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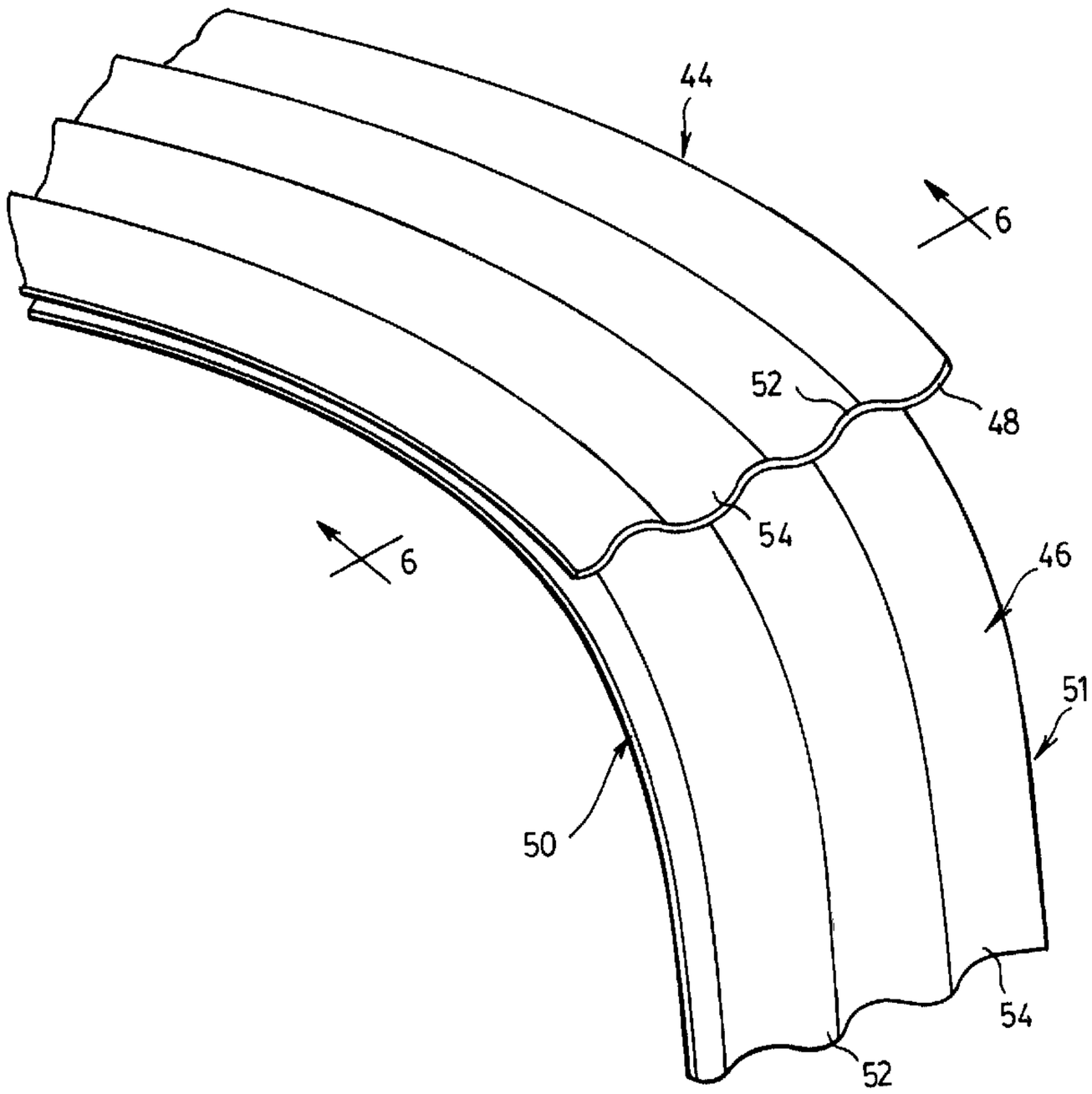
(54) Titre : FORMAGE A FROID PRODUISANT UNE COURBE DE FAIBLE RAYON DANS UNE PLAQUE DE METAL ONDULEE PROFONDE

(54) Title: COLD ROLL FORMING A SHORT RADIUS CURVATURE INTO DEEP CORRUGATED METAL PLATE



(57) **Abrégé/Abstract**:
A deep corrugated structural metal plate having a cold roll formed, uniform uninterrupted short radius of curvature along at least a portion of the plate's length in the range of about 450 mm up to about 3100 mm.

ABSTRACT

A deep corrugated structural metal plate having a cold roll formed, uniform uninterrupted short radius of curvature along at least a portion of the plate's length in the range of about 450 mm up to about 3100 mm.

COLD ROLL FORMING A SHORT RADIUS CURVATURE INTO DEEP CORRUGATED METAL PLATE

Field of the Invention

This invention relates to soil/metal supporting structures which are usually in the form of culvert, arch or box culvert applications. Such structures may include thick short radius panel sections which in the past have been impossible to roll form.

Background of the Invention

Soil/metal supporting structures are most commonly in the form of culverts which are either circumferentially continuous or have an open bottom commonly referred to as either a box culvert or a re-entrant arch shaped culvert. These culverts are used to direct water ways and for use as bridges in roadways, railways and the like. The design of the soil/metal supporting structures is to accommodate designed soil loads and as well anticipated rolling loads and static loads which might travel on the roadway, railway and the like. Usually such structures are formed from steel or aluminum. The plates used in forming the support structure are corrugated in the direction of their longitudinal length. The deeper the corrugation, the greater the minimum radius of curvature in the panel.

Culverts in the form of elliptical, round, pear, arch or pipe-arch shapes, re-entrants, arches or the box culverts include portions across their section which are curved and have a relatively short radius of curvature. Such short radius of curvature were usually in the range of 750 mm to 2,500 mm in the longitudinal direction of the panel having shallow corrugations. For example, such short radius regions in the box culvert structure is described in respect of applicant's U.S. Patent 5,326,191. That patent in particular relates a form of continuous reinforcement in an uninterrupted manner to provide an optimum

load carrying capacity for a selected extent of reinforcement. Although the short radius of curvature for the panels for this box culvert can be formed using existing types of bending presses, the equipment is expensive and complex to use in order to achieve the manufacture of short radius panels having consistent dimensional configurations so that the panels can be readily attached to one another by way of appropriate alignment of the bolt holes. The same approach applies with respect to other culvert styles involving short radius of curvature sections. It is generally understood that even with the rather expensive approach to cold forming such radius of curvature panels, such as described in applicant's U.S. Patent 5,375,943, some distortion can occur due to the short radius which can hamper erection of the structure and hence, delay field insulation.

Another problem to be considered in the cold forming of these thick gauge panels to the short radius specifications is that cold working normally decreases ductility of the panels. Such decrease in ductility can be such that the structure can no longer be designed on the basis of plastic analysis and instead must be designed on the basis of elastic analysis which requires the use of even thicker gauge materials with considerably more reinforcing. It therefore becomes very important that in such cold working of the panels to provide the specified short radius, the bending be carried out in a manner which does not reduce the ductility, induce case hardening in the outside of the structure and also avoids the possibility of forming micro-cracks in the outside portions of the structure.

Such problems are addressed in U.S. Patent 5,118,218. It is suggested that when forming short radius of curvature panel sections, that such forming be done while the panels are hot to avoid any case hardening problems. It is also suggested that aluminum sheet material be used in place of steel since it is more easily bent. However, as described, aluminum has less ductility than steel when it comes to plastic design analysis for the soil/metal structure.

There continues to be a problem in respect of cold forming short radius of curvature panel sections particularly with "deep" corrugations of a depth of about 65 mm and up. This is to be compared to "shallow" corrugated panels of a depth less than 65 mm which have been roll formed into a short radius such as described in U.S. Patent 4,232,540.

