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(54) Titre : SYSTEME PHOTOVOLTAIQUE DE CONCENTRATION ET PROCEDE DE CONCENTRATION ASSOCIE
 (54) Title: CONCENTRATION PHOTOVOLTAIC SYSTEM AND CONCENTRATION METHOD THEREOF

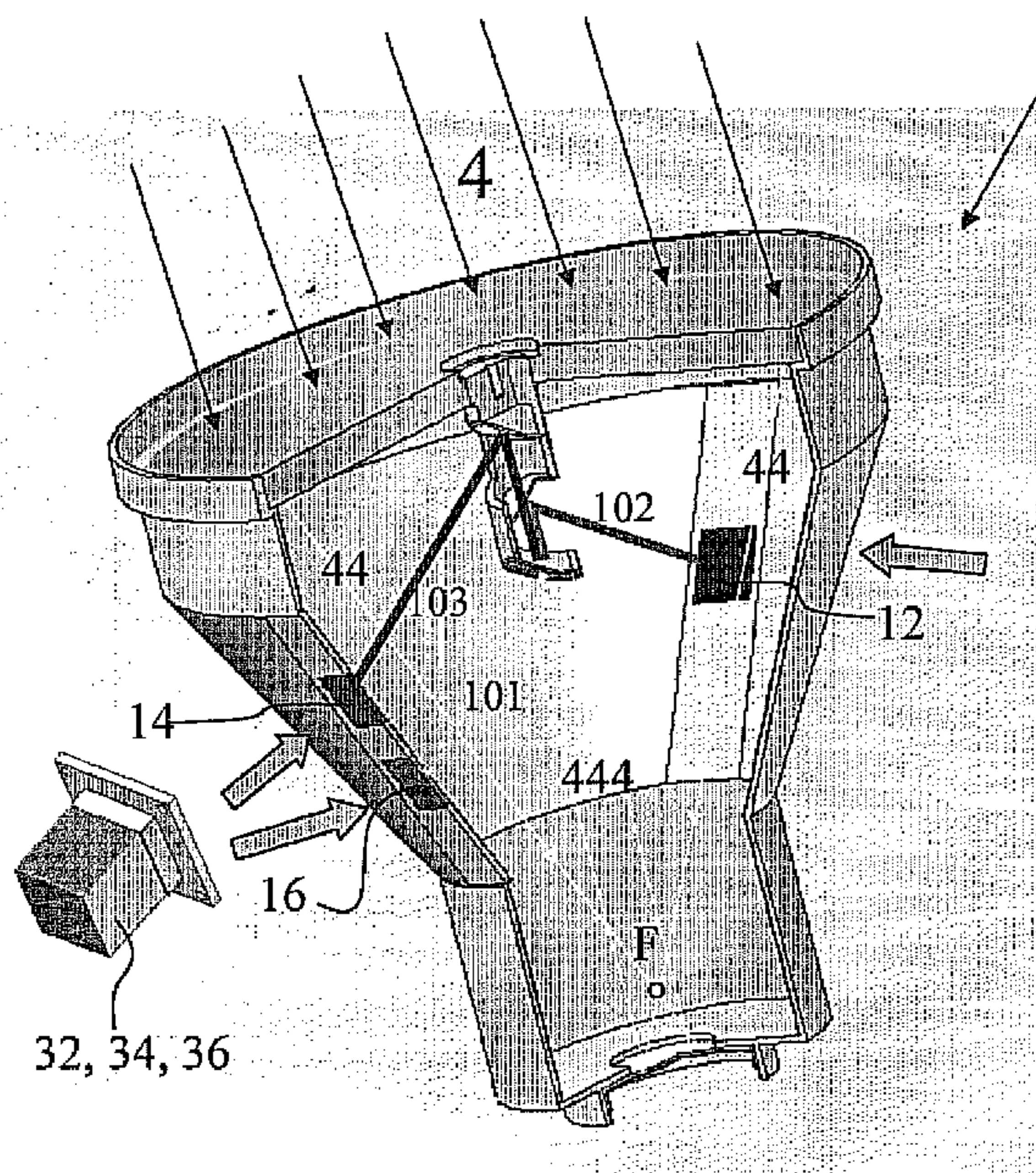


Fig. 4

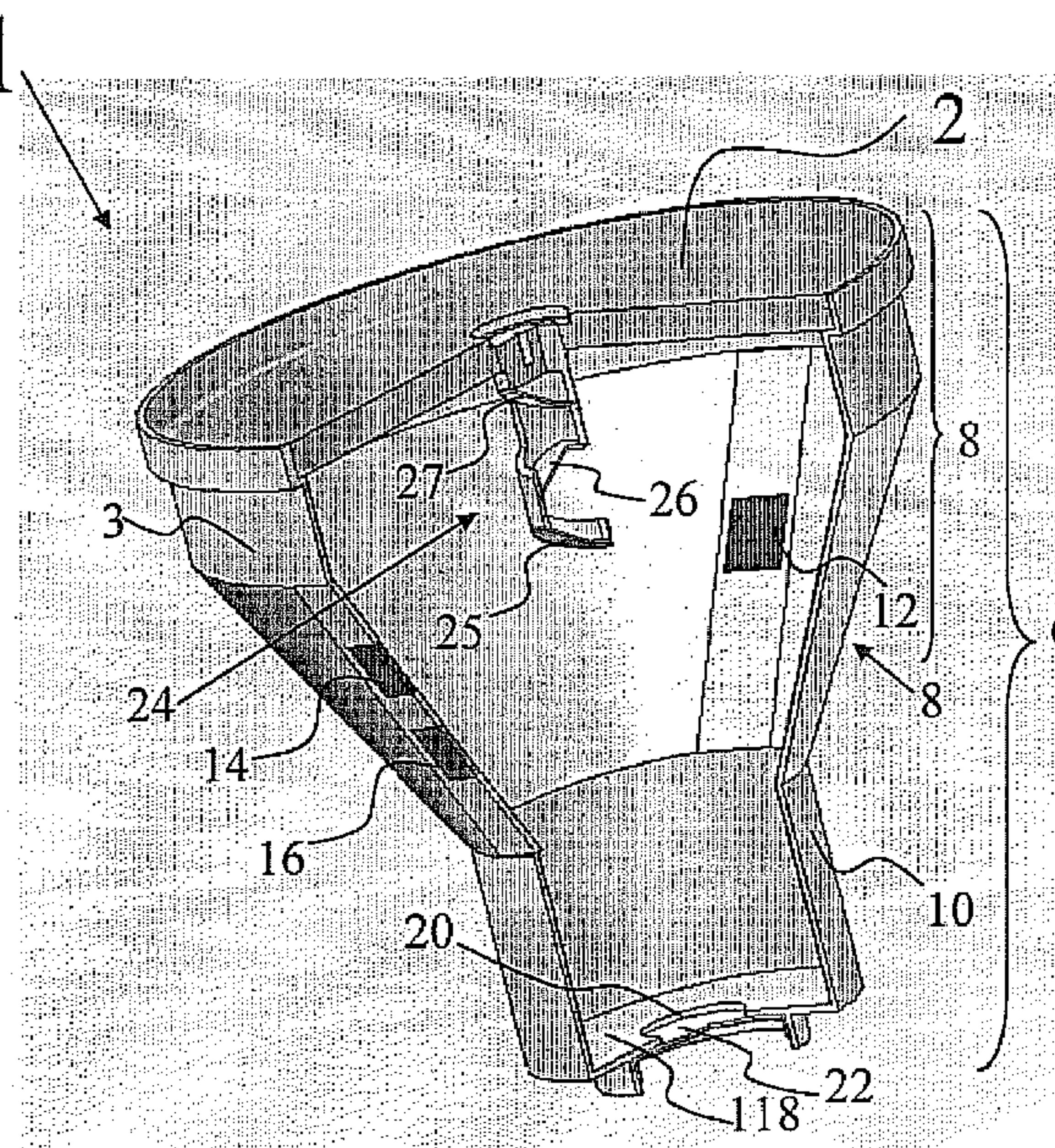


Fig. 3

(57) Abrégé/Abstract:

A concentration photovoltaic system (1,11) comprises lens-type concentrator means (2) for intercepting and concentrating beams of incident solar rays (4,114), and is characterized in that it comprises selection means (24,124), for selecting the frequencies of beams of solar rays entering the photovoltaic system (1,11), capable of direct selected rays towards a plurality of photovoltaic cells (12, 14, 16, 502, 602, 702). The invention also comprises a method for concentrating beams of incident solar rays (4, 114) which uses the concentration photovoltaic system described.

