i et termisk lag af den termiske lagringstank (51) med en temperatur, der i det væsentlige er lig med temperaturen af det varmeoverføringsfluid, der er beregnet til at fordeles, hvor mindst én (2e) af fordelingselementerne (2a-2e) omfatter et diffusorelement (3) af varmeoverføringsfluid,
- 15 hvor faststofmassefylden (ρ_s) af faststoffdelen af fordelingsystemet (1), der omfatter flerheden af fordelingselementer (2a-2e), i det væsentlige er lig med fluidmassefylden (ρ_l) af fluiddelen af fordelingsystemet (1), der omfatter den varmeoverføringsfluid, der er beregnet til at fordeles inden for det termiske mållag, ved injektion og/eller aftapning, for at gøre det muligt for diffusorelementet (3) at flyde på niveau med et termiske mållag,
- 20 alle eller enkelte fordelingselementer (2a-2e) omfatter mindst ét flydeelement (7), der er konfigureret til at give flerheden af fordelingselementer (2a-2e) i fordelingsystemet (1) en massefylde (ρ_s), der i det væsentlige er lig med massefylden (ρ_l) af den varmeoverføringsfluid, der er beregnet til at fordeles,
- 25 og hvor det mindst ét flydeelement (7) er integreret indvendigt i en sidevæg (8) af mindst ét fordelingselement (2a-2e).
- 30 2. System ifølge krav 1, **kendetegnet ved, at** flerheden af fordelingselementer (2a-2e) er fremstillet af et eller flere materialer med en massefylde (ρ_s), der i det væsentlige er lig med massefylden (ρ_l) af den varmeoverføringsfluid, der

er beregnet til at fordeles.

3. System ifølge krav 1 eller 2, **kendetegnet ved, at** det mindst ét flydeelement (7) er en luftflyder (7).

5

4. System ifølge et hvilket som helst af de foregående krav, **kendetegnet ved, at** alle eller enkelte fordelingselementer (2a-2e) omfatter mindst ét materiale med variabel massefylde (9), der er integreret i et fleksibelt hylster, der gør det muligt at udvides og/eller sammentrækkes afhængigt af temperaturen på det varmeoverføringsfluid, der er beregnet til at fordeles, for at ændre den samlede massefylde af fordelingselementerne (2a-2e).

10

5. System ifølge et hvilket som helst af de foregående krav, **kendetegnet ved, at** det omfatter et proksimalt fordelingselement (2a), der er forsynet med et middel (4) til fastgørelse til indretningen til lagring af termisk energi (50), et distalt fordelingselement (2e), der er forsynet med et varmeoverføringsfluid-diffusorelement (3) og et eller flere mellemliggende fordelingselementer (2b, 2c, 2d), hvor fordelingselementerne (2a-2e) successivt indpasses i hinanden fra det proksimale fordelingselement (2a) til det distale fordelingselement (2e), hvor passagesektionen (Sa-Se) til varmeoverføringsfluid af fordelingselementerne (2a-2e) især gradvist forøges fra det proksimale fordelingselement (2a) til det distale fordelingselement (2e) af fordelingsystemet (1), hvor diffusorelementet (3) af det distale fordelingselement (2e) især omfatter radiale diffusionsmidler (3a) af varmeoverføringsfluidet.

15

20

25

6. System ifølge et hvilket som helst af de foregående krav, **kendetegnet ved, at** fordelingselementerne (2a-2e) har form af cylindriske rør med forskellige diametre.

5 **7.** System ifølge et hvilket som helst af de foregående krav, **kendetegnet ved, at** indpasningen af et første fordelingselement (2b) i et andet fordelingselement (2c) opnås ved samvirke mellem en distal del med cylindrisk keglestubform (5b) af det første fordelingselement (2b) og en proksimal del med keglestubform (6c) af det andet fordelingselement (2c), hvor den proksimale del med keglestubform (6c) af det andet fordelingselement (2c) dækker den distale del med cylindrisk keglestubform (5b) af det første fordelingselement (2b) for at komme i indbyrdes anlæg, når det første (2b) og andet (2c) fordelingselement glider væk fra hinanden.

10

8. System ifølge et hvilket som helst af de foregående krav, **kendetegnet ved, at** fordelingselementerne (2a-2e) ikke er fastgjort til hinanden.

15

9. System ifølge et hvilket som helst af de foregående krav, **kendetegnet ved, at** fordelingselementerne (2a-2e) er fremstillet af et eller flere polymermaterialer, især valgt blandt: polycarbonat (PC), polyamid (PA), polyoxymethylen (POM), polyphenylether (PPE), polytetrafluorethen (PTFE), polyetheretherketon (PEEK), polyethersulfon (PES), polysulfon (PSU), polyethylenimin (PEI), phenylenpolysulfid (PPS) og/eller polyvinylidenfluorid (PVDF).

20

10. Indretning til lagring af termisk energi (50), især en indretning til lagring af termisk energi med mærkbar varme, **kendetegnet ved, at** den omfatter:

- en lagdelt, termisk lagringsbeholder (51), som omfatter en varmeoverføringsfluid til lagring af termisk energi, og

25

- et system (1) til fordeling af varmeoverføringsfluid ifølge et hvilket som helst af de foregående krav, der strækker sig inde i den termiske lagringstank (51) til indsprøjtning og/eller aftapning af varmeoverføringsfluid.

30

11. Indretning ifølge krav 10, **kendetegnet ved, at** fordelingssystemet (1) er fastgjort ved den ene af sine ender til en indvendig væg (51a) af den termiske

lagringsbeholder (51), især den øvre indvendige væg (51a), hvor den anden af enderne især omfatter diffusorelementet (3) af varmeoverføringsfluid.

5 **12.** Indretning ifølge krav 10 eller 11, **kendetegnet ved, at** den desuden omfatter et styreelement (12), der passerer gennem det indre af fordelingselementerne (2a-2e) i fordelingsystemet (1) over hele længden deraf og især er fastgjort til den øvre indvendige væg (51a) af det termiske lagringstank (51) og til den nedre indvendige væg (51b) af den termiske lagringstank (51).

10 **13.** Fremgangsmåde til fordeling af en varmeoverføringsfluid i en indretning til lagring af termisk energi (50) ifølge et hvilket som helst af kravene 10 til 12 til injektion og / eller aftapning af varmeoverføringsfluiden i den termiske lagringstank (51), **kendetegnet ved, at** den udføres ved hjælp af et distributionssystem (1) ifølge et hvilket som helst af kravene 1 til 10, og **ved, at** den omfatter
15 et trin med indsprøjtning af en varmeoverføringsfluid i et termisk lag i den termiske lagringstank med den samme temperatur som varmeoverføringsfluiden via fordelingsystemet (1), især via varmeoverføringsfluid-diffusorelementet (3), og/eller et trin med at trække en varmeoverføringsfluid med en forudbestemt temperatur ud af et termisk lag i den termiske lagringstank med den
20 samme temperatur som varmeoverføringsfluiden via fordelingsystemet (1), især via varmeoverføringsfluid-diffusorelementet (3).

14. Fremgangsmåde ifølge krav 13, **kendetegnet ved, at** den omfatter et trin med at bestemme faststofmassefylden (ρ_s) af faststoffdelen af fordelingsystemet (1), der omfatter flerheden af fordelingselementer (2a-2e), således at de i
25 det væsentlige er lig med fluidmassefylden (ρ_l) af fluiddelen af fordelingsystemet (1), som omfatter den varmeoverføringsfluid, der er beregnet til at fordeles, ved injektion og/eller tilbagetrækning.