Even the roll forming of the short radius of curvature for heated deep corrugated structure panels does not work satisfactorily. The properties of the plate in terms of its yield, tensile strength and elongation is changed by the hot forming. Furthermore, the rolled shape for the heated panel changes as the panel is cooled and once cooled cannot be worked back to the desired dimensions. Furthermore, reheating of the panel precludes galvanizing of the panel before rolling. Although the cold forming stamping system of applicant's U.S. Patent 5,375,943 produces a quality short radius panel product, the costs of manufacture are relatively high. Furthermore, the cross-corrugations which are introduced to the panel to facilitate bending to the desired short radius inherently weakens the structure which requires the use of thicker plate. The holes to be provided in the plate cannot be prepunched because of interference by cross corrugation nor can the plate be pre-galvanized before stamping because the stamping process tends to remove the layer of galvanizing.

An example of the cross-corrugated roll formed panels are shown in Figure 1 and identified as Prior Art. The panel 10 has a short radius of curvature, as demonstrated by the outline of edge 12 of the panel. The short radius of curvature is usually in the range of about 450 mm to about 3,100 mm. In order to form the short radius, as described in U.S. Patent 5,375,943, cross-corrugations 14 are introduced to the troughs 16 of the corrugated panel 10. This allows the panel to be bent in the shape of the short radius while maintaining proper alignment of the troughs 16 and peaks 18 along the length of the panel. Similarly, cross-corrugations 20 are formed in a reinforcing second panel 22 which is secured on top of the first panel 10. This is commonly done to enhance the structural strength of the soil/metal supporting structure as described in applicant's U.S. Patent 5,833,394. The cavities

defined between the peaks 18 of the second panel and the troughs 16 of the first panel, which cavity is identified as 24 in Figure 2, may be filled with concrete 26. Shear bond connectors can be placed on the interior of the cavity, as described in applicant's U.S. Patent 5,833,394. This structural system functions very well, however, problems can arise, such as the concrete 26 leaking through the cross-corrugation 20 which defines a space 28 between cross-corrugation 20 and cross-corrugation 14. The concrete 26 that leaks through the space 28 flows along the first panel and down into trough 16 which can result an unsightly collection of spilled concrete 30. This might suggest that the strength of the structure is compromised and it could be due to concrete leaking out of the cavity 24. More likely, however, the cavity 24 is filled and the concrete 30 that has leaked out becomes waste and adds to the overall costs of the structure.

In accordance with this invention, a cold roll formed deep corrugated structural metal plate is provided which overcomes some or all of the above disadvantages. The new form of plate greatly facilitates assembly and erection of the structure to reduce on site costs. By virtue of the curved metal plate being stronger, a thinner gauge metal plate may be used because the cross-corrugations are avoided. Smaller holes can be prepunched in the plates before rolling where rolling is carried out in a manner that results in the holes of the rib plate being aligned with a complementary holes of the adjoining plate. The sheets with prepunched holes can be galvanized before rolling. This reduces the amount of zinc used in the galvanizing process to make the galvanizing process more efficient. More sheets in the flat corrugated format can be processed at one time. This is compared to galvanizing curved sheets having the cross-corrugations. Without cross-corrugation, short radius can be accomplished without buckling and even using a thinner gauge sheet and as a result, production becomes more efficient. The metal for the cold rolled plate may be steel or aluminum.

Summary of the Invention

According to one aspect of the invention, there is provided a deep corrugated structural metal plate having a cold roll formed uniform uninterrupted short radius of curvature along at least a portion of said plate's length in the range of about 450 mm up to about 3100 mm, wherein said plate has prepunched holes about its perimeter and is galvanized prior to roll forming said curvature but after said holes are prepunched.

According to another aspect of the invention, there is provided a load bearing structure in the form of an arch or box culvert having a short radius section of about 450 mm to 3100 mm, said structure being erected by interconnecting a first set of deep corrugation structural metal plates, each plate having:

a predetermined curvature along its length to match a corresponding section of said structure profile;

for said short radius section, a cold roll formed uniform uninterrupted short radius curvature along said plate's length; and

prepunched holes for receiving fasteners to complete plate interconnection in erecting said structure, said prepunched holes being aligned with complementary prepunched holes in said interconnected plate to facilitate fastener insertion, wherein said plate is galvanized prior to roll forming said curvature but after said holes are prepunched.

According to yet another aspect of the invention, there is provided a method of forming a deep corrugated structural metal plate, the method comprising:

roll forming a flat steel plate thereby forming a deep corrugated plate;

punching a plurality of holes about the perimeter of the deep corrugated plate;

galvanizing the punched deep corrugated plate; and

cold rolling the galvanized, punched deep corrugated plate into a uniform uninterrupted short radius of curvature along at least a portion of said plate's length in the range of about 450mm up to about 3100mm.

Brief Description of the Drawings

Preferred embodiments of the invention are shown in the drawings wherein:

Figure 1 is a perspective view of two corrugated steel plates in accordance with the prior art;

Figure 2 is a section along the lines 2-2 of FIG. 1 which is a section through the prior art;

Figures 3A, B, C and D demonstrate the steps of corrugating flat steel plate prepunching holes and galvanizing the flat prepunched plate;

Figure 4 shows the shape of the short radius for the plate after cold rolling;

Figure 5 is perspective view of the cold rolled plates having a uniform uninterrupted short radius of curvature along the length;

Figure 6 is a section along the lines 6-6 of Figure 5;

Figure 7 shows the aligned bolt holes of first and second plates with the galvanized coating covering the interior surfaces of the holes; and

Figure 8 shows partial sections of upper and lower plates being assembled with the respective set of holes being aligned with complementary holes in the other plate.

Detailed Description of the Preferred Embodiments

A novel deep corrugated structural metal plate having a cold roll formed short radius, brings significant improvements to soil/metal structures. Such soil/metal supporting structures may be in the form of culverts, box culverts or re-entrant arches. The culverts may be in the form of a elliptical, round , pear, arch or pipe arch shapes which are well understood by those skilled in the art.

The soil/metal load bearing structure is erected by interconnecting the cold roll formed plates where each plate is of desired length and curvature to match the overall outline of the load bearing structure. Normally the plates are all the same width, having holes provided therein to permit erection of the arch. In accordance with this invention the holes are prepunched and are thereby provided in the curved plate. This is different from the system of the prior art, which necessitated drilling the holes or cutting the holes with a plasma torch at the plant during pre-erection assembly or at the site during erection. The cutting of the holes with a plasma torch necessitated the use of washers with the bolts. There is a considerable cost saving and efficiencies at the installation site with the new panels. Each of the panels is formed from a flat planar stock which is a flat plate, as shown in Figure 3A. The planar stock 32 is passed through a roll forming machine or brake press, common in the industry, for forming deep corrugated plate 34, as shown in Figure 3B. The deep corrugated plate 34 has holes 36 punched therein, that is, prepunched before the

subsequent galvanizing and curving steps. Additional holes may be punched in the plate to provide for offset of the plates during erection. In accordance with the process outlined in Figure 3D, the corrugated plate 34 with the punched holes 36 is galvanized, as demonstrated by dipping galvanizing material 38 contained in tank 40. This step of galvanizing the corrugated plate with the prepunched holes results in the holes being covered as well with galvanizing material.

The corrugated plate 34 with the prepunched holes and galvanizing 38, was passed through a roll forming machine which is capable of cold rolling the flat sheet 34 into a uniform, uninterrupted short radius curvature 42 as shown in Figure 4, without inducing any fissure cracks, variations in the width of the panel along its length and causing the holes 36 to migrate from their original prepunched position. These are indeed very significant advantages, several of them unexpected over the prior art approaches for making short radius curved panels.

