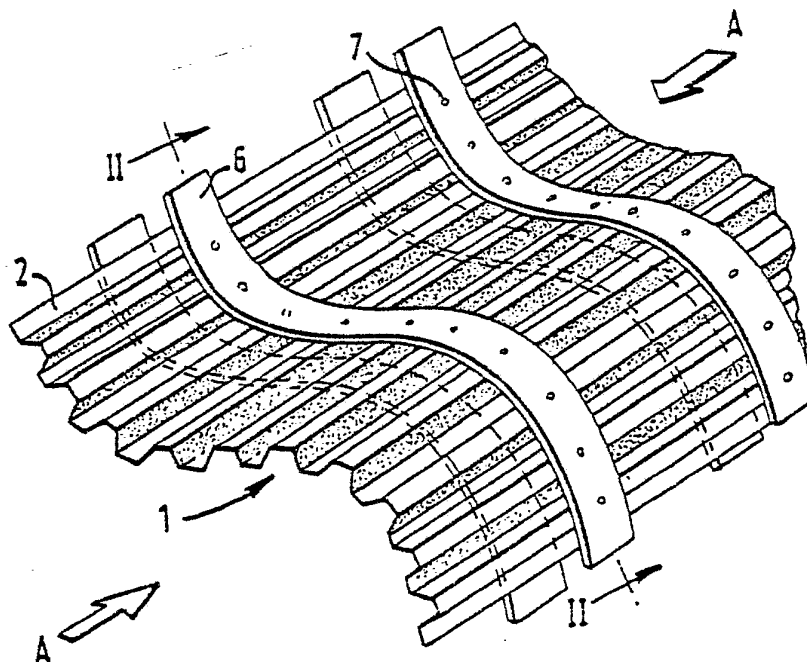




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(21) International Application Number: PCT/GB81/00270		(71) Applicant (for GB NL SE only): FORD MOTOR COMPANY LIMITED [GB/GB]; Eagle Way, Brentwood, Essex (GB).	
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(71) Applicant (for DE only): FORD-WERKE AKTIENGESELLSCHAFT [DE/DE]; Ottoplatz 2, D-5000 Koeln (DE).		Published With international search report.	
(71) Applicant (for FR only): FORD FRANCE SOCIETE ANONYME [FR/FR]; 344 Avenue Napoleon Bonaparte, BP 307, F-92506 Reuil Malmaison Cedex (FR).			

(54) Title: ENERGY ABSORBING STRUCTURE



(57) Abstract

An energy absorbing structure (1) suitable for example for use in a motor vehicle body panel to absorb impact loads comprises a wall (3) having a plurality of ridges (2) extending in a longitudinal direction corresponding to the expected direction of an applied load, and at least one reinforcement (6) secured to the wall on adjacent ridges. The dimensions of the ridges and the points (7) at which the reinforcement is secured are so arranged that the wall undergoes progressive collapse under impact in the longitudinal direction (A).

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DESCRIPTION"Energy Absorbing Structure"

This invention relates to energy absorbing structures.

Energy absorbing structures are used in assemblies which are susceptible to impact loads to control the amount of damage suffered by the assembly or to protect the occupants or contents thereof. For example energy absorbing structures are incorporated in motor vehicles to absorb impact energy and thereby reduce the risk of injury to passengers; in containers for cargo to protect the cargo from damage by impact loads; and in air landing pallets to absorb ground impact loads when the pallet has been dropped from an aircraft, thereby protecting the load carried by the pallet.

In a paper presented by Porsche at the 8th International Technical Conference on Experimental Safety Vehicles in Wolfsburg in October 1980 there is disclosed a vehicle body panel supporting a frontroad wheel suspension assembly and incorporating two plane parallel tubes arranged longitudinally of the vehicle. The tubes collapse under longitudinal impact loads thereby absorbing the energy of the impact load and reducing the amount of damage suffered by the rest of the vehicle.

We have observed that in energy absorbing structures which include a wall which is designed to buckle or fold under impact loads, thereby absorbing energy, the buckling or folding usually proceeds in a relatively uncontrolled manner, particularly where the wall is not in the form of a tube. For example the wall may form an initial fold which then acts as a hinge around which the whole structure can then bend. After such large scale bending of the structure has started to occur the structure offers little resistance to the applied load and the amount of additional energy absorbed by the structure is relatively small.

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1 According to the present invention there is
provided an energy absorbing structure comprising
a wall having a plurality of ridges extending in
longitudinal direction, and at least one reinforce-
5 ment secured to the wall on or adjacent each ridge
at one or more points along the length of the wall.
By providing appropriate spacing between the said
points and the ends of the wall and by choosing
appropriate dimensions for the ridges, the structure
10 undergoes a progressive collapse, without bending,
when a load is applied in the longitudinal direction.

The precise spacing of the points at which the
or each reinforcement is secured to the wall in relation
to the ends of the wall, and the precise dimensions of
15 the ridges used will depend upon the material used for
the wall, and the thickness and shape of the wall.
However, the optimum spacing and the dimensions can
easily be established by routine experiment.

The ridges may be formed by bending or moulding
20 the sheet material of the wall, so that at least one
ridge is formed by one or more folds of the longitud-
inally extending U-shaped ridge. For example the
ridges may be generally U-shaped or V-shaped.

Alternatively, a ridge may be formed by two
25 mutually inclined surfaces each having a flange along
one longitudinally extending edge, the flanges of the
two surfaces being secured together in abutment with
each other. It may be appropriate to use both these
constructions in a single wall.

30 The wall of the structure may be of any shape.
For example it may be tubular or alternatively it may
be planar or curved. In general, however, the



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1 corrugations should extend along straight lines in
the direction in which an impact load is expected
to be applied. In one construction, which is
particularly useful in the manufacture of structural
5 members for motor vehicles, the wall has a square or
rectangular cross-section.

The reinforcements may generally take the
form of straps. Where the wall is tubular, the
reinforcements may be in the form of a plate extending
10 diametrically across the tube or, preferably, a tube
coaxial with the wall and secured thereto along its
length. The tube may lie outside, or preferably,
within the tubular wall.

Any deformable material may be used for the
15 wall. In some cases where only light compact loads
are expected, a flexible plastics material may be
used. Where heavier loads are expected however,
a metal would be more suitable. Aluminium is a
preferred metal in view of its light weight. Mild
20 steel can however also be used.

The invention is especially suitable, but
not exclusively so, for use in motor vehicle body
panels. For example, the body panel may be in the
form of a vehicle suspension mounting panel which
25 in use is aligned in the fore- and -aft direction.
In this case, the ridges also extend in the fore-
and -aft direction so that the structure absorbs
frontal impact loads. Alternatively, the body panel
may comprise a motor vehicle floor pan, especially
30 a rear seat support and the ridges extend in the
transverse direction of the vehicle so that the
structure absorbs side impact loads.