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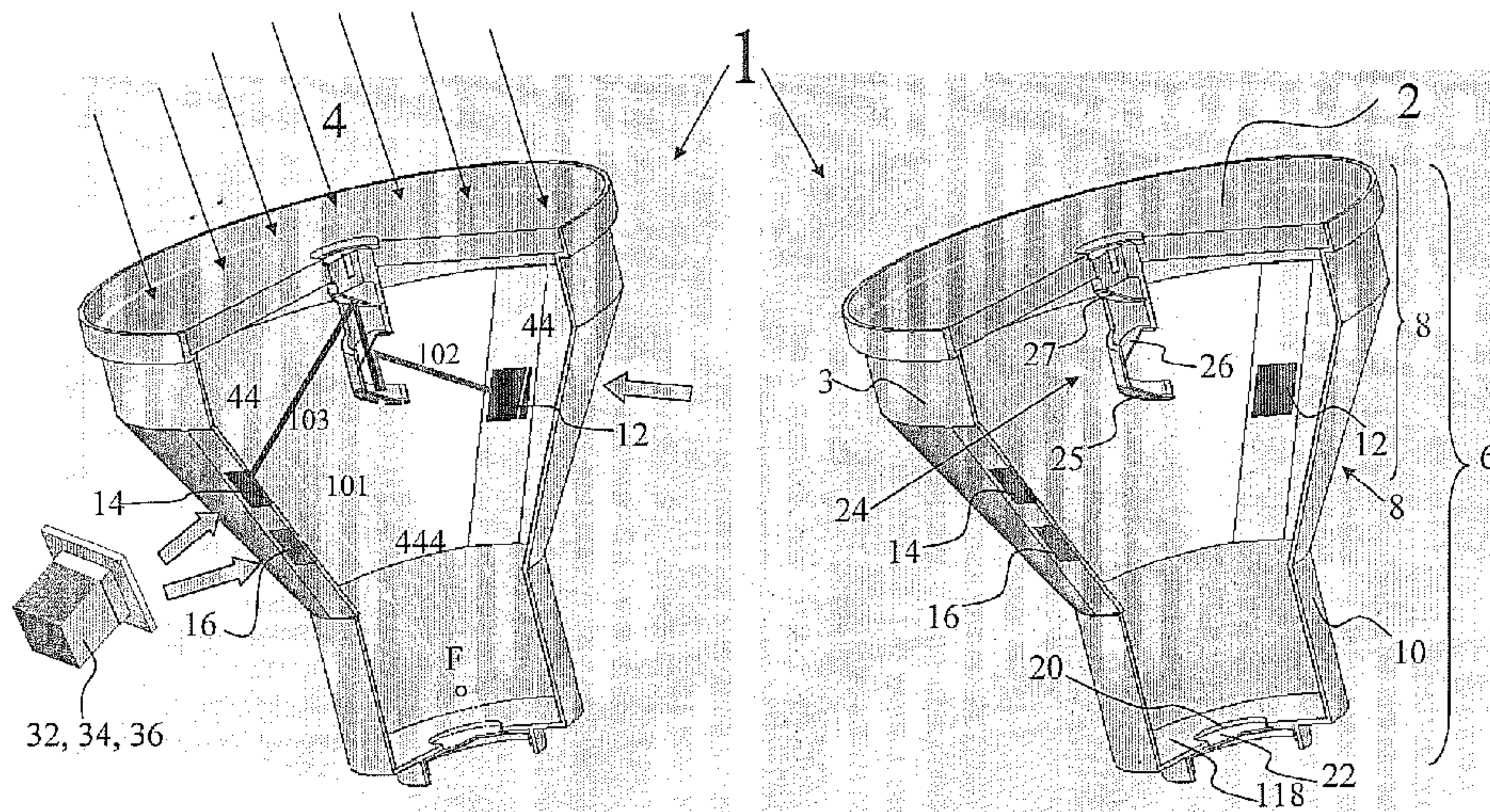


Fig. 4

Fig. 3

(57) Abstract: A concentration photovoltaic system (1,11) comprises lens-type concentrator means (2) for intercepting and concentrating beams of incident solar rays (4,114), and is characterized in that it comprises selection means (24,124), for selecting the frequencies of beams of solar rays entering the photovoltaic system (1,11), capable of direct selected rays towards a plurality of photovoltaic cells (12, 14, 16, 502, 602, 702). The invention also comprises a method for concentrating beams of incident solar rays (4, 114) which uses the concentration photovoltaic system described.

WO 2008/125642 A3

"Concentration photovoltaic system and concentration method thereof"

DESCRIPTION

Technical field

5 The invention relates to a concentration photovoltaic system based on concentrator means for intercepting and concentrating beams of incident solar rays; the invention relates, moreover, to a method for concentrating solar energy on photovoltaic cells,
10 based on concentrator means for intercepting and concentrating beams of incident solar rays.

Prior art

 As is well-known, photovoltaic systems comprise a certain number of photovoltaic cells which allow the
15 reception and conversion of solar rays into energy, for example electrical energy, for the end use.

 The most common photovoltaic systems are so-called "flat" photovoltaic systems in which the quantity of electrical energy produced is proportional to the
20 surface area of the photovoltaic cells used; for this reason, these cells cover practically the whole of the surface of the panels exposed to the sun's rays, these surfaces necessarily having large dimensions in order to produce a quantity of energy which can be used in an
25 efficient manner.

 A serious drawback of these systems consists in the cost of the photovoltaic cells which represents most of the overall cost of a panel. The possibility of reducing the costs is therefore dependent almost
30 exclusively on the reduction in the cost of the photovoltaic cells.

 Research in this sector, which is not a new

sector, could result in limited improvements and only at the expense of huge investments mainly in the technology of the cells.

5 An evolution in the photovoltaic systems consists in so-called "concentration" photovoltaic systems which use a concentrator device which intercepts the sun's rays and concentrates them on a photovoltaic cell having dimensions which are inversely proportional to the concentration factor of the concentrator device.

10 Concentration photovoltaic systems ensure a performance which is far superior to that of conventional flat photovoltaic systems, reduce the proportional cost of the cells and constitute a young technology with room for improvement and more
15 extensive research.

A problem which is encountered, however, is that the concentration also results in raising of the temperature of the cells up to dangerous levels, so that suitable heat dissipators are nearly always
20 envisaged.

Raising of the temperature is due to the fact that the quantity of photons (solar light) which causes the movement of electrons (electric power) is not high (low efficiency) and therefore many studies have been
25 focussed on solutions for improving the photon-electron "conversion".

One solution to this problem envisages the use of multi-joint cells, i.e. a type of multilayer photovoltaic cell which effectively increases in a
30 significant manner the overall efficiency of the cell, allowing a lowering of the temperature. However, these cells are produced using costly and rare materials,

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such as germanium, and the technology is somewhat sophisticated, so that this solution is not easy to realise.

An example of this solution is shown in the publication "Toward 40% and higher solar cells in a New Cassegrainian PV module" disclosing a concentrator photovoltaic module with multijunction (MJ) cell using a Cassegrainian mirror configuration splitting the sun's spectrum using a dichroic hyperbolic secondary mirror, the concentrations being carried out by reflection.

The patent application WO 2006/108806 in the name of Giuliano Martinelli et al., published on 19 October 2006, is described a system which envisages dividing up the solar energy into two or more bands (dichroic, trichroic and more generally polychroic systems) by means of two or more coaxial reflector dishes, the first of which reflects the solar radiation with a certain spectral composition, allowing the remaining parts of the radiation to pass towards the other dishes.

In the case of two dishes, each of them reflects the portion of corresponding energy towards its own focal point which does not coincide with that of the other dish. The incoming solar energy is then divided into two beams which have a different spectral composition and an energy content equal to a fraction of the total incident energy even though obviously the sum of the energies associated with each beam corresponds to that prior to division.

This division has two effects:

- it reduces the energy load on each cell for the same concentration factor;
- it results in a higher efficiency in the photon/electron conversion process.

The overall result is that the amount of solar energy which is converted into electrical energy is higher and that the heat generated in each cell is reduced significantly.

The system described in the cited patent

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application, although it constitutes an improvement in terms of heat dissipation, has further defects:

- the parabolic reflectors have an overall geometry which differs greatly from the mathematical area of the paraboloid and this gives rise to problems of a constructional nature which make mass-production difficult;

- the entire surface of the parabolic dishes must incorporate within it the passband filter functions for the desired frequency band together with the non-passband reflection function;

- owing to the significantly large dimensions, it is not possible to use easily low-cost technology such as plastics injection technology;

- the cells are arranged on the focal points of the parabolic dishes with an arm which projects beyond the said dishes and which, by nature, is very delicate;

- cleaning of the dishes which periodically must be performed in order to ensure the optimum efficiency of the system is difficult to perform with automatic systems which may be envisaged in large installations.

- the whole system, in general, has a complex functioning and it is complex to carry out.

These defects make the system proposed difficult to apply on a large scale.

A dichroic system is also disclosed in the US patent 4, 158, 356 wherein a solar collector tracks the sun through changes in the relative position between the sun and the earth; a reflective concave surface provides concentrated solar radiation at a transducer that includes on its curved surface a dichroic pellical outer coating acting as a reflector for the UV -Vis radiation.

A background for the present invention is also disclosed in the following documents:

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- 4a -

US patent 6,469,241 discloses a solar concentrator including a first high concentrating optics concentrating collected solar light and a second spectrum splitting optics splitting collected solar light; the second lens spectrum splits the light by refraction along a axis, the second lens being either a curved prismatic Fresnel lens or a linear prism type Fresnel lens.

