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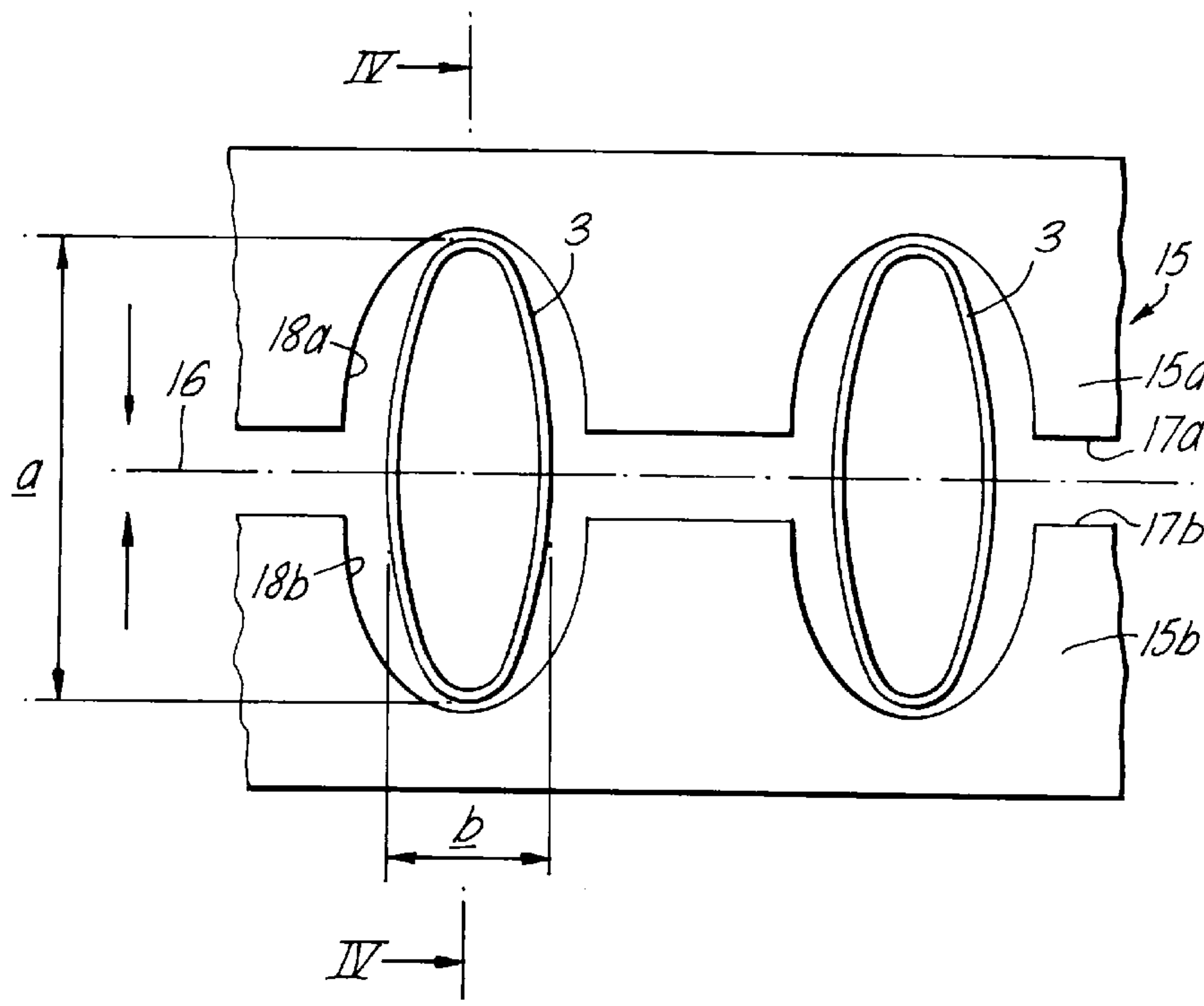
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(54) **ECHANGEUR DE CHALEUR ET METHODE DE MONTAGE
ETANCHE D'UNE PLAQUE D'EXTREMITÉ A UN FAISCEAU
D'ELEMENTS ECHANGEURS DE CHALEUR**

(54) **HEAT EXCHANGER AND A METHOD FOR A LIQUID-TIGHT
MOUNTING OF AN END PLATE TO AN ARRAY OF HEAT
EXCHANGING ELEMENTS OF THE HEAT EXCHANGER**



(57) Disclosed is a heat exchanger assembled of a plurality of oval heat exchanging pipes whose end portions are mounted in a leakage proof manner in oval openings of top and bottom plates. The ratio of major and minor diameters of intermediate portions of the pipes is 2.5 : 1 through 8 : 1 whereas the ratio of the major and minor diameters of the oval openings in the end plates is 1.2 : 1 through 3 : 1. A method of mounting the pipe end portions in the oval openings is based on a preliminary shaping of the end portions by the application of pressure from the outside toward the center axis of the end portions in the direction of their major diameter. The preshaped end portions are inserted into sealing collars surrounding the edges of respective plate openings. Thereafter the end portions are expanded by means of mandrels to sealingly close the openings.

ABSTRACT

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Disclosed is a heat exchanger assembled of a plurality of oval heat exchanging pipes whose end portions are mounted in a leakage proof manner in oval openings of top and bottom plates. The ratio of major and minor diameters of intermediate portions of the pipes is 2.5 : 1 through 8 : 1 whereas the ratio of the major and minor diameters of the oval openings in the end plates is 1.2 : 1 through 3 : 1. A method of mounting the pipe end portions in the oval openings is based on a preliminary shaping of the end portions by the application of pressure from the outside toward the center axis of the end portions in the direction of their major diameter. The preshaped end portions are inserted into sealing collars surrounding the edges of respective plate openings. Thereafter the end portions are expanded by means of mandrels to sealingly close the openings.

Heat Exchanger And A Method For A Liquid-Tight Mounting Of
An End Plate To An Array Of Heat Exchanging Elements Of The
Heat Exchanger

The present invention relates to a heat exchanger
having a network of heat exchanging elements which includes a
plurality of pipes of oval cross-section and end plates
5 provided with a plurality of openings for receiving end
portions of the oval pipes, a plurality of sealing elements
arranged in the openings and the end plates being attached
to the end portions by expanding the end portions of the oval
pipes. The invention also relates to a method for liquid-
10 tight mounting of at least one end plate to the network of
heat exchanging elements.

The mounting of heat exchanging networks on end
plates of a heat exchanger, such as used for example in a
motor vehicle radiator still involves problems when the pipes
15 of the heat exchanging network have an oval cross-section and
are supposed to be secured to the end plates by expanding
their end portions only, that means without the use of any
soldering, cementing and the like. Inasmuch the end plates
serve for supporting a collecting vessel which accumulates
20 the cooling medium flowing through the pipes of the heat
exchanger, the mounting of the end plate must be not only
liquid-tight or gas-tight but also mechanically stable to such
an extent that the unavoidable shaking or vibrations
resulting during the use of the heat exchanger do not impair
25 the mount and can withstand the hydraulic pressure of the

1 cooling medium. This condition, particularly when using oval
pipes as heat exchanging elements, cannot always be met
because the ratio of diameters of the oval pipes (i.e.
the ratio of the major outer diameter to the minor outer
5 diameter) is greater than about 2.5 : 1. In heat exchanging
pipes of this kind, the fastening of long pipe wall portions
extending substantially parallel to or in the direction of the
major diameter, in the elastic sealing collars of the end
wall, was frequently insufficiently strong. In spite of the
10 expansion of the end portions of the pipe there is still
the risk that the pipe wall portions extending parallel or
in the direction of the minor pipe diameter collapse and
thus preclude a reliable seal or a mechanically stable
connection.

15 The prior art heat exchanger of this kind (DE-OS
27 47 275), therefore have reinforced long sides of the
heat exchanging pipes, by providing for example wall portions
of greater thickness or annular inserts or a step-wise
enlargement. Such conventional measures however have
20 proved as unsatisfactory for a mass production.

