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Applicant: **TRW INC.**  
**23555 Euclid Avenue**  
**Cleveland Ohio 44117(US)**

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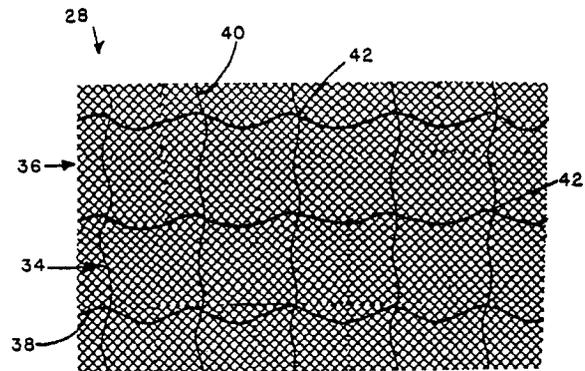
Inventor: **Weinstein, Samuel**  
**40211 Village 40**  
**Camarillo California 93010(US)**

Designated Contracting States:  
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Representative: **Alden, Thomas Stanley et al**  
**A.A. THORNTON & CO. Northumberland**  
**House 303-306 High Holborn**  
**London WC1V 7LE(GB)**

**Hybrid mesh and rf reflector embodying the mesh.**

A hybrid microwave reflective mesh and an antenna reflector having an RF reflecting surface composed of the mesh. The hybrid mesh includes a supporting mesh of any conveniently fabricatable mesh size, which may be substantially larger than the RF wavelengths to be reflected, and a relatively fine, compliant, electrically conductive mesh fabric overlying and secured to the supporting mesh and having a mesh gauge sized to reflect the desired RF wavelengths. The preferred supporting mesh is the welded wire mesh described in U.S. Patents 3961153, 3987457 and 3982248, whereby the hybrid mesh is resiliently stretchable in an edgewise direction and provides shunt paths for any electrical breaks occurring in the conductive mesh.



**FIG. 3**

**EP 0 290 124 A2**

## HYBRID MESH AND RF REFLECTOR EMBODYING THE MESH

### BACKGROUND OF THE INVENTION

#### FIELD OF THE INVENTION

This invention relates generally to antennas and more particularly to a novel hybrid RF reflective mesh and to an antenna having an RF reflective surface composed of the mesh.

#### PRIOR ART

The prior art is replete with a vast assortment of antennas for both terrestrial and space use. The antenna and the hybrid antenna mesh of this invention have features which are beneficial for both space and terrestrial applications. However, the invention is particularly concerned with parabolic antennas for spacecraft and will be described in this context.

Simply stated, a parabolic antenna comprises a parabolic reflector and a feed at the focus of the reflector. In a transmitting antenna, the feed radiates RF energy to the reflector which then reflects the energy as a beam along the axis of the reflector. In a receiving antenna, the incoming RF energy incident on the reflector along its axis is reflected to and focused at the feed. A parabolic antenna may be designed to operate as either or both a transmitting antenna and a receiving antenna.

Among the primary requirements of a spacecraft parabolic antenna are these: relatively light weight, capability of being stowed in a compact configuration during launch and deployed to its operating configuration in space, and precise conformance of the parabolic reflecting surface to the desired parabolic configuration when deployed in space. The present invention satisfies these requirements. Although terrestrial parabolic antennas do not have these same requirements, it will become evident that the present invention may be utilized to advantage in many terrestrial applications, notably radio telescopes.

While most if not all terrestrial parabolic antennas, except perhaps large radio telescopes, may utilize rigid parabolic reflectors, the deployment and weight requirements of spacecraft antennas preclude the use of rigid reflectors on spacecraft. For this reason, a wide variety of deployable parabolic antenna reflectors have been devised. Some utilize rigid foldable petals which are deployable to

a parabolic configuration. These petal-type reflectors have the advantage of providing a relatively smooth and precise parabolic surface when deployed but tend to be quite heavy and complex. Another type of deployable parabolic reflector utilizes a foldable metallic net or mesh or metalized plastic film as the parabolic reflecting surface. This reflecting surface is attached to a frame having ribs extending out from a hub which are foldable to retract and deploy the reflector. The ribs are shaped to conform the reflecting surface to a parabolic curvature when the reflector is deployed. The earlier mentioned Patent Nos. 3961153, 3982248, 3987457 disclose deployable parabolic reflectors of this latter type. The preferred embodiment of this invention is an improvement on these latter deployable antennas which permits much higher frequency operation.