US patent 5, 089, 055 discloses in one of its embodiments an optical waveguide photovoltaic power generation system including concentrators concentrating solar radiations into an optical fiber link and passing through a photovoltaic protection device; solar radiations are split into one or more beams of selected wavelength by selective beam splitter comprising selectively reflecting mirrors, the beam being reflected by mirrors towards photovoltaic cells.

US patent application 2005/0046977 discloses a solar energy utilization unit comprising a solar radiation concentrating optics and a solar radiation receiver including first and second receiver components.

The concentrating optics comprise a concave primary reflector and a convex secondary reflector; the first receiver converts into electric energy radiation in a first part of the solar spectrum, the second receiver converts into electric energy radiation in a second part of the solar spectrum.

The object of the present invention is to provide a concentration photovoltaic system which is improved in terms of costs and manufacturing simplicity in order to overcome the drawbacks of the prior art.

Summary of the invention

The object indicated above is achieved by a concentration photovoltaic system according to claim 1

Moreover the present invention relates to a method for concentrating beams of incident solar rays on photovoltaic cells, according to claim 20

5 With the invention it is possible to achieve a significant improvement in the manufacturing costs and efficiency levels.

Lenses and cells are produced using conventional and low-cost technology.

10 The efficiency of the system is greater than the efficiency of the systems of the prior art.

The characteristic features and the further advantages of the invention will emerge from the description, provided hereinbelow, of an example of embodiment thereof provided purely by way of a non-
15 limiting example with reference to the accompanying drawings.

Brief description of the drawings

- Figure 1 shows a partially cut-away perspective view of a photovoltaic system according to a first
20 embodiment of the invention in the rest condition, namely in the condition where there is no solar radiation;

- Figure 2 shows the system according to Figure 1 in the operating condition;

25 - Figures 2a, 2b and 2c show details of the figures 1 and 2.

- Figure 3 shows a partially cut-away perspective view of a photovoltaic system according to a second embodiment of the invention in the rest condition,
30 namely in the condition where there is no solar radiation;

- Figure 4 shows the system according to Figure 3

in the operating condition;

- Figure 5 shows a top plan view of the system according to Figures 3 and 4;

- Figure 6 shows a sectioned view of a detail of the system of the invention.

Detailed description

With reference to these Figures, in Figure 1 a concentration photovoltaic system 1 comprises a container 16, only partially shown in figures 1 and 2, preferably composed of a first portion 18, that rests, in the region of its inferior base, on a second portion 110, open in the region of its top base.

The first and second portions 18 and 110 may also have a frusto-pyramidal shape, a parallelepiped shape, frusto-conical shape, or shapes which are similar to these.

The first portion 18 supports a first concentrator device 2, in particular a surface 2 for receiving and concentrating, without reflecting, beams of incident solar rays 14 (shown in Fig. 2).

According to the invention, the surface 2 is a lens, in particular a Fresnel lens, and may have different perimetral shapes, in particular a square or circular shape, corresponding to the shape of the first portion 18 of the container 16.

The container 16 therefore is a support for the Fresnel lens and for the other indicated components and protects and insulates all the components of the system.

The special feature of the Fresnel lens is that it, referring to the particular case of a circular lens shown in figure 6, performs the same function as a

conventional semi-spherical lens of equivalent dioptric power that causes incident rays to converge in a point called focal point, with the advantage that it has a small thickness and weight; this lens is obtained by
5 splitting up a conventional semi-spherical lens into a series of concentric annular sections called Fresnel rings, as shown in cross-section in Figure 6, converting the continuous curve of a conventional semi-spherical lens into a series of surfaces 2a-2e which
10 have the same curvature, but are radially not continuous.

The lens concentrates the incident and parallel solar ray beams 14 into beams of converging rays 144, as shown in Figure 2, 2a and 2b; in figure 2 is
15 illustrated the same system as in Figure 1, that shows specifically the paths of the solar rays 14 which strike the surface 2 and pass through it without being reflected.

According to the invention, the concentrator
20 device 2 functions independently of the frequency of the incident solar rays 14. The beam of converging rays 144, therefore, is only a redirected and not an attenuated, filtered or reflected beam.

In the figure 2a, the system is shown from the
25 opposite side with respect to figure 2, that is components 501, 601 and 701 are in reverse order.

Rays 144, according to the features of the surface 2, are redirected towards the focal point of the lenticular surface 2, as shown in figure 2b.

30 According to the first embodiment of the invention, converging rays 144 are directed towards means for selecting frequencies, that is a first

filtering device 124 placed near the inferior base of the second portion 110. The filtering device 124 is placed above the focal point of the Fresnel lens thus converging rays 144 are stopped and redirected before reaching the focus F1 of the surface 2 (figure 2b).

The device 124 comprises (figures 1, 2 and 2a) filtering optical elements, for instance two band-pass filters 501, 601 to which two corresponding photovoltaic cells 502, 602 and a mirror 127 are coupled.

Band-pass filters are known per se; each transmits rays comprised in a certain frequency bandwidth (the band-pass frequency) and reflects rays at other frequencies.

Photovoltaic cells are known being portions of semiconductor material able to convert light radiations into electrical supply.

Since each semiconductor material is able to convert with high efficiency only in a specific frequency bandwidth, three different photovoltaic cells with three separated bandwidths have been used.

In the figures, the three cells used are similar; as a matter of the fact, the semiconductor material changes.

Specifically, a portion of the rays 144 with frequencies comprised in the band-pass, is transmitted from the first band-pass filter 501 towards the first photovoltaic cell 502, while the portion of the rays 144 non comprised in the band-pass is reflected towards a second band-pass filter 601; this reflects a part of the rays (those non comprised in the band-pass) towards a second photovoltaic cell 602 and transmits

the other part of the rays (those comprised in the band-pass) towards the mirror 127 that, in turn, reflects them towards the third photovoltaic cell 702.

5 The system of the invention works in the whole solar spectrum (from 350 nm to 1800nm); thus, the sum of the three bands of frequencies affected by the filtering optical elements 502,602 and by the other reflecting elements 127 is substantially the whole solar spectrum.

10 The filtering device lies on supporting elements 126 in turn fixed on a heat dissipater that has a first function of supporting the photovoltaic cells and it anchors the supporting elements for the band-pass filters and the mirror and a second function of
15 discharging the heat generated into the photovoltaic cells.

A second embodiment of the invention will be now described according to figures 3-5 in which components similar to those of the first embodiment will maintain
20 the same numbers and the same features of the described components (band-pass filters, mirrors, selection means).

A concentration photovoltaic system 1 comprises a container 16, preferably composed of a third portion 8,
25 with a hollow frustoconical shape, open at both the bases and with the large base arranged at the top; this third portion 8 rests, in the region of its small base, on a fourth portion 10, which is preferably cylindrical, hollow, open in the region of its top base
30 and provided with a hole in the bottom base 118; the portion 10 of the container 6 acts as support for the concentration photovoltaic system.

The third and fourth portions 8 and 10 may also have the same shape of the first and second portions of the first embodiment of the invention.

5 The third portion 8 has, in the region of its top base, a kind of flange 3 which supports a concentrator device 2, in particular a surface 2 for receiving and concentrating beams of incident solar rays 4 (shown in Fig. 4).

10 According to the invention, the surface 2 is a lens, in particular a Fresnel lens, and may have different perimetral shapes, in particular a square or circular shape, corresponding to the shape of the first portion 8 of the container 6.

15 The lens concentrates the incident and parallel solar ray beams 4 into converging ray beams 44, as shown in Figure 4; such a figure illustrates the same system as in Figure 3, that shows specifically the paths of the solar rays 4 which strike the surface 2 and pass through it without being reflected.

20 The bottom base 118 of the fourth portion 10 has a hole 20 where the converging ray beams 44 converge.

25 As for the first embodiment, the concentrator device 2 functions independently of the frequency of the incident solar rays 4. The beam of converging rays 44, therefore, is only a redirected and not an attenuated, filtered or reflected beam.

30 A parabolic mirror 22 with an upwardly directed concavity is mounted in the hole 20, the focal point F thereof, shown in Fig. 2, coinciding with the focal point of the Fresnel lens, namely the point towards which the beam of rays 44 converges.

The parabolic mirror 22 reflects the beam of

converging rays 44, in the form of a beam of parallel rays 444, onto frequency selection means , that is a second filtering device 24 situated inside the container 6 and fixed along its axis within the third portion 8. The device 24 performs a division, according to predefined frequency intervals, of the beam of parallel rays 444 in the same way shown in the first embodiment.

The beam, which is divided up according to predefined frequencies, is directed towards a certain number of photovoltaic cells arranged, for example, on the side surface of the third portion 8.

The number of photovoltaic cells and the position thereof on the side surface of the third portion 8 (second embodiment) or on the inferior base of the second portion 110 (first embodiment) depends on the manufacturing specifications and operation of the complete concentration photovoltaic system 1.

Special mirrors may be envisaged in place of the cells, said mirrors allowing reflection, where necessary, of the divided beam.

For the second embodiment of the invention (figures 3-5), it is possible, therefore, to decide upon the lay-out, on the side surface, of the first portion 8 of the photovoltaic cells which may be, for example, opposite each other or arranged vertically alongside each other.