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1 Embodiments of the invention will now
be described, by way of example only, with
reference to the accompanying drawings, in which:

5 Figure 1 is a perspective view of a first
energy absorbing structure in accordance with the
invention;

Figure 2 is a partial cross section of
the structure of Figure 1 taken along line II-II;

10 Figure 3 is a perspective view of the
structure of Figure 1 and Figure 2 under a load;

Figure 4 is a perspective view of a
structure not forming part of the present invention
under a similar load to that illustrated in Figure
3;

15 Figure 5 is a perspective view of part of
a second energy absorbing structure in accordance
with the invention;

Figure 6 is a partial cross-section of the
structure of Figure 3 taken along line VI-VI;

20 Figure 7 is a perspective view of a third
energy absorbing structure in accordance with the
invention;

Figure 8 is a perspective view of the
structure of Figure 7 after collapse under a
25 load;

Figure 9 is an end view of a fourth energy
absorbing structure in accordance with the invention;

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1 Figure 10 is a side view of the structure of
Figure 9 after collapse under a load;

Figure 11 is a perspective view of a first body
panel of a motor vehicle incorporating a structure in
5 accordance with the invention;

Figure 12 is a perspective view of a second body
panel of a motor vehicle incorporating a structure in
accordance with the invention; and

Figure 13 is a perspective view of a container
10 incorporating a structure in accordance with the invention.

Referring to Figures 1 and 2, an energy absorbing
structure 1 comprises a wall 2 composed of a sheet metal
such as aluminium. The sheet is formed with a plurality
of ridges or corrugations 3 which extend parallel to
15 each other in a longitudinal direction. The ridges
may be formed by carrying out a series of bending
operations on a flat blank of metal, or by pressing
the flat blank between two dies.

As best illustrated in Figure 2, the ridges are
20 generally U-shaped with inclined side walls so that
each ridge has two parallel fold lines 4,5 extending
longitudinally along its length.

The wall 2 carries a set of spaced reinforcements
in the form of straps 6 which are also made of aluminium.
25 The straps extend transversely to the ridges and are fixed
by means of rivets 7, at points adjacent to and on top
of each ridge, the straps 6 being disposed in pairs
opposite each other on either side of the wall.

Alternatively, the straps may be secured to the wall by
30 welding or by a suitable adhesive such as an epoxide
resin. The structure may be shaped to any desired
curvature in the transverse direction, provided that
the ridges remain aligned along parallel straight lines.

1 If a longitudinal compressive load is applied to
the structure in the direction of the arrows (Figure 1),
it is found that, provided that the points at which
the straps 6 are secured to the wall 2 are properly
5 spaced in relation to each other and the ends of the
wall and that the ridges 3 are properly dimensioned,
the structure collapses progressively from one end in
the longitudinal direction.

The precise dimensions necessary to achieve this
10 regular collapse will depend upon the thickness and
nature of the material from which the wall 3 is composed
and are best determined by routine experiment. By way
of example however, a structure in which the wall and
straps are formed from 20 gauge aluminium sheet bent
15 into the configuration shown in Figures 1 and 2, the
distances a and b in Figure 2 being both 20 mm, and
the angles θ_1 and θ_2 being both 30° , and the straps
are 2.5 cm wide and separated from each other and from
the ends of the wall 3 by no more than 15 cm, has good
20 collapse characteristics.

Figure 3 illustrates the behaviour of such a
structure under such a load. It can be seen that each
ridge 3 folds into a large number of convolutions 8
whilst the structure 1 itself retains its generally
25 longitudinal alignment without bending. Continued
application of the load causes the folding to continue
progressively along the structure past each of the straps
6 in turn. Since the formation of each successive
fold in the wall requires additional energy, the
30 total amount of energy absorbed by the structure is
extremely high.

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1 Referring now to Figure 4, a structure 10 similar
to that shown in Figure 2 is illustrated after having
been loaded in a manner similar to that described with
reference to Figure 3. Although the structure 10 has
5 ridges 3 similar to the structure 2 of Figure 2, it has
no reinforcing straps 6. It can be seen that the
application of a compressive load in the direction of
the arrow A causes bending of the structure generally
about a central pivot region 11. Once such bending
10 has started the structure offers a much smaller
resistance to the load and rapidly collapses in an
uncontrolled manner. The total energy absorbed by
the structure is therefore substantially less than
that absorbed by the structure of the invention.

15 Figures 5 and 6 illustrate an alternative structure
in accordance with the invention in which the ridges 3'
are shaped similarly to that illustrated in Figures 1
and 2. The straps 6', 6' however are provided with tabs
12, 12 which project from the spine 13 of the straps 6'
20 outwardly and downwardly into the channels between
adjacent ridges 3'. The straps may then be secured to
the wall at points adjacent to and on top of ridge 3'
by riveting or welding at the ends of the tabs 12, as
indicated at 14, and at the spine 13, as indicated at
25 15 in Figure 6.

Figures 7 and 8 illustrate a further alternative
embodiment of the invention, before and after collapse
under load. In this structure, the wall 2" is tubular
with V-shaped ridges 3" arranged axially. The rein-
30 forcements comprise hexagonal plates 15, 15 arranged
diametrically across the interior of the tubular wall.
The plates each have upstanding flanges 16 which are
riveted to the wall 2" between the ridges 3" as
indicated at 17.

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1 In this example, the tube is 15 cm in diameter,
the reinforcements 15, 15 and the wall 2" are composed
of 20 gauge aluminium plate, the ridges are formed
with two 25 mm side walls inclined at 60° and the
5 spacings between the two reinforcements and the ends
of the tube are no greater than 15 cm.

Figure 8 illustrates the tube after collapse.
A compressive axial load in the direction of the arrow
A of more than 58 kN is required to effect this collapse.
10 As indicated in the drawings, the collapse occurs
progressively in a controlled manner by the sequential
formation of folds along the ridges 4" of the ridges 3".

Figures 9 and 10 illustrate a third embodiment of
the invention in which the wall 2" is tubular with a
15 square cross-sectional shape. The four sides of the
tubular wall are formed from four separate plates 50
each of which is provided with a 45° flange 51 along
its two longitudinally extending edges. The flanges
of the adjacent plates 50 are secured together in
20 abutment with each other by spot welding, as indicated
at 52 in Figure 10, so that the surfaces of adjacent
pairs of plates 50 form the four V-shaped ridges 3"
along the length of the wall.

The reinforcement comprises a single cylindrical
25 tube 53 positioned within the wall 2" in contact with
each of the four plates 50 and secured thereto adjacent
each ridge 3" by a series of spot welds 54 (Figure 10)
extending along the length of the wall 2". In this
example the wall 2" has an internal cross-sectional
30 length of 8 cm, the wall 2" and the reinforcement 53
are composed of 22 gauge mild steel and the spot welds
54 are spaced apart by no more than 3 cm in the
longitudinal direction. As illustrated in Figure 10
the structure has good collapse characteristics under
35 loads applied in the direction of the ridges 3".



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- 1 Figures 11 and 12 illustrate motor vehicle body
panels incorporating energy absorbing structures in
accordance with the invention. In Figure 11 the panel
19 is a mounting for a road wheel suspension arm 20
5 illustrated on the fore- and -aft direction of the
vehicle and the forward part of the panel includes
a wall 25 having ridges 26 which are aligned parallel
with the fore- and -aft direction. Straps 27 are
secured to both faces of the wall 25 in the manner
10 described with reference to Figures 1 and 2. By
suitably shaping the corrugations and spacing the
straps 27, the panel 19 will collapse in a controlled
manner on application of a frontal force indicated by
the arrow 28.
- 15 In Figure 12 the panel 30 comprises a floor pan
of a motor vehicle which is shaped to form the base of
a rear seat in the vehicle adjacent a door aperture 31.
The panel comprises ridges 32 which extend transversely
of the vehicle and straps 33 secured to both faces of
20 the panel and extending at right angles to the ridges.
By suitably shaping the ridges and spacing straps 33,
the panel will collapse in a controlled manner on
application of a side load indicated by the arrow 34.