1 / 5

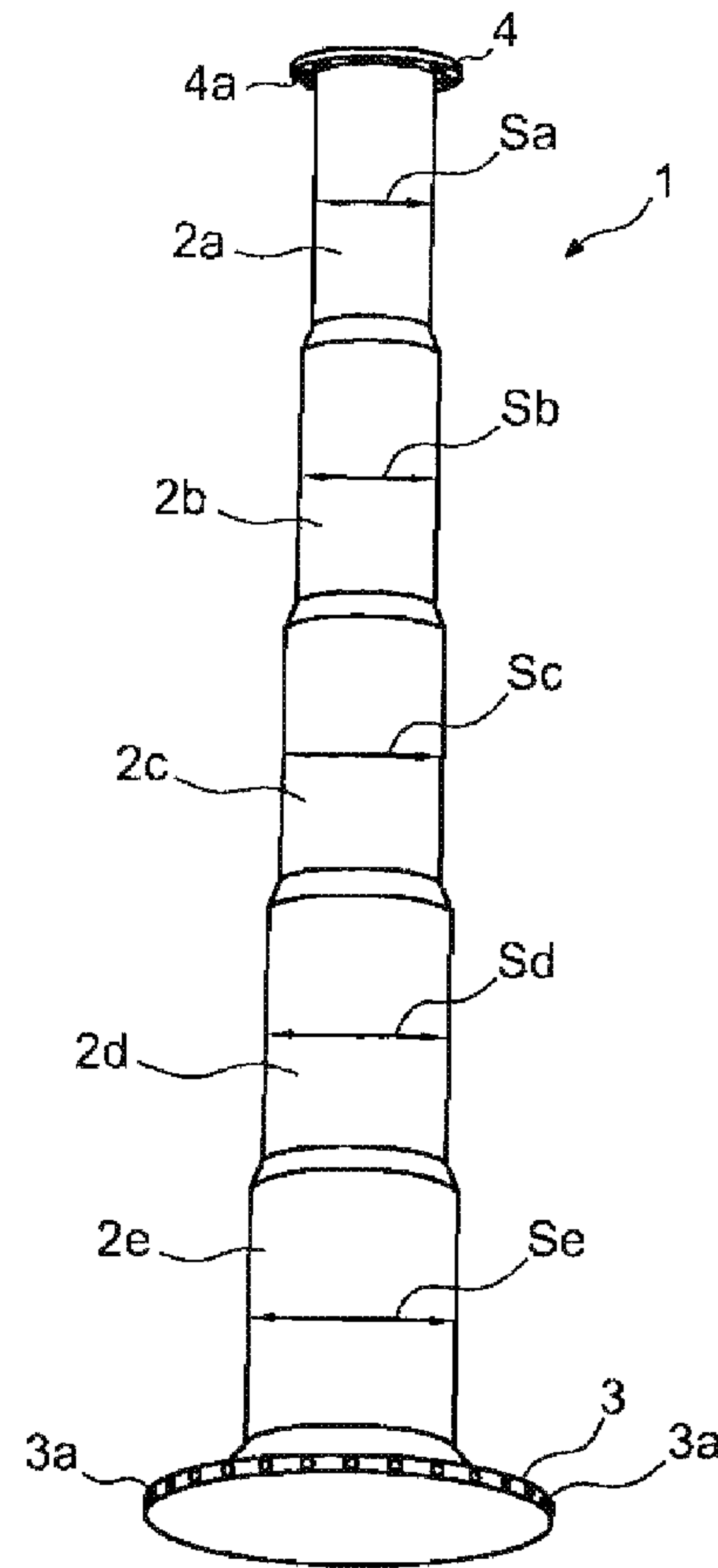


FIG. 1

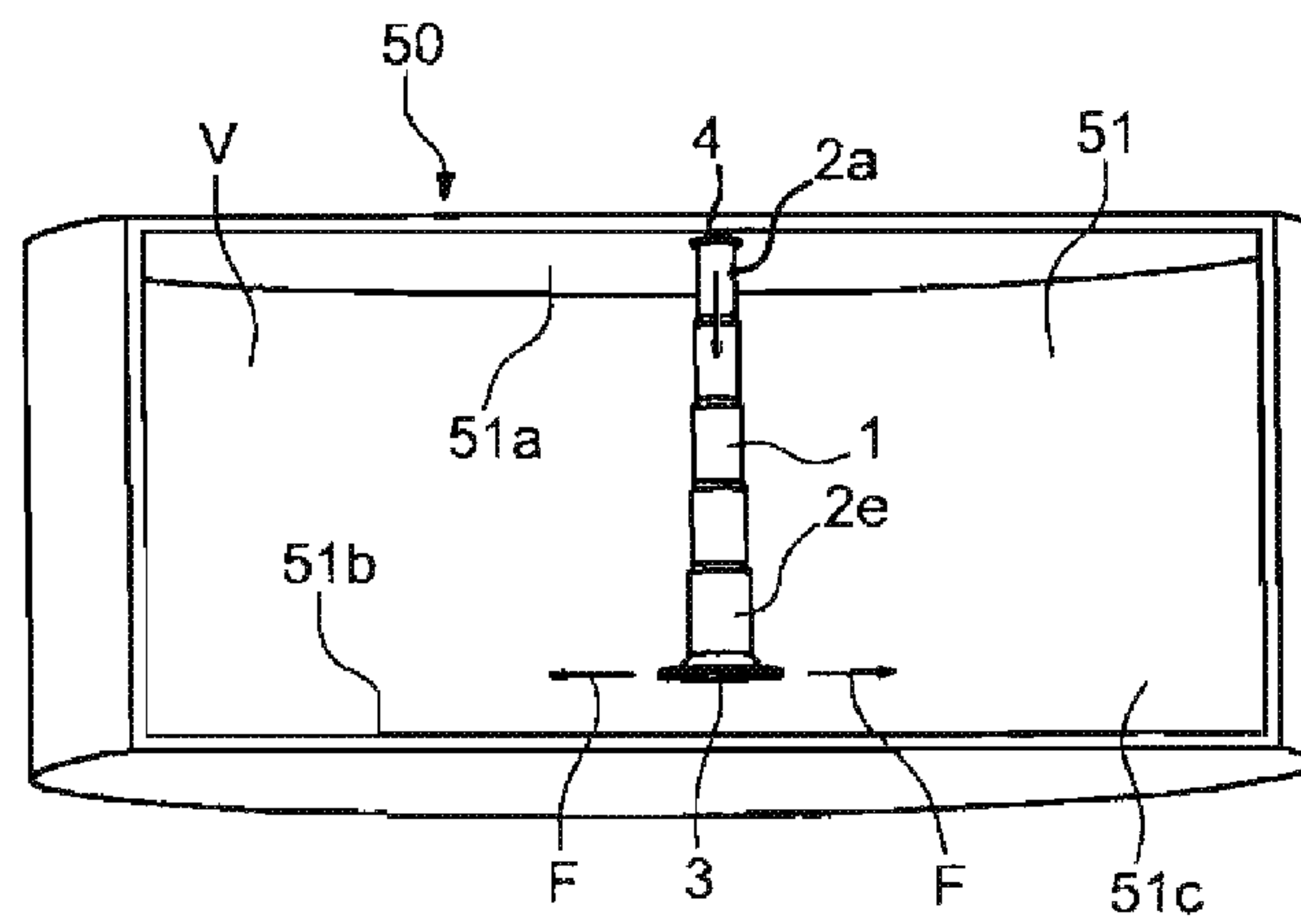


FIG. 2