For avoiding this disadvantage a heat exchanger
has been proposed (DE-PS 1,751,710) wherein the bottom end
plate is provided with circular cutouts or openings for
receiving sealing elements also of a circular cross-section
25 and the throughgoing oval end portions of the heat exchanging

1 pipes have been expanded to form a cylindrical or conical
configuration. By this measure the risk of collapsing is
practically eliminated. Of course, it must be taken into
account that such prior art heat exchanger and the
5 corresponding method for mounting the heat exchanging pipes
is suitable only for oval pipes having a diameter ratio of
approximately 2 : 1. When using the ratio of major to the
minor diameter of 2.5 : 1 and more, as required for heavy
duty motor vehicle radiators and the like, such expansion of
10 end portions of the pipes results in excessively long
transition zones between the pipe portion having a circular
cross-section and the pipe portion having an oval cross-
section. This brings about the danger that the pipes them-
selves or the sheet metal fins drawn thereon crack or
15 rupture or the immediately adjoining sheet metal fin is
shifted and thus the cooling efficiency is decreased. In
addition the use of cylindrical end portions of the heat
exchanging pipes in a series of side-by-side arranged heat
exchanging networks necessitate substantially increased
20 spacing between the pipes in comparison with oval
configuration of the end portions and consequently a
corresponding reduction of efficiency of heat exchanging
network in a heat exchanger of the same size would result.
Such substantial disadvantages can be only insignificantly
25 reduced by using heat exchanging pipes of an increased major

1 diameter corresponding to the diameter of the sealing collar,
and shaping the end portions of the pipe first by means of
an inserted expansion mandrel and the like in such a manner
that the major diameter is reduced and the minor diameter
5 is increased to provide the cylindrical cross-sections in the
end portions which are slightly smaller in diameter than the
sealing collars. Even this mounting procedure results in
large transition zones between the ranges of oval and
circular cross-sections, thus exhibiting again the above
10 mentioned problems.

It is therefore an object of the present invention
to provide a heat exchanger of the above described type which
enables a liquid-tight and a mechanically stable fixing of
oval end portions of the heat exchanging pipes having a
15 relatively large ratio of their diameters, for example 2.5 : 1
through 8 : 1, without the need of soldering or cementing.

Another object of this invention is to provide a
method for mounting the expanded end portions of the heat
exchanging pipes in an end plate wherein the risk of damage
20 of the pipe and/or of the guiding metal sheet and/or of the
sealing collar is eliminated.

Accordingly, the present invention relates to a heat exchanger having a heat exchanger core comprising a plurality of tubes of oval cross-section, each tube having a first end and a second end, each end and each tube having a major diameter, a minor diameter and a diameter ratio defined by the major diameter divided by the minor diameter, the diameter ratio of the tubes being greater than the diameter ratio of the tube ends. A first end plate and a second end plate are fixed to the first ends and the second
10 ends of the tubes, respectively, each end plate having a plurality of apertures. Sealing elements with through openings are aligned with the apertures. The sealing elements include sealing collars arranged in the apertures for surrounding the tube ends. The diameter ratio of the tubes is 2.5:1 to 8:1, and the tube ends are deformed by squeezing from the outside and subsequent widening from the inside whereby they have a diameter ratio of 1.2:1 to 3:1 in the region of the end plates.

Another aspect of the present invention relates to a
20 method for producing the above identified heat exchanger comprising the steps of deforming the tube ends into a non-circular form by squeezing from the outside, introducing the tube ends into the through openings, and expanding the tube ends in all directions transversely of their longitudinal direction from the inside, thereby providing a fluid-tight connection with the sealing collars. The deformation of the tube ends takes place in such manner that after the expansion they have a diameter ratio of 1.2:1 to 3:1.

1 The invention brings about the unexpected advantage
that, by selecting the dimensions of the cross-sections
of pipes in the range of their end portions, permanent good
connections between the end plates and the end portions of
5 the heat exchanger are obtained, even when the oval pipes
have a relatively large ratio of their major and minor
diameters namely between 2.5 : 1 and 8 : 1 and the end
portions preserve their oval form. With these ratios of
major and minor diameters the clamping of the end portions
10 of the pipes in the sealing collars is sufficient for all
practical applications even if made by a mass production and
the end portions preserve their oval shape. In this manner
it is made possible to design a heat exchanger assembled of
one or more arrays or series of heat exchanging pipes having
15 a high density of pipes per unit area, a high ratio of
major and minor diameters and a realiable liquid-proof
mounting to the end plates. With regards the method of this
invention it has the advantage that the mounting process of
the end portions of the pipes in the openings of the end

1 plate is very safe against damage so that even if using
large ratios of the major and minor diameters there is no
risk of damaging the pipe or the conductive metal sheet fins
attached thereto.

5 The invention will be explained in the description
of a preferred exemplary embodiment when read in connection
with the accompanying drawings, wherein:

FIG. 1 is a perspective view of a heat exchanger
having a series of oval heat exchanging pipes;

10 FIG. 2 is a top plan view of a portion of the heat
exchanger of FIG. 1 showing on an enlarged scale the ends
of the oval pipes together with applied pressing jaws shown in
their released position;

15 FIG. 3 is a view similar to FIG. 2 showing two rows
or series of oval pipes after shaping their end portions by
the pressing jaws shown in their closed position;

FIG. 4 is a sectional side view taken along the line IV-IV of FIG. 2, after the pressing jaws have been removed and shaped end portions of the pipes have been inserted into the openings in an end plate;

FIG. 5 is a view similar to FIG. 4 showing the insertion of tapered plugs or mandrels for expanding the shaped end portions of the pipes in the end plate;

FIG. 6 is a top plan view of partly cut-away portions of the heat exchanging network after the end portions of respective oval pipes have been secured to the end plate; and

FIG. 7a shows an elevation view, 7b a side view and 7c a plan view of the shaping mandrel of FIG. 5, illustrated on an enlarged scale.

FIG. 1 illustrates a heat exchanger having a single row of heat exchanging elements assembled in accordance with conventional pipe radiators. It includes a plurality of parallel sheet metal fins 1 stacked at a distance one above each other and each being formed with a series of oval openings which in the stack of the conductive metal fins 1 are in alignment so as to receive corresponding heat exchanging pipes 3. The edges of the openings in the conductive metal fins 1 are provided with collars 30 of a cross-section corresponding to the oval cross-section of the pipes 3 (FIGS. 4 and 5). The upper and lower end portions of respective pipes 3 project through openings 5 in the bottom end plate 6 and in the top end plate 7. As illustrated in FIGS. 4 and 5, the edges of the openings 5 are also bent to form peripheral collars 8 serving for attaching sealing means as it will be explained later on. A conventional cooling fluid collecting vessel 9 is attached to the bottom end plate 6; a connection piece 10 serves for feeding a liquid medium such as cooling water flowing through the pipes 3 into and from the collecting vessel 9. A corresponding, non-illustrated storage tank or collecting vessel is connected to the top end plate 7. The conductive metal fins 1 can be also provided with conventional arrays of gills for whirling a second cooling medium, such as air.

Referring to FIG. 2, each oval heat exchanging pipe 3 defines a major outer diameter a, in the following "a large diameter" which is about 2.5 through 8 times larger than the minor outer diameter b in the following "a small diameter" so that the ratio of the large to small diameters is 2.5 : 1 through 8 : 1. As indicated in FIG. 3, the heat exchanger can be assembled of a plurality of parallel rows or series of heat exchanging pipes arranged side-by-side in alignment with their small diameters b.

In this exemplary embodiment it is assumed that the large diameter a is 12.4 mm and the small diameter b is 3.6 mm and that the wall thickness of the pipes is 0.4 mm. Further it is assumed that the pipes 3 are firmly connected to the conducting metal fins 1, thus forming therewith a so-called heat exchanging network 11 (FIG. 1) This interconnection is achieved in conventional manner, known for example from the manufacturing of oil or water cooled radiators for motor vehicles.

To connect the heat exchanging network 11 with the end plates 6 or 7, it is proceeded in accordance with the below described method of this invention. Since either end plate 6 and 7 is secured to the heat exchanging pipes 3 in the same manner, in the following description only the attachment of the top end plate 7 will be described.

In this embodiment the end plate 7 is formed with a

1 plurality of oval cutouts or openings 5 whose maximum inner
diameter is 13.2 mm and whose minimum inner diameter is
8.7 mm. The same dimensions are valid for the diameters of
the collars 8. The bottom plate 7 is further provided with
5 sealing elements 12 (FIGS. 4 and 5) each defining a sealing
collar 14 surrounding an assigned collar 8 of the openings
and delimiting a throughgoing passage 13 for receiving an
end portion of the pipe. The sealing element 12 if desired
can be connected to a sealing mat or plate extending over the
10 width and length of the top end plate 7. The sealing plate
is loosely laid on the surface of the end plate so that the
sealing collars 14 project into the collars 8 of the plate 7
and firmly engage the inner surface of the collars 8. In a
modification, the sealing elements 12 can be applied by
15 spraying and firmly connected to the end plate 7 by
vulcanization (DE-OS 35 05 492). The sealing elements 12 are
made of a sufficiently elastic material, for example of an
elastomer. In this example, throughgoing passages 13 of the
sealing collars 14 have a maximum inner diameter of 11.3 mm
20 and a minimum inner diameter of 6.8 mm.