The present invention may be best understood by first understanding the parabolic antenna reflector described in the above patents. That reflector has a frame including a plurality of generally parabolically curved ribs spaced circumferentially about and pivotally attached at their inner ends to a central hub. The ribs are rotatable inwardly relative to the hub to retracted positions wherein the ribs are gathered together over the front side of the hub and rotatable outwardly relative to the hub to extended or deployed positions wherein the ribs conform to a parabolic surface.

Attached to these ribs is a wire mesh including first parallel wires which extend between and are fixed at their ends to adjacent ribs in spaced relation along the ribs and second parallel wires which extend generally lengthwise of the ribs in crossing relation to the first wires. The first and second wires are welded to one another at their intersections to form a welded mesh structure which conforms to a parabolic surface when the reflector ribs are extended or deployed. The mesh is foldable to permit retraction of the ribs.

A unique feature of this prior welded mesh resides in the fact that its wires which extend between the reflector ribs are preformed into a spring-like configuration which permits these wires to stretch and contract in response to the changing temperatures to which the mesh is exposed in space. The mesh is applied to the reflector frame in such a way that the spring wires are stressed in tension with a predetermined tension preload sufficient to maintain the wires under tension and thereby maintain the welded mesh reflector in its parabolic configuration over the entire temperature range which the reflector encounters in space.

The welded mesh is fabricated in the welding

machine of patent no. 3,961,153. This machine is operable to feed the crossing wires of the mesh thru the machine and to weld the wires at their crossing points or intersections.

The welded mesh has certain characteristics which tend to limit its usefulness for future space applications. The present invention overcomes this deficiency of the mesh.

In this regard, it is well known that in order for a wire mesh to be an effective RF reflector, its mesh size, that is the size of its openings or the spacing between the parallel mesh wires must be small in comparison to the RF wavelengths to be reflected. For the RF frequencies which have been used to date, it has been possible to fabricate welded mesh of sufficiently small mesh size to provide an effective RF reflecting surface. Future space communication applications, however, contemplate the use of much higher frequencies and correspondingly smaller wave lengths for which it is difficult or impossible to fabricate useful welded mesh with the required small mesh size.

Fabrication of small size welded mesh for such higher frequencies is difficult or impossible for two reasons. First, the number of welds required to fabricate a welded mesh for a typical spacecraft parabolic reflector would be so large as to be impractical or impossible to produce, at least economically. Secondly, the welds of the resulting welded mesh would be so close together that the mesh would be much too stiff for a deployable parabolic reflector. A definite need exists, therefore, for an improved RF reflecting mesh for use with these future higher frequencies.

#### SUMMARY OF THE INVENTION

This invention provides such an improved high frequency reflecting mesh which may be sized for operation at the very high frequencies contemplated for future space communication applications, may be easily fabricated, and has sufficient flexibility or compliancy for use on a deployable spacecraft antenna reflector, such as a parabolic dish reflector.

The improved mesh is a hybrid mesh including a supporting mesh and an electrically conductive mesh overlying and secured to the supporting mesh. The conductive mesh forms the RF reflective surface of the hybrid mesh and has a relatively small mesh size appropriate for the high frequency electromagnetic wavelengths to be reflected. In this regard, the conductive mesh of the present best mode embodiment of the invention is a knit wire fabric-like mesh which can be fabricated with a very small mesh size on the order of 16 wires per

inch for use at frequencies on the order of 24 GHZ.

The described embodiment of the invention is a deployable parabolic antenna reflector for space craft which utilizes the present hybrid mesh as the parabolic reflecting surface of the reflector. The supporting mesh of this embodiment is the resilient, welded wire mesh described in the earlier mentioned patents which may have any conveniently fabricated mesh size. The hybrid mesh is relatively compliant or flexible, such that it can readily fold and unfold to accommodate collapsing and deployment of the reflector. The resiliency of the supporting and woven meshes enables the hybrid mesh to maintain its parabolic contour over the temperature range encountered in space.