Figure 5 demonstrates, as previously discussed with respect to the structural arrangement of Figure 1, two cold roll formed, deep corrugated structural metal plates, are provided and designated 44 and 46. The top plate 44 has an edge portion 48 which is truncated to show the shape of the corrugated plate 46 therebeneath. The sharp radius of curvature 50 for the panel 46 is shown by the edge 50. The curvature is uniform along the length of each peak 52 of plate 46 and valley 54 of plate 46. The peaks and valleys do not have cross-corrugations and hence, as shown in Figure 6 where the troughs 54 align with the peaks 52 there is minimal, if no space, at that there juncture 56. This ensures that any material introduced to cavity 58 or 60 between the peaks and troughs of the plates 44 and 46, does not leak out of that cavity nor migrate over into the other adjacent cavity or spill out on to the bottom plate 46. This dam juncture 56 ensures the structural strength of the system is maintained by preventing loss of material introduced into the respective cavity. As well, the cold roll formed product is considerably less expensive and without the cross-corrugations is structurally stronger. As shown in Figure 6,

the cavities may include shear bond connectors 62 which further enhance the overall strength of the system in the manner described in applicant's U.S. Patent 5,833,394.

The cold roll formed deep corrugated structural metal plate has a uniform, uninterrupted curvature along the plates length. This implies that the line of curvature, as shown at 50, is smooth without any waves, peaks or valleys which would interrupt that smooth curvature. Furthermore, the line along the peaks and valleys which are in parallel relationship as shown in Figure 3D and indicated by lines 64 and 66, is maintained after the cold roll forming of the short radius. This ensures the alignment and good contact between the troughs 54 and peaks 52 where their inside surfaces 68 and 70 contact at abutment 56, as shown in Figure 6. Furthermore, the uninterrupted curvature also implies that the radiused section is not interrupted by cross-corrugations or the like of the prior art which were relied on to achieve the short radius of curvature and which, as previously mentioned, is in the range of about 450 mm up to about 3,100 mm. It is understood that the radius of curvature may extend over the entire length of each panel or a portion of the panel. This type of curvature depends upon where the panel is positioned in the structure relative to the position of the short radius bend in the structure. For example, two end to end connecting panels may each include a portion of the short radius section to make up the complete short radius bend in the structure. Alternatively, the short radius bend may occur along the entire length of one panel as positioned in the structure.

In accordance with the preferred embodiments of the invention, the cold roll formed plate of steel has a thickness of about 2 mm to about 10 mm, a corrugation pitch of about 205 mm to about 450 mm and a corrugation depth of about 60 mm to about 225 mm. Usually the ratio of a selected corrugation pitch to corrugation depth is in the range of about 3:1 to about 6:1. Preferably the steel structural plate has a maximum yield strength of about 379 MPa, a maximum tensile strength of about 538 MPa and a percent elongation of about 25% to 35%. Aluminum plate in accordance with a preferred embodiment of

this invention has a thickness about 2mmto about 10 mm, a corrugation pitch of about 230 mm to about 600 mm and a corrugation depth of about 65 mm to about 225 mm. Preferably the aluminum plate has a maximum yield strength of about 241MPa; a maximum tensile strength of about 262 MPa and a percent elongation of about 4% to15%. The metal plate of aluminum or steel is processed by cold roll forming where micro-cracks, fissures and the like are not induced in the short radius and with the lack of cross-corrugations, thinner gauge plate of aluminum and steel may be used. Although the steel plate may be untreated for roll forming, it is preferred that the steel plate has prepunched holes where required and is galvanized prior to cold roll forming of the curvature in the plate. Most preferably the corrugated plate has two or three corrugations across its width, as defined by opposing edges 50 and 51. By three corrugations it is apparent that there are four peaks 52 in lower plate 46 and three troughs 54 provided across the width of the upper plate 44. It is understood that the upper reinforcement plate 44 is upside down and may only be of a single corrugation width for support.

As shown in Figure 7, the plates 44 and 46 have a desired plate thickness 72 which is in the range of about 2 mm to 10 mm. The plates 44 and 46 have the prepunched holes 36 which have been covered by galvanizing 38 as well as on the inner and outer surfaces 74 and 76 and all other surfaces and edges of each plate. Fasteners 78 in the form of a bolt 80 and nut 82 are used to complete the interconnection of plates 44 and 46 at their respective troughs 54 and peaks 52. A washer is not required because the holes are punched and are of the desired diameter. This was difficult to achieve with the prior art plasma torch cutting process.

As shown in Figure 8, the prepunched holes 36 in plate 44 are readily aligned with the prepunched holes 36 in plate 46. The uniform uninterrupted curvature of the plates, as provided by cold roll forming, does not cause the holes to migrate during the forming step. In addition, because the plates are cold rolled rather than hot rolled, distortion is avoided in the plates. As a result of the holes properly aligning, site erection is greatly facilitated and expedited

to reduce significantly the overall costs of manufacture and installing the structure. It is also understood that the prepunched holes 36, instead of being round, may be oval to accommodate a very slight misalignment of the holes. Although applicant's have found that oval holes are optional. Usually the holes are about 25 to 26 mm in diameter.

As previously discussed, a load bearing structure in the form of an arch, culvert or box culvert is customarily made up of several structural metal plates. Each plate has a predetermined shape or curvature along its length to match a corresponding section of the structure profile. Each plate which encompasses part of or all of the short radius section is designed to have a uniform, uninterrupted curvature along the plate's length. The second set of plates may be provided on top of the first set of plates for additional reinforcement, for example, in the manner described in applicant's U.S. Patent 5,833,394. Concrete may be readily introduced into the cavity where by virtue of the uniform, uninterrupted curvature of the plates, a dam between the plates at 56, as described with respect to Figure 6, blocks, minimizes or prevents the leakage of the concrete slurry from the cavity defined between the first and second set of structural plates. By virtue of being able to galvanize the plates before roll forming the curved radius in the plates, the plates are straight to facilitate the galvanizing process and optimize galvanize coating on the plates.

Although preferred embodiments of the invention have been described herein in detail, it will be understood by those skilled in the art that variations may be made thereto without departing from the spirit of the invention or the scope of the appended claims.

What is claimed is:

1. A deep corrugated structural metal plate having a cold roll formed uniform uninterrupted short radius of curvature along at least a portion of said plate's length in the range of about 450 mm up to about 3100 mm, wherein said plate has prepunched holes about its perimeter and is galvanized prior to roll forming said curvature but after said holes are prepunched.

2. The corrugated plate of claim 1, wherein said plate has:
   i) a thickness of about 2 mm to about 10 mm;
   ii) a corrugation pitch of about 230 mm to about 600 mm; and
   iii) a corrugation depth of about 65 mm to about 225 mm.

3. The corrugated plate of claim 2, wherein said structural metal plate is of steel and has a maximum yield strength of about 379 MPa, a maximum tensile strength of about 538 MPa and a percent elongation of about 25% to 35%.

4. The corrugated plate of claim 1, wherein said structural metal plate is of aluminum and has a maximum yield strength of about 241 MPa, a maximum tensile strength of about 262 MPa and a percent elongation of about 4% to 15%.

5. The corrugated plate of any one of claims 1 to 4, for use as a structural metal plate in an arch or box culvert, said plate spanning a short radius haunch for the arch or box culvert.

6. The corrugated plate of claim 5, wherein said plate has two or three corrugations across its width.

7. The corrugated plate of claim 5 or 6, wherein said prepunched holes are circular or oval in shape and accept fasteners for interconnection of said plate to other like plates.

8. A load bearing structure in the form of an arch or box culvert having a short radius section of about 450 mm to 3100 mm, said structure being erected by interconnecting a first set of deep corrugation structural metal plates, each plate having:

a predetermined curvature along its length to match a corresponding section of said structure profile;

for said short radius section, a cold roll formed uniform uninterrupted short radius curvature along said plate's length; and

prepunched holes for receiving fasteners to complete plate interconnection in erecting said structure, said prepunched holes being aligned with complementary prepunched holes in said interconnected plate to facilitate fastener insertion, wherein said plate is galvanized prior to roll forming said curvature but after said holes are prepunched.