Prior to the insertion of the pipes 3 into the
sealing collars 14, the end portions of the pipes 3 are
shaped by the application of pressure from the outside toward
the center axis of the end portions in such a manner that the
25 large diameter a is reduced to 11.1 mm and the small

1 diameter b is increased to 6.6 mm. For this preshaping
process a pressing tool 15 illustrated in FIG. 2 is employed.
The pressing tool consists of two plate-shaped pressing or
shaping jaws 15a and 15b which extend from opposite sides
5 along an axis 16 coinciding with the minimum diameters of the
oval pipes 3 arranged in a row. The pressing jaws 15a and
15b have abutment surfaces 17a and 17b extending parallel to
the axis 16, and opposite shaping recesses 18a and 18b
provided between the respective abutment surfaces or edges 17a
10 and 17b. The recesses 18a and 18b have a semi-oval cross-
section to delimit in the closed position of the pressing
tool 15 illustrated in FIG. 3 a closed oval outline 19 whose
maximum inner diameter is normal to the axis 16 and whose
minimum inner diameter coincides with the axis 16. The
15 spacing between the respective shaping recesses 18a and 18b
in the direction parallel to the axis 16 corresponds to the
spacing between the pipes 3 in a row or series. The closed
oval outline 19 in this example has a maximum diameter 11.1 mm
the minimum diameter 6.6 mm. The thickness of the plate-
20 shaped pressing jaws 15a and 15b is preferably so large as
is the length of the sealing collars 14 plus a distance of
the end portion of the pipe which projects above the sealing
elements 12 when viewed in the axial direction of the pipes.
The overlapping length of the end portions serves for
25 neutralizing longitudinal and angular tolerances of the pipes

1 and of the end plates. In addition, the width of the pressing
tool also includes a transition range of a length l (FIG. 4)
corresponding to the transitory region between the prepressed
end portions of the pipes and the oval cross-section of the
5 unchanged parts of the pipe in the network.

The pressing jaws 15a and 15b, as seen from FIGS. 2
and 3, are applied against the upper surface of the end
portions of the heat exchanging pipes 3. The two pressing
jaws are then compressed one against the other by means of a
10 non-illustrated mechanical, pneumatic, hydraulic or electrical
device in the direction of arrows (FIG. 2) until the abutment
surface portions 17a and 17b contact each other whereupon the
pressure is released by moving the jaws in the direction
opposite to the arrows. As a result, the end portions are
15 preshaped from the outside to the shape of the oval contours
19 of the pressing jaws (FIG. 3) such that the large diameter
of the end portions is reduced to 11.1 mm and the small
diameter is increased to 6.6 mm. Accordingly, the end
portions of the pipes have a cross-section which permits the
20 insertion into the sealing collars 14 which was not possible
prior to the prepressing step. Line 20 in FIG. 3 indicates
the outline of the end portions in their original condition
prior to their preshaping; the line 20 also corresponds to
the outline of the remaining unshaped part of the pipes 3
25 which are partially visible in the plan view of the end

1 portions.

2 If the exchanging networks contain several rows
3 of heat exchanging pipes 3 as it is schematically indicated in
4 FIG. 3, the end portions of the remaining pipe rows are
5 preshaped in the same fashion whereby the individual rows are
preferably treated one after the other with the same pressing
tool 15.

6 In the subsequent step the end plate 7 provided with
7 the sealing elements 12 is laid on the preshaped end portions
8 of the network of heat exchanging pipes as shown on an
9 enlarged scale in FIG. 4. It is evident that the preshaping
10 enables the insertion of the end portions into the free spaces
delimited by the sealing collars 14. In reality the free
space amounts for example to only one to two tenth of a
15 millimeter. The top end plate 7 of course has been provided
with the corresponding number of rows of cutouts or openings
5.

16 The final fastening of the end plate 7 to the
17 heat exchanging network 11 is effected such that the end
18 portions are expanded in a conventional manner by means of
19 tapered plug or mandrel 21. For this purpose a number of
20 mandrels 21 is inserted into the corresponding number of pipe
end portions and are connected via supporting elements 22 to
a common driving device. According to FIG. 5, each mandrel 21
25 has an oval outer cross-section connected via sloping

1 surfaces 23 with a tip region 24 of smaller diameter which is
first inserted into the pipe end portion. In this example
the outer diameter of the mandrel 21 is selected such that
the pipe end portions are expanded through a single insertion
5 of the mandrel 21 to match their outer outline defining a
large diameter of 12 mm and a small diameter of 7.9 mm. Due
to the expansion, the elastic walls of the sealing collar 14
are expanded in the direction of its large diameter by 0.35 mm
and in the direction of its small diameter by 0.55 mm, that
10 means the pipe end portions are more strongly shaped in the
direction of their small diameters.

Inasmuch as when using heat exchanging pipes
dimensioned in accordance with this example the danger is
present that the pipe end portions during their tulip-shaped
15 expansion by means of the mandrel 21 might crack, it is
preferred to perform the expansion in two steps whereby each
of the steps includes two processing stages.

In the first expanding step the mandrels 21
according to FIG. 7 are used whose large diameter $\underline{m}$ and small
20 diameter $\underline{n}$ are for example 0.6 mm smaller than the diameters
of final inner cross-sections of the pipe end portions. In
the second expanding step are again used the mandrels 21 of
FIG. 7 whose diameters $\underline{m}$ and $\underline{n}$ correspond to the final
dimensions of the pipe sections. An advantage of this measure
25 in comparison with the shaping by means of a single step is

1 in the more gentle treatment of the end portions resulting in
the greatly reduced possibility of cracking the pipes.

5 It is also of particular advantage when each of the
two steps is performed in two stages whereby the pipe end
portions are first gradually expanded over the large diameter
and then while maintaining the resulting value of the large
diameter, are gradually expanded over the small diameter that
means transversely to the long sides of the pipes. This
10 procedure has an advantage in comparison with the gradual
simultaneous expansion of the end portions in all directions
in that the shaping of the particularly crack susceptible
portions of the pipe having small radius of curvature are
protected by allowing the influx of material from the
adjoining pipe portions of a larger radius of curvature, since
15 the latter portions at time point of shaping are not yet
brought in contact with the flanks of the mandrel and there-
fore are not yet frictionally attached to the latter.

20 According to FIGS. 7a through 7c the tip 24 of the
mandrels 21 is shaped to form a knife-like edge so that the
pipe in the transition region between the end portion and the
intermediate pipe portion does not collapse due to compressive
strain and does not diminishes its diameter in this range.
Such an upsetting of the pipe 3 might appear during the
sliding travel of the mandrel and the resulting thrust in the
25 longitudinal direction of the pipe 3. In particular, the

1 tip 24 is shaped such that its small diameter is somewhat
shorter than the small inner diameter of the intermediate
portion of the heat exchanging pipe, and its large diameter is
somewhat smaller than the large inner diameter of the pipe
5 end portions after the compressing. In this manner it is
guaranteed that the long side walls of the pipes 3 contact
the tip 24 and are supported thereon only then when they have
actually buckled out inwardly.

As seen from FIG. 7a, the tip portion 24 is
10 connected with an intermediate mandrel section 25 extended
in the feeding direction of the mandrel to provide the above
explained first expansion stage in the direction of the large
diameter to a preselected value; the large diameter of the
intermediate portion 25 gradually increases from the tip
15 portion outwardly up to the value m of the large diameter
whereupon up to the end of the mandrel it remains substanti-
ally constant. The intermediate mandrel portion 25 is
connected - when viewed in the feeding direction of the
mandrel- to receiving mandrel portion 26 which performs the
20 aforescribed second expanding stage in the direction of the
small diameter to a preselected value. The smaller diameter
of the receiving portion 26 has a gradually increasing value
when viewed from the beginning of the mandrel portion 25 to
reach the value n of the small diameter (FIG. 7b) whereupon it
25 remains substantially constant up to the end of the mandrel.

1 As seen in FIGS. 7a and 7b, difference k denotes the
distance at which, when viewed in the feeding direction of the
mandrel 21, the large diameter m is completed ahead of the
small diameter n. The two portions 25 and 26 of the mandrel
5 can be arranged one after the other in such a manner that the
expansion in the direction of the small diameter starts only
after the expansion in the direction of the large diameter
is completed. It is also possible to offset the two mandrel
sections 25 and 26 one from the other and to make them
10 partially overlapped so that the expansion parallel to the
small diameter starts before the expansion parallel to the
large diameter is fully completed.

As indicated in FIG. 6, the end portions of pipes 3
are permanently and firmly connected with the end plate 7.
15 Subsequently the completed heat exchanging network 11 is
connected in conventional manner with the lid of an assigned
cooling liquid collecting vessel whose peripheral rim is
inserted for example in a corresponding peripheral groove 27
provided with a sealing agent; subsequently the vessel is
20 fastened to the plate 7 by bending its clamping prongs.
In the case of end plates 6 and 7 and the covers of the
collecting vessels made of a plastic material the connection
may be made for example by means of vibration welding,
glueing and the like.

