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(54) **Title**: RECIRCULATING-FLOW WIND TUNNEL, IN PARTICULAR FOR FREE-FALLING OR PARACHUTING SIMULATIONS

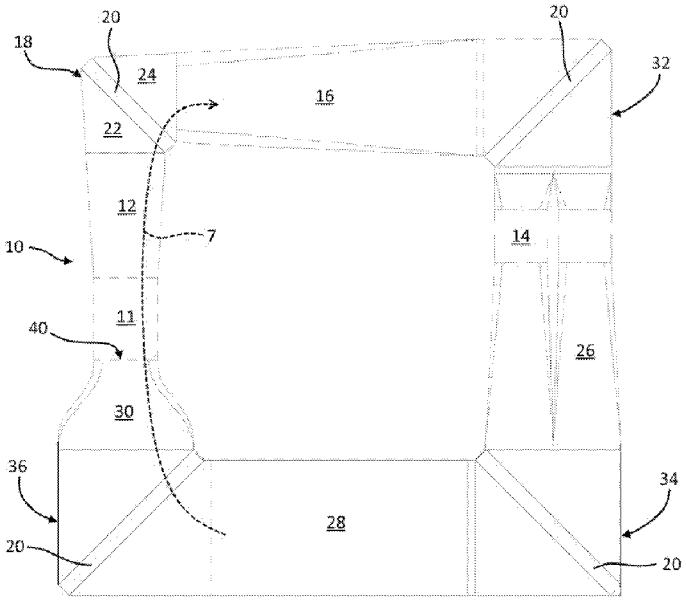

Fig. 1

(57) **Abstract**: A recirculating-flow wind tunnel, in particular for free-falling or parachuting simulations, comprising: a substantially vertical duct including a substantially vertical flight chamber (10), for housing a person who will fluctuate when hit by an air flow; a recirculation apparatus (16, 26, 28, 18, 32, 34, 36) in fluidic communication with the flight chamber (10), defining a substantially closed path for the air flow; and a blower device (14) for producing the air flow that will circulate between the flight chamber (10) and the recirculation apparatus (16, 26, 28, 18, 32, 34, 36). The substantially vertical duct includes: a cylindrical portion (11) having a circular cross-section; and a truncated cone portion (12), connected at the top to the cylindrical portion (11), having the shape of an upward-diverging truncated cone.

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TITLE: "Recirculating-flow wind tunnel, in particular for free-falling or parachuting simulations"

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DESCRIPTION

Technical field

The present invention relates to a recirculating-flow wind tunnel, in particular for free-falling or parachuting simulations.

Background art

Wind tunnels are known in the art, in particular wind tunnels for free-falling or parachuting simulations. Wind tunnels, which generally have a closed-circuit design, suffer from a few drawbacks.

One drawback is that they have a bulky and complex structure.

Another drawback is that they have a structure that can generate a tortuous, or anyway energy-consuming, air flow.

Summary of the invention

It is one object of the present invention to provide a wind tunnel of the closed-circuit or recirculating-flow type, which can overcome these and other drawbacks of the prior art, while at the same time being simple and economical to manufacture.

In particular, one of the technical problems that are solved by the present invention is how to create a wind tunnel having a simple structure and a flight chamber with an advantageous conformation.

Another object of the invention is to create an energetically efficient wind tunnel.

It is a further object of the invention to create a wind tunnel that can generate an innovative air flow.

According to the present invention, this and other objects are achieved through a wind tunnel having the features set out in the appended independent claim.

It is to be understood that the appended claims are an integral part of the technical teachings provided in the following detailed description of the invention. In particular, the appended dependent claims define some preferred embodiments of the present invention, which include some optional technical features.

Brief description of the drawings

Further features and advantages of the present invention will become apparent from the following detailed description, which is supplied by way of non-limiting example with particular reference to the annexed drawings, wherein:

- Figure 1 is a front view of a wind tunnel in accordance with a preferred embodiment of the present invention;
- Figures 2, 3, 4, 5 show details of the wind tunnel.

Detailed description of the invention

Figure 1 schematically shows a wind tunnel in accordance with a preferred embodiment of the present invention.