For the first embodiment of the invention (figures 1-2) it is possible to decide upon the lay-out, on the inferior base, of the second portion 110 of the photovoltaic cells which may be, for example, appropriately spaced or side by side.

According to the preferred embodiments of the invention, three photovoltaic cells have been shown, only for an easier explanation.

5 The cells are designed especially to receive solar rays in a suitable frequency range and to optimize the energy produced on the basis of these frequencies. The number of band-pass filters and the characteristics of the photovoltaic cells onto which the rays are reflected are adjusted a priori on the basis of the
10 division of the incident rays on the device 2 into predetermined frequency ranges, which can be selected as required, with a view to optimising the energy produced, maximising the efficiency of the system. In the technical jargon it is usually said that the
15 photovoltaic cells are "tuned" to the frequencies of the reflected solar rays which they must receive. According to the second embodiment, depending on the concavity of the parabolic mirror 22, the position of the focal point of the parabolic dish, and consequently
20 the amplitude of the beam of reflected rays 444, is determined, always with a view to maximising the efficiency of the system.

In both the embodiments, optionally, heat dissipators are envisaged and can be associated with
25 the photovoltaic cells in order to reduce the operating temperature thereof. These dissipators are known per se, being liquid or air operated, and are situated outside the container so as not to affect in any way the ray beam passing inside the system.

30 Usually, this is not necessary since the energy density is divided up over several destination cells in a manner directly proportional to the number of cells,

with a consequent reduction in the temperature.

Several concentration photovoltaic systems according to the invention may be easily coupled together and made to move in synchronism, but not
5 integrally within a frame which also has small dimensions that can be installed on any type of horizontal or vertical surface, including roofs and facades of buildings.

In this way a further improvement in the
10 efficiency is ensured on a large scale.

From the description provided hitherto it is possible to understand operation of the concentration photovoltaic system according to the present invention which operates using an innovative method for
15 concentrating solar energy.

The concentrator device 2 is positioned so as to intercept solar rays as a beam of incident parallel solar rays 4,114. Owing to its intrinsic physical characteristics, this device causes the beam of solar
20 rays to converge, independently of their frequency, in the form of a beam of concentrated solar rays 44,144.

In the first embodiment, the beam 144 is directed to a first band-pass filter 501. Rays incide on the first band-pass filter 501, upstream of the focus F1 of
25 the concentrator device 2. The band-pass filter 501 transmits rays in the band-pass frequencies towards the first photovoltaic cell 502, while rays 144 non in the band-pass are reflected towards a second band-pass filter 601 that reflects rays not in a second bandwidth
30 towards a second photovoltaic cell 602 and transmits rays in the band-pass towards a mirror 127 that reflects them towards a third photovoltaic cell 702.

In the second embodiment, rays 44 of the beam strike the parabolic mirror 22, downstream of the focal point F of the concentrator device 2. The focal point F of the Fresnel lens coincides with the focal point of the parabolic mirror 22.

The parabolic mirror reflects the concentrated solar rays 44 in the form of a beam of rays 444 which are again parallel, but have a diameter smaller than the beam of incident rays 4.

This beam 444, the diameter of which depends on the predefined requisites of the system, strikes the selection device 24, that work as the selection device 124. The rays of the band not in the band-pass of the two previous filters are reflected by means of the mirror 27 onto a last cell 14.

The energy is then extracted from the cells 12, 14, 16, 502, 602 and 702 for the end use.

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Clean claims

CLAIMS

1. Concentration photovoltaic system (11) comprising:

- concentrator means (2) for intercepting beams of incident solar rays (114) that strike and pass through said concentrator means (2) and are concentrated, independently on the frequency, in beams of concentrated solar rays (44, 144);

- means (124) for the selection of frequencies comprising a plurality of filtering optical elements (501, 601) capable of selecting, according to predefined ranges, the frequencies of said beams of concentrated solar rays (144), and a plurality of photovoltaic cells (502, 602) receiving beams of said rays (144) from said corresponding filtering optical elements (501, 601),

characterised in that

said filtering optical elements comprise band-pass filters (501, 601) wherein a first band-pass filter (501) is capable of filtering rays in a first range of frequencies, reflecting them towards a second band-pass filter (601), non reflected rays being capable of being transmitted towards a first photovoltaic cells (502), and wherein a second band-pass filter (601) is capable of filtering rays in a second range of frequencies, non reflected rays being capable of being transmitted towards a second photovoltaic cell (602).

2. Concentration photovoltaic system (11) according to claim 1 wherein said selection means (124) comprise a third photovoltaic cell (702) capable of receiving rays from corresponding reflecting optical elements (127).

3. Concentration photovoltaic system (11) according to Claim 2 wherein said reflecting optical element (127) comprise a mirror (127) capable of reflecting said beams of concentrated solar rays (144), not previously reflected from said plurality of band-pass filters (501, 601), towards a photovoltaic cell (702).

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Clean claims

4. Concentration photovoltaic system (11) according to Claim 1, in which beams of incident solar rays (114) are beams of parallel straight rays.
5. Concentration photovoltaic system (11) according to one of the preceding Claims, wherein said concentrator means (2) are of the lens type.
- 5 6. Concentration photovoltaic system (11) according to one of the preceding claims, wherein said concentrator means (2) comprise a Fresnel lens.
7. Concentration photovoltaic system (11) according to Claim 1 wherein said beams of concentrated rays (144) are beams of straight rays directed to the focal point (F1) of said concentrator means (2).
- 10 8. Concentration photovoltaic system (11) according to Claim 7 wherein said focal point (F1) is the focal point of a Fresnel lens.
9. Concentration photovoltaic system (11) according to Claim 8 wherein said focal point (F1) is placed below said selection means (124) and not reached from said rays (144).
- 15 10. Concentration photovoltaic system (11) according to any one of the preceding claims comprising a supporting elements (126) supporting the selection means (124) and fixed on a heat dissipater capable of discharging the heat generated into the photovoltaic cells.
11. Method for concentrating beams of solar rays (114) striking photovoltaic
20 cells (502, 602, 702), which uses the concentration photovoltaic system (11) according to Claims 1 to 10, comprising the steps of:
 - intercepting beams of incident solar rays (114) by means of concentrator means (2) that strike and pass through said concentrator means (2) and are concentrated, independently of the frequency, in concentrated solar rays beams
25 (144) characterized in that it comprises the step of

AMENDED SHEET

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Clean claims

- selecting, according to predefined frequencies ranges, said beams of concentrated solar rays (144,) by means of selection means (124) comprising a plurality of band-pass filters (501, 601) wherein a first band-pass filter (501) is capable of filtering rays in a first range of frequencies, reflecting them towards a second band-pass filter (601), non reflected rays being capable of being transmitted towards a first photovoltaic cells (502), and wherein a second band-pass filter (601) is capable of filtering rays in a second range of frequencies, non reflected rays being capable of being transmitted towards a second photovoltaic cell (602).

10 12. Method according to claim 11 wherein the second band-pass filter (601) transmits rays in the band-pass towards a mirror (127).

13. Method according to claim 11 wherein said mirror (127) reflects towards a third photovoltaic cell (702) rays in the range of frequencies in the band-pass frequency.

15 14. Method according to one of the claims from 11 to 13 wherein said cells (502, 602, 702) convert the received solar rays into energy for the end use.