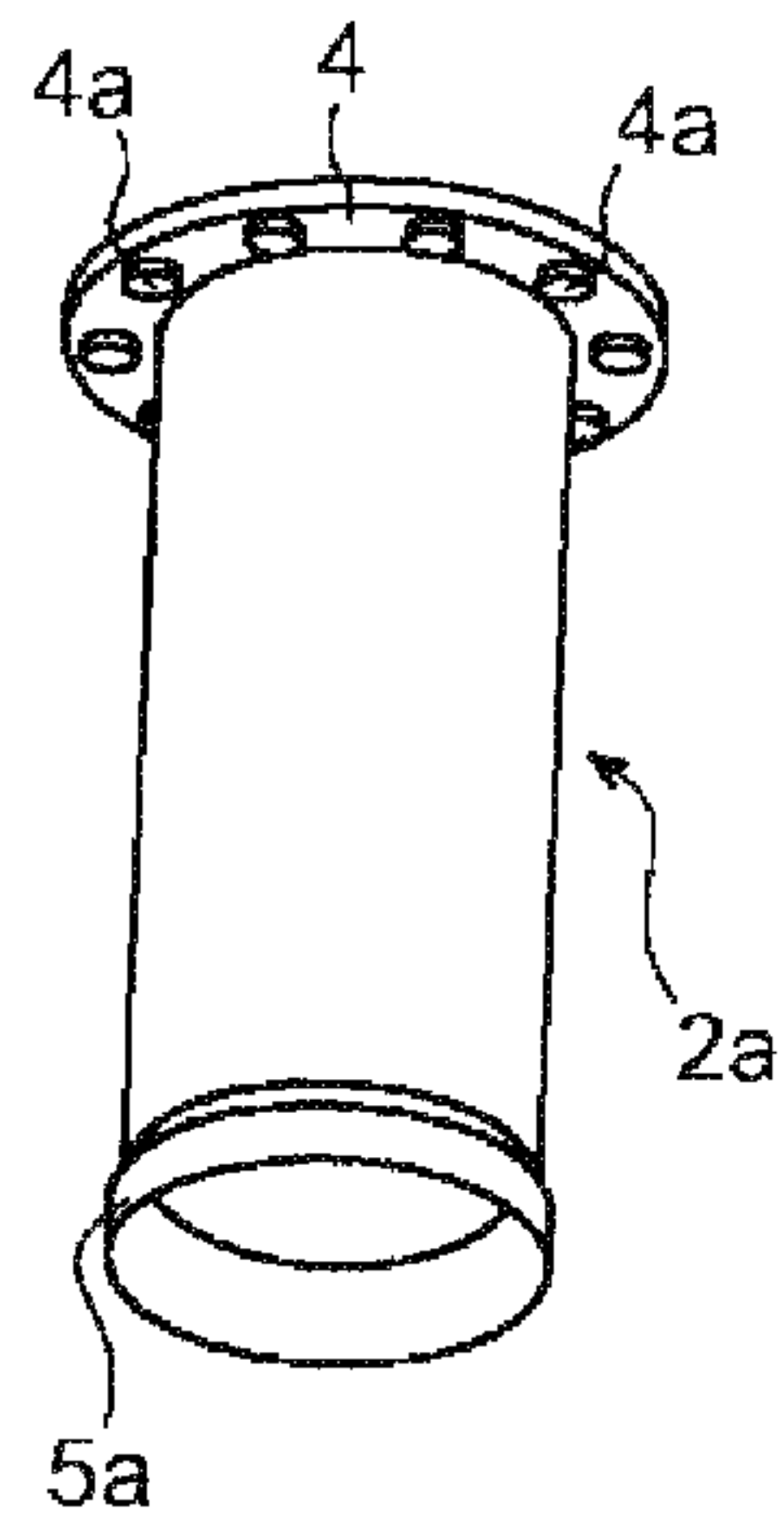


FIG. 3A

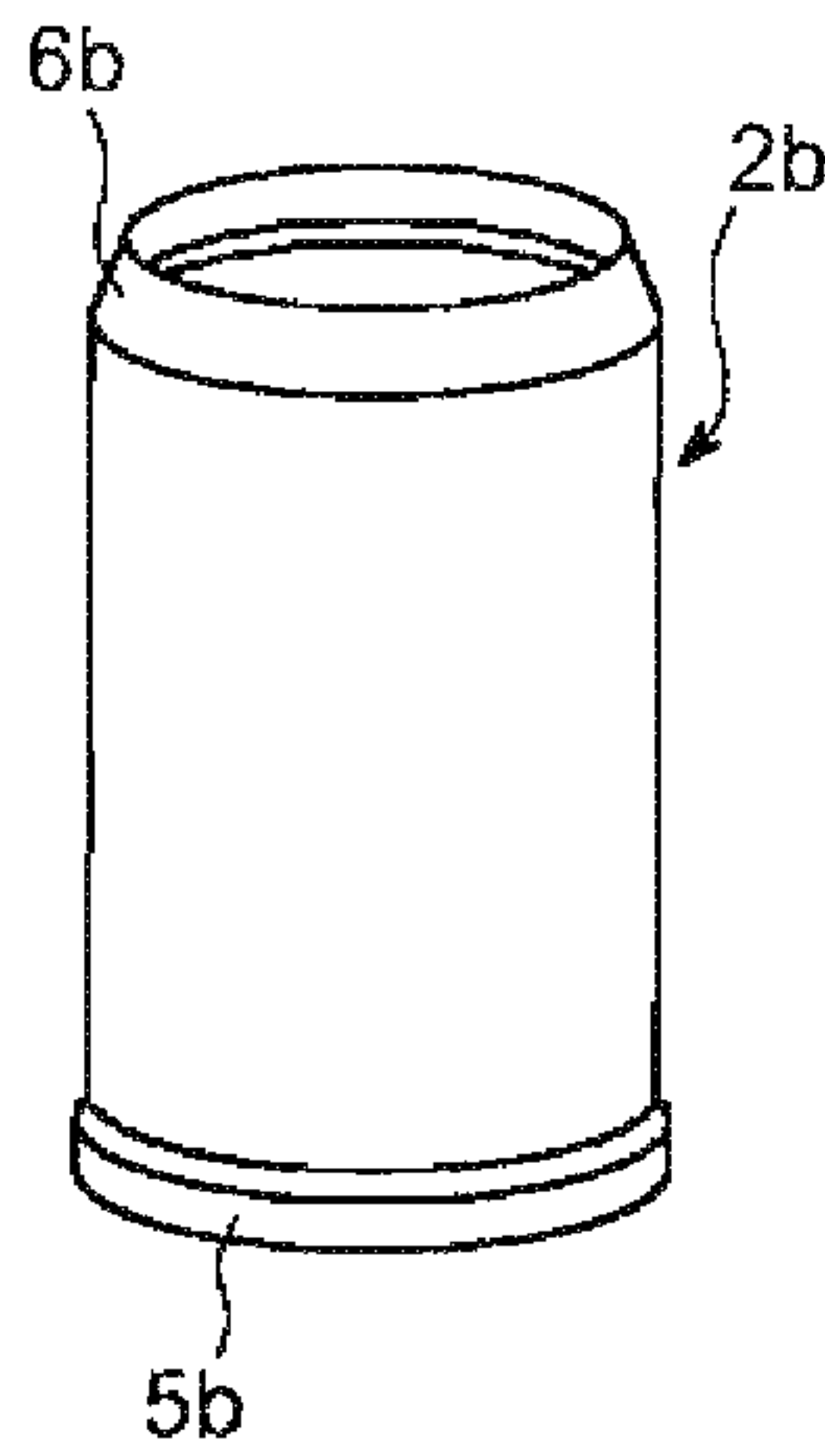


FIG. 3B