The wind tunnel comprises:

- a substantially vertical duct including a substantially vertical flight chamber 10, for housing a person who will fluctuate when hit by an air flow,
- a recirculation apparatus in fluidic communication with flight chamber 10, defining a substantially closed path for said air flow, and
- a blower device 14 for producing said air flow that will circulate between flight chamber 10 and the

recirculation apparatus;

Said substantially vertical duct includes:

- a cylindrical portion 11 having a circular cross-section,
- a truncated cone portion 12, connected at the top to cylindrical portion 11, having the shape of an upward-diverging truncated cone.

Preferably, flight chamber 10 comprises cylindrical portion 11 and truncated cone portion 12. However, according to a preferred embodiment, during the flight simulation the user can also gain access to the area designated by number 22, since no barriers are provided between said area 22 and truncated cone portion 12.

In particular, truncated cone portion 12 is a straight truncated cone, the bases of which are parallel to each other.

The air flow in the vertical duct, and hence in flight chamber 10, is ascending. The vertical duct has a substantially straight vertical axis z-z. The air flow runs through flight chamber 10 in a substantially axial, or vertical, direction. Cylindrical portion 11 and truncated cone portion 12 are aligned with vertical axis z-z. The cross-sections of cylindrical portion 11 and of truncated cone portion 12 are circular.

One of the advantages of the particular conformation of cylindrical portion 11 and of truncated cone portion 12 lies in the possibility of supplying an adequate air flow for free-falling simulations, while minimizing the energy consumption required for maintaining said air flow. In fact, truncated cone portion 12 reduces the velocity of the fluid, resulting in less load losses and lower energy consumption.

With reference to the variant shown in the drawings, the air circulates in the wind tunnel in clockwise direction, as indicated by dashed arrow 7.

As can be seen in the drawings, the recirculation apparatus comprises a first duct 16 in fluidic communication with truncated cone portion 12 through an angular connection 18, which comprises deflecting means 20 (which may hereafter be referred to simply as “deflectors” 20) interposed between a pair of angular portions 22, 24, wherein at least one of said angular portions 22, 24 has diverging surfaces that diverge like truncated cone portion 12, so as to create a substantially continuous profile with said truncated cone portion 12. In other words, angular connection 18 is a duct that can put the first duct 16 in fluidic communication with truncated cone portion 12. Deflectors 20 are located in the inner of the angular connection 18. Figure 5 shows, by way of example, a particular type of deflecting means 20, in particular associated with angular portion 22. The particular deflecting means 20 illustrated therein is of the grid type.

Therefore, with particular reference to Figures 2 and 3, the first angular portion 22 and truncated cone portion 12 create a continuous profile shaped like an (upward-diverging) truncated cone, wherein upper edge 22a of the first angular portion 22 lies in a plane that is not perpendicular to vertical axis z-z of flight chamber 10. In particular, upper edge 22a has a substantially elliptical shape.

Preferably, the second angular portion 24 has diverging surfaces with the same divergence angle as the first angular portion 22.

Therefore, the assembly made up of portions 12, 22, 24 forms a diverging angular duct for the air flow, thanks to which the velocity of the fluid is reduced, thereby minimizing the load losses and hence the energy consumption. In addition, a user's flight experience can occur in a volume with no discontinuities mainly due to cross-section changes or non-circular cross-sections. Also, it is possible to build a closed-circuit wind tunnel that is not very bulky.

In particular, the first duct 16 extends along a longitudinal axis, and is inclined relative to flight chamber 10, and hence relative to the vertical duct. Therefore, angular connection 18 deflects the air flow exiting flight chamber 10 towards the first duct 16.

Thanks to deflecting means 20, the wind tunnel can be made more efficient by promoting the passage of the air flow between the air duct located downstream of deflecting means 20 and the one located upstream of deflecting means 20. According to a different embodiment, angular connection 18 is not provided with deflecting means 20, therefore the first angular portion 22 and the second angular portion 24 are directly connected to each other.

With reference to the illustrated example, the first duct 16 is substantially horizontal, and the recirculation apparatus further comprises:

- a second substantially vertical duct 26 in fluidic communication with said first duct 16;
- a substantially horizontal lower duct 28 in fluidic communication with said second substantially vertical duct 26 and said flight chamber 10.