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1 Figure 13 illustrates a container for a
road or rail vehicle incorporating an energy
absorbing structure in accordance with the invention.
The container comprises a cylindrical tank 40 having
5 a domed end 41 carrying two tubular structures 42,43
in accordance with the invention mounted concentric-
ally. Each structure 42,43 comprises a set of
axially extending ridges 44 and circumferential
straps 45. An end plate 46 is mounted on the ends
10 of the energy absorbing structures 42,43. By
shaping the ridges and spacing the straps 45
appropriately, the structures 42,43 will collapse
in a controlled manner on the application of an
axial load in the direction indicated by the arrow
15 48, thereby protecting the tank 40 from damage.

Although the energy absorbing structures
have been described in relation to road and rail
vehicles it will be appreciated that the structures
of the invention have many more possible uses.

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CLAIMS

- 1 1. An energy absorbing structure comprising a wall having a plurality of parallel ridges extending in a longitudinal direction, and at least one reinforcement secured to the wall on or adjacent to each ridge
- 5 at one or more points along the length of the wall, the dimensions of the ridges and the spacing between the said points and the ends of the wall being such that the wall collapses progressively when a load is applied thereto in the longitudinal direction.
- 10 2. A structure according to Claim 1 wherein the ridges each include at least one longitudinally extending fold line.
3. A structure according to Claim 1 wherein the ridges are V-shaped.
- 15 4. A structure according to any one of Claims 1 to 3 wherein at least one ridge is formed by one or more folds in the wall.
5. A structure according to any one of Claims 1 to 4 wherein at least one ridge is formed by two mutually
- 20 inclined surfaces each having a flange along one longitudinally extending edge, and the flanges of the two surfaces are secured together in abutment with each other.
6. A structure according to any one of Claims 1 to
- 25 5 wherein the wall is tubular.
7. A structure according to Claim 6 wherein the wall has a square or rectangular cross-sectional shape.



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- 1 8. A structure according to Claim 6 or Claim 7
 wherein the reinforcement comprises a tube coaxial
 with the wall and secured thereto along its length.
9. A structure according to Claim 8 wherein the
5 tube lies within the wall.
10. A structure according to any one of Claims 6 to
 9 wherein the reinforcement comprises a plate
 extending diametrically across the tubular wall.
11. A structure according to any one of Claims 1 to
10 10 wherein the reinforcement comprises a strap.
12. A structure according to any one of Claims 1 to
 11 wherein the wall is composed of aluminium.
13. A motor vehicle body panel incorporating a
 structure according to any one of Claims 1 to 12.
- 15 14. A body panel according to Claim 13 in the form
 of a suspension mounting which in use extends generally
 in the fore-and -aft direction of the vehicle, the
 ridges extending in the fore- and -aft direction.
15. A body panel according to Claim 13 in form of a
20 floor pan which in use extends generally in the trans-
 verse direction of the vehicle, the ridges extending
 in the transverse direction.