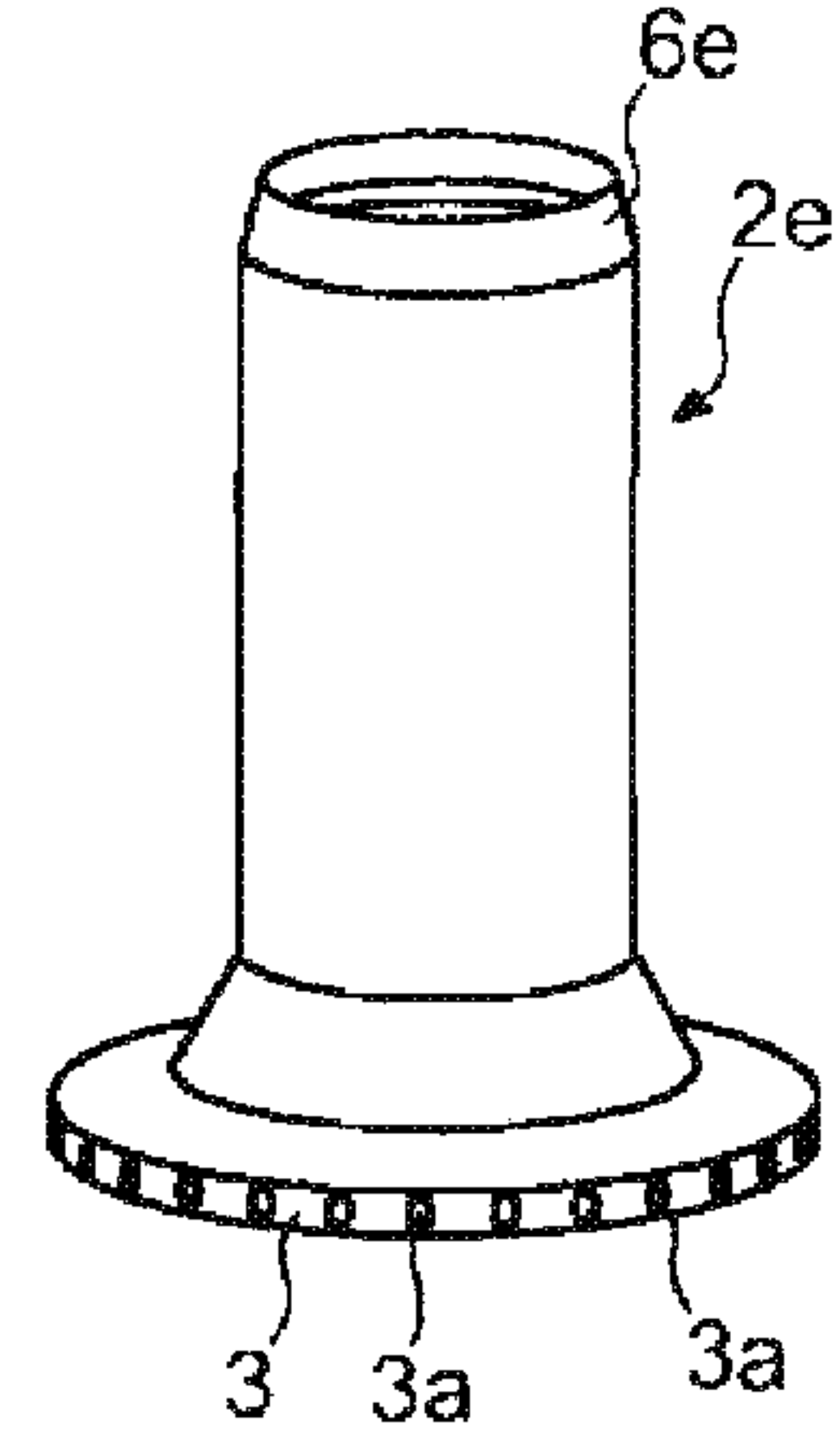


FIG. 3C

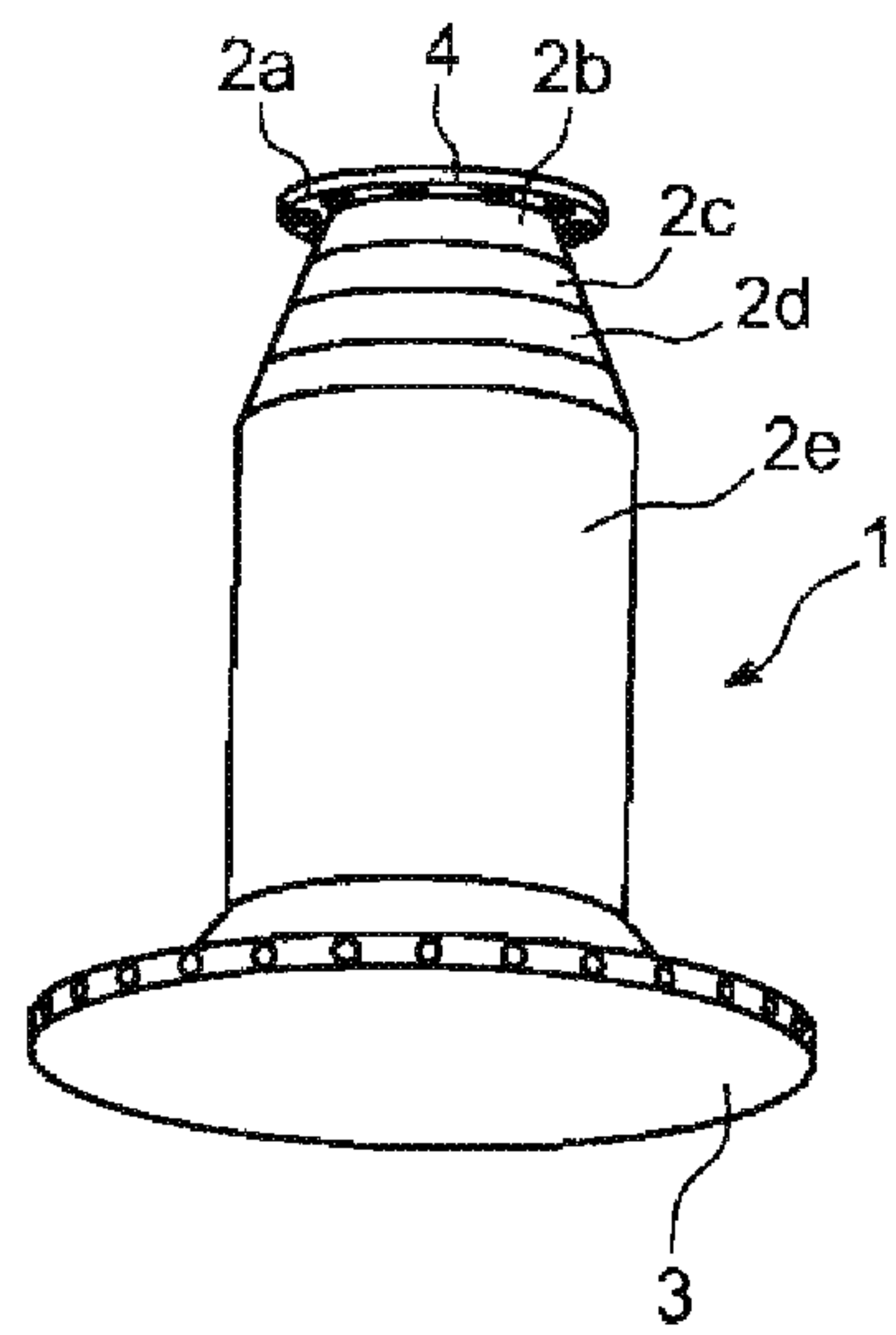


FIG. 4A