Starting from flight chamber 10, the air flows through angular connection 18 into the first horizontal duct 16,

and then into the second vertical duct 26 in a downward motion. Afterwards, the air flows into the horizontal lower duct 28, and finally into the vertical duct, where it arrives at flight chamber 10. The ducts belonging to the particular wind tunnel illustrated herein are thus so arranged as to substantially form a parallelepipedon.

Preferably, the first duct 16 is divergent with reference to the air flow. Load losses, and hence energy requirements, can thus be reduced even further. With particular reference to Figure 1, the second vertical duct 26 is divergent with reference to the air flow. Preferably, the cross-section of the first duct 16 is substantially circular; load losses can thus be further reduced.

With reference to the preferred example illustrated herein, starting from truncated cone portion 12 up to the end of the second substantially vertical duct 26, the cross-section through which the air flow will flow increases, possibly with short segments having a constant cross-section. In this way it is possible to reduce the load losses and avoid abrupt cross-section changes, thus minimizing the energy consumption.

With reference to the preferred example illustrated herein, the vertical duct comprises a tapered part 30 in fluidic communication with the lower part of cylindrical portion 11; the inner surface of tapered part 30 has, in its longitudinal section, a concave part 30a and a convex part 30b (see Figure 4). Said tapered part 30 becomes narrower, with particular reference to the air flow, towards cylindrical portion 11. Tapered part 30 accelerates the velocity of the air that enters from below into flight chamber 10, in particular into cylindrical portion 11, in order to let the user fluctuate when the latter is hit by

an air flow. In particular, tapered part 30 is coaxial to vertical axis z-z, and the section shown in Figure 4 is cut along a plane including said vertical axis z-z. Concave part 30a and convex part 30b, shown in Figure 4, meet at a saddle point designated as F. Conveniently, the cross-section of tapered part 30 is substantially circular.

In the illustrated example, a first fitting 32 puts the first duct 16 in fluidic communication with the second vertical duct 26. A second fitting 34 puts the second vertical duct 26 in fluidic communication with horizontal lower duct 28. And a third fitting 36 puts horizontal lower duct 28 in fluidic communication with the vertical duct, and therefore with flight chamber 10. Fittings 32, 34, 36 have an angular shape and deflect the fluid. Preferably, such fittings 32, 34, 36 internally house respective deflecting means 20, which are advantageously of the same or an equivalent type as those used in angular connection 18.

According to a particular embodiment, deflecting means 20 comprise a plurality of fins secured to a support structure, which may be, for example, a peripheral support structure (e.g. having an elliptical, square, rectangular, circular, etc. shape). The fins may be curved to improve the deflection of the air flow.

In the particular example illustrated herein, blower device 14 is located in the second vertical duct 26. It may however be located in other parts of the wind tunnel. Also, a plurality of blower devices 14 may be employed, arranged in different zones of the wind tunnel, in accordance with the required aeraulic performance. For example, blower device 14 may be a single blower; a plurality of blowers may nevertheless be used, as well as other *per se* known

apparatus.

Blower device 14 may be controlled via a control system; for instance, the control system may be able to control the activation/deactivation of blower device 14 according to an operator's commands issued, for example, from a remote control panel. Optionally, the control system may be able to control the operation of blower device 14 as a function of parameters read by sensor means associated with the wind tunnel.

In accordance with a preferred variant of the invention, flight chamber 10 comprises an air-permeable wall 40 that can be crossed by the air flow. For example, permeable wall 40 may be a grate, a net, a reticular wall or a perforated plate having holes of any shape and size, according to specific requirements.

In the illustrated embodiment, permeable wall 40 lies in a plane substantially transversal to the vertical axis z-z of flight chamber 10.

In the illustrated example, permeable wall 40 also acts as a support plane, or floor, for the people within flight chamber 10, as well as for any objects. Permeable wall 40 lies at the base of cylindrical portion 11, in particular between cylindrical portion 11 and tapered part 30.