Fig. 2

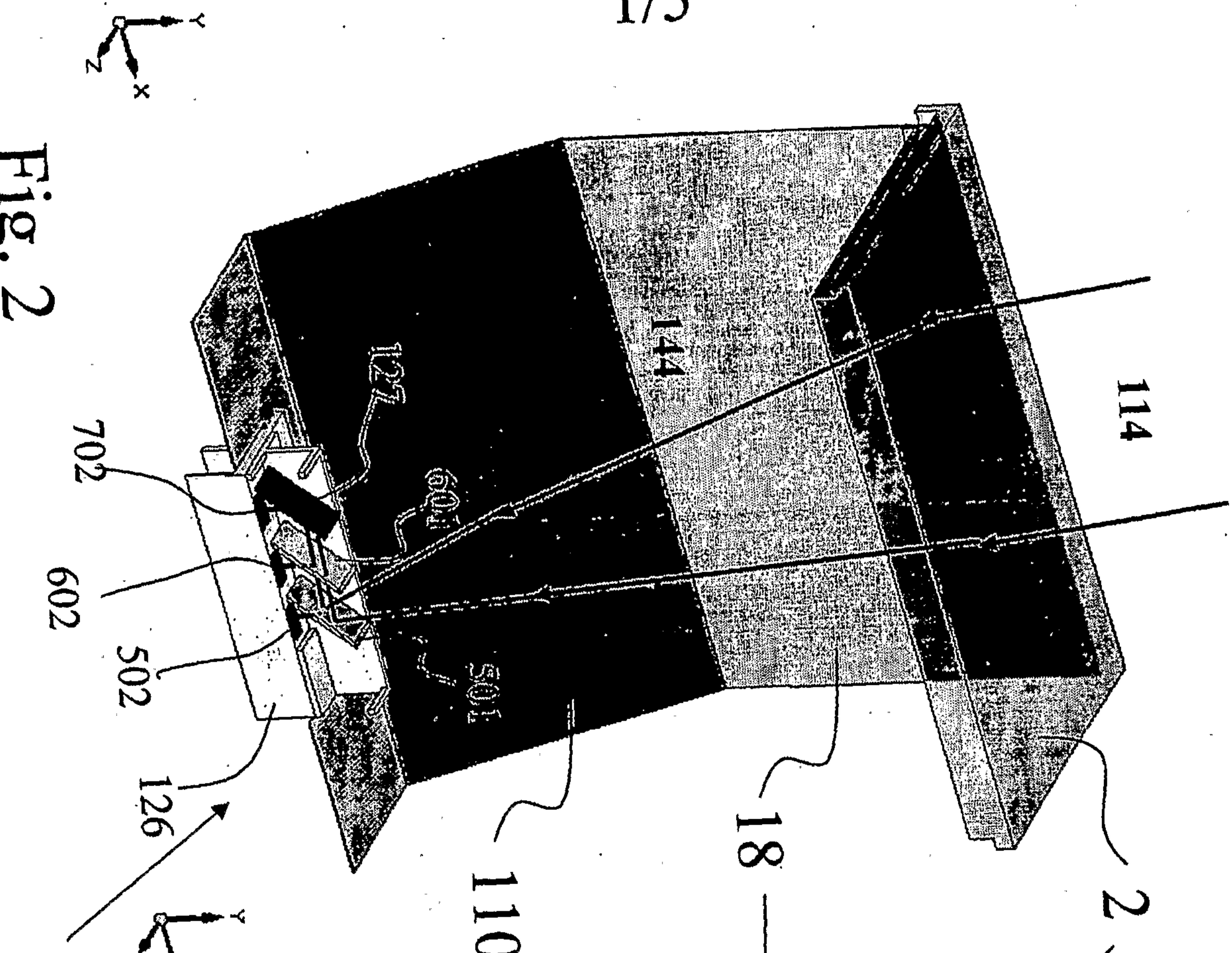
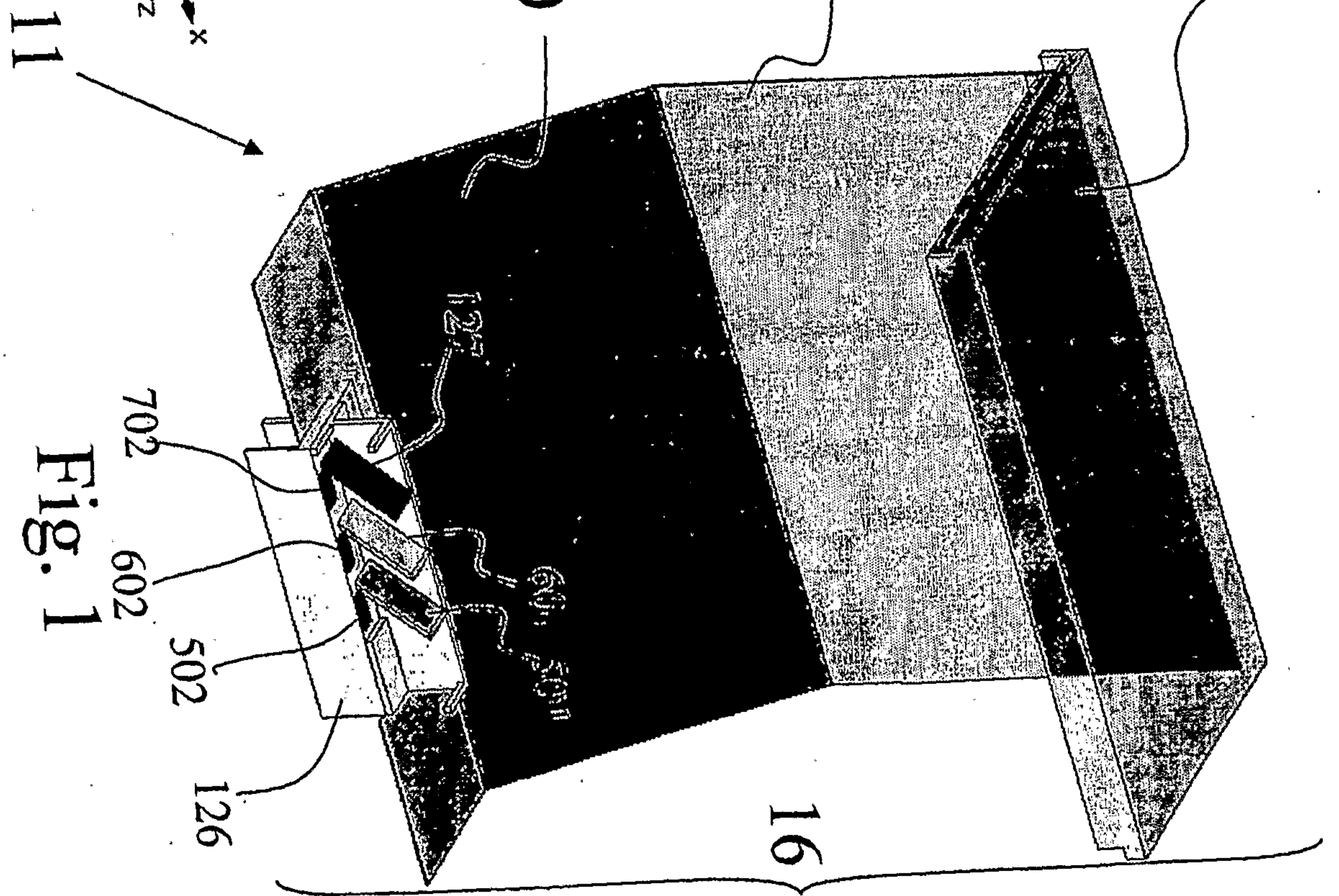