9. The load bearing structure of claim 8, wherein a second set of deep corrugation structural metal plates are secured to said first set of plates forming a first pair of plates for said load bearing structure, each plate of said second set of plates having a cold roll formed uniform uninterrupted curvature along said plate's length to provide thereby a dam along abutting peaks and troughs of said first and second set of plates at least for said short radius section of said structure, said dam blocking leakage of concrete slurry from cavities defined between said first set of plates and said second set of plates.

10. The load bearing structure of claim 9, wherein said second set of structural plates has prepunched holes which align with said complementary prepunched holes in said first set of structural plates.

11. The load bearing structure of claim 10, wherein said plate of said second set of structural plates is galvanized prior to roll forming said curvature but after said holes are prepunched.

12. The load bearing structure of any one of claims 9 to 11, wherein said first set of plates and said second set of plates have shear bond connectors which project into said cavities.

13. The load bearing structure of any one of claims 8 to 12 wherein each cold roll formed plate is of steel.

14. A method of forming a deep corrugated structural metal plate, the method comprising:

roll forming a flat steel plate thereby forming a deep corrugated plate;

punching a plurality of holes about the perimeter of the deep corrugated plate;

galvanizing the punched deep corrugated plate; and

cold rolling the galvanized, punched deep corrugated plate into a uniform uninterrupted short radius of curvature along at least a portion of said plate's length in the range of about 450mm up to about 3100mm.

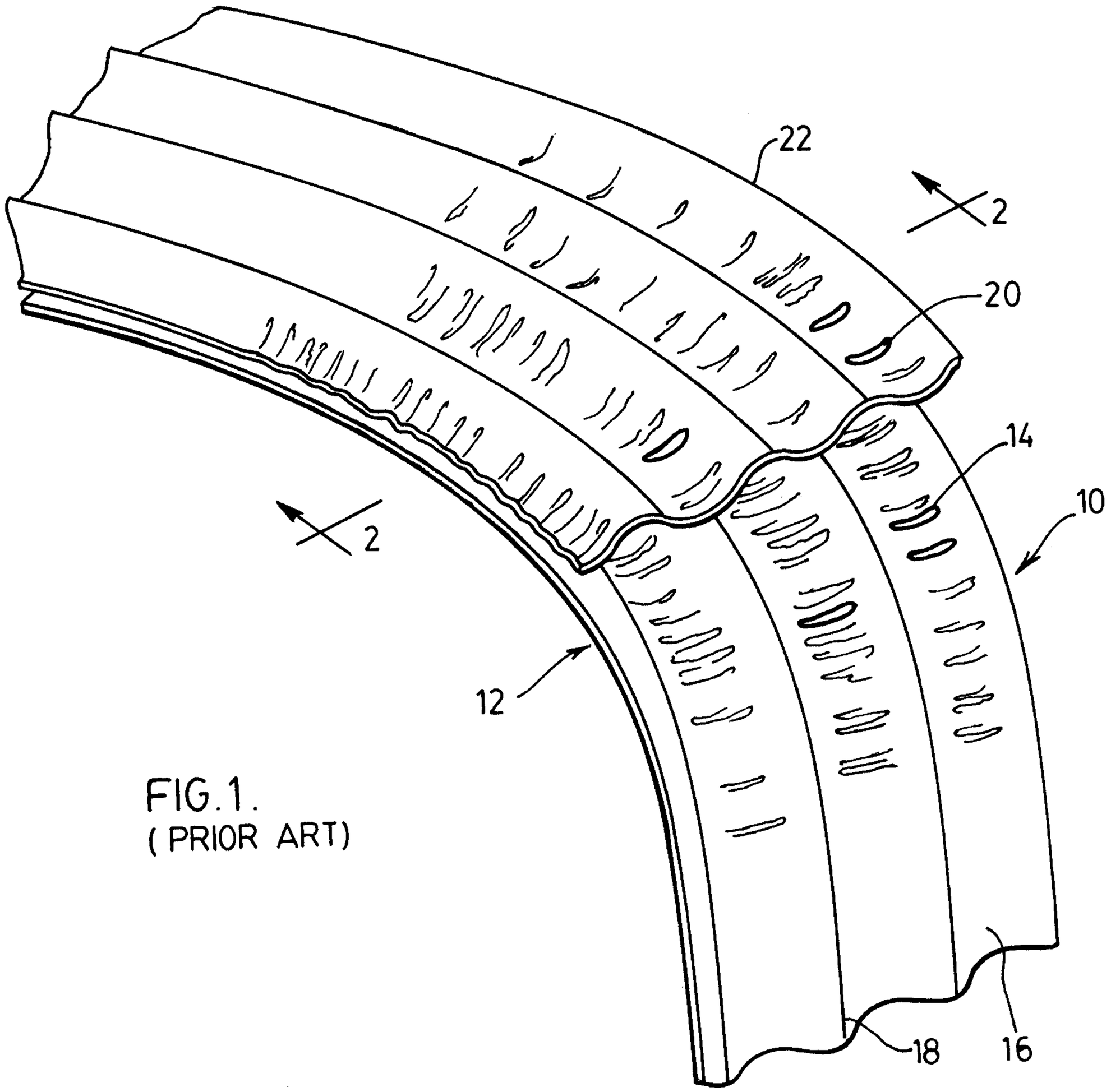


FIG.1.
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FIG.2.
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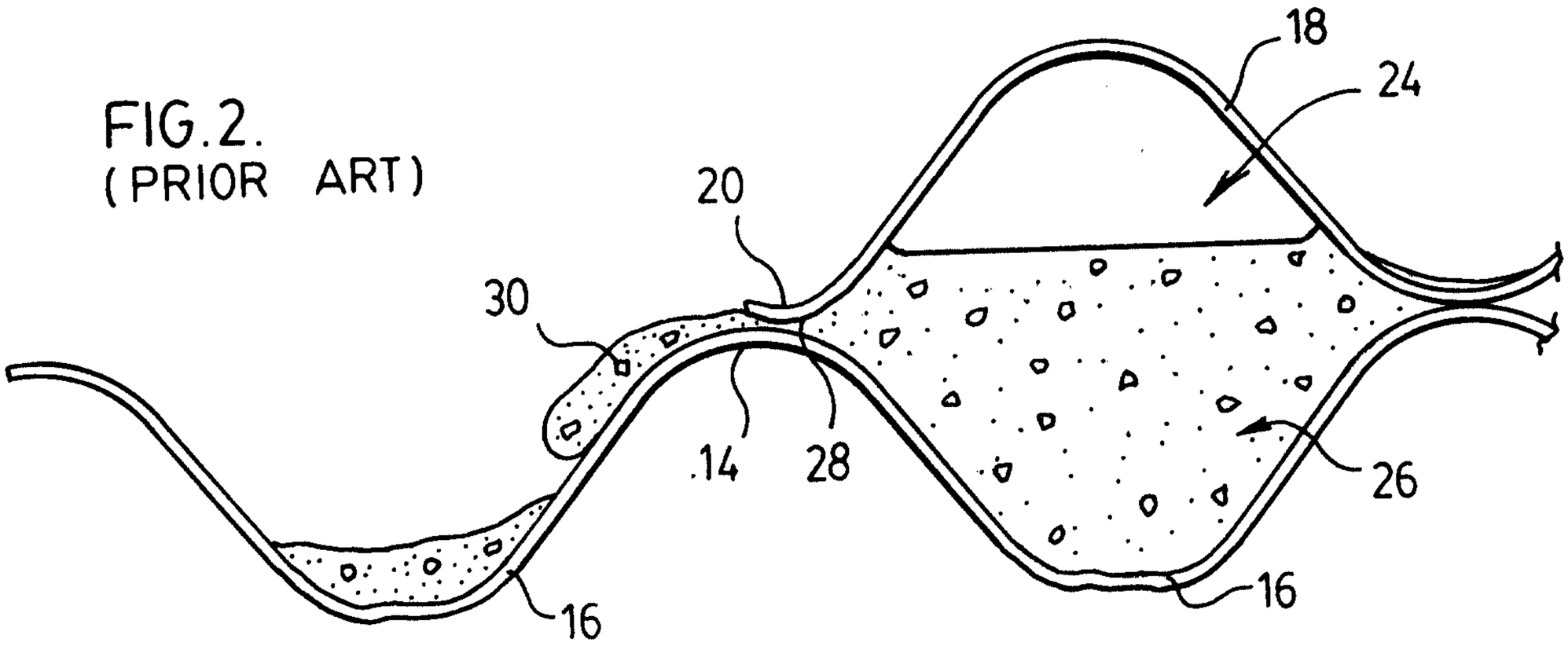


FIG. 3A.