25 As mentioned before, in this exemplary embodiment

1 the original ratio of diameters of the pipe 3 ($12.4 : 3.6 =$
3.44) is first changed by means of the pressing jaws 15a and
15b to $11.1 : 6.6 = 1.68$ and then by expansion through the
mandrels 21 is changed to $12 : 7.9 = 1.52$ to smaller values.

5 A particular advantage of the preshaping by means of
pressure being applied from outside on the outer surfaces of
the pipe end portions is to be seen in the fact that even
if the pipes 3 have been shaped the circumference is
substantially unchanged. Therefore the shaping process takes
10 place without stretching the pipe walls and without the so-
called stiffening of participating layers of material
resulting from such a stretching; therefore during the final
expansion of the end portions there is no risk of cracking
of the pipe walls or of the collars. The expansion can be
15 also performed in such a manner that the sealing collars 14
are prestressed uniformly in all radial directions, that means
substantially radially to a center axis of the pipes and if
desired also in a preferred direction, for example parallel
to the small diameters provided that such a prestressing is
20 advantageous for individually employed sealing collars.

Another substantial advantage of the method of this
invention is to be seen in the fact that the large diameter
of the pipe can be larger than the large diameter of the end
portions after their expansion. As a result it is possible
25 to produce compact, narrow heat exchangers wherein the

1 minimum spacing between the walls of pipes 3 in heat
exchanging networks (dimension c in FIG. 6) in the direction
of the large diameter is smaller than the corresponding
spacing of the inner walls of the sealing collars after the
5 insertion of the latter into the collars of the end plate.
For this reason the method of this invention is suitable
primarily for connecting the heat exchanging network with
end plates of metal wherein this spacing, in contrast to end
plates made of plastic, is limited for manufacturing reasons.
10 Still another essential advantage of this invention is in the
fact that the expansion of the end portions can proceed
without gradation and therefore the pipe end portion does not
become overloaded.

It will be understood that this invention is not
15 limited to the details of this exemplary embodiment but can
be modified without departing from the spirit of this
invention. For example the exemplary ratio of the diameters
of the pipe in the heat exchanger of this invention can be
varied within broad limits. For example ratio of diameters
20 preferably of 2.5 : 1 through 5 : 1 but also 5 : 1 through
8 : 1 for the oval pipes 3 of the heat exchanging network,
and ratios of 1.2 : 1 through 3 : 1 for the pipe end portions
in a completed heat exchanger have been proved particularly
suitable. It is also conceivable to make the preshaping of
25 cross-section of the pipe end portions to match the cross-

1 section of the sealing collars by applying pressure from the
interior outwardly as long as only the preshaping of a
substantially constant periphery is desired. Furthermore, it
is not necessary to perform the preshaping such that the
5 modified cross-section of the pipe end portions is exactly
oval since other configurations of the cross-section for
example rhombic cross-sections or the like may provide
comparable results. In addition, it is also possible during
the shaping process to introduce a mandrel into the pipe end
10 portion which during the shaping acts as an inner abutment
support for the pipe walls. Furthermore, the invention is
not limited to the use of end plates provided with the plate
collars 8. Especially when using end plates of plastic the
collars 8 can be completely dispensed with. By a suitable
15 selection of the wall thickness of the plastic end plates it
is insured that the inner surface of the cutouts or openings
in the end plates are sufficient for reliably holding via
the sealing elements 12 and the sealing collars 14 the pipes
in the end plate openings. If desired, the inner surface of
20 the plate openings can have also a stepped configuration.
Another advantage of end plates of plastic material resides
in that for manufacturing and technological reasons
(production of end plates by injection molding without
drawing the plate collars) the spacing between pipe rows and
25 thus the depth of the heat exchanging network can be made

1 still smaller than when using end plates of metal.

5 The invention is not limited to oval pipe cross-sections in a strictly mathematical sense. Under the term "oval" for the purposes of this invention are to be understood all approximately oval or elliptical or eggs-shaped and the like cross-sections defining for example two parallel straight opposite sides whose ends are connected by oval, elliptic, semi-circular and the like curved end portions. Also the pipes having such modified cross-sections should define the ratio of the major diameter to the minor diameter amounting between 2.5 : 1 through 8 : 1.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. A heat exchanger having a heat exchanger core comprising:
a plurality of tubes of oval cross-section, each tube having a first end and a second end, each end and each tube having a major diameter, a minor diameter and a diameter ratio defined by the major diameter divided by the minor diameter, the diameter ratio of the tubes being greater than the diameter ratio of the tube ends;
a first end plate and a second end plate fixed to the first ends and the second ends of the tubes, respectively, each end plate having a plurality of apertures; and
sealing elements with through openings aligned with the apertures, the sealing elements including sealing collars arranged in the apertures for surrounding the tube ends;
wherein:
the diameter ratio of the tubes is 2.5:1 to 8:1; and
the tube ends are deformed by squeezing from the outside and subsequent widening from the inside whereby they have a diameter ratio of 1.2:1 to 3:1 in the region of the end plates.

2. The heat exchanger according to claim 1, wherein the major diameters of the tubes are greater than the major diameters of the tube ends in the region of the end plate.

3. A method for producing the heat exchanger according to claim 1 or 2, comprising the steps of deforming

the tube ends into a non-circular form by squeezing from the outside;

introducing the tube ends into the through openings; and expanding the tube ends from the inside, in all directions transversely of their longitudinal direction, thereby providing a fluid-tight connection with the sealing collars; wherein the deformation of the tube ends takes place in such a manner that after the expansion they have a diameter ratio of 1.2:1 to 3:1.

4. The method according to claim 3, wherein the cross-sections of the through openings are oval and are only slightly larger than the cross-sections of the tube ends obtained after the squeezing operation.

5. The method according to claim 3 or 4, wherein the expanding takes place in such manner that the major diameter of the tube ends remain smaller than the major diameter of the tubes.

6. The method according to claim 3, 4 or 5, wherein the expanding of said pipe end is performed in two steps.

7. The method according to claim 6, wherein each step is carried out in two stages and the full major diameter of the tube ends is reached in each case before the full minor diameter of the tube ends.

8. The method according to any one of claims 3 to 7, wherein mandrels having a first portion preceding in the

direction of insertion and producing a preselected major diameter and a following second portion producing a preselected minor diameter are pushed into the tube ends for expanding them.

9. The method according to claim 8, wherein tips of the mandrels preceding the first mandrel portions prevent falling-in of the tubes in transitional zones between the tube ends and intermediate tube portions located therebetween.

10. The methhodo according to any one of claims 3 to 9, wherein the squeezing is carried out in such manner that the circumference of the tube ends remains substantially unchanged.

11. A method of liquid-tight mounting of an end plate to a plurality of heat exchanging tubes with substantially oval cross-sections, each tube having a first major diameter, a first minor diameter, and a first diameter ratio of the first major diameter to the first minor diameter of 2.5:1 to 8:1, said method comprising the steps of:
providing the end plate with a plurality of openings for receiving the heat exchanging tubes;
providing a plurality of sealing elements extending into said plurality of openings and defining elastically-deformable and substantially oval passages having, in an undeformed condition of said sealing elements, second major diameters and second minor diameters;

preshaping end portions of the heat exchanging tubes by applying outer pressure to the end portions in a direction of the first major diameter to reduce the first major diameter to a third major diameter and to increase the first minor diameter to a third minor diameter at the end portions without substantial change of the circumferences of said end portions and such that said end portions can be inserted into said passages without substantial stress and force; inserting the end portions of the heat exchanging tubes into the elastically deformable passages of said plurality of sealing elements; and providing liquid-tight and mechanically-stable connections of the end portions of said heat exchanging tubes with the end plate by expanding the end portions and said sealing elements in all directions from inside thereof; whereby cross-sections of the tube ends remain substantially oval, have fourth major diameters greater than said second major diameters and fourth minor diameters greater than said second minor diameters, and have second diameter ratios of the fourth major diameters to the fourth minor diameters of 1.2:1 through 3:1, the first ratios being always larger than the second ratios.

12. The method according to claim 11, wherein said step of providing a plurality of sealing elements comprises the steps of providing a plurality of sealing elements having collars defining elastically deformable oval passages and of inserting said sealing elements into said openings, and said preshaping step includes preforming the end portions of the heat exchanging tubes in such a manner that

the end portions have substantially oval cross-sections that are smaller by a minute clearance when compared with cross-sections of the elastically deformable oval passages defined by the collars of the sealing elements.