Fig. 1



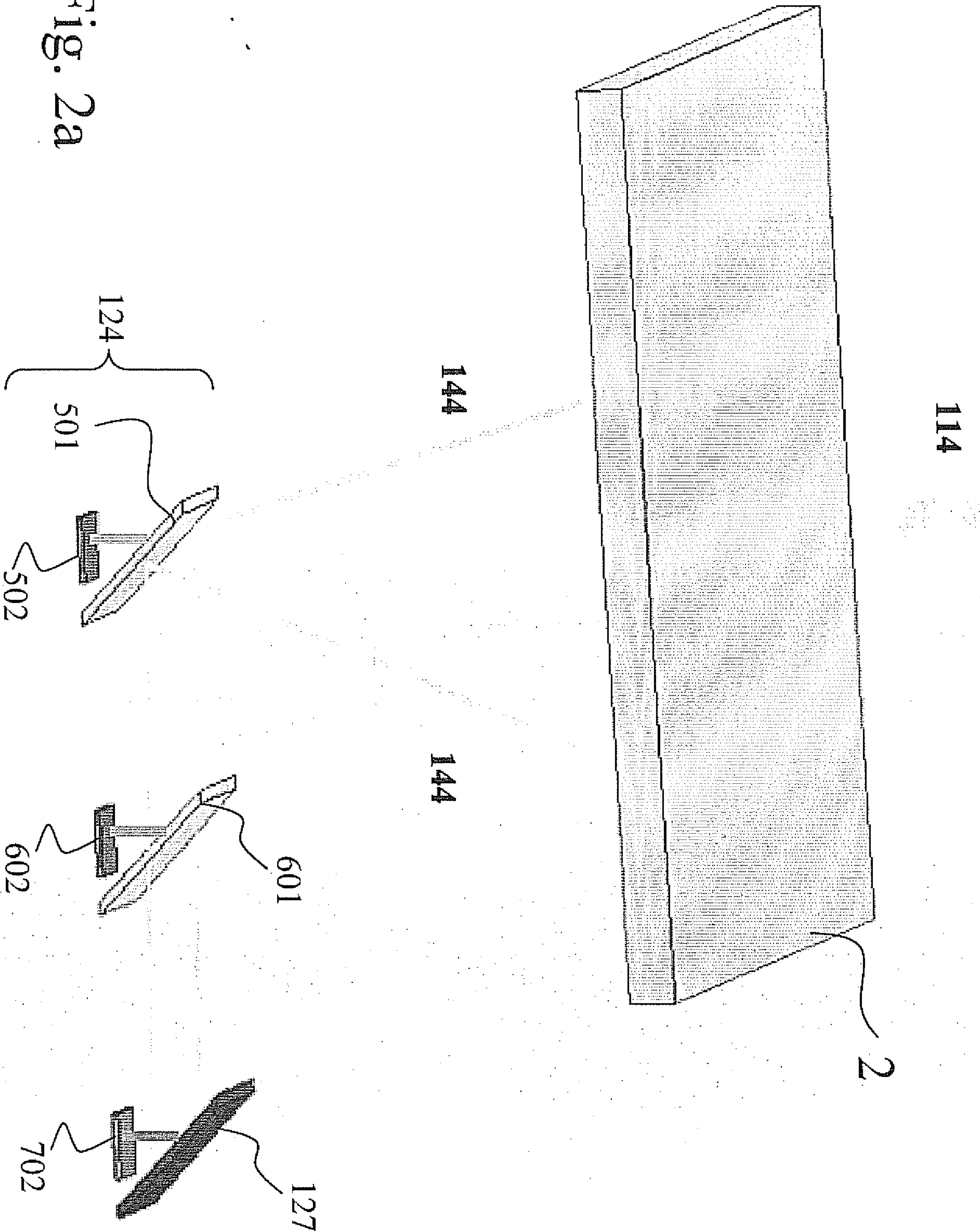


Fig. 2a

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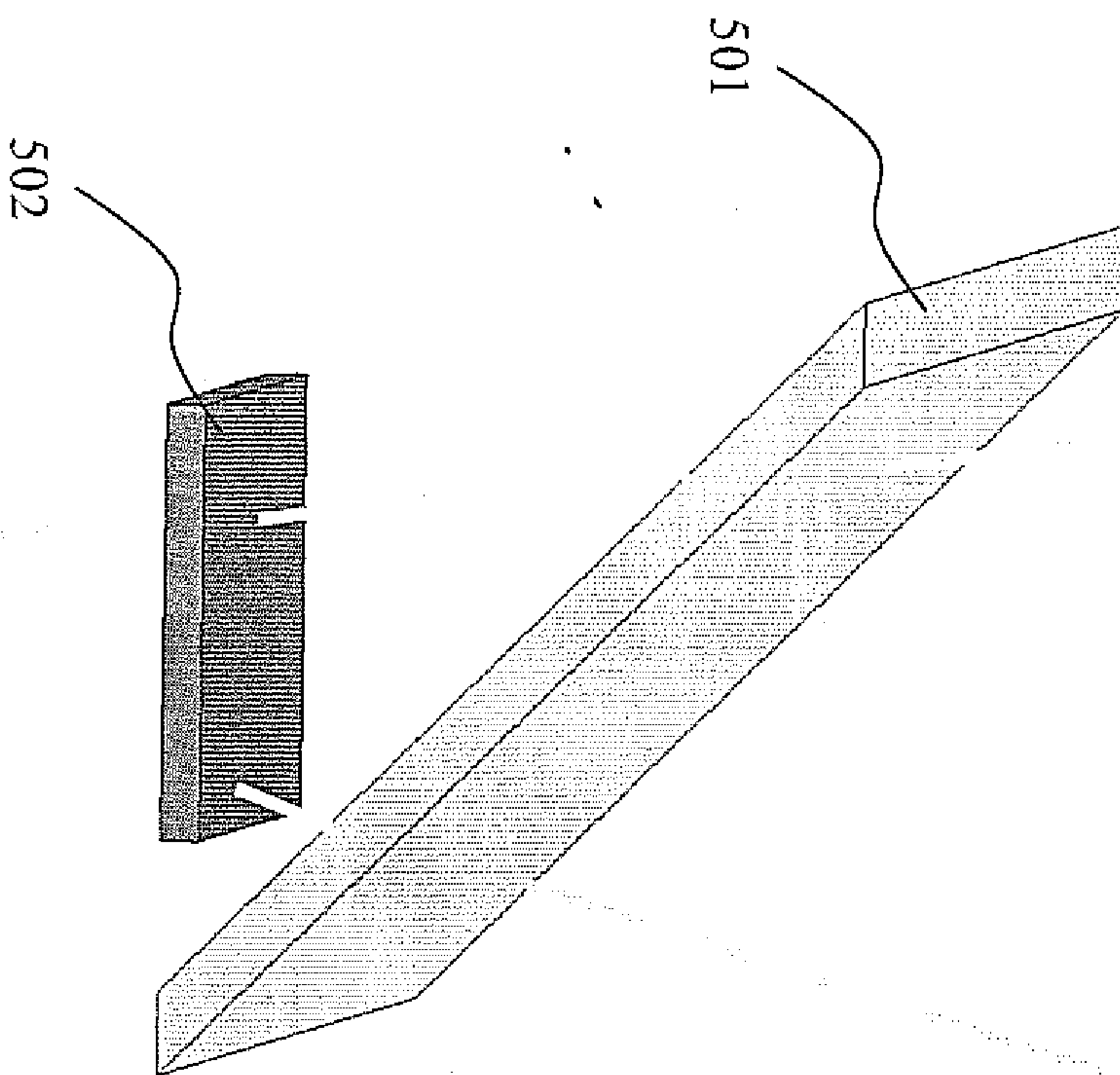