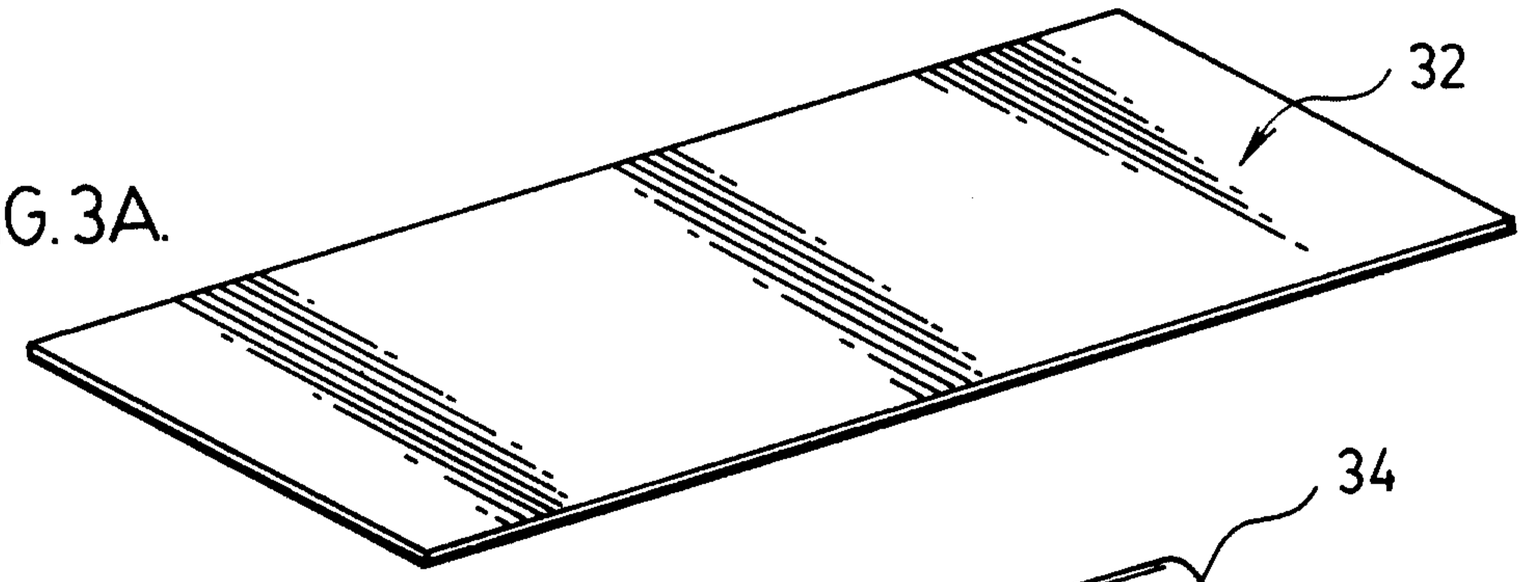


FIG. 3B.

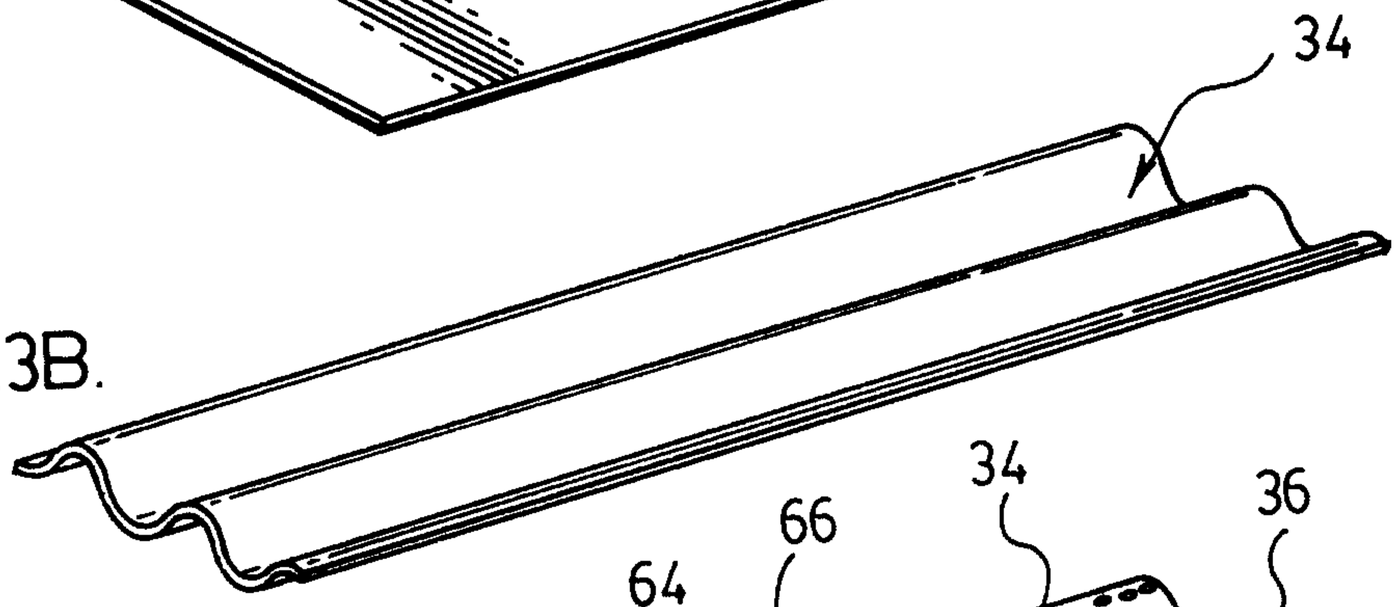


FIG. 3C.