13. The method according to in claim 11 or 12, wherein said expanding step is performed in two steps.

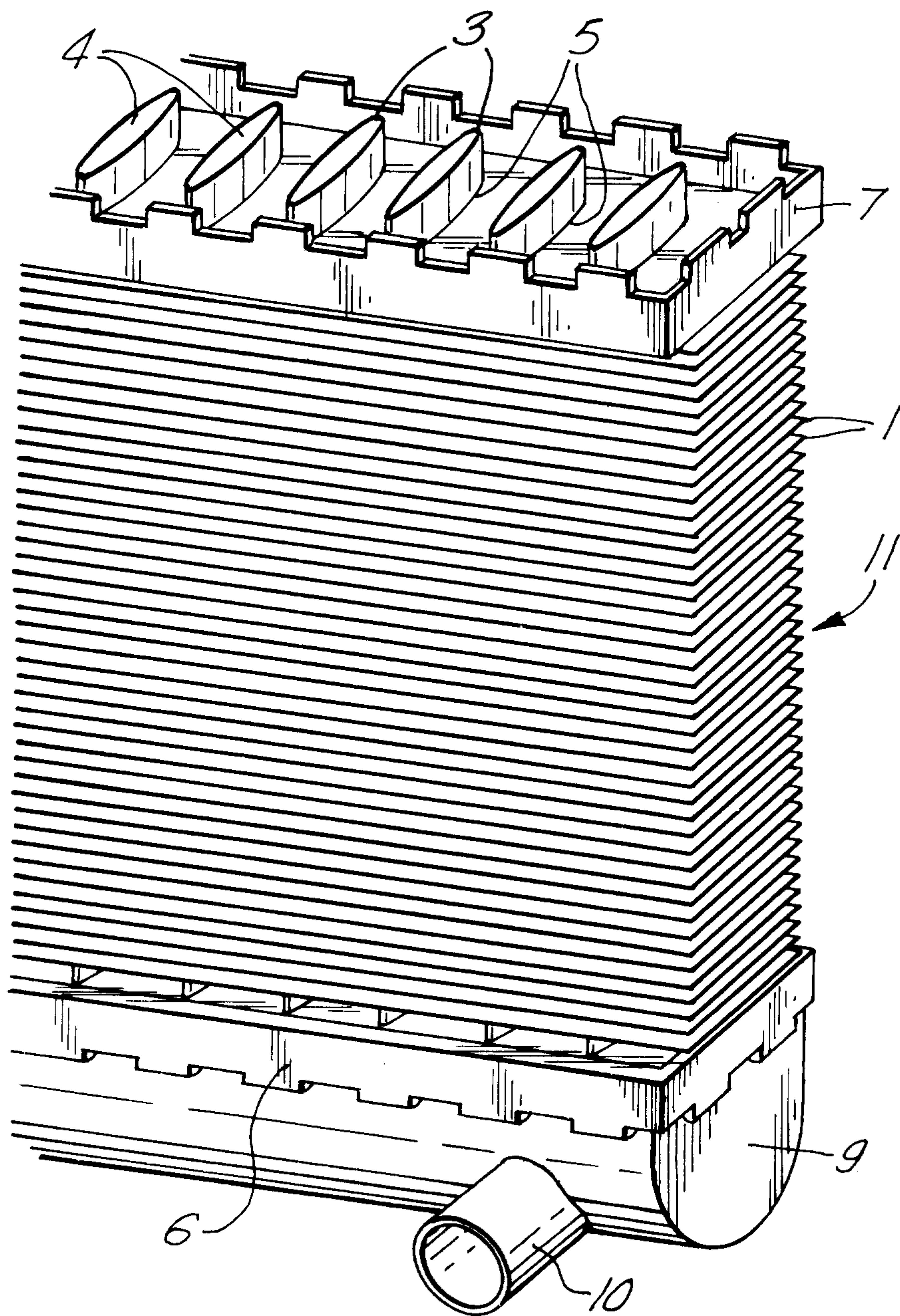
14. The method according to claim 13, wherein each of said two steps is performed in two stages in such a manner that expansion in a direction of the fourth major diameters is completed before expansion in a direction of the fourth minor diameters.

15. The method according to claim 13 or 14, wherein said expanding step includes the step of providing mandrels for each of said two steps axially insertable into said end portions and having leading regions for producing predetermined fourth major diameters of the end portions and having trailing regions for producing predetermined fourth minor diameters of the end portions.

16. The method according to claim 15, wherein said mandrel providing step includes providing mandrels having an edge-like projecting tip portion for preventing deformation of transition regions between the end portions and intermediate portions of the heat exchanging tubes.

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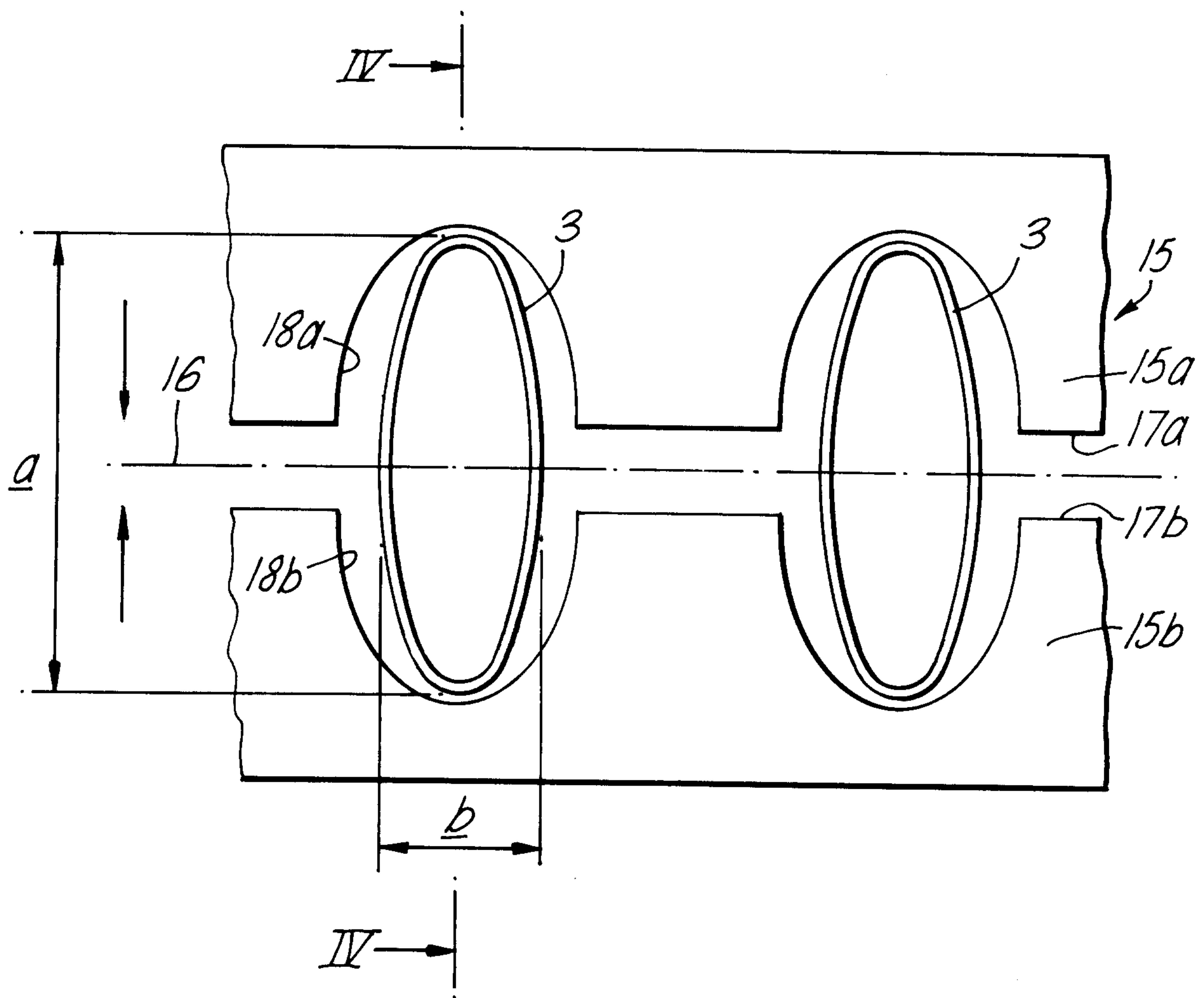
Fig. 1.