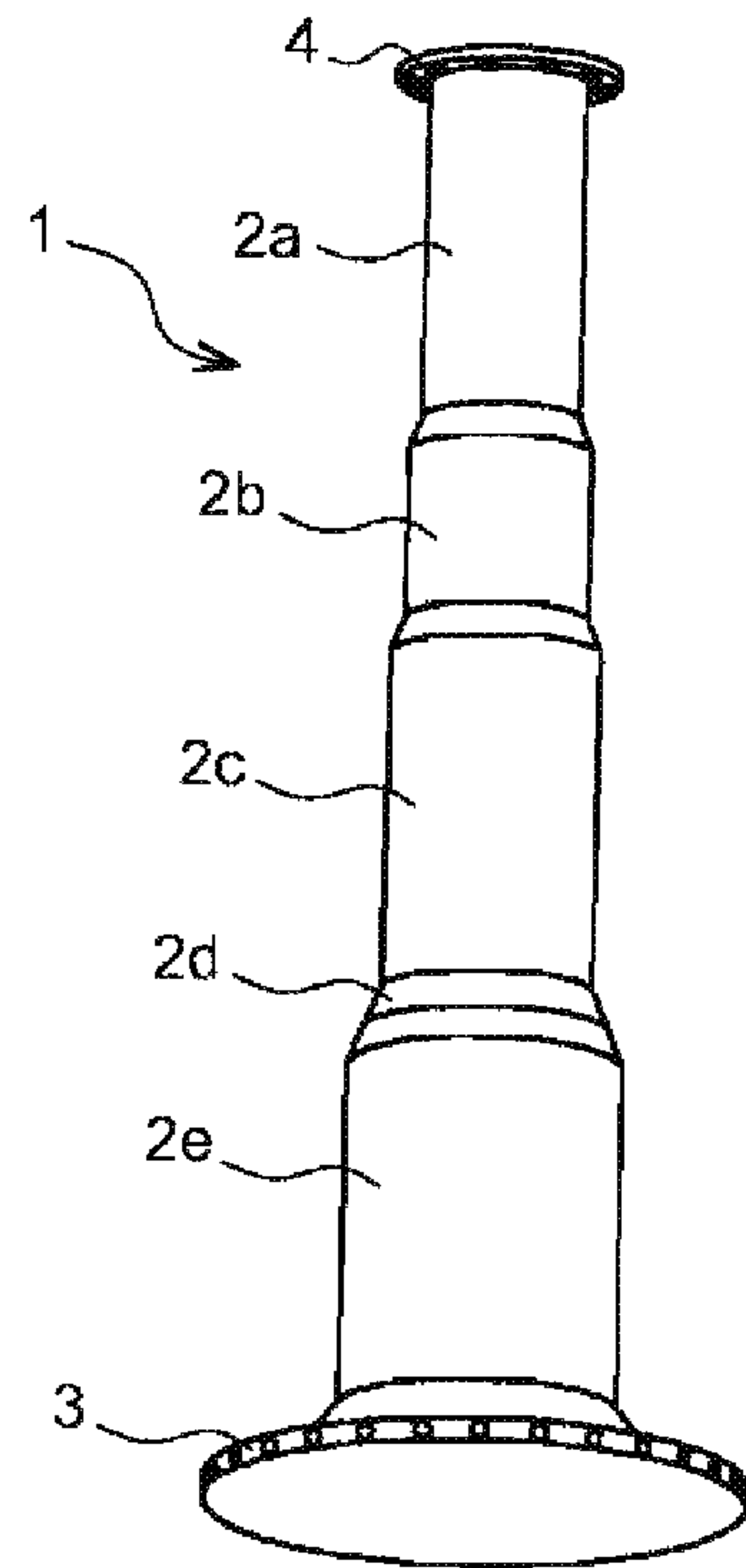


FIG. 4B

3 / 5

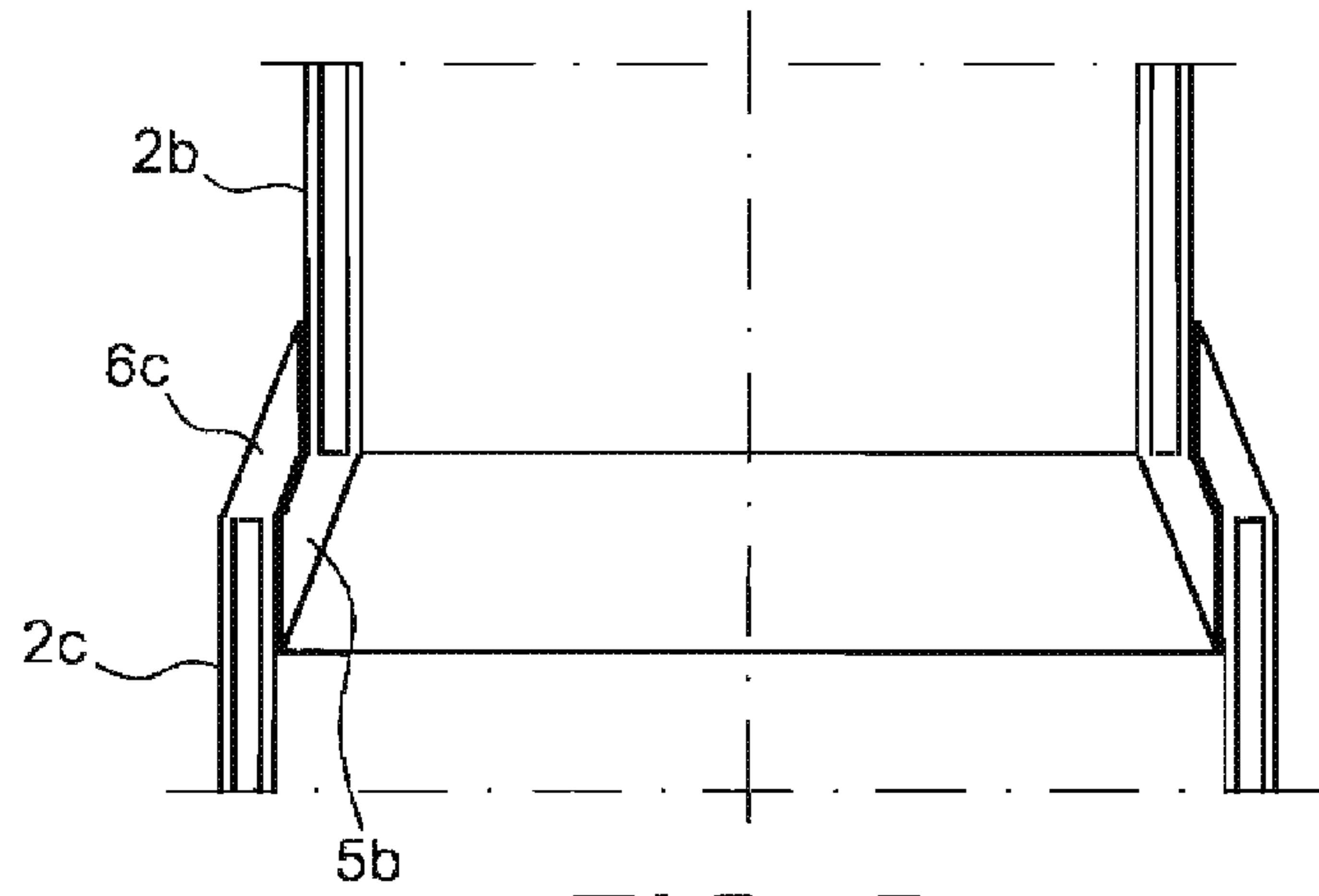