Optionally, in the upper part of flight chamber 10 there is a second permeable wall, which is also useful for holding the people or the objects fluctuating in the air flow, e.g. in order to prevent them from undesirably hitting other parts of the wind tunnel. Therefore, the second permeable wall minimizes the risk that people or objects might by pushed by the air flow towards parts of the wind tunnel, such as, for example, the recirculation

apparatus or blower device 14, thus avoiding the risk of accidents as well as the risk of malfunctioning or jamming of the wind tunnel itself. For example, the second permeable wall may consist of deflecting means 20. As an alternative, the second permeable wall may be arranged between the portions designated by numbers 12 and 22. In these variant embodiments, therefore, permeable wall 40 and the second permeable wall delimit the region of flight chamber 10 in which a user can hover in a vertical or upward air flow for making a free-falling or parachuting simulation in safe conditions.

In accordance with a convenient variant of the invention, flight chamber 10 is at least partly made of transparent material, such as: glass, crystal, transparent plastic, polymethylmethacrylate (also known as Plexiglas), etc. The transparent material is convenient because it offers the possibility of seeing through flight chamber 10; for example, it will allow people standing outside the wind tunnel to watch a user engaged in a free-falling or parachuting simulation within the wind tunnel.

It is particularly advantageous that a whole part of flight chamber 10 is made of transparent material, thus allowing 360-degree vision of the inside of chamber 10. For example, it is conceivable to use a segment, comprised between two parts orthogonal to the main axis z-z, in which the vertical duct is made of transparent material. For example, cylindrical portion 11 and possibly also truncated cone portion 12 may be made of transparent material. As an alternative, portions 11 and/or 12 have a windowed surface made of transparent material.

In accordance with a preferred variant of the invention, the wind tunnel comprises an access to allow the

entry and exit of a person or an object into/from flight chamber 10. Said access crosses, for example, cylindrical portion 11 and/or truncated cone portion 12, particularly in a substantially radial or transversal direction. Merely by way of example, the access comprises only a door; or it may comprise a generic element for controlling the entry and exit of a person or an object into/from flight chamber 10, such as a shutter or a sliding door. The door(s) may be of a *per se* known type, such as a single-wing door, a double-wing door, a shutter, etc. Conveniently, the access is also made of transparent material.

Optionally, the part of the wind tunnel which is comprised between the air-permeable walls (one of which is numbered as 40) is made of transparent material. More preferably, the access, which is also made of transparent material, is located between the permeable walls.

Of course, without prejudice to the principle of the invention, the forms of embodiment and the implementation details may be extensively varied from those described and illustrated herein by way of non-limiting example, without however departing from the scope of the invention as set out in the appended claims.

CLAIMS

1. Recirculating-flow wind tunnel, in particular for free-falling or parachuting simulations, comprising:

- a substantially vertical duct including a substantially vertical flight chamber (10), for housing a person who will fluctuate when hit by an air flow,
- a recirculation apparatus (16, 26, 28, 18, 32, 34, 36) in fluidic communication with said flight chamber (10), defining a substantially closed path for said air flow, and
- a blower device (14) for producing said air flow that will circulate between said flight chamber (10) and said recirculation apparatus (16, 26, 28, 18, 32, 34, 36);

said substantially vertical duct including:

- a cylindrical portion (11) having a circular cross-section, and
- a truncated cone portion (12), connected at the top to said cylindrical portion (11), having the shape of an upward-diverging truncated cone.

2. Wind tunnel according to claim 1, wherein said recirculation apparatus (16, 26, 28, 18, 32, 34, 36) comprises a first duct (16) in fluidic communication with said truncated cone portion (12) through an angular connection (18), which comprises deflecting means (20) interposed between a pair of angular portions (22, 24), wherein at least one of such angular portions (22, 24) has diverging surfaces that diverge like said truncated cone portion (12), so as to create a substantially continuous profile with said truncated cone portion (12).

3. Wind tunnel according to claim 2, wherein the second angular portion (24) has diverging surfaces with the same divergence angle as the first angular portion (22).

4. Wind tunnel according to claim 2 or 3, wherein said

first duct (16) is substantially horizontal, and said recirculation apparatus (16, 26, 28, 18, 32, 34, 36) further comprises:

- a second substantially vertical duct (26) in fluidic communication with said first duct (16);
- a substantially horizontal lower duct (28) in fluidic communication with said second substantially vertical duct (26) and said flight chamber (10).

5. Wind tunnel according to any one of claims 2 to 4, wherein said first duct (16) is divergent with reference to the air flow.