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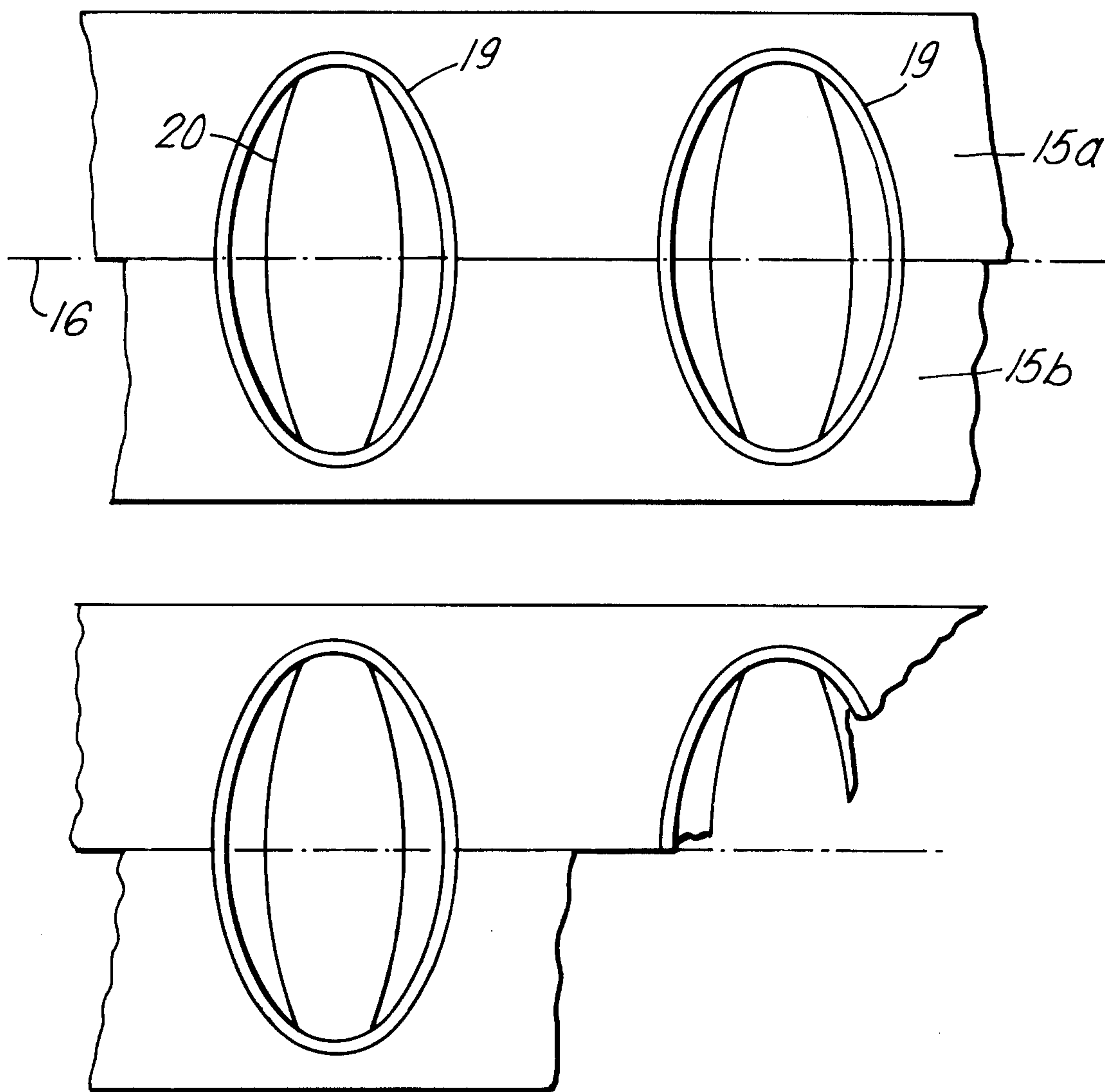
Fig. 2.



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Fig. 3.



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Fig.4.