Fig. 2b

F10

144

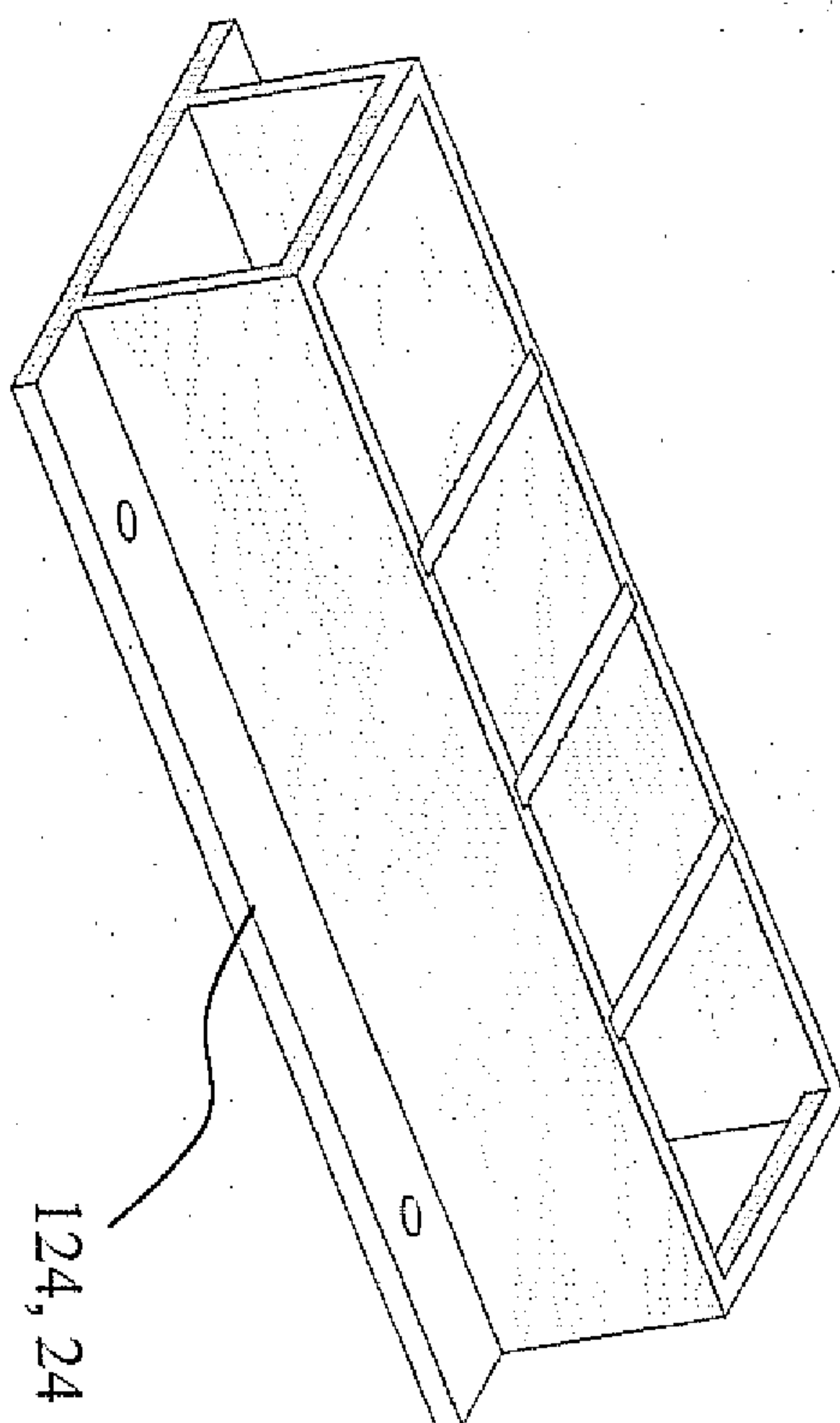


Fig. 2c

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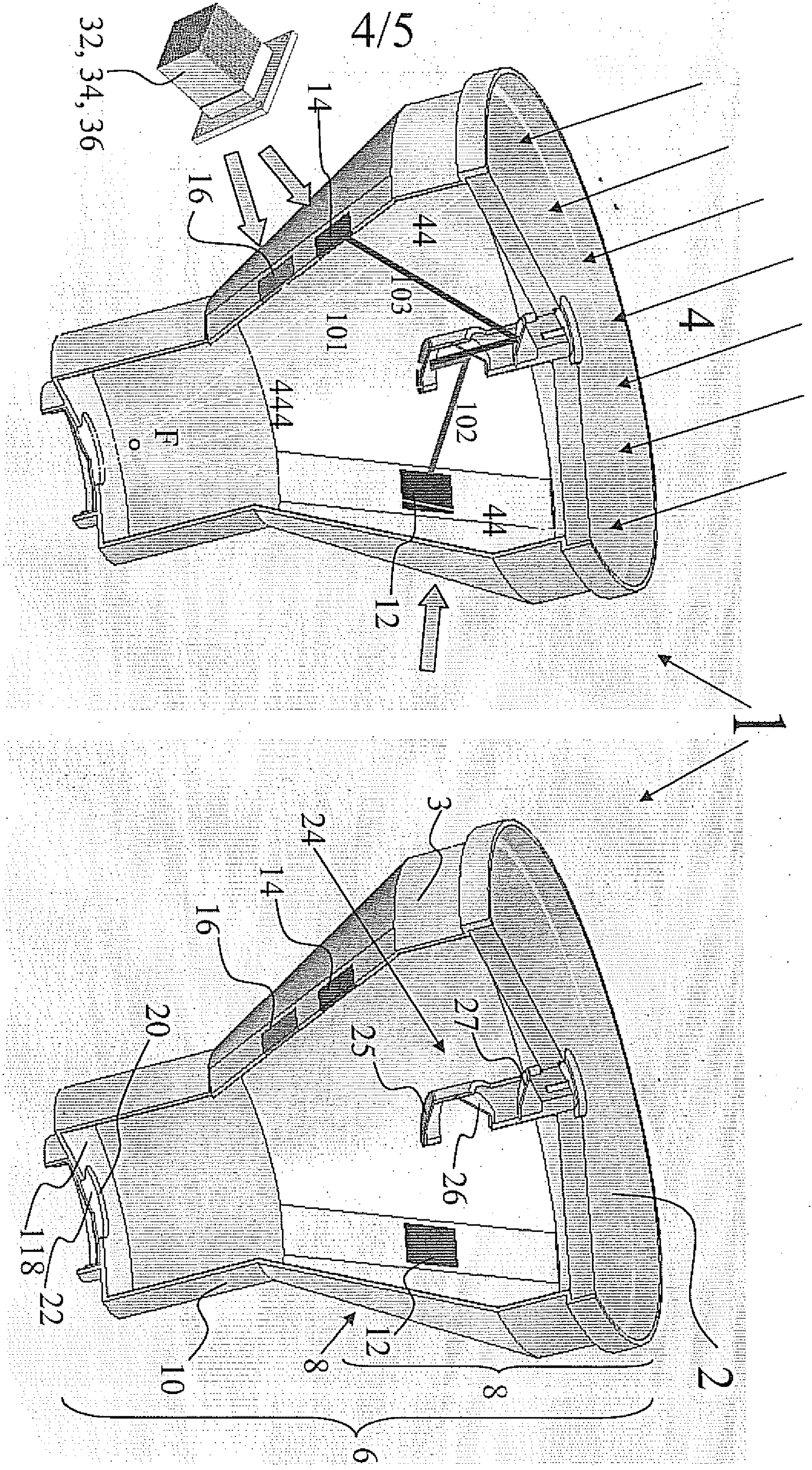


Fig. 4

Fig. 3

Fig. 6

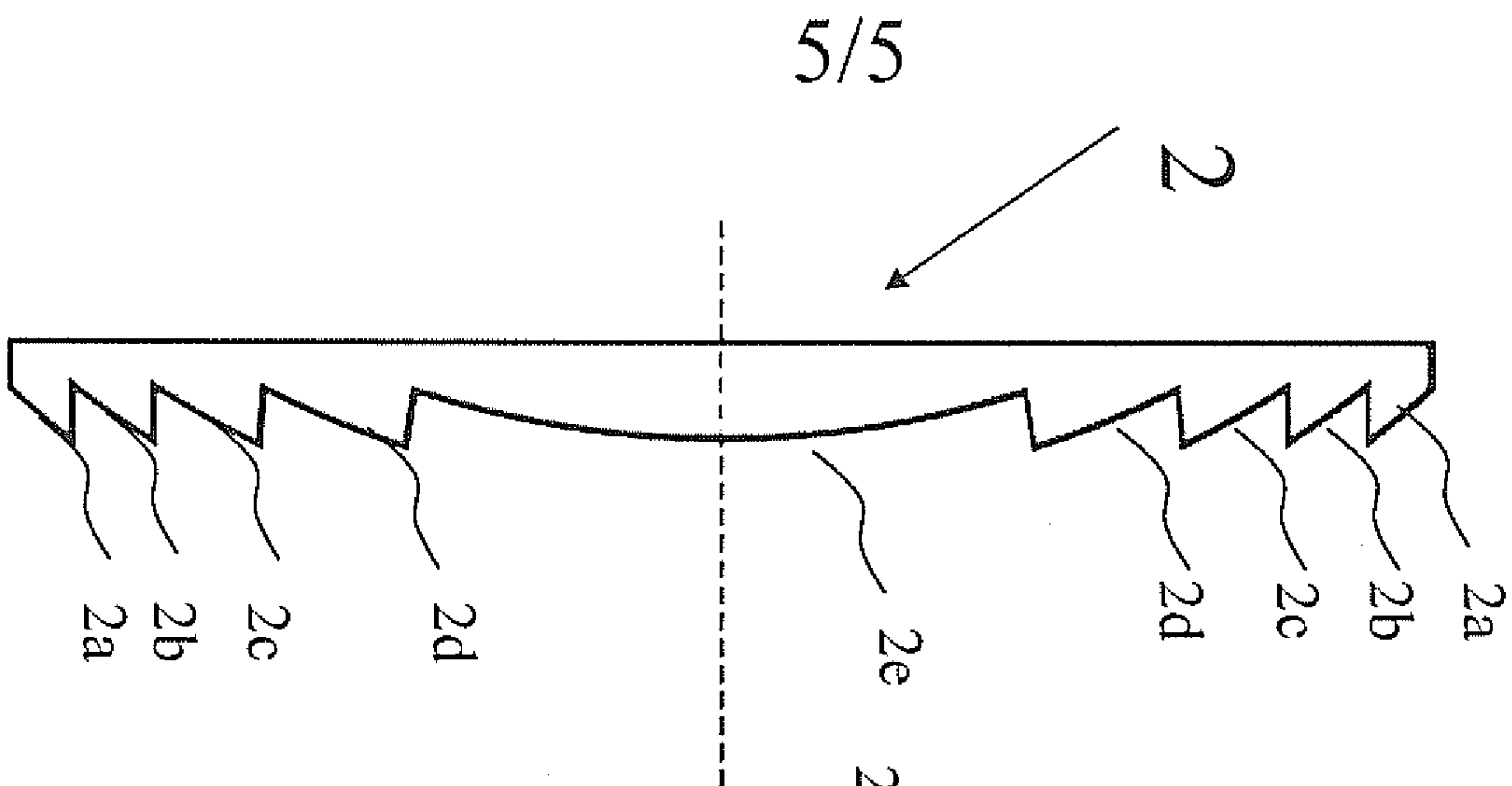
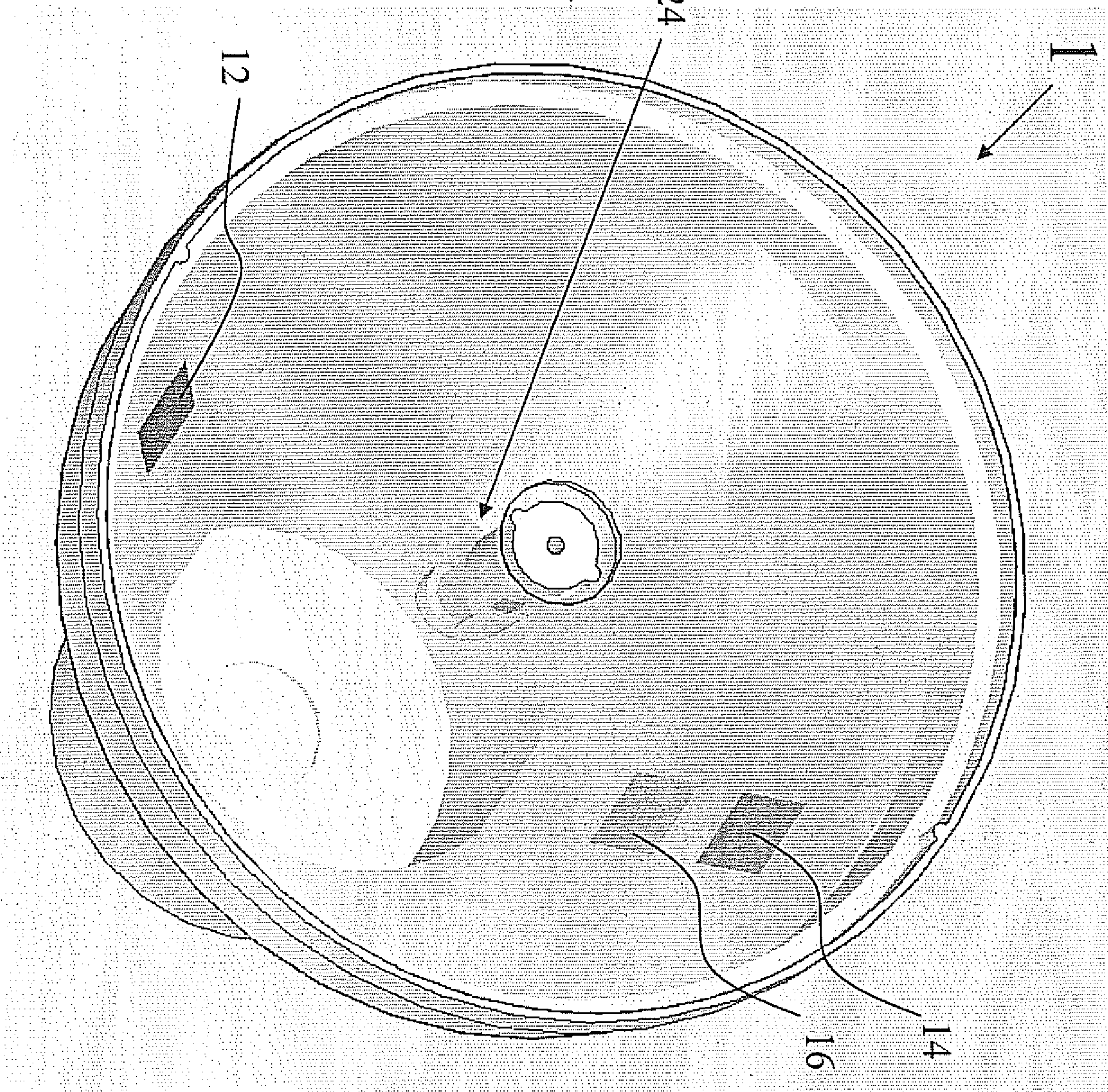