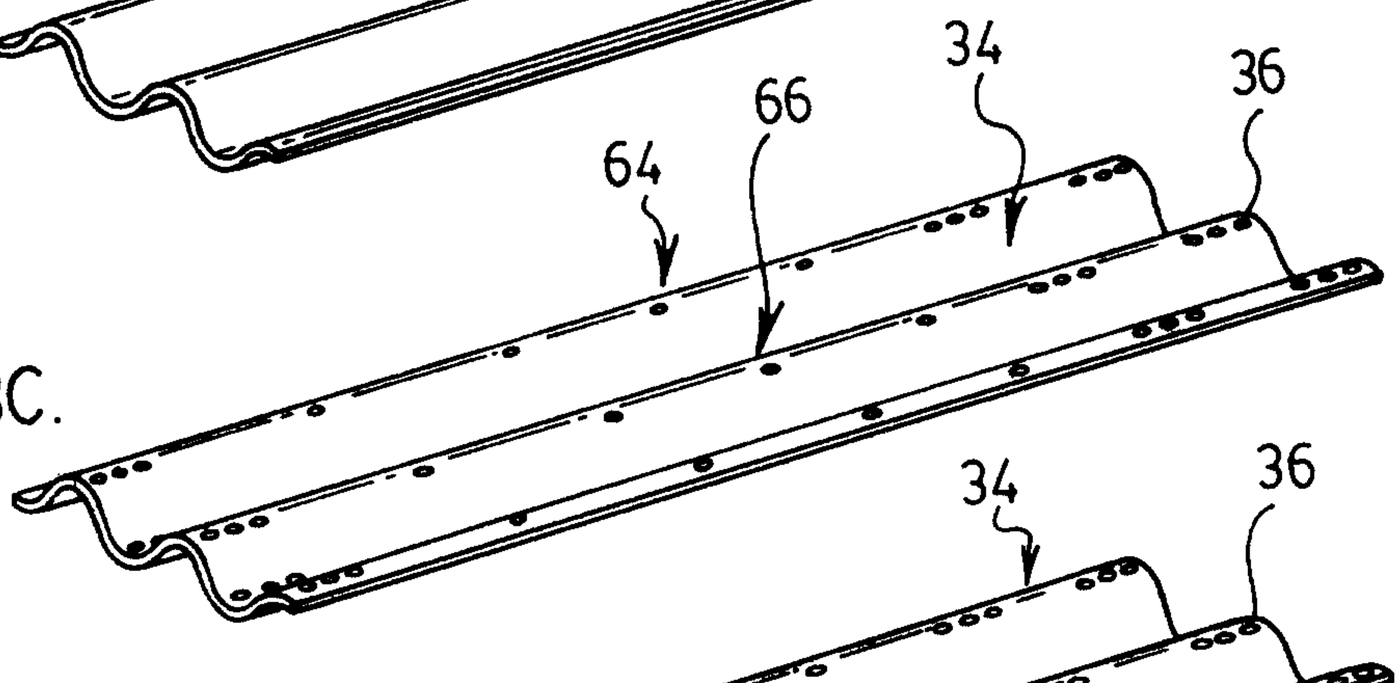


FIG. 3D.

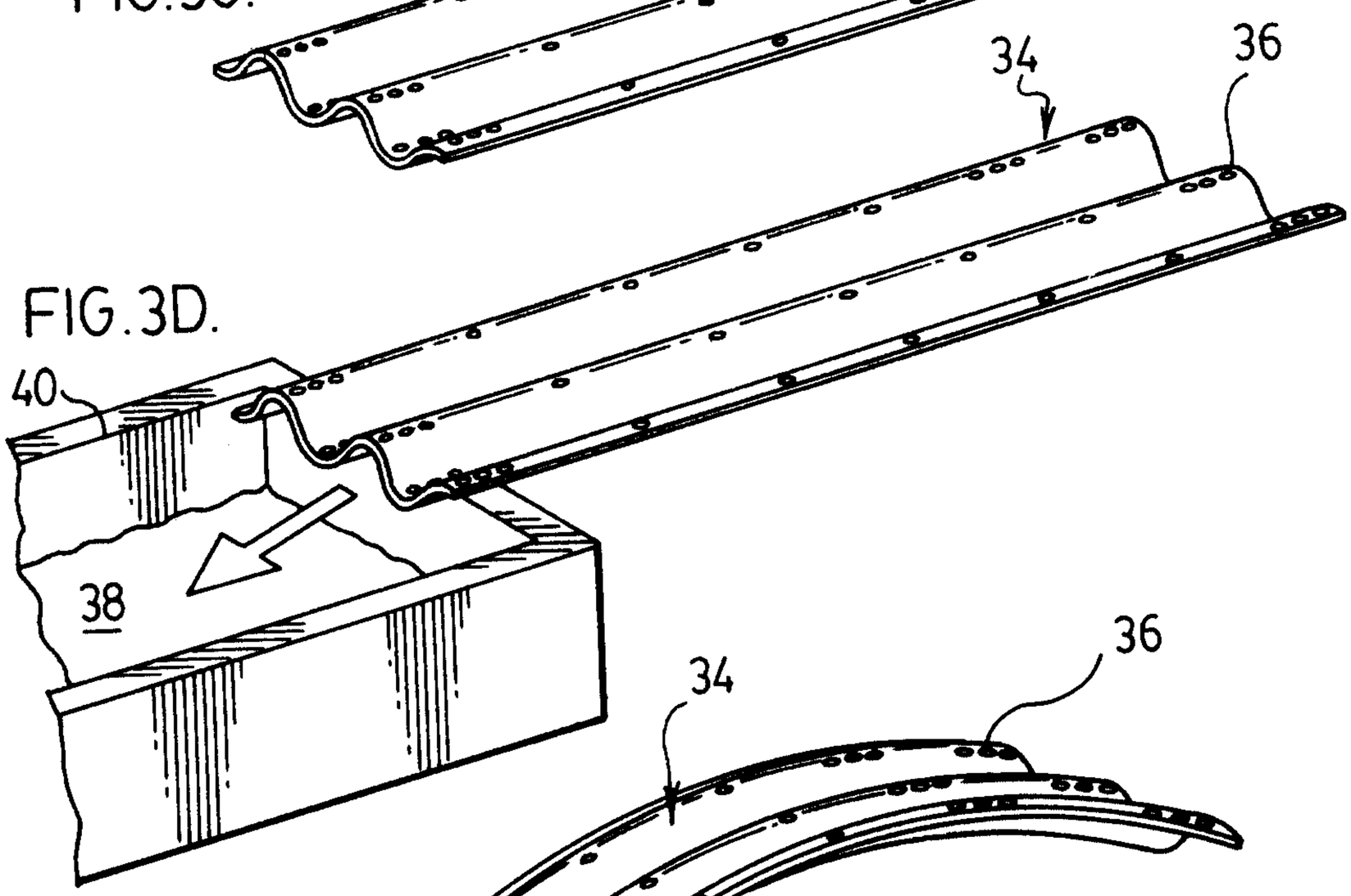


FIG. 4.