6. Wind tunnel according to any one of the preceding claims, wherein said substantially vertical duct comprises a tapered part (30) in fluidic communication with the lower part of said cylindrical portion (11), said tapered part (30) becoming narrower towards said cylindrical portion (11); the inner surface of said tapered part (30) having, in its longitudinal section, a concave part (30a) and a convex part (30b).

7. Wind tunnel according to any one of claims 4 to 6, comprising:

- a first fitting (32) that puts said first duct (16) in fluidic communication with said second substantially vertical duct (26);
- a second fitting (34) that puts said second substantially vertical duct (26) in fluidic communication with said substantially horizontal lower duct (28); and
- a third fitting (36) that puts said second substantially horizontal lower duct (28) in fluidic communication with said substantially vertical duct;

such fittings (32, 34, 36) internally housing respective deflecting means (20).

8. Wind tunnel according to any one of claims 4 to 7, wherein said second substantially vertical duct (26) is divergent with reference to the air flow.

9. Wind tunnel according to any one of claims 4 to 8, wherein the cross-section of said first duct (16) is substantially circular.

10. Wind tunnel according to any one of claims 4 to 9, wherein, starting from said truncated cone portion (12) up to the end of said second substantially vertical duct (26), the cross-section through which said air flow will flow increases, possibly with short segments having a constant cross-section.