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FIG. 1

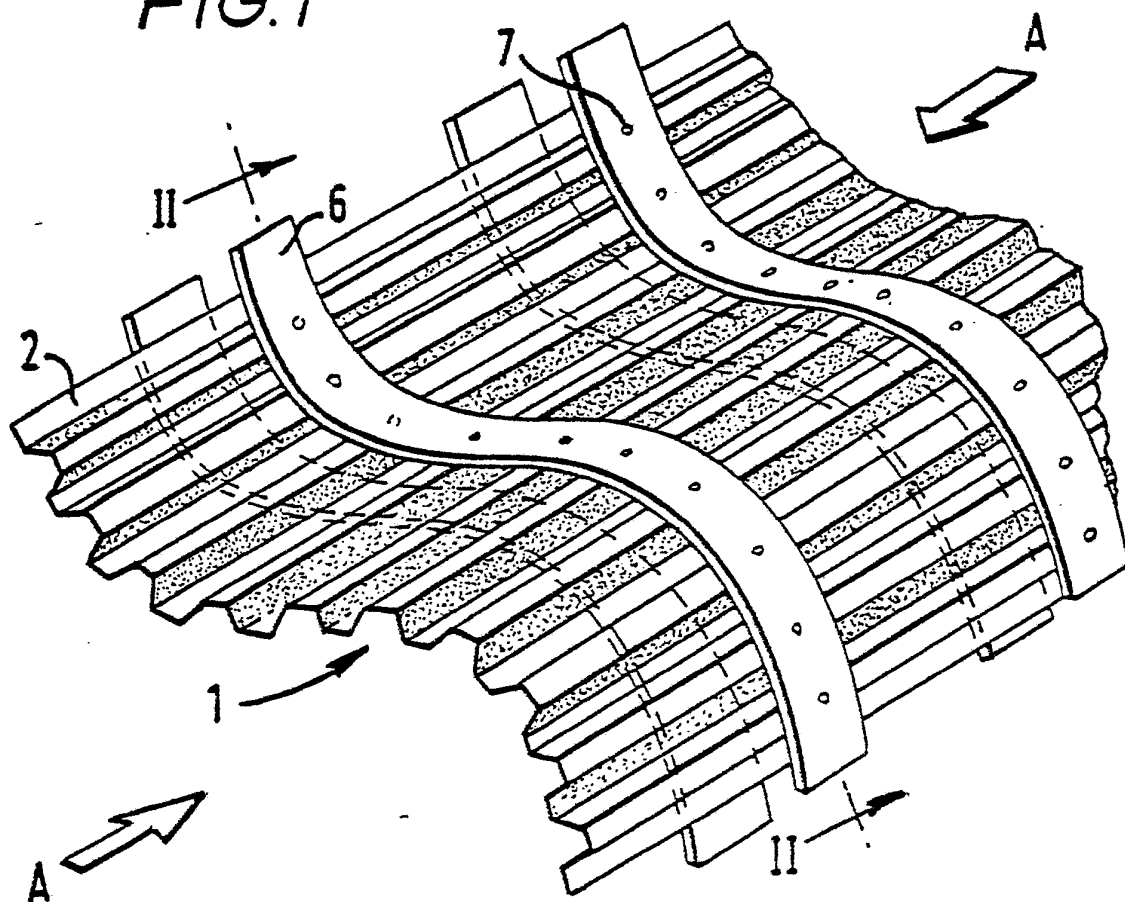
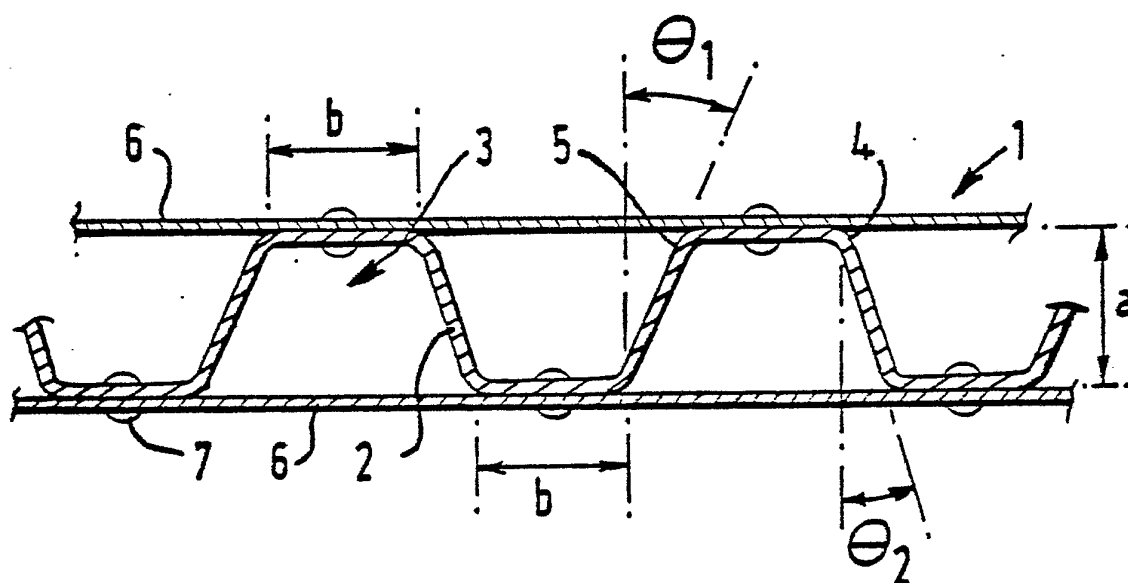
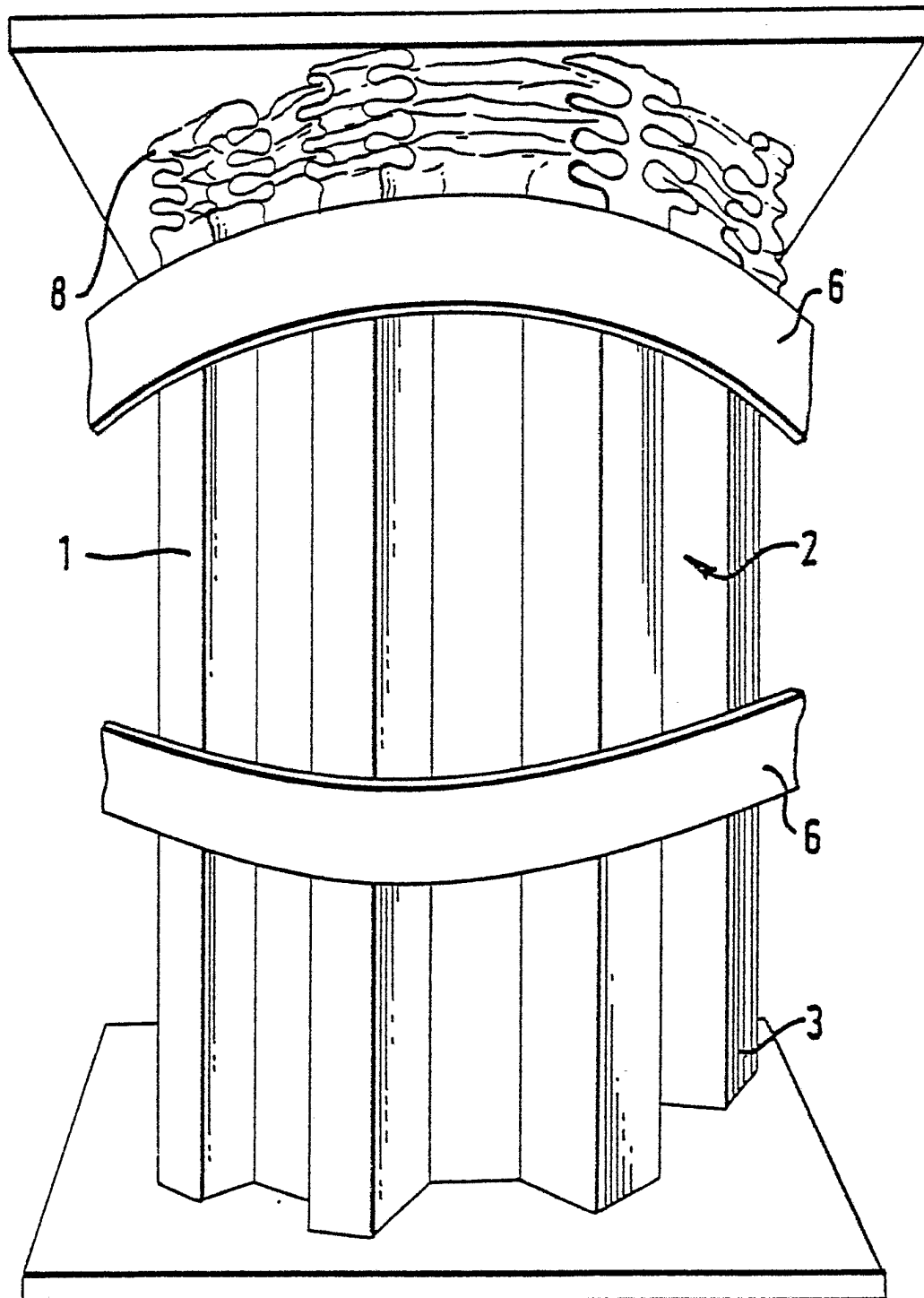