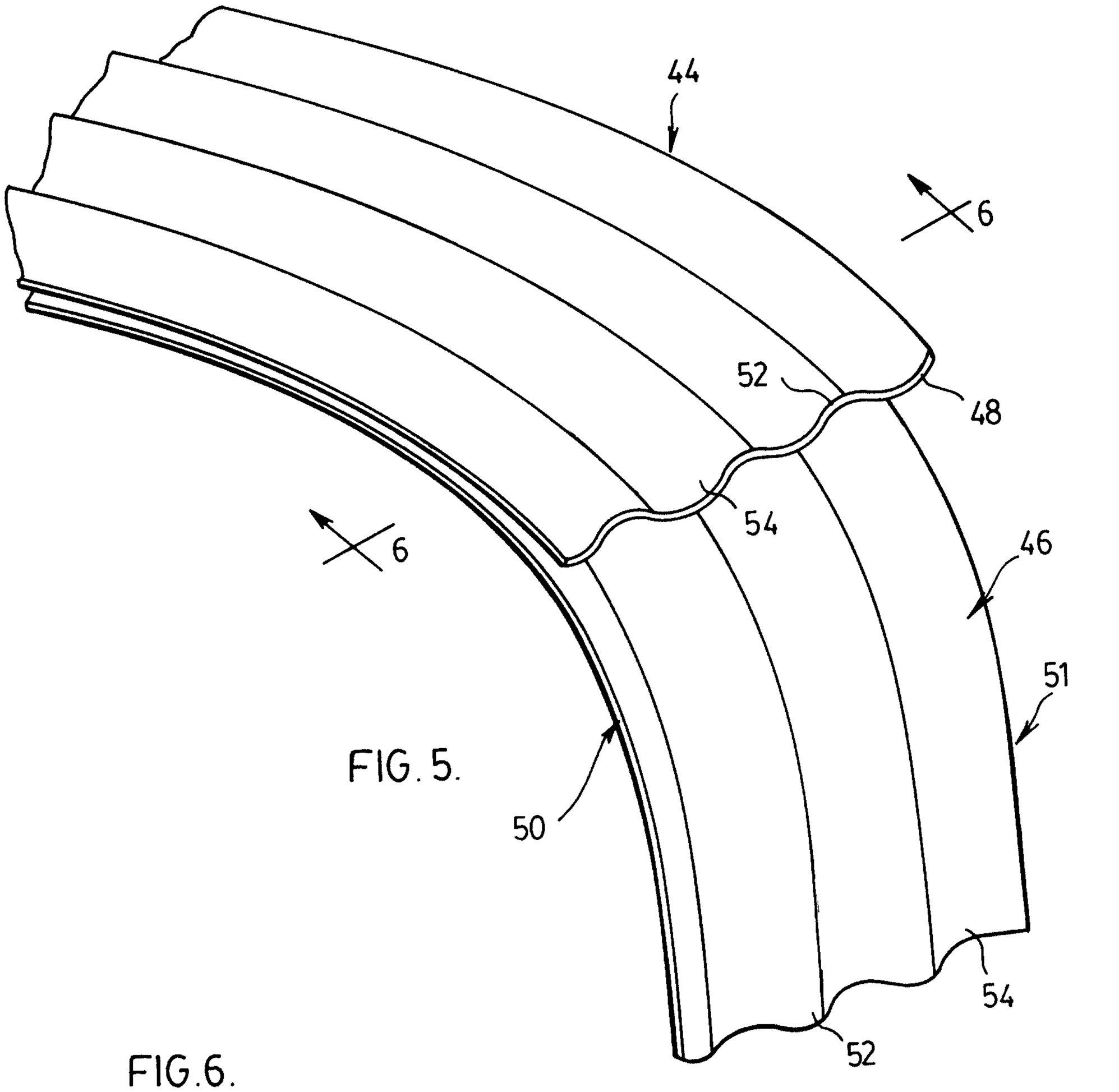
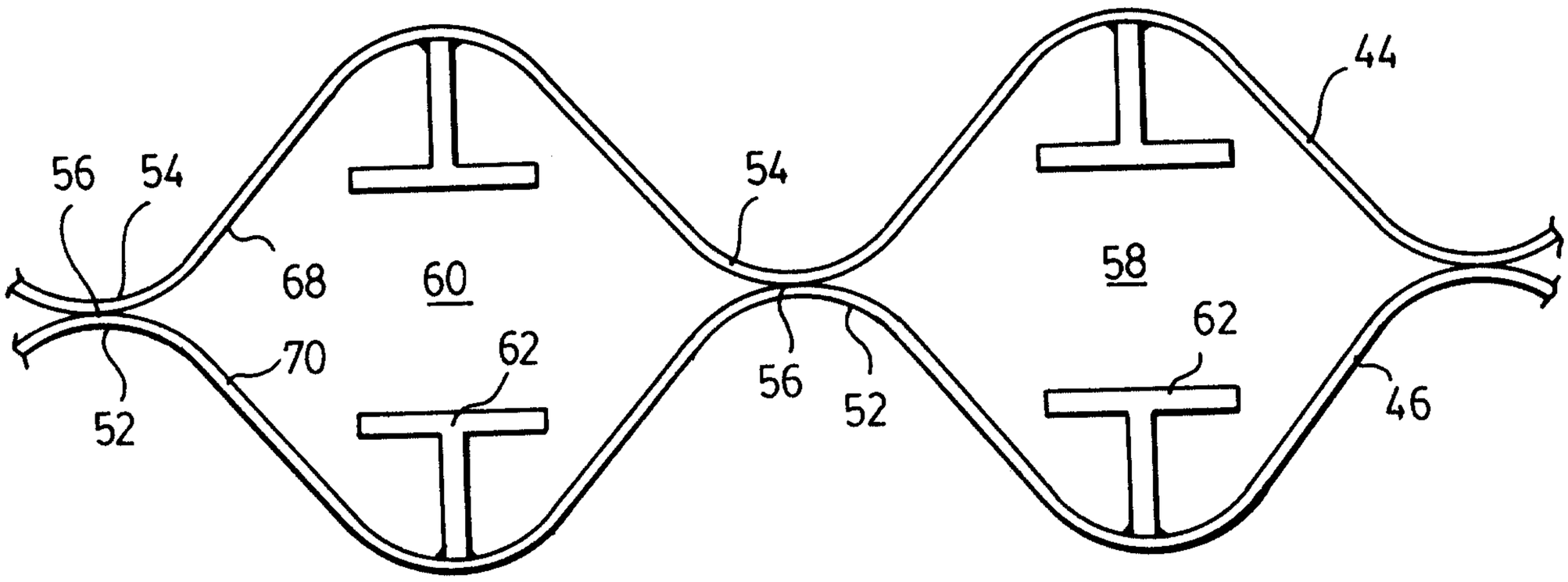


FIG. 5.

FIG. 6.



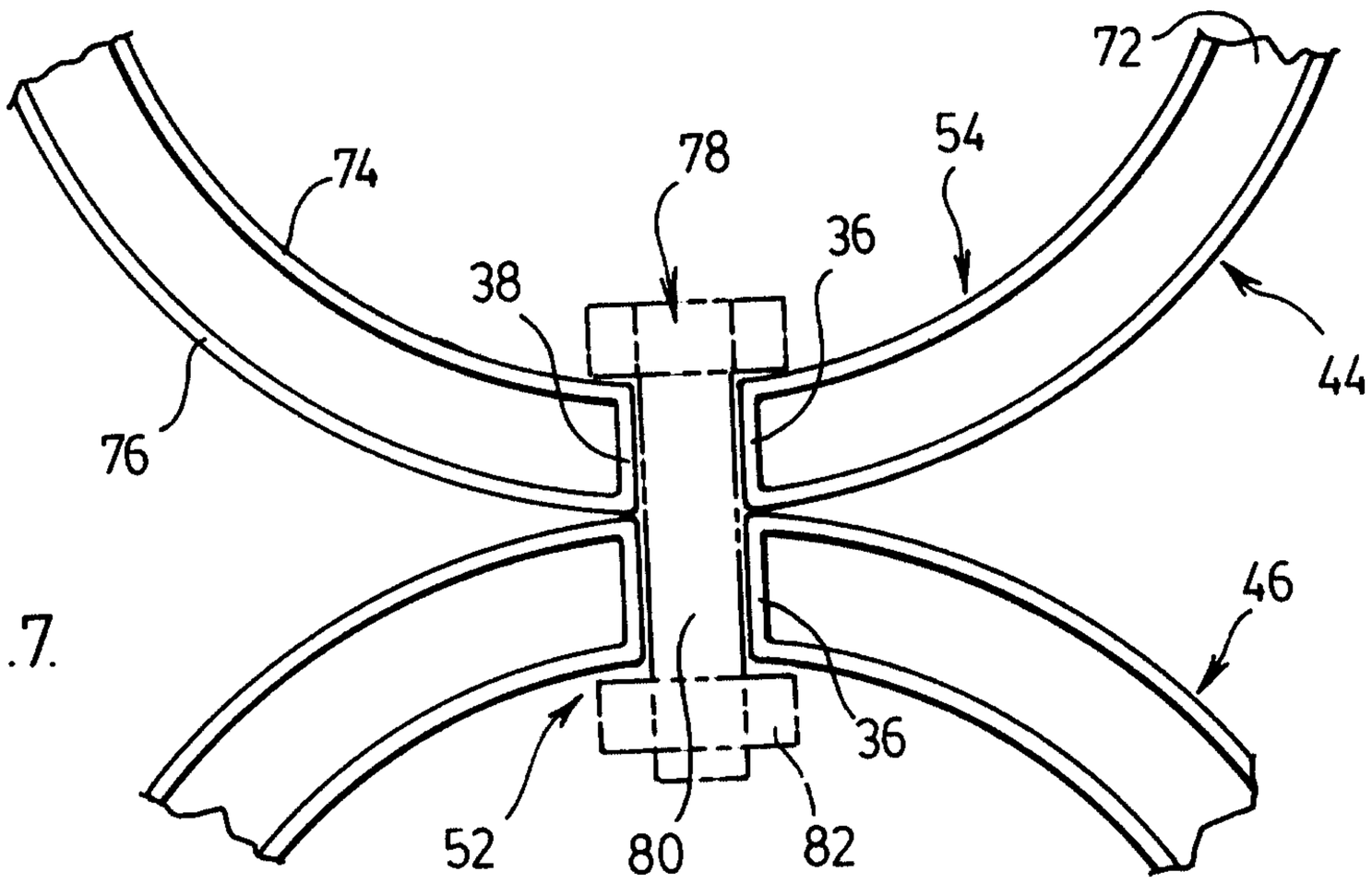


FIG.7.