#### BRIEF DESCRIPTION OF THE DRAWINGS

FIGURE 1 is a perspective view of a parabolic antenna embodying a hybrid, mesh reflector according to the invention;

FIG. 2 is an enlarged fragmentary detail of the reflector;

FIG. 3 is an enlarged view of the hybrid mesh in the antenna of FIGS. 1 and 2;

FIG. 4 is a further enlarged view of the hybrid mesh;

FIG. 5 is an enlargement of a spring wire embodied in the supporting mesh of the hybrid mesh;

FIG. 6 illustrates a hybrid mesh panel of the reflector in FIG. 1; and

FIG. 7 is an enlarged perspective view of the panel.

#### DESCRIPTION OF THE PREFERRED EMBODIMENT

The deployable parabolic antenna 10 of Figs. 1 and 2 is conventional except for the RF reflecting surface 12 of its parabolic reflector or dish 14. Accordingly, an elaborate description of the antenna is unnecessary. Suffice it to say that the antenna reflector 14 has a frame 15 including a central hub 16 mounted on a support 18 which may be part of the space craft, for example, and parabolic ribs 20 attached at their inner ends to the hub by hinges 22.

The ribs are rotatable between their folded or contracted positions shown in broken lines in Fig. 2 and their unfolded or deployed positions shown in full lines in the figure. In their contracted positions, the ribs extend generally longitudinally forward of the hub and are contained within an envelope of

about the same diameter as the hub. In their deployed positions, the ribs conform to a common parabolic surface with the front face 24 of the hub. Springs 26 urge the ribs to their deployed positions. Releasable means (not shown) are provided for retaining the ribs in their contracted positions.

As explained in more detail presently, the R.F. reflecting surface 12 of the parabolic reflector 14 comprises the hybrid mesh 28 of this invention. This mesh is attached to the reflector ribs 20 for contraction and deployment with the ribs. When the ribs are deployed, the reflecting mesh 28 and the front hub face 24 conform to a parabolic surface having a focus  $f$ .

Extending forwardly from the hub 16 along its central axis is the antenna feed 30. This feed includes a radiator and/or receptor 32 situated at the focus  $f$ .

The primary subject matter of this invention is the construction of the hybrid mesh 28 which forms the RF reflecting surface 12 of the parabolic reflector 14. This mesh will now be described with reference to Figs. 3-7.

The hybrid mesh 28 comprises a supporting mesh 34 and an electrically conductive mesh 36 overlying and secured to the conductive mesh. The supporting mesh 34 may have any easily fabricatable mesh size. The conductive mesh 36 comprises a wire mesh or a metalized synthetic fiber mesh and has a mesh size appropriate for the RF wavelength to be reflected. The primary advantage of the invention resides in the fact that the conductive mesh may be fabricated with a very small mesh size, suitable for the very high frequencies contemplated for future space application, using conventional knitting or weaving techniques and equipment. For example, as will be seen presently, the mesh may be a knit wire fabric-like mesh with a mesh size on the order of 0.10 inch which is suitable for frequencies in the range of 5 to 6 gigahertz.

Referring in more detail to the drawings, the preferred supporting mesh 34, illustrated, is a welded wire mesh like that described in the earlier mentioned prior patents. This preferred supporting mesh has strands or wires 38 extending between adjacent ribs 20 of the reflector 14, generally circumferentially of the reflector, and strands or wires 40 extending transverse to the wires 38 and generally radially of the reflector. The wires 38, 40 cross one another and are welded together at their intersections 42. The circumferential wires 38 are crinkled in the manner shown in Fig. 5 and described in the earlier mentioned patents to provide these wires with a spring-like configuration which renders these wires resiliently stretchable in their endwise directions. Thus, the supporting mesh 14 is resiliently stretchable in its edgewise directions

parallel to the wires 38.

The spring wires 38 are stressed with a preload tension as described in the patents.