FIG. 2



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FIG. 3



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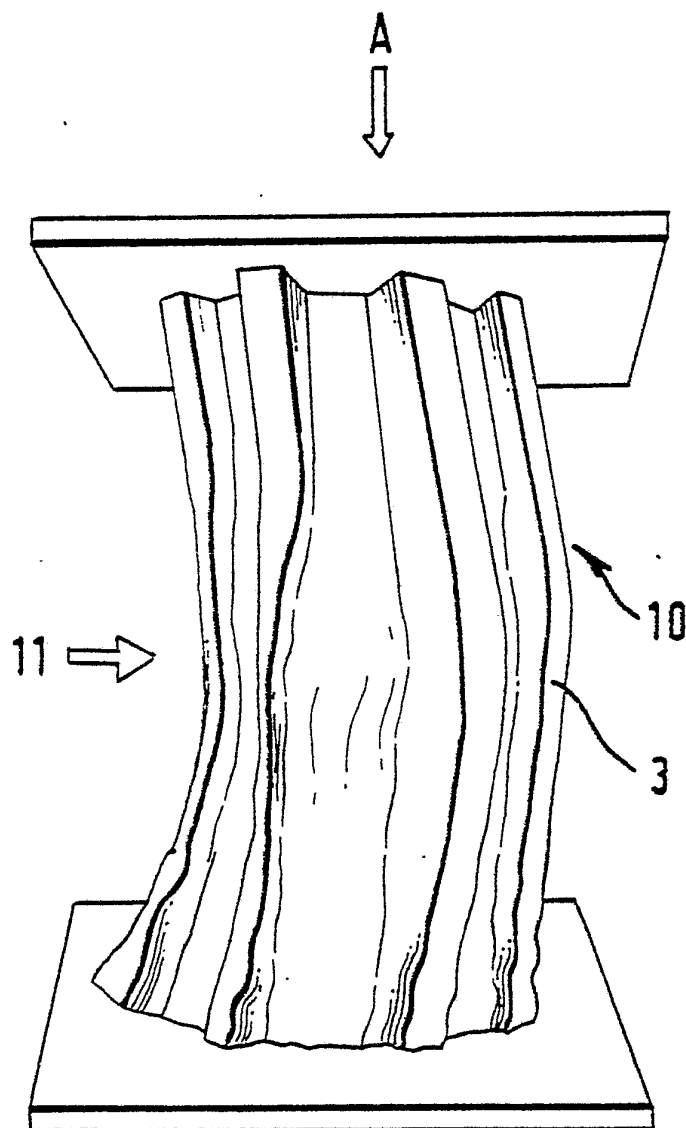
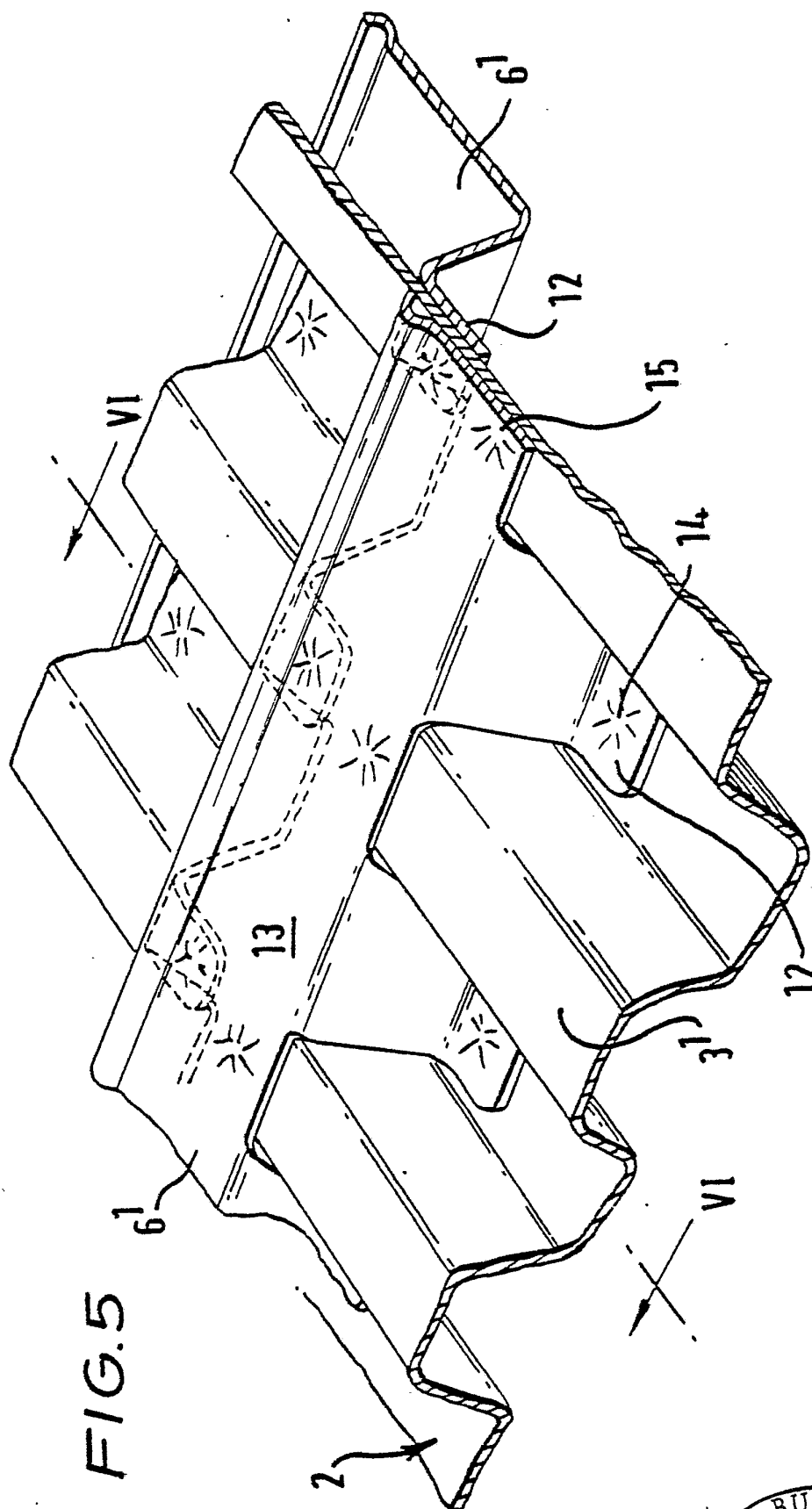


FIG. 4

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FIG. 6

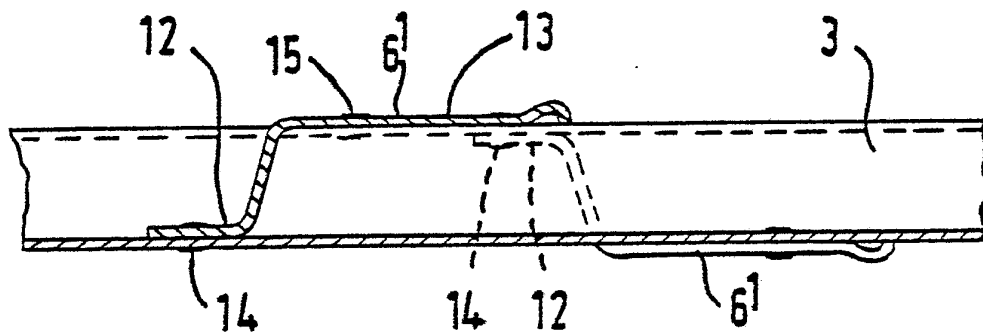
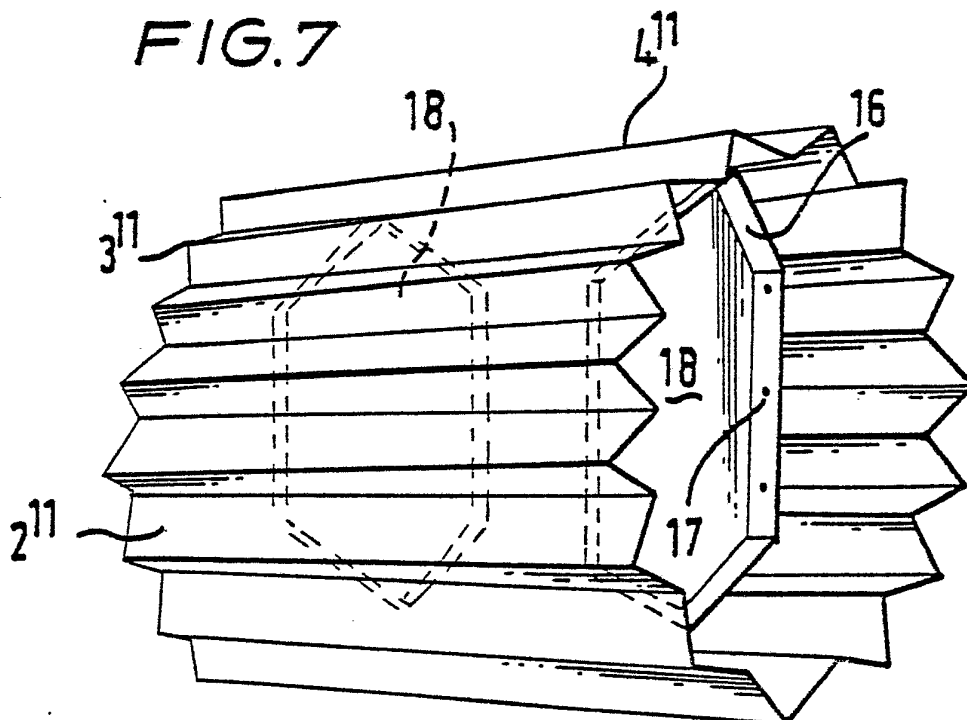