Fig. 5



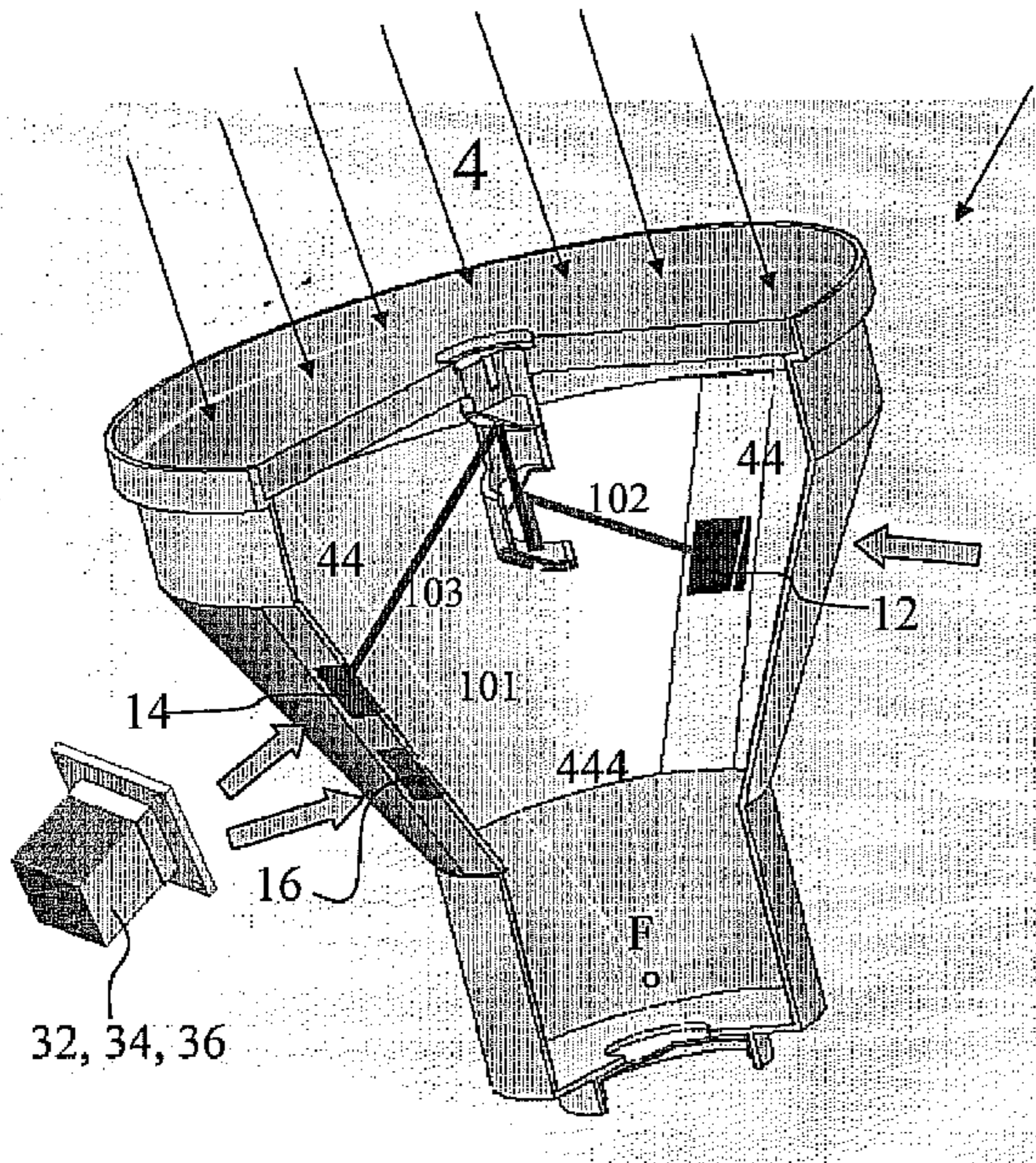


Fig. 4

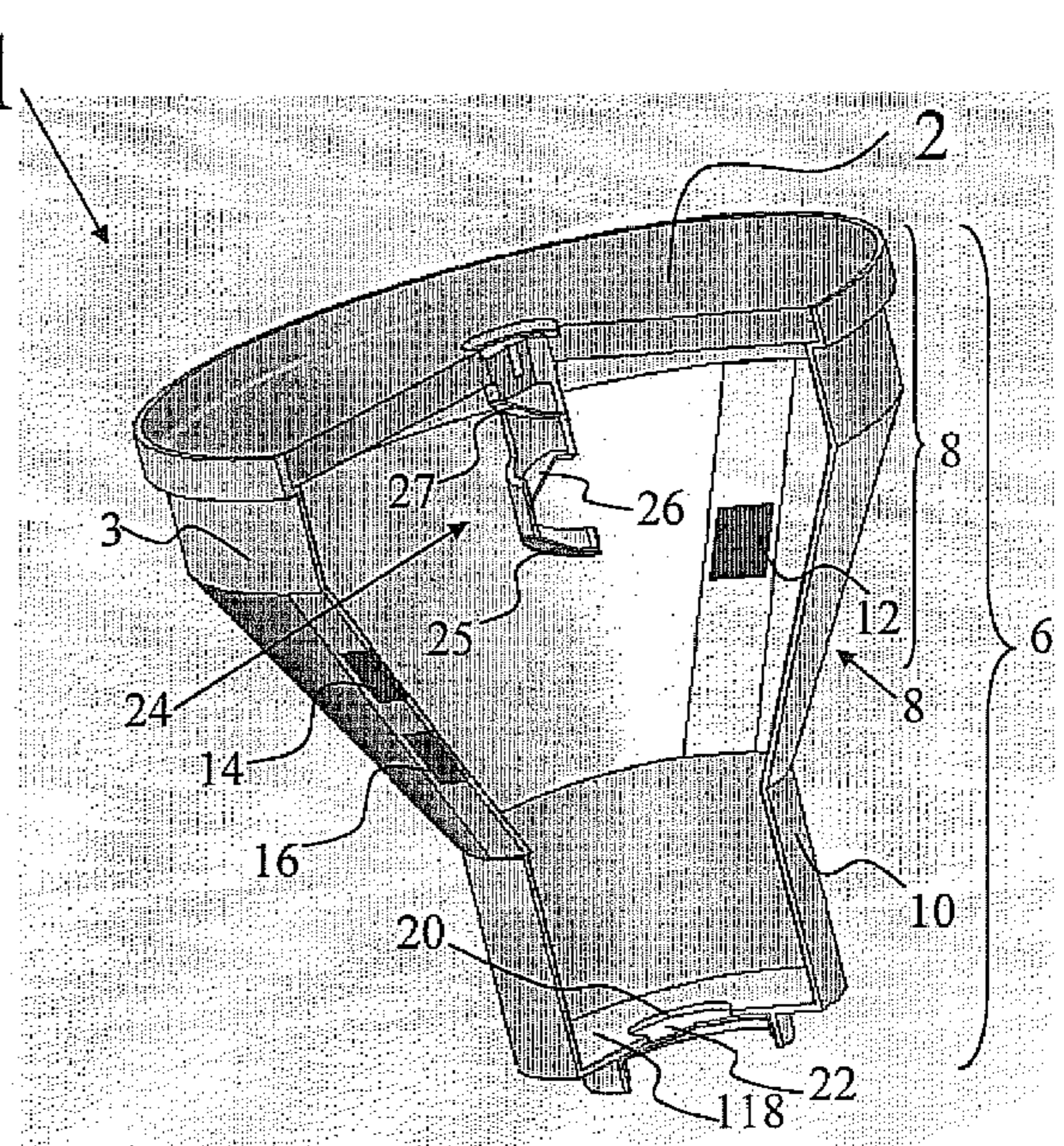


Fig. 3