The knit wire mesh 36 is essentially a knit wire fabric comprising knit wire chains 44 running in one edgewise direction of the mesh and knit wire chains 46 running crosswise of the chains 44 and interlocked with the latter chains at the chain intersections. The knit mesh may comprise various open knit patterns. The preferred pattern shown in Fig. 4 is a tricot 2 bar knit pattern. This knit pattern is well known and hence need not be further described. The resulting knit mesh 36 is a compliant wire fabric which has some degree of in plane stretchability in all edgewise directions but primarily in the diagonal directions of the mesh openings 48.

The conductive mesh fabric 36 is arranged on the supporting mesh 34 with the supporting mesh wires 38, 40 running diagonally of the openings 48 in the knit mesh. The knit mesh is welded to the supporting mesh at appropriate intersections of the supporting mesh wires 38, 40 and the knit mesh wire chains 44, 46. From the description to this point, it will be understood that the hybrid mesh 28 is resiliently stretchable in the edgewise direction of the resilient spring wires 38 of the supporting mesh 34.

In the particular parabolic reflector 14 illustrated, the hybrid mesh reflecting surface 12 comprises a plurality of individual panels 50. Each panel is disposed between and secured to two adjacent reflector ribs 20. Figs. 6 and 7 illustrate one of these panels in enlarged detail. Each reflector panel 50 comprises a pair of metallic mounting strips 52 to which are firmly attached the ends of the supporting mesh spring wires 38. These mounting strips are secured to the reflector frame ribs 20.

It will now be understood that when the reflector 14 is fully deployed, the supporting mesh 34 conforms substantially to a parabolic surface, as described in the earlier mentioned patents. The electrically conductive mesh fabric 36 is supported by the supporting mesh 34 and conforms substantially to the parabolic surface defined by the supporting mesh. The supporting mesh may have any conveniently fabricatable mesh size. The conductive mesh fabric 36 is fabricated with a mesh size appropriate for the particular RF wavelengths to be reflected. By way of example, a ten gauge mesh size i.e. 10 conductors (10 wire chains 44/46 per inch) is appropriate for frequencies in the range of 5 to 6 gigahertz.

As noted earlier, the preferred knit pattern for the conductive mesh fabric 36 is a two bar tricot knit. Other knit patterns may be used, however, such as a Raschel knit. Moreover, the conductive

mesh fabric 36 may be a woven fabric rather than a knit fabric.

The particular conductive mesh fabric 36 described is a knit wire fabric. Alternatively the conductive mesh fabric may comprise metallized synthetic fibers.

The supporting mesh 34 may be a wire mesh or a synthetic fiber mesh. An advantage of a wire supporting mesh over a non-conductive fiber supporting mesh is that the wire supporting mesh provides a shunt path for any breaks in the conductive mesh fabric. This disadvantage may be overcome by metalizing a synthetic fiber supporting mesh.

**Claims**

1. A hybrid microwave reflective mesh, comprising: A flexible supporting mesh; and A compliant, electrically conductive mesh fabric overlying and secured to said supporting mesh.

2. A hybrid microwave reflective mesh according to claim 1 wherein: said supporting mesh comprises a wire mesh including crossing wires welded to one another at their intersections; and said mesh fabric comprises a wire mesh.

3. A hybrid microwave reflective mesh according to claim 1 wherein: said supporting mesh has a mesh size larger than the wavelengths to be reflected; and said mesh fabric has a mesh size smaller than the wavelengths to be reflected.

4. A hybrid microwave reflective mesh according to claim 2 wherein: said mesh fabric is welded to said supporting mesh at selected positions spaced about the woven mesh.

5. hybrid microwave reflective mesh according to claim 1 wherein: said supporting mesh and mesh fabric are resiliently stretchable edgewise of said hybrid mesh.

6. A hybrid microwave reflective mesh according to claim 5 wherein: said supporting mesh comprises spring-like longitudinally resilient first strands extending in said one edgewise direction of said screen and second strands extending crosswise of and joined to said first wires; and said mesh fabric comprises intersecting conductors joined at their intersections.

7. A microwave antenna reflector comprising: a supporting frame; and a hybrid microwave reflective mesh supported by said frame including a supporting mesh secured to said frame, and an electrically conductive mesh fabric overlying, secured to, and supported by said supporting mesh.