FIG. 7



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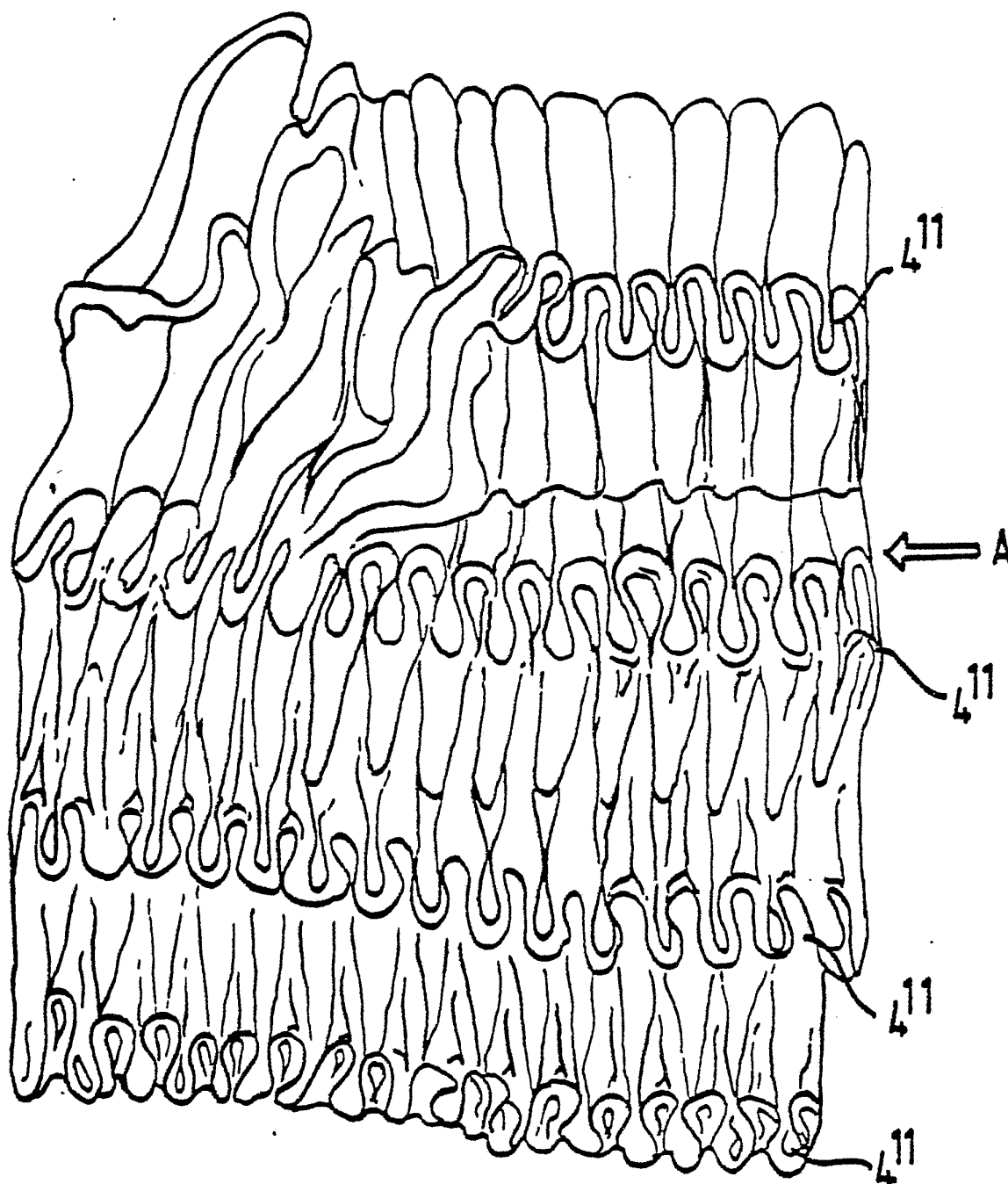