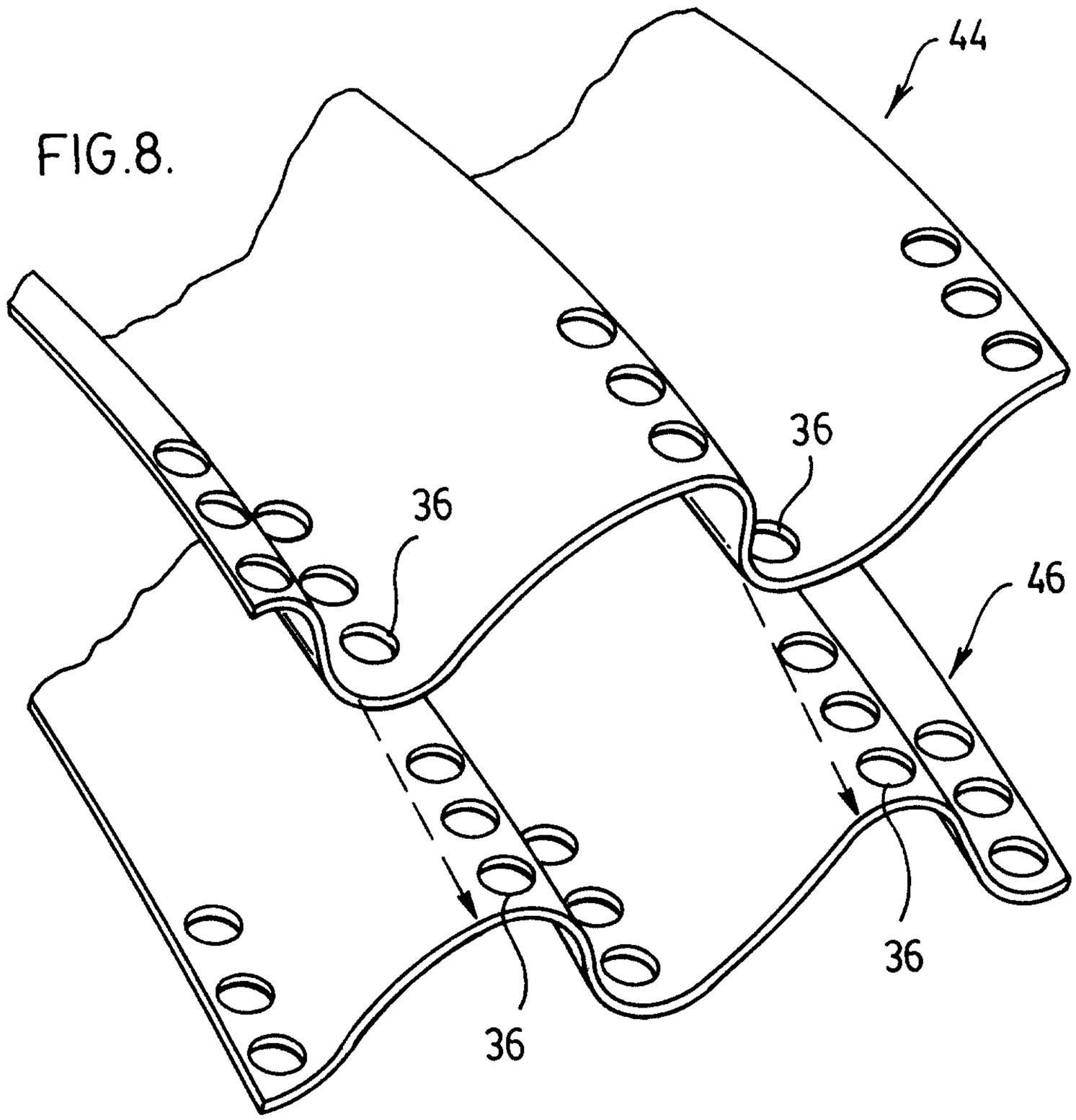
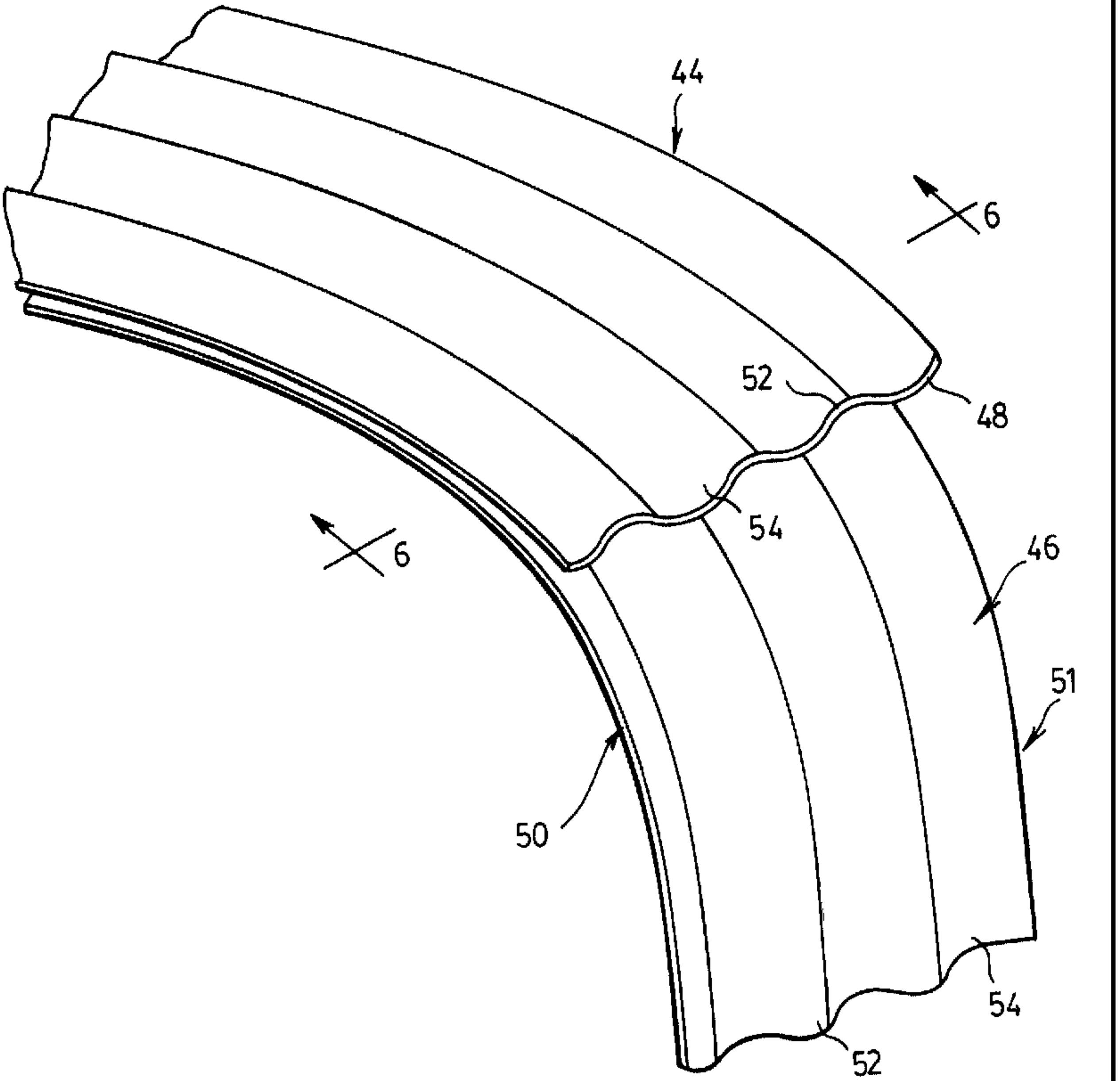


FIG.8.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