8. A microwave antenna reflector according to claim 7 wherein:

said supporting mesh comprises a wire mesh including crossing wires welded to one another at their intersections; and said mesh fabric comprises a wire mesh.

9. A microwave antenna reflector according to claim 7 wherein:

said supporting mesh has a mesh size larger than the wavelengths to be reflected; and said mesh fabric has a mesh size smaller than the wavelengths to be reflected.

10. A microwave antenna reflector according to claim 9 wherein:

said mesh fabric is welded to said supporting mesh at selected positions.

11. A microwave antenna reflector according to claim 7 wherein:

said supporting mesh comprises spring-like longitudinally resilient first strands and second strands extending crosswise of and joined to said first strands; and said mesh fabric comprises intersecting conductors joined at their intersections.

12. A microwave antenna reflector according to claim 11 wherein:

said reflector comprises a parabolic reflector dish; said frame comprises a hub, ribs extending out from said hub in radial, circumferentially spaced planes of the hub and curved to conform substantially to a parabolic surface; and said hybrid mesh is secured to said ribs with said first longitudinally resilient strands of said supporting mesh extending generally circumferentially of said dish.

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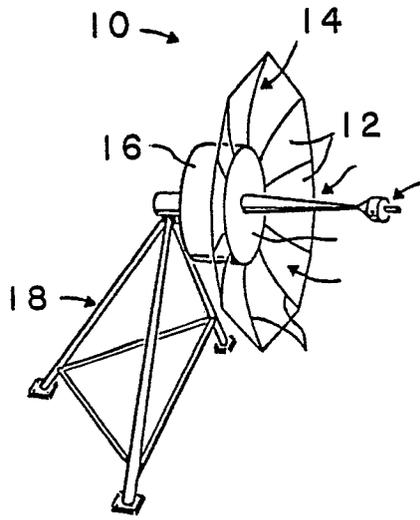