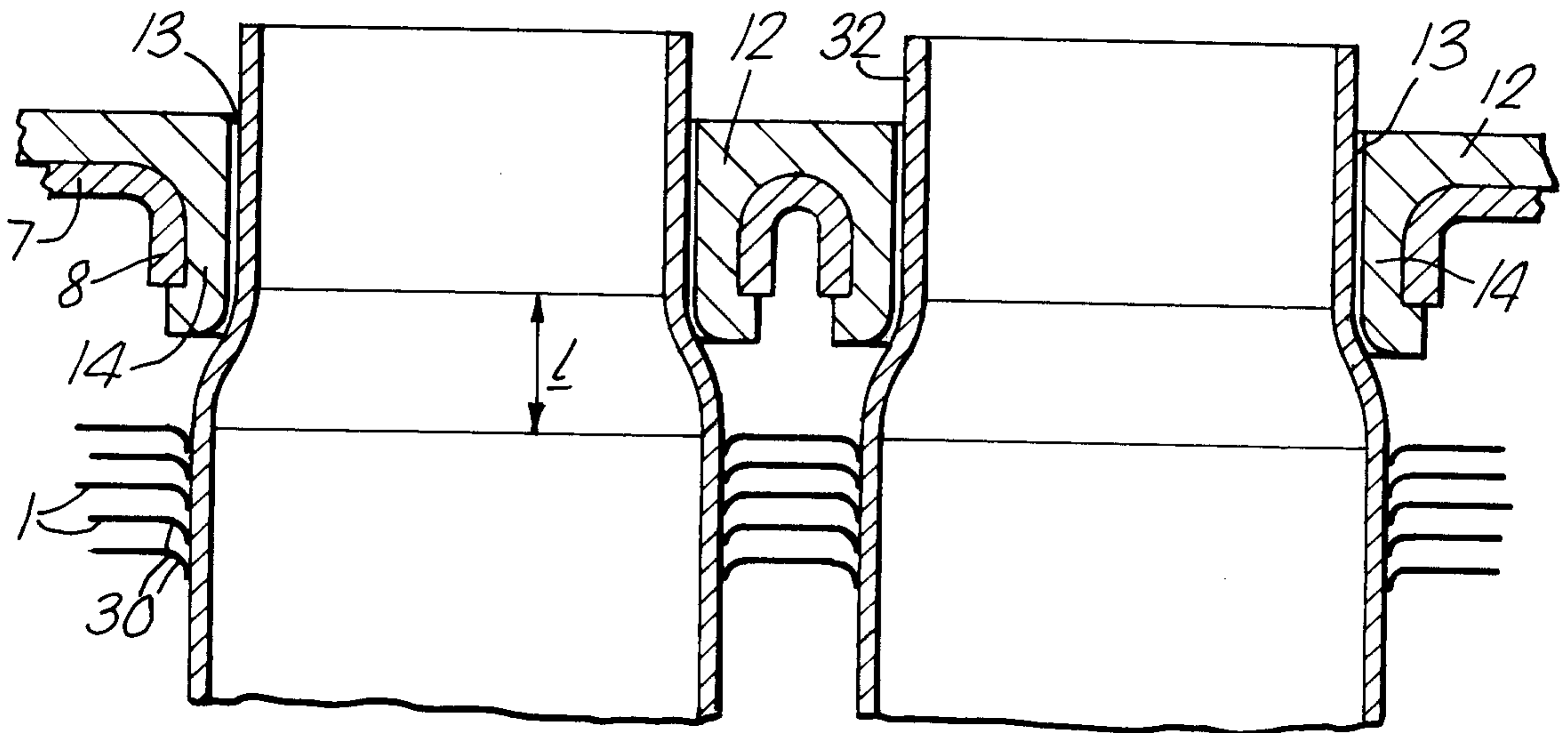
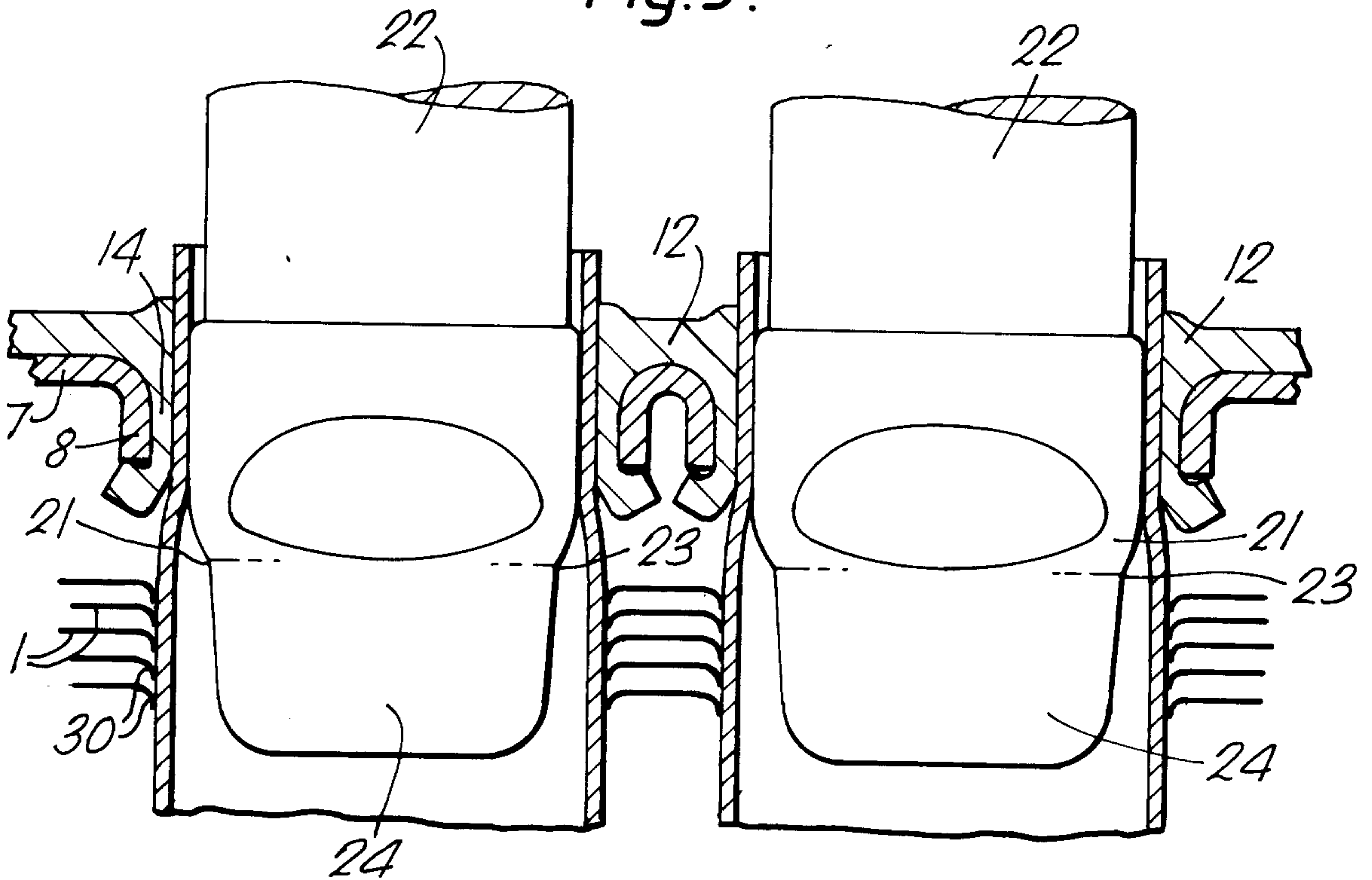
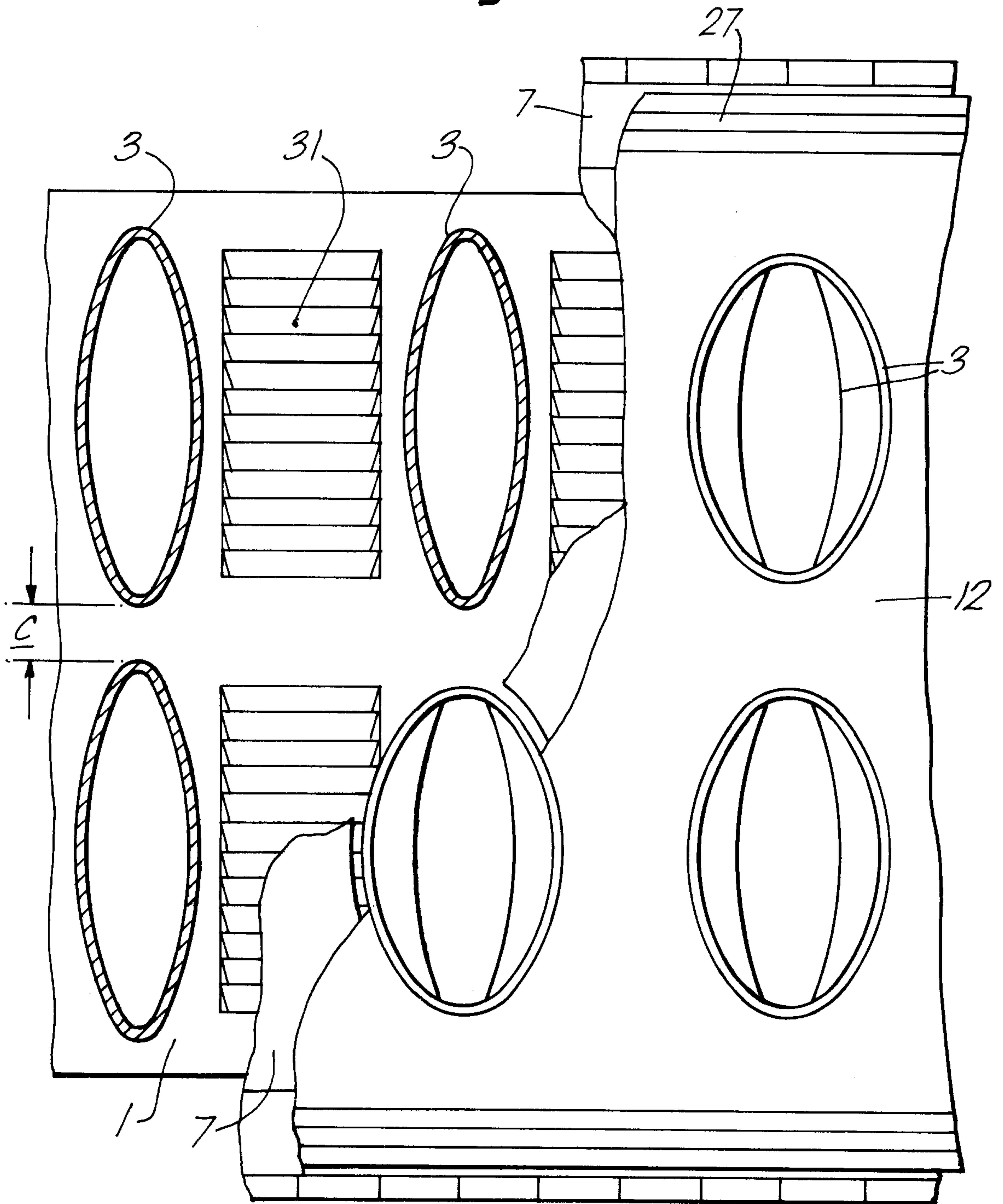


Fig.5.



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Fig.6.