FIG. 5

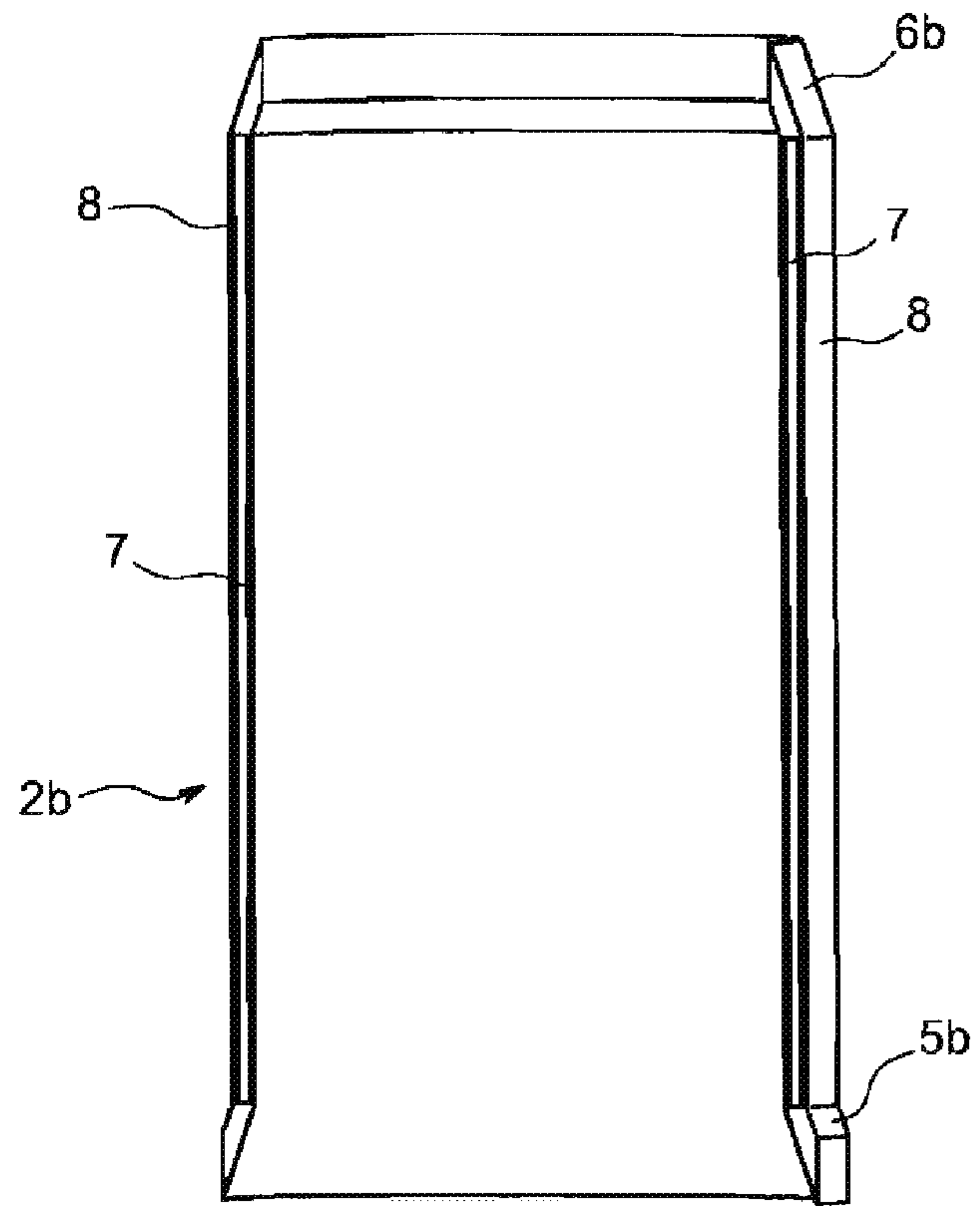


FIG. 6

4 / 5

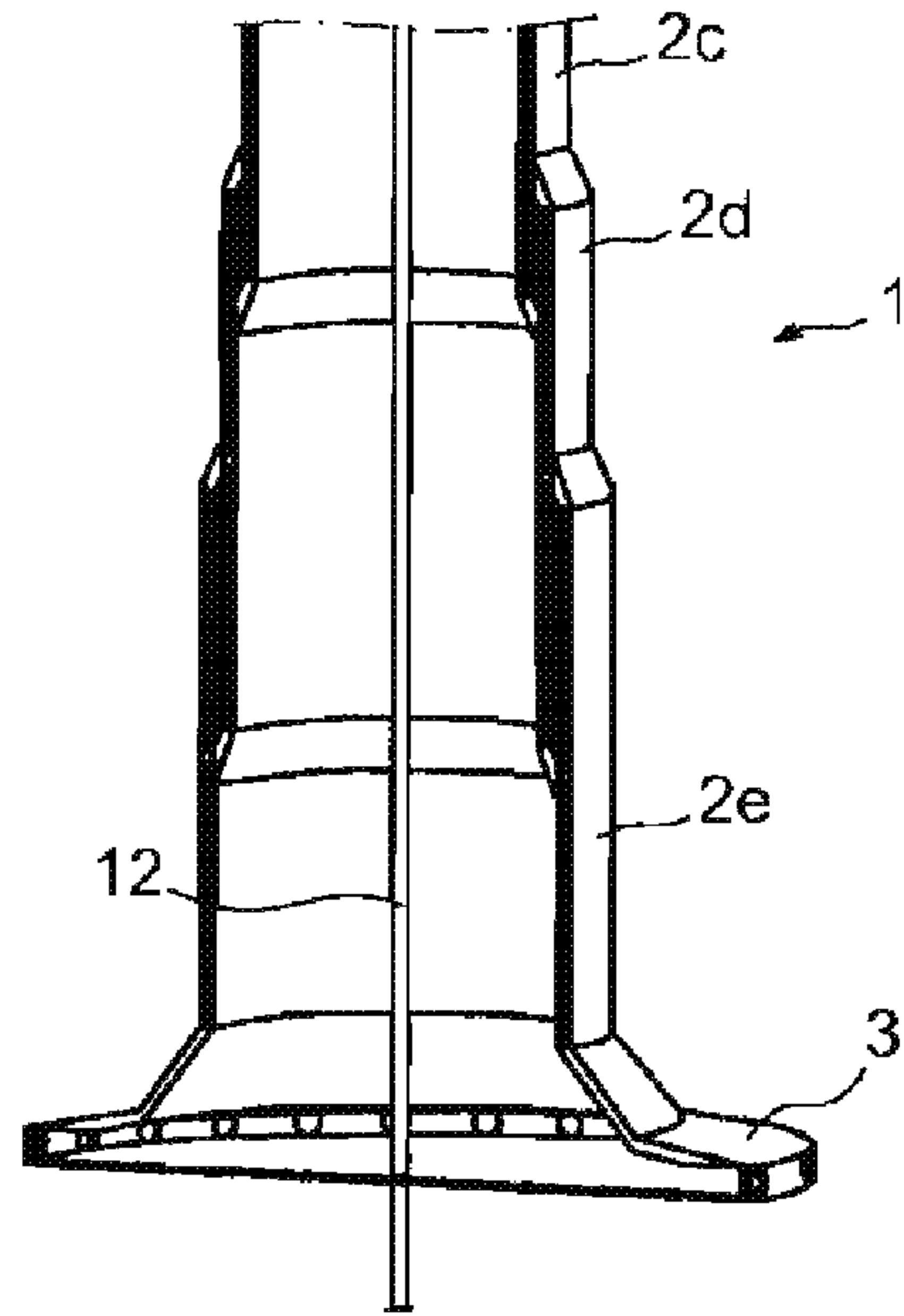