FIG. 1

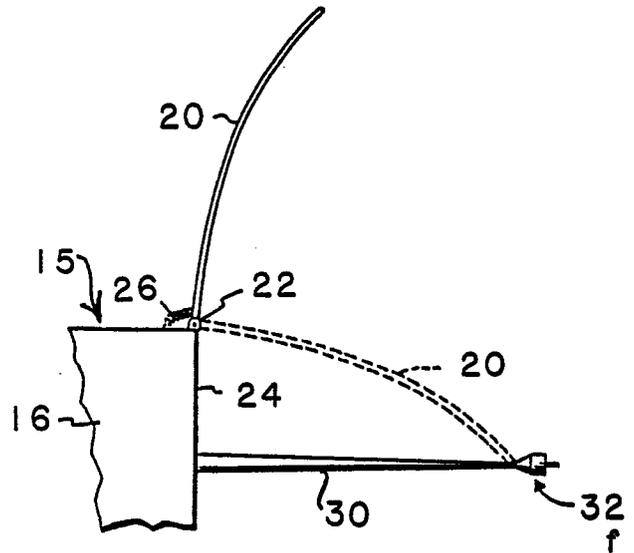


FIG. 2

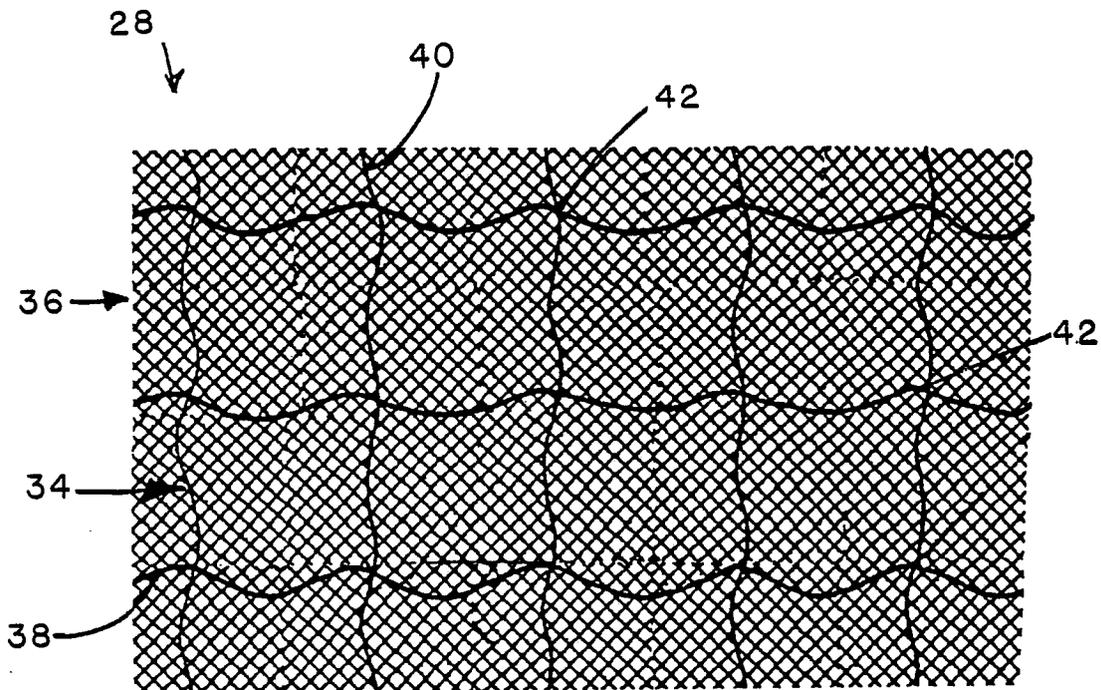


FIG. 3

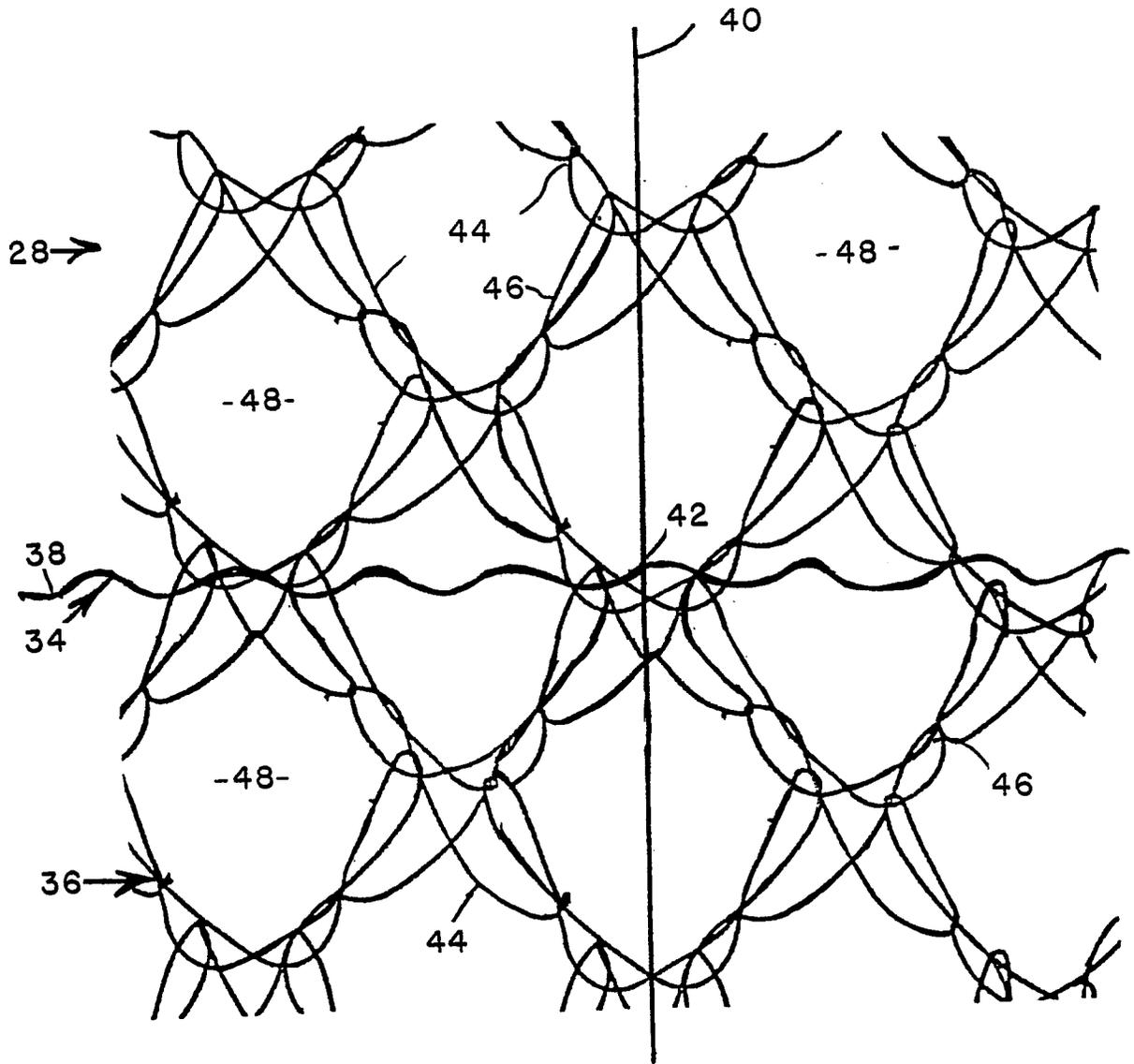