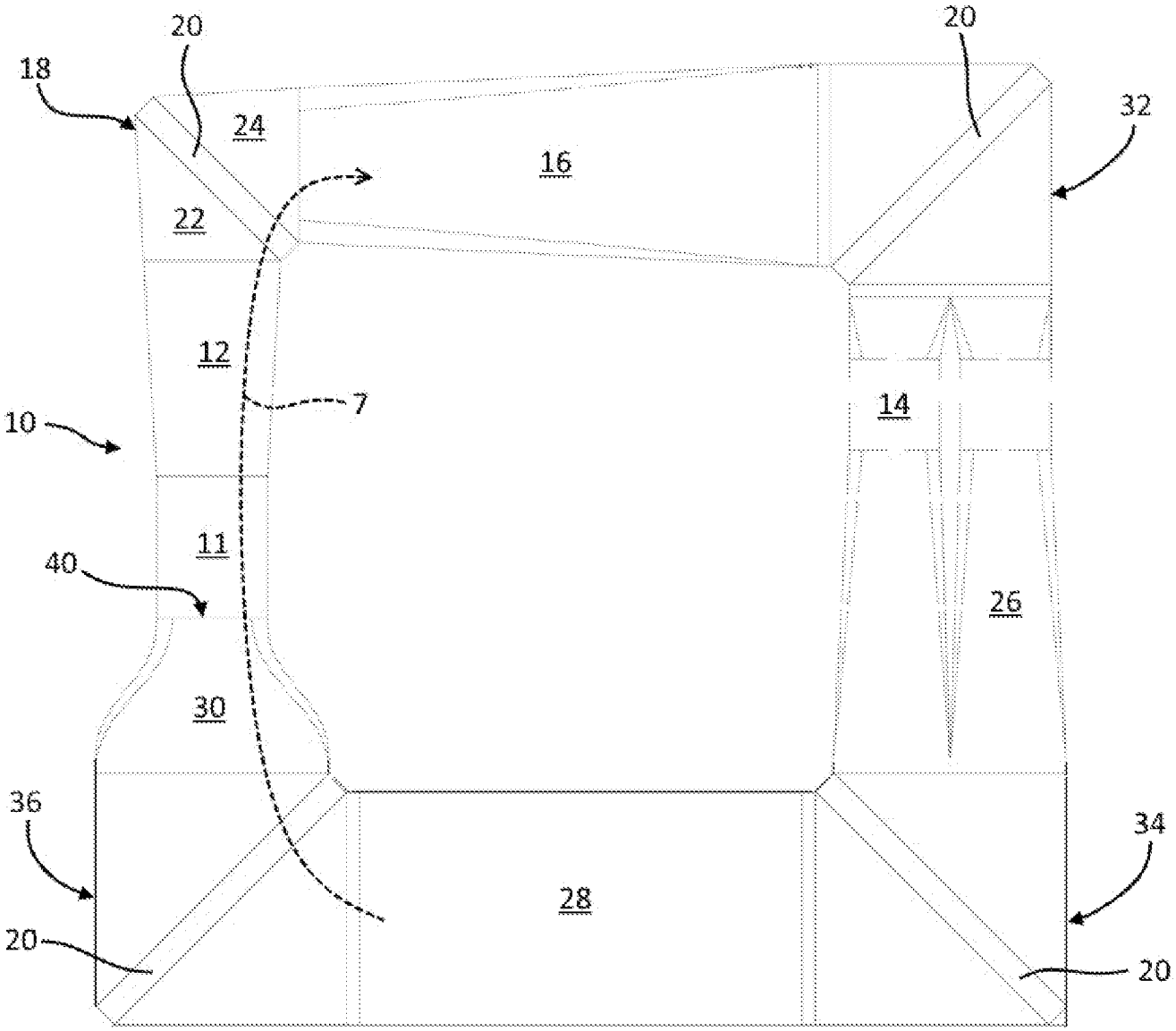

Fig. 1

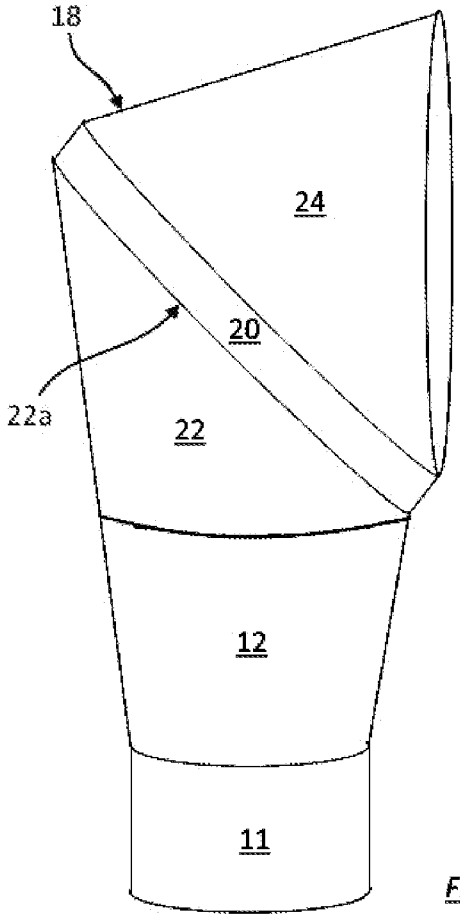

Fig. 2

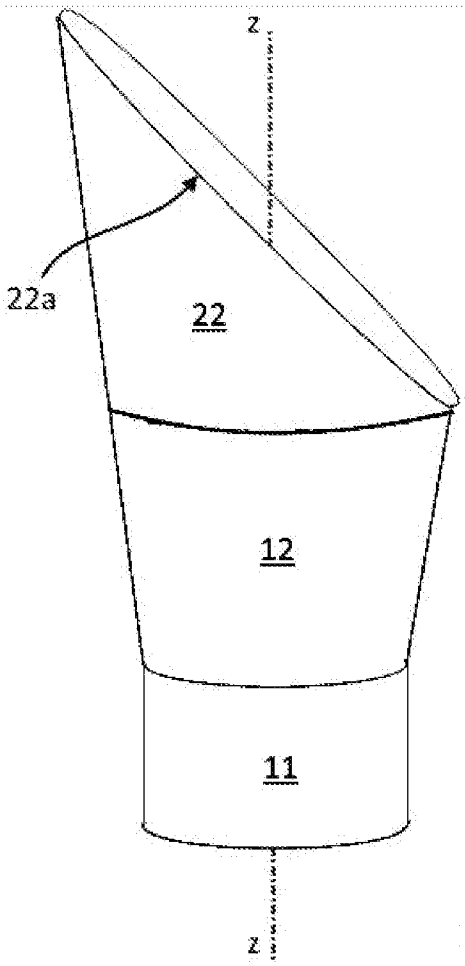

Fig. 3

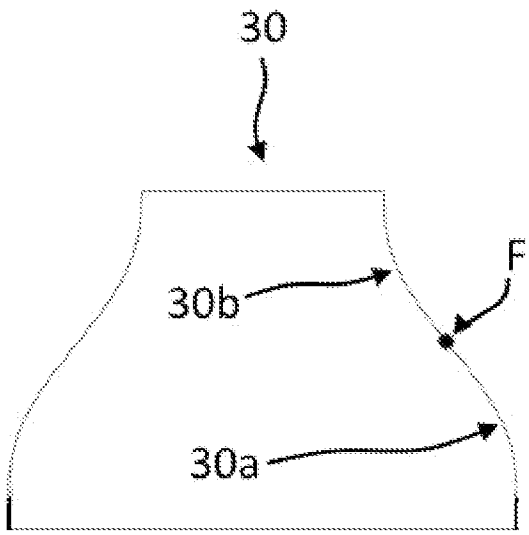

Fig. 4

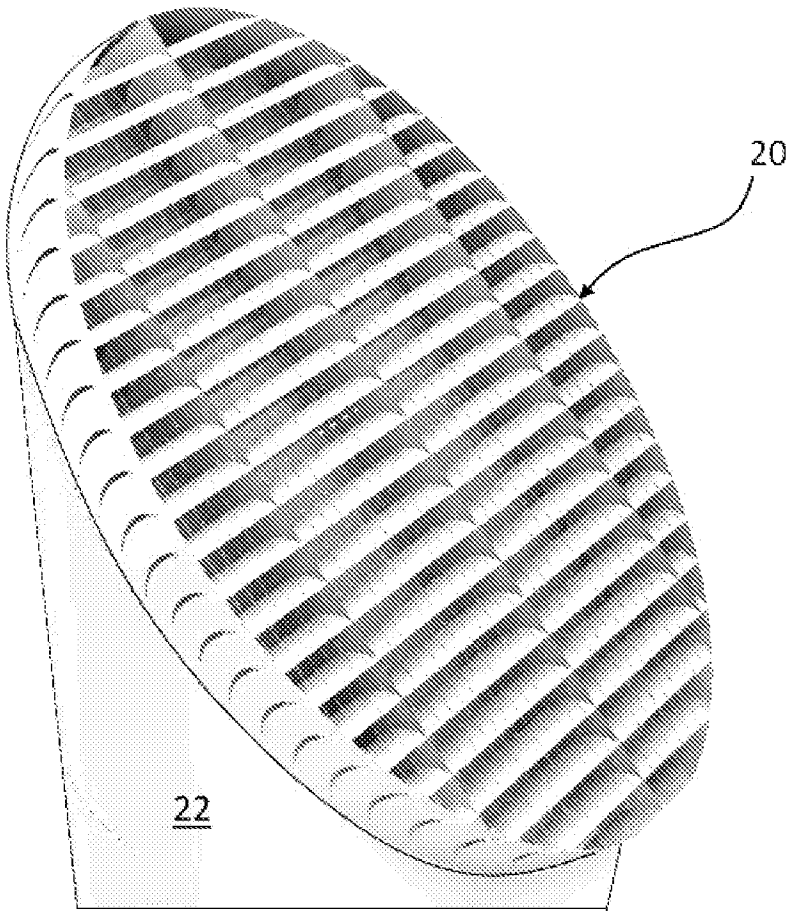

Fig. 5

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2016/054036

A. CLASSIFICATION OF SUBJECT MATTER
INV. G01M9/02
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
G01M B64D A63G

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 8 668 497 B2 (NEBE BORIS [DE] ET AL) 11 March 2014 (2014-03-11) abstract page 1, column 1, lines 14-16 page 3, column 6, lines 28-45, 66-67 page 4, column 7, lines 1-22, 35-37, 57-64 figures 1, 2	1-10
Y	US 9 045 232 B1 (BURKE TIMOTHY A [US] ET AL) 2 June 2015 (2015-06-02) page 2, column 3, lines 24-30 page 2, column 4, lines 9-11 figures 3, 4	1-10
A	US 2011/100109 A1 (KIM HYUN-GOO [KR] ET AL) 5 May 2011 (2011-05-05) figure 1	1-10

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
30 September 2016	14/11/2016

Name and mailing address of the ISA/	Authorized officer
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/IB2016/054036

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