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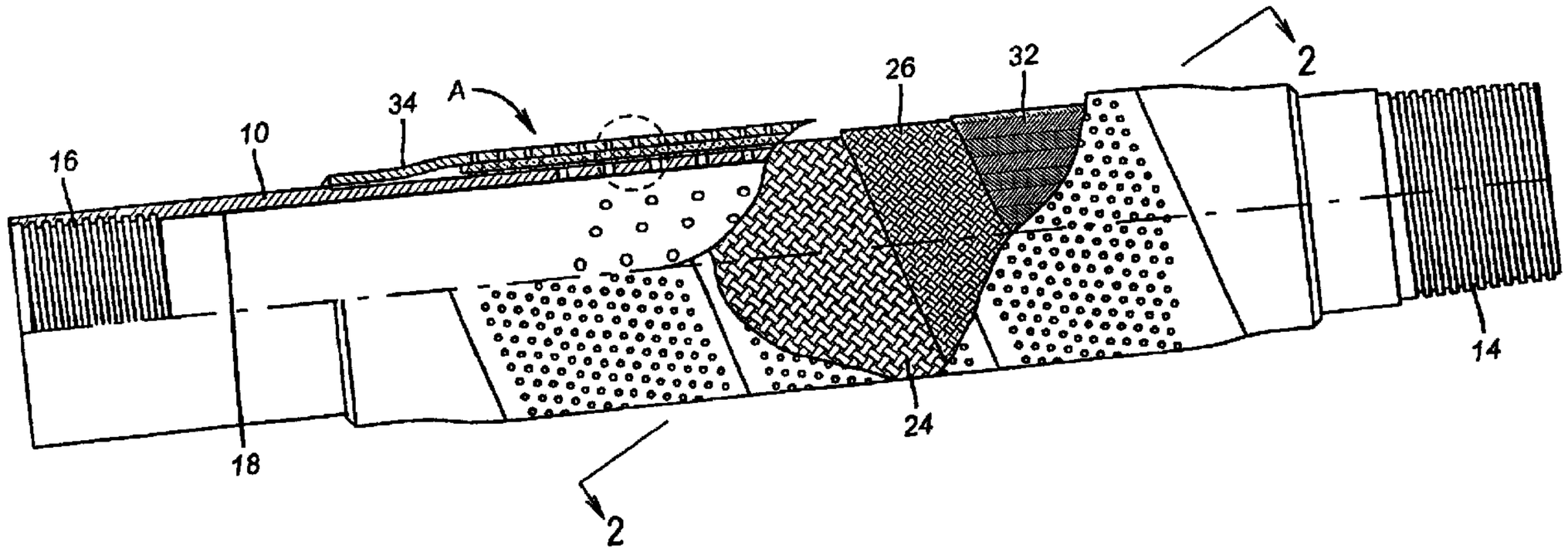
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(54) Titre : ECRAN MULTICOUCHE ET PROCEDE D'ACHEVEMENT DE FOND DE TROU
(54) Title: MULTI-LAYER SCREEN AND DOWNHOLE COMPLETION METHOD



(57) Abrégé/Abstract:
A downhole completion method and an expandable filtration apparatus are disclosed. The filter assembly comprises a plurality of layers beginning with a coated perforated base pipe. The coating reduces the force required for expansion. A drainage layer overlays the base pipe with the filtration layer above it. The drainage layer improves flow through the filtration layer and protects it from burrs in the base pipe. A filtration enhancement layer fits over the filtration layer and an outer shroud protects the assembly during run in. The assembly can be used as made or expanded downhole in one or a series of expansions.

ABSTRACT

A downhole completion method and an expandable filtration apparatus are disclosed. The filter assembly comprises a plurality of layers beginning with a coated perforated base pipe. The coating reduces the force required for expansion. A drainage layer overlays the base pipe with the filtration layer above it. The drainage layer improves flow through the filtration layer and protects it from burrs in the base pipe. A filtration enhancement layer fits over the filtration layer and an outer shroud protects the assembly during run in. The assembly can be used as made or expanded downhole in one or a series of expansions.

MULTI-LAYER SCREEN AND DOWNHOLE COMPLETION METHOD

Field of the Invention

The field of the present invention relates to downhole screens, which can be expanded into contact with a formation.

Background of the Invention

Downhole screens are used in a variety of different applications. As part of a common procedure called gravel packing, the screens are deposited adjacent the producing formation and the surrounding annular space is filled with sand known as gravel. Various fabrication techniques have been developed for manufacturing such screens and a typical example is illustrated in U.S. Patent No. 5,611,399.