FIG. 7

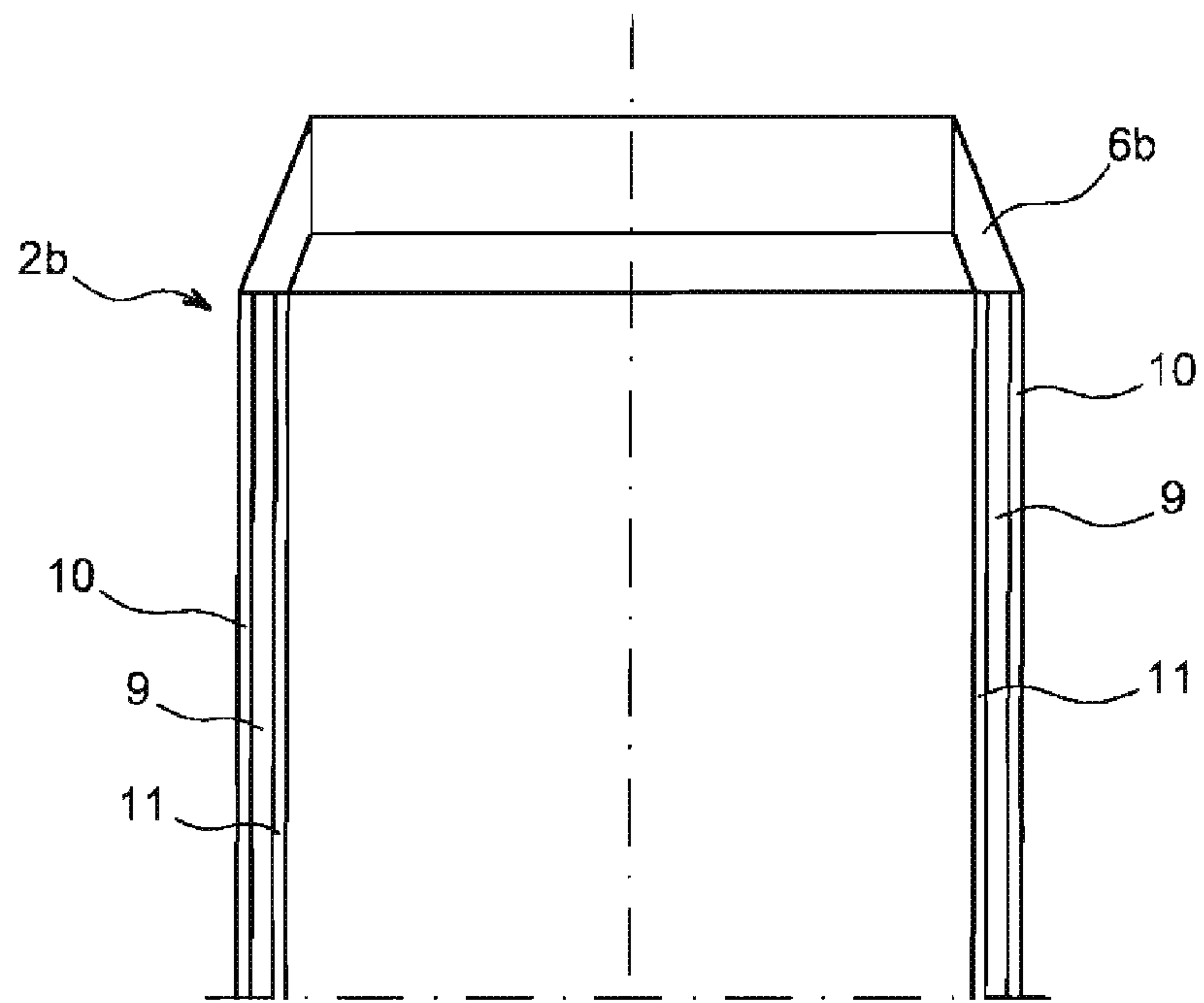


FIG. 8

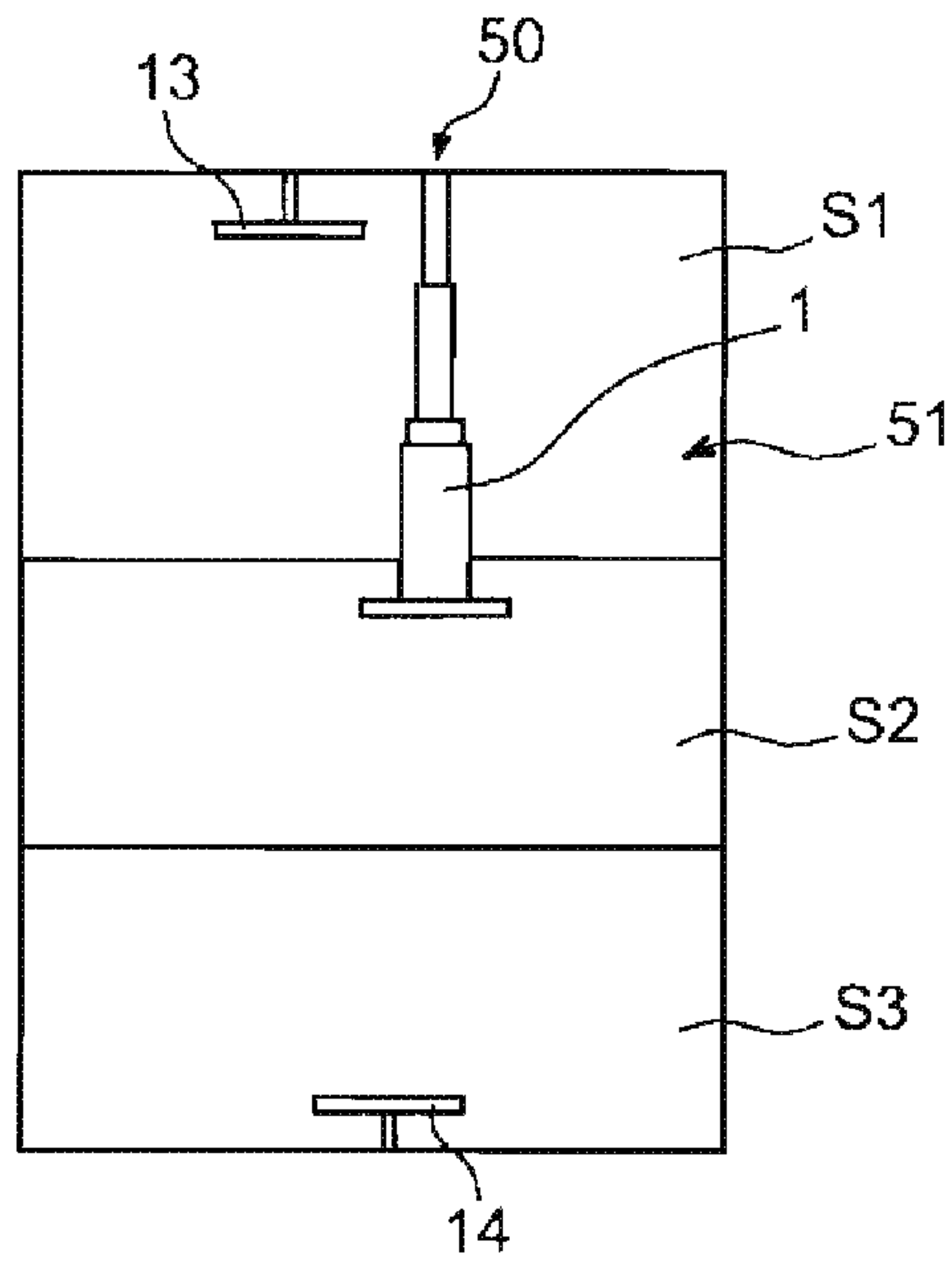


FIG. 9