FIG. 8

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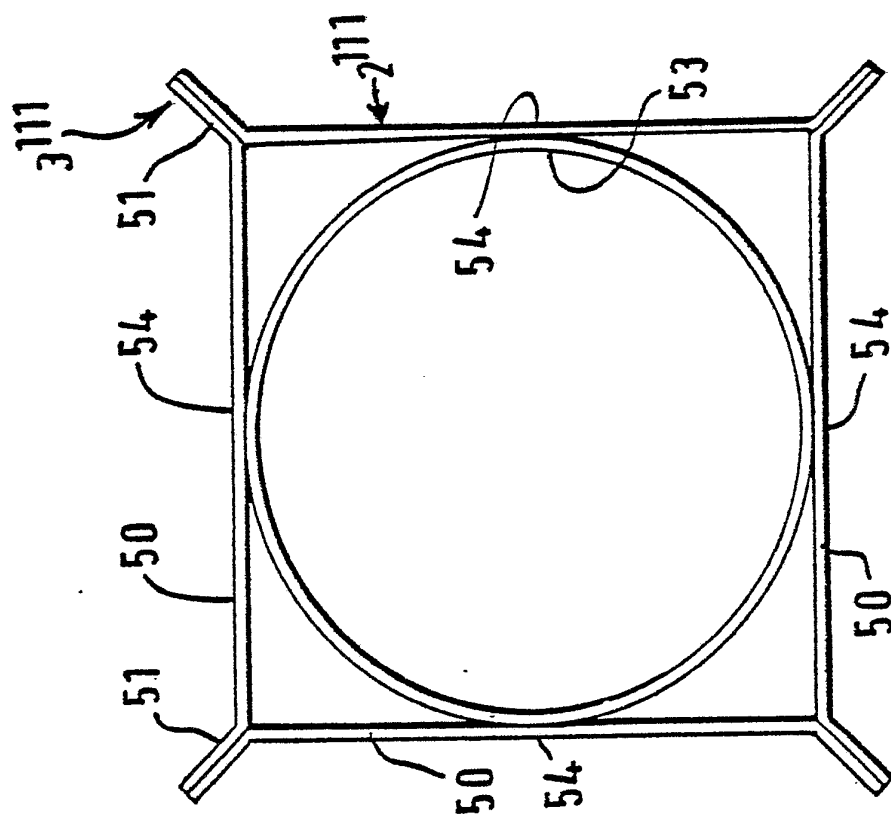
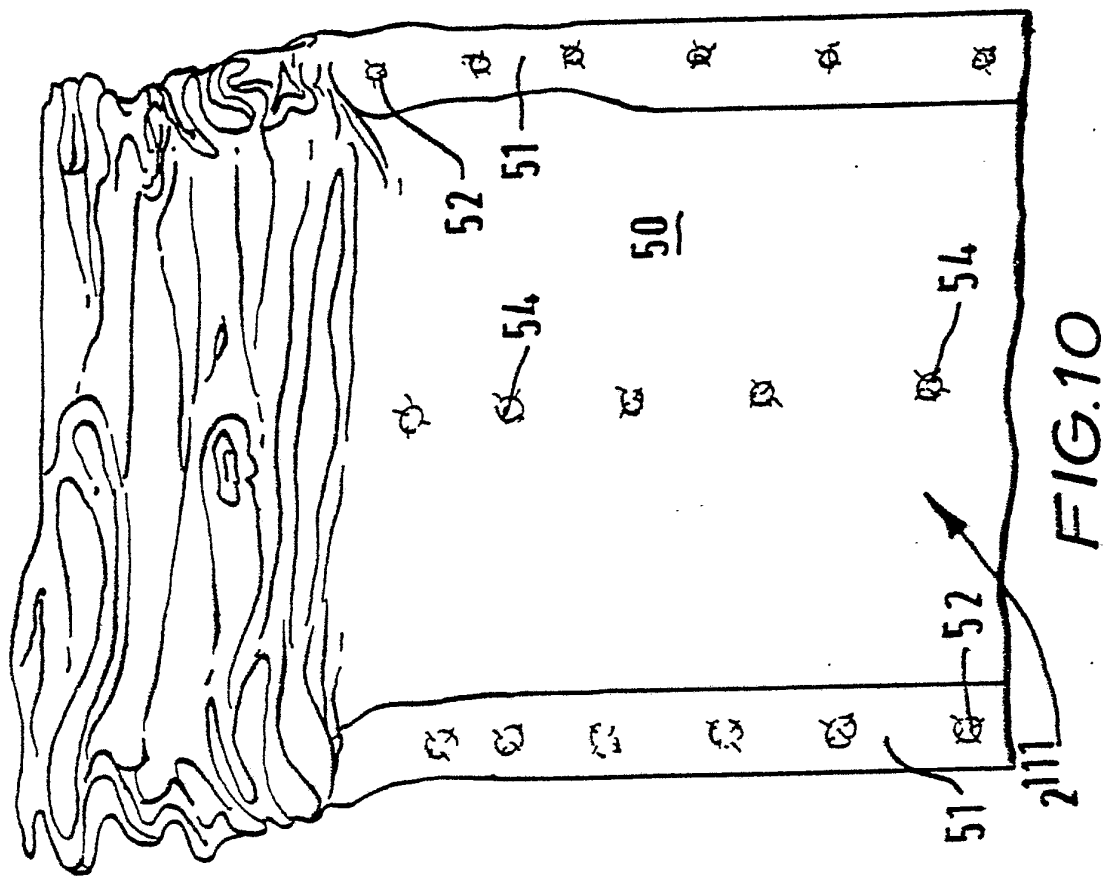
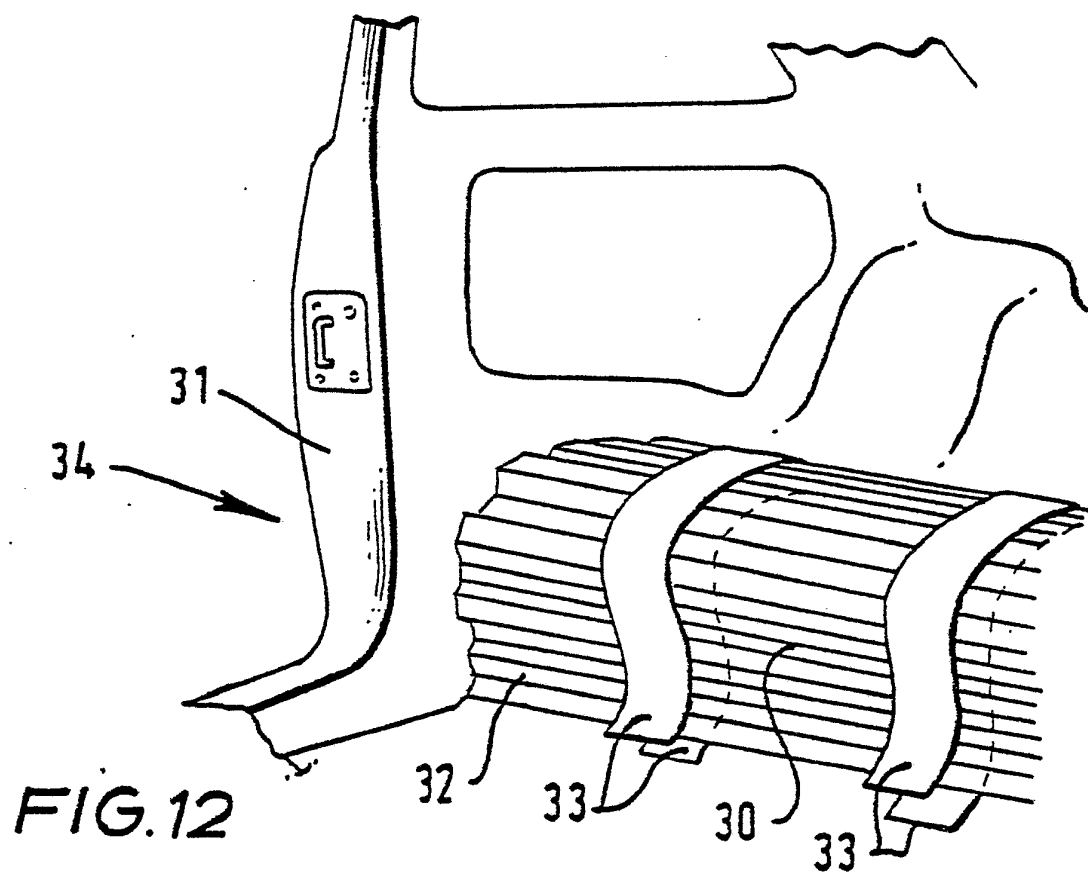
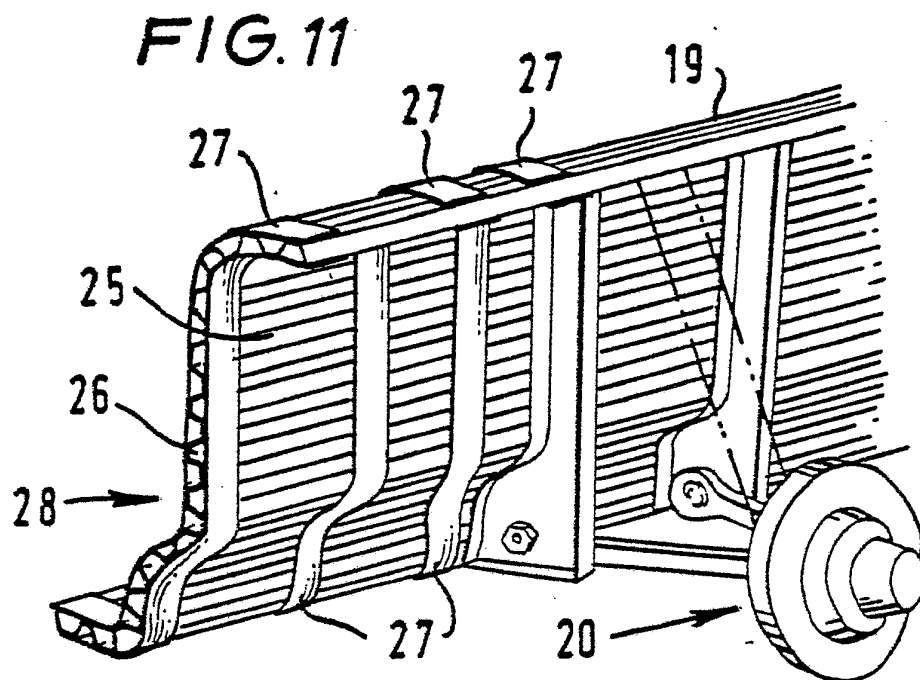