More recently it has been determined that it is desirable to reduce the size of the annular space between the screen and the formation. Reduction of the volume of the annular space around the screen discourages fluid flow along the screen, which, in turn, lessens the production of sand. In order to be able to produce the reservoir longer, it has been desirable to insert screens in well bores or laterals and thereafter expand them. A good example of the expansion techniques for a downhole screen is shown in U.S. Patent No. 6,012,522. In this patent, overlapping segments of screen are placed on a base pipe, which is ultimately expanded from within when placed in position in the well bore or lateral. The shortcoming of this technique is that portions of the filtering material must be moved relative to each other which subjects them to tearing, which, in turn, can result in a failure of the expanded screen assembly to control the production of sand. Another shortcoming of such designs is the limited capacity to withstand collapse.

Other patents relating to pipe expansions are: U.S. Patent Nos. 5,901,789 and 5,366,012.

It is one object of an aspect of the present invention to allow easy installation of the screen to the desired location followed by expansion to reduce the volume of the annular space around the screen. Yet another object of an aspect of the present invention is to expand the screen against the formation to entirely eliminate the annular space around it. Yet another object of an aspect of the present invention is to allow the use of the structure of the screen downhole even without expansion. Another object of an aspect of the present invention is to decrease the amount of

stress on the filtration member when expanded. Yet another object of an aspect of the present invention is to provide a significantly stronger structure for the finished product, which even after expansion presents a greater resistance to collapse. Another object of an aspect of the present invention is to provide, as much as possible, uniformity in the opening size of the filtration layer after the assembly is expanded. Another object of an aspect of the present invention is to provide sufficient strength in the assembly, after expansion to allow it to better resist differential pressures. Still another object of an aspect of the present invention is to reduce the effort required for expansion and to stage the overall expansion in discrete steps.

Summary of the Invention

Accordingly, in one aspect of the present invention there is provided an expandable filter assembly for downhole use, comprising:

a base pipe having an inside surface, a longitudinal axis, and a plurality of openings;

at least one filtration layer mounted over said base pipe; and

an expander capable of multi-stage expansion of said base pipe and said at least one filtration layer.

These and other advantages of the present invention will be appreciated by those skilled in the art from a review of the description of the preferred embodiment, which appears below.

Brief Description of the Drawings

Embodiments of the present invention will now be described more fully with reference to the accompanying drawings in which:

Figure 1 is cutaway view, partly in section, showing the filter assembly;

Figure 2 is a section view along lines 2-2 of Figure 1;

Figure 3 is a section view of a first step in a multi step expansion of the filter assembly;

Figure 4 is a section view of a second step in a multi step expansion of the filter assembly;

Figure 5 is a comparison performance chart comparing a known filter made by

Baker Hughes called Excluder* and two variations of the filter of the present invention;

Figure 6 is a schematic view showing various layers being fed into a sintering furnace and rolled up on the other side;

Figure 7 is a section view through a tube formed by the process shown in Figure 6;

Figure 8 is an alternative embodiment in section view made by running the inner and filter layers only through the sintering furnace;

Figure 9 is a section view showing an end connection on a formed tube from the process shown in Figure 6 or from the end product from a modified version of the process whose end product is shown in Figure 8;

Figure 10 is a cut-away view of an alternative embodiment showing a perforated based pipe with outer threads having a wire wound in the threads with an outer jacket cut back to facilitate viewing of the threads and wire;

Figure 11 is a view of an alternative embodiment to Figures 6 and 7 using end openings and a partial filtration membrane;

Figures 12 and 13 show expanding the assembly mechanically from above;

Figure 14 shows expanding the assembly mechanically from below;

Figures 15 and 16 show expanding the assembly using an inflatable bladder;

Figure 17 shows placement of a tube made of half sections of the sheet shown in Figure 11 over a thin wall pipe;

Figure 18 is the view of Figure 17 after expansion.

Detailed Description of the Preferred Embodiments

Referring to Figure 1, the various layers of a filter assembly A are shown. The innermost layer is a perforated base pipe 10, which has a plurality of openings 12. Base pipe 10 provides a firm foundation for the layers above. The pattern of the holes 12 is optimized to strike the best balance between collapse resistance after expansion and minimization of the force required to expand this layer and those positioned outside it, as will be described below. This optimization allows expansions in the range of up to about 30%. The base pipe 10 can have threads 14 and 16 at opposite ends to allow sections of the filter assembly A to be secured together, giving greater

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torsion and tension strength for the filter assembly A. A coating 18 made preferably from a plastic material can be applied to the inside of the base pipe 10. The Whitford Corp. manufactures the coating under the name Xylan* 1052. Ultimately, when an expander 20 (see Figure 3) is moved through base pipe 10, the coating 18 will reduce the required expansion force. The greater collapse resistance of the base pipe 10 promotes borehole stability after expansion. The optimization of the openings 12 promotes the highest expansion rate for a given material for base pipe 10 while still leaving sufficient inflow area through the pipe openings or perforations 12. Using round, rounded, or oval openings instead of slots provides for a mechanically stronger filter assembly A. The Xylan* coating 18 can provide a reduction in required force for a given expansion by as much as 50%. The coating 18 also helps resistance to galling by the expander 20 or a subsequent expander such as 22 (see Figure 4).