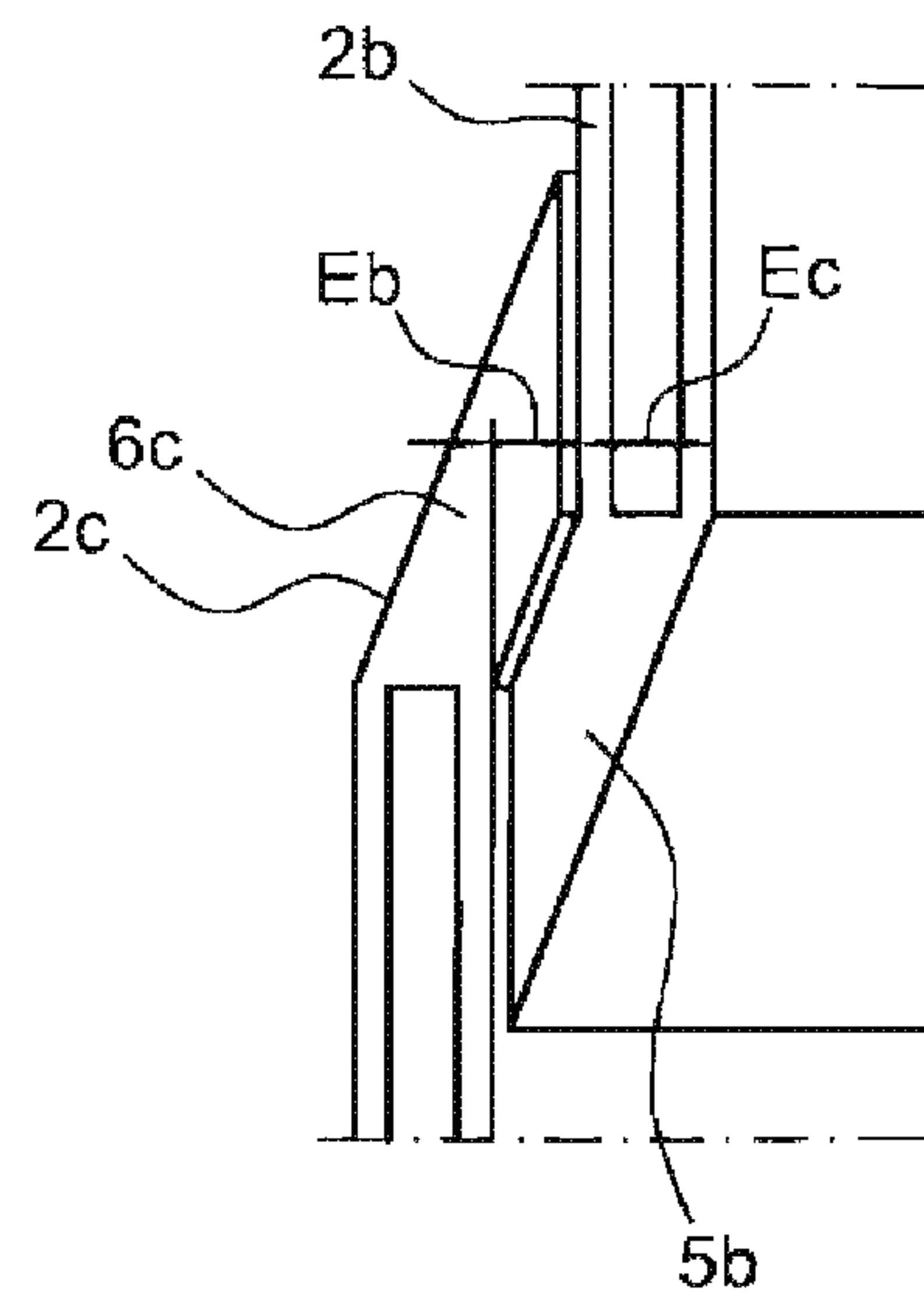


FIG. 10

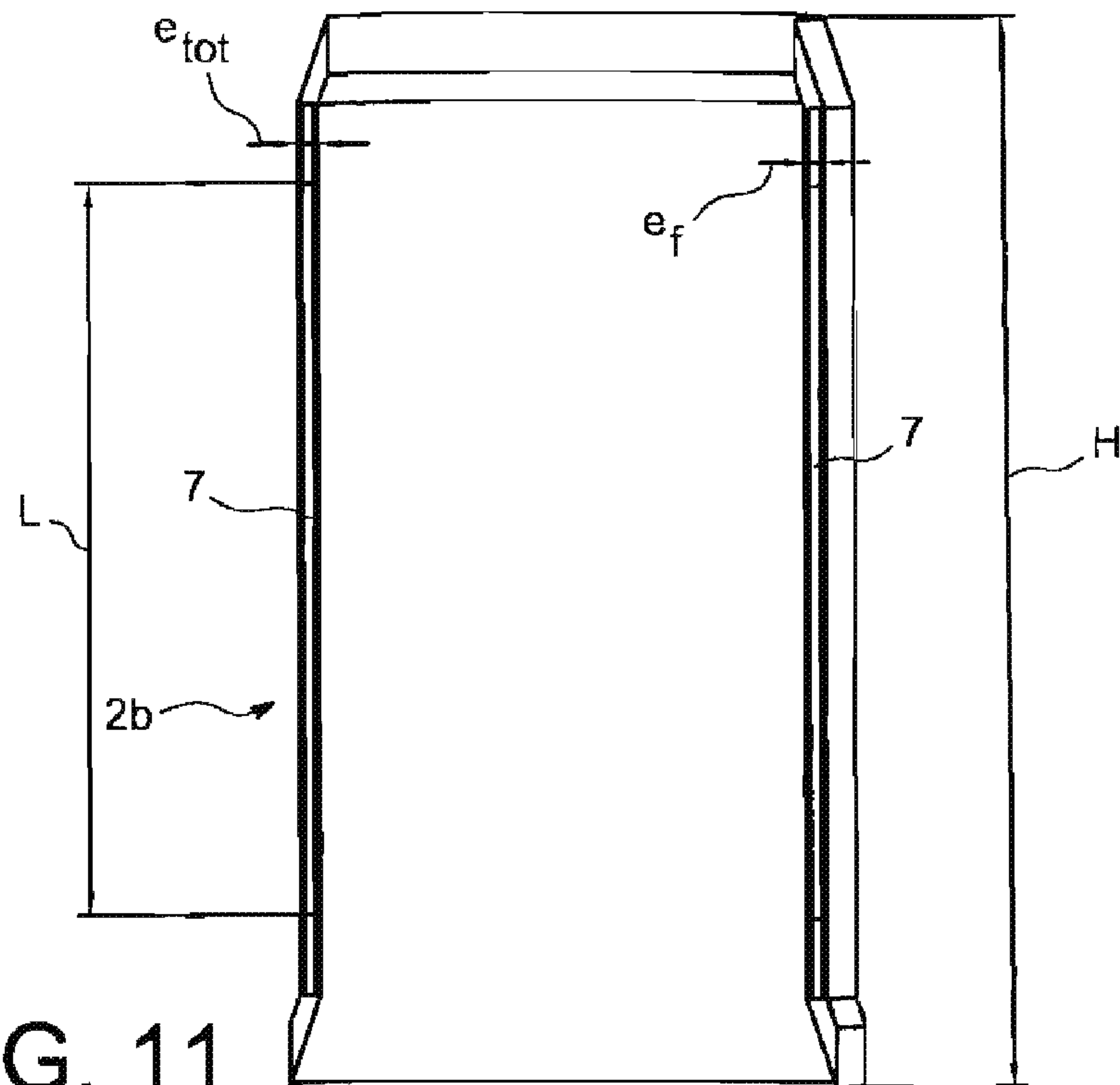


FIG. 11