FIG. 4



FIG. 5

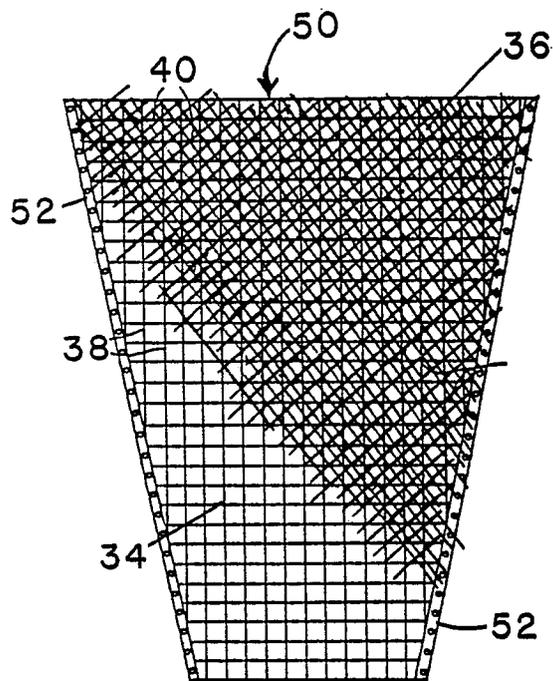


FIG. 6

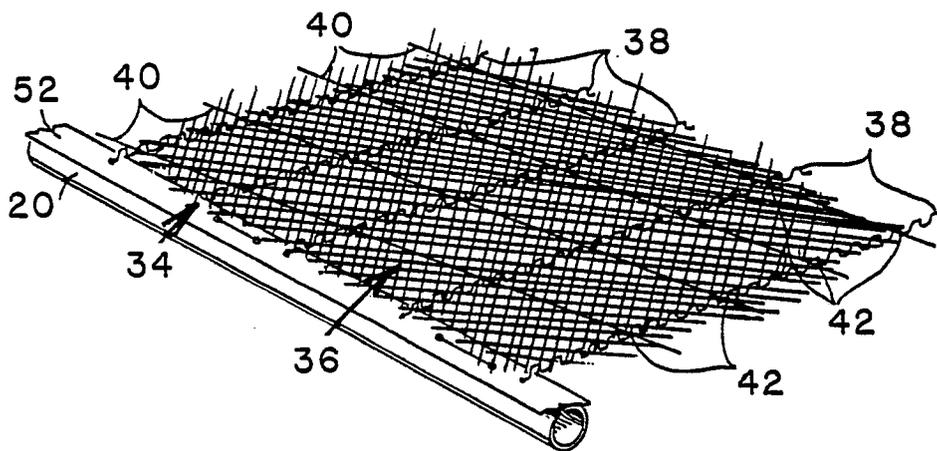


FIG. 7