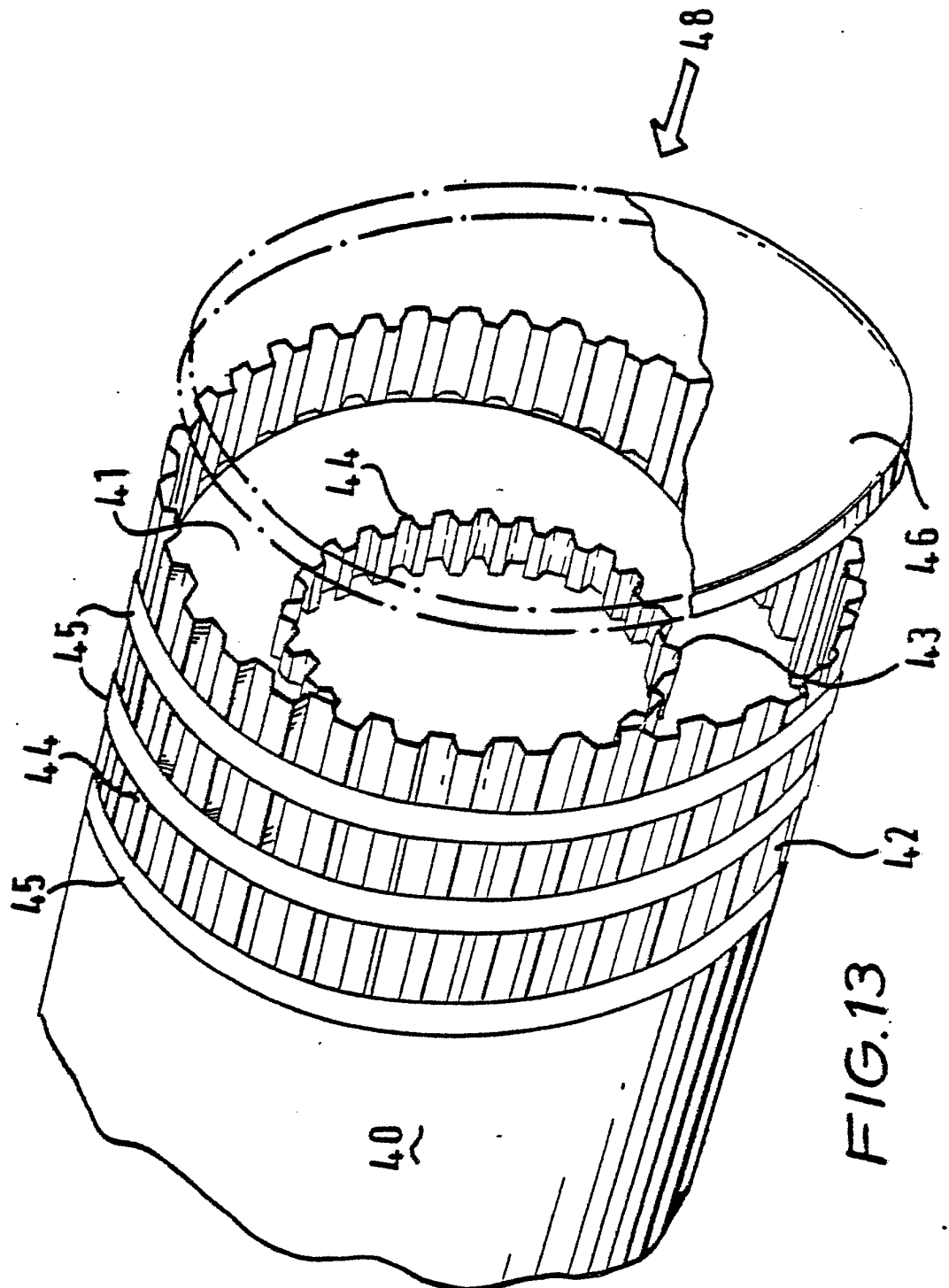
FIG. 9

FIG. 10

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INTERNATIONAL SEARCH REPORT

International Application No PCT/GB 81/00270

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) ¹ According to International Patent Classification (IPC) or to both National Classification and IPC IPC³: F 16 F 7/12; B 60 R 19/06				
II. FIELDS SEARCHED Minimum Documentation Searched ⁴ <table style="width: 100%; border: none;"> <tr> <td style="width: 25%; border: none; vertical-align: top;"> Classification System IPC³ </td> <td style="width: 75%; border: none; vertical-align: top;"> Classification Symbols B 60 R; F 16 F </td> </tr> </table> Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched ⁵			Classification System IPC³	Classification Symbols B 60 R; F 16 F
Classification System IPC³	Classification Symbols B 60 R; F 16 F			
III. DOCUMENTS CONSIDERED TO BE RELEVANT ¹⁴				
Category *	Citation of Document, ¹⁶ with indication, where appropriate of the relevant passages ¹⁷	Relevant to Claim No. ¹⁸		
X	US, A, 3466733 (PAJAK et al.) 16 September 1969 see the entire document, in particular figures 2,3,4 --	1-6,8,9,12,13		
X	US, A, 4227593 (BRICMONT et al.) 14 October 1980 see the entire document & GB, A, 1588328 & FR, A, 2336490 & NL, A, 7710885 --	1-7,13,14		
X	GB, A, 1489065 (BRITISH STEEL) 19 October 1977 see the entire document --	1-6,8,9,13,14		
X	DE, A, 2334121 (RASSELSTEIN) 6 February 1975 see figures 1,3,4 --	1-6,8,9,13,14		
A	US, A, 3831997 (MYERS) 27 August 1974 see figures 1,2, numbers 36,37 --	1,13,14 ./		
¹⁵ * Special categories of cited documents: "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier document but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art. "&" document member of the same patent family				
IV. CERTIFICATION				
Date of the Actual Completion of the International Search ¹ 4th March 1982		Date of Mailing of this International Search Report ² 16th March 1982		
International Searching Authority ¹ EUROPEAN PATENT OFFICE		Signature of Authorized Officer ²⁰ G.L.M. Kreyenberg		

III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)		
Category *	Citation of Document, ¹⁶ with indication, where appropriate, of the relevant passages ¹⁷	Relevant to Claim No ¹⁸
A	DE, B, 1186695 (PARSONS) 4 February 1965 see the entire document & GB, A, 991525 & NL, B, 111702 --	1
A	DE, A, 2441557 (M.B.B.) 11 March 1976 see figures 3,4; pages 3 and 6 --	1, 14
A	Machine Design, Volume 49, no. 24, October 1977 (US), J.A. Kirk et al., "One-shot shock absorbers", see pages 152-157 --	1, 14
A	US, A, 3506295 (YANCEY) 14 April 1970 --	1
A	US, A, 3564688 (DE GAIN) 23 February 1971 & DE, B, 1303268 & AU, 430287 --	1
A	US, A, 3983963 (NAKAMURA) 5 October 1976 & GB, A, 1433167 --	1
A	FR, A, 974763 (DENIS) 26 February 1951 --	1
A	FR, A, 2205147 (CHAUSSON) 24 May 1974 & NL, A, 7313687 --	1
A	FR, A, 2288648 (RENAULT et al.) 5 March 1974 & DE, A, 2509265 --	1
A	FR, A, 2315039 (BERLIET) 14 January 1977 & US, A, 4221413 & NL, A, 7606621 --	1
A	FR, A, 2362308 (C.E.A.) 17 March 1978 --	1
A	DE, A, 2413772 (STRAZA) 26 September 1974 --	1
A	DE, A, 2613655 (VW) 13 October 1977 --	1
A	GB, A, 1436175 (NISSAN) 19 May 1976 -----	1