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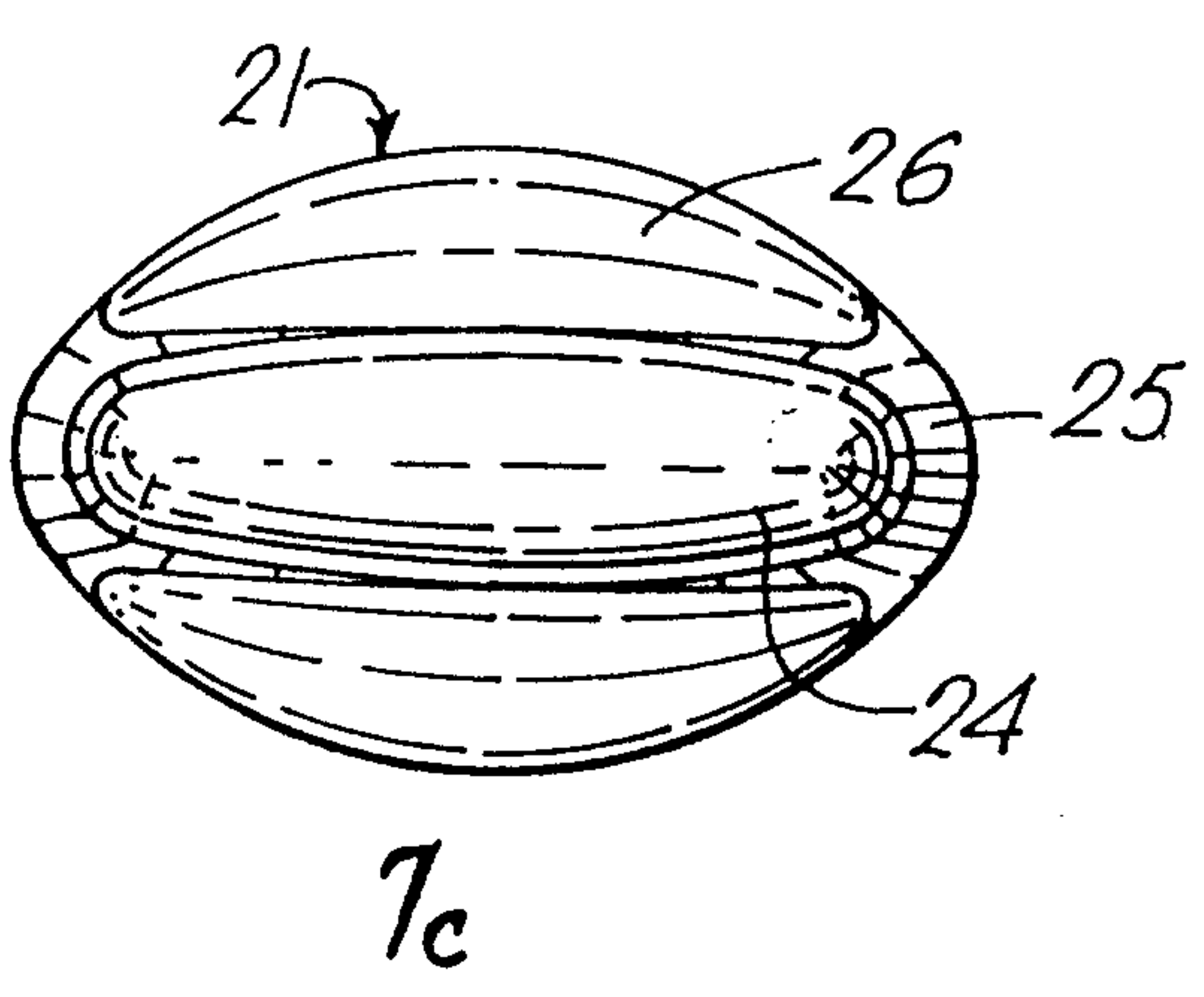
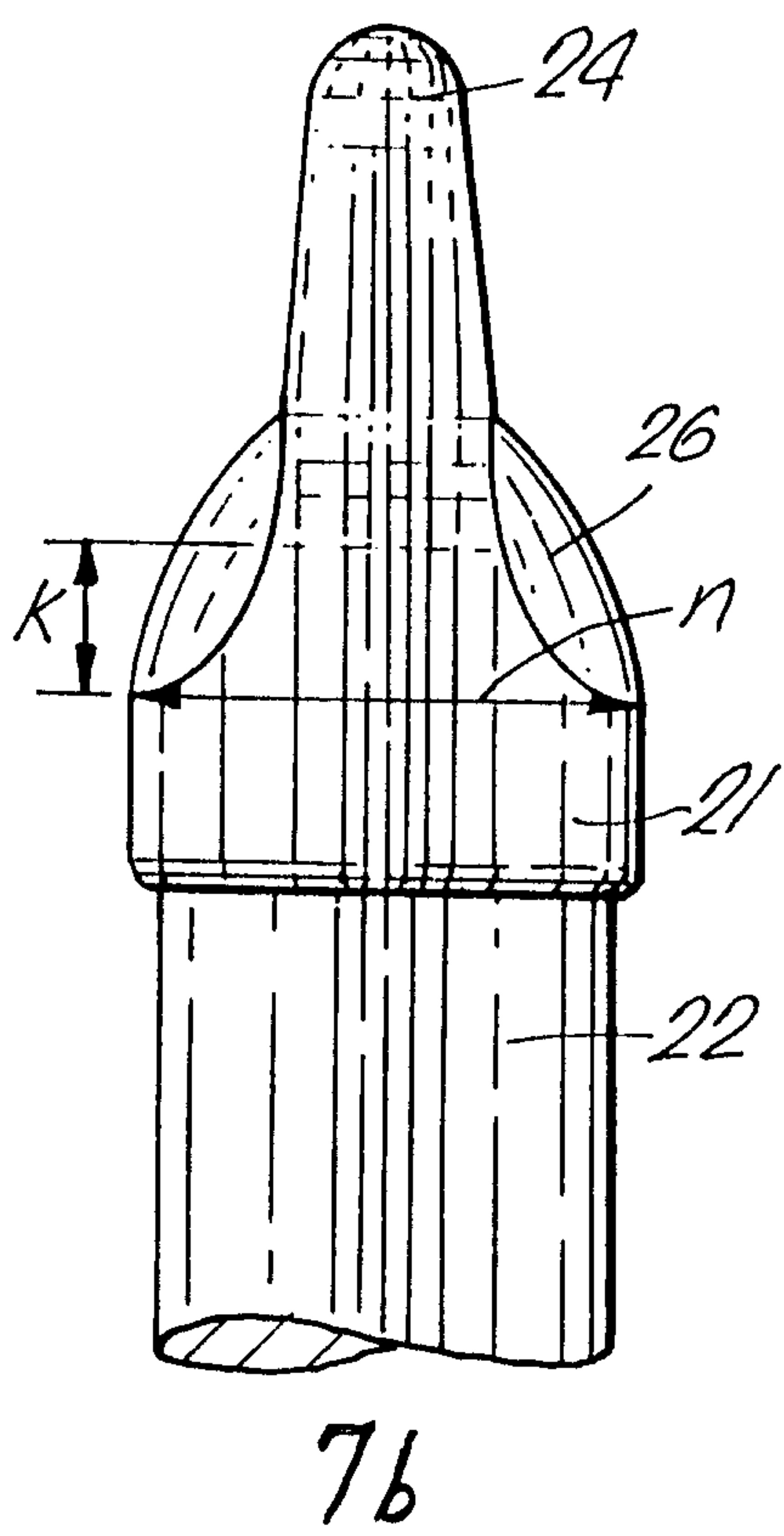
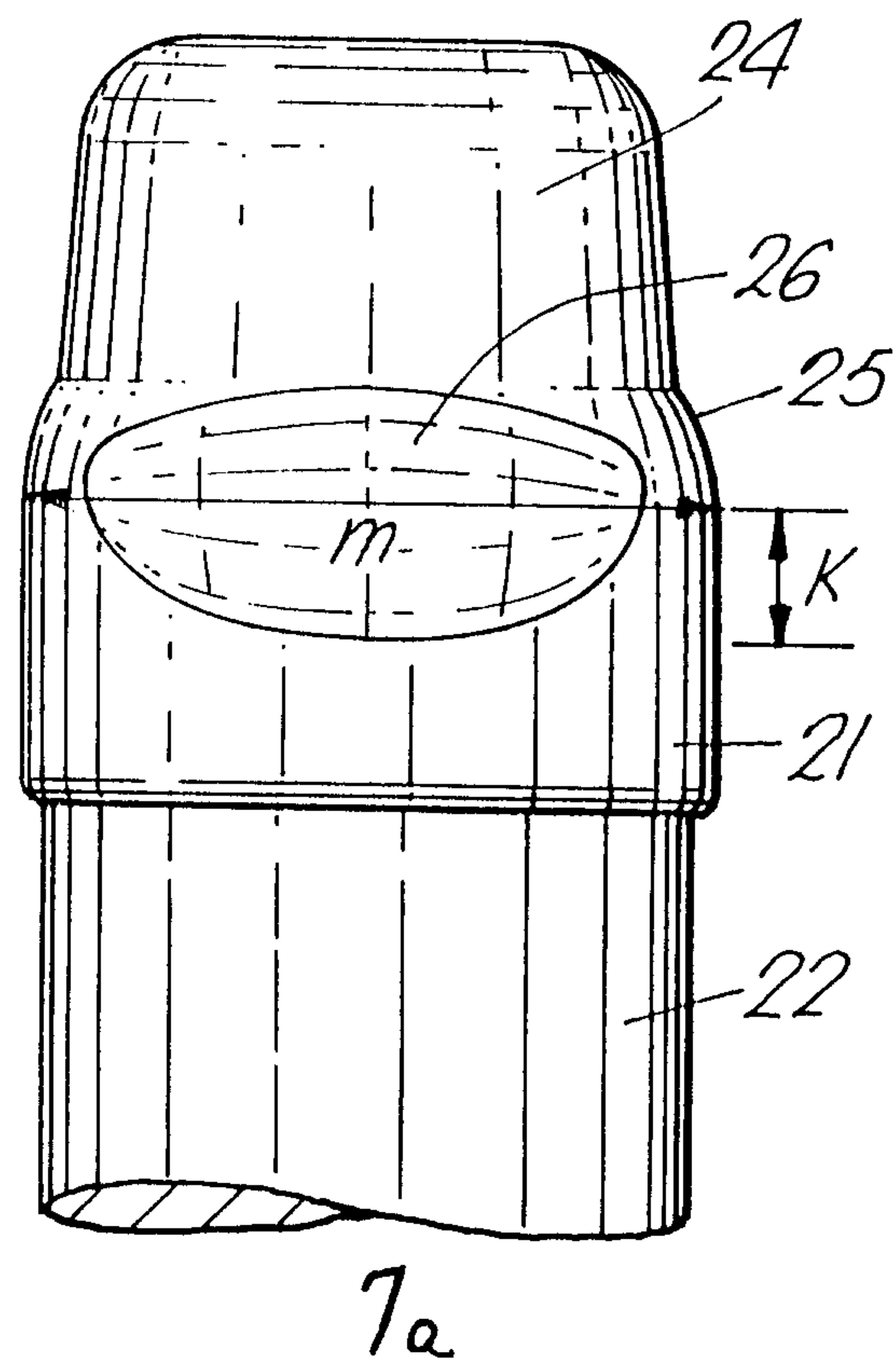


Fig. 7.