Mounted above the base pipe 10 is a drainage layer 24. Drainage layer 24 is between base pipe 10 and a filtration layer 26. The drainage layer 24 promotes flow between the filtration layer 26 and the openings 12 of the base pipe 10. In the preferred embodiment, the drainage layer 24 is a weave, selected from a broad array of metals. A braided weave design is currently preferred, although other weave patterns can be used. The preferred material is available from Jersey Hose as - 6" 304 SS Braid 600-304B. The drainage layer 24 protects the filtration layer 26 from burrs or puckers around the edges of openings 12. In the event of high differential pressures due to production, the presence of the drainage layer 24 provides structural support for the filtration layer 26. The braided wire drainage layer 24 could be substituted with a shroud of some type, akin to outer shroud 34, that would have standoff from the base pipe 10.

The filtration layer 26 has uniform openings. The preferred material is a special type of Twill Dutch weave. This material gives very reliable uniformity to the opening size, after expansion. In this manner there can be confidence in the particle size, which will not pass filtration layer 26 while giving greater protection against plugging or the passage of too many particles. As shown in Figure 1, the filtration layer 26 is oriented at an angle to the longitudinal axis of the filter assembly A. This angle can be in the range of about 10 to about 80 degrees with about 20 degrees being preferred. Orienting the filteration layer 26 at an angle allows minimization of change

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in opening size and uniformity, resulting from expansion. The Dutch Twill weave provides greater durability and particle holding capacity. Negative effects on hole size and uniformity as a result of expansion are further minimized by using a reverse weave Twill Dutch pattern. A reverse weave is one where the diameter of the weft (shute) wires 28 (see Figure 2) is larger than the warp wires 30 by as much as about 50 percent. The combination of the angular placement of the filtration layer 26 by a spiral winding technique coupled with a reverse weave yields a more predictable and uniform opening size after expansion.

Mounted over the filtration layer 26 is a filtration enhancement layer 32. This layer promotes greater flow conductivity from the outermost layer, the outer shroud 34. Layer 32 acts as a coarse filter to filtration layer 26 and prolongs the life of filtration layer 26. This can be seen in the graph of Figure 5, where the addition of the filtration enhancement layer 32 is curve 36. The same filter assembly A of the present invention but without the filtration enhancement layer 32 is illustrated by curve 38. Curve 40 represents the performance of a known product made by Baker Hughes called Excluder*. Figure 5 readily demonstrates that the addition of the filtration enhancement layer 32 nearly triples the time it takes to build up a backpressure of 40 PSIG for the same flow conditions. Leaving out the filtration enhancement layer 32 also makes that version of the present invention perform somewhat comparably to the known Excluder* design. Several different weave types are suitable for layer 32 such as: square weave, Compound Balanced, Tight Tuck, and Braided Weave. A suitable Compound Balanced material is available from Porous Metal Products, model # CB-3-96-192-21/24. A metallic material is preferred.

The outer shroud 34 is preferably formed from spirally winding a perforated sheet into a tube. The hole size and pattern is optimized to facilitate expansion and yet provide sufficient collapse resistance in the expanded state. It is desired to have the inflow area of the openings maximized but to limit the opening size and use a staggered pattern so that the outer shroud will not buckle or tear, when expanded. The primary purpose of the outer shroud 34 is to protect the layer below from damage during run in.

The layers can be joined together by swaging to reduce the outside diameter of the filter assembly A. Swaging also makes the various layers act as one with regard

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to expansion and provides greater strength against collapse after expansion. It is preferred to anneal the components individually before swaging or to anneal the filtration assembly A after all the components have been assembled. Doing this permits a greater degree of expansion without failure. This benefit is particularly applicable to the base pipe 10. The type of annealing envisioned is solution annealing to 1800 degrees F. Annealing of the base pipe 10 is done before applying the coating 18 due to the inability of the coating 18 to withstand the annealing temperatures. Sintering can be used instead of swaging to join the layers together. The layers are preferably assembled in the following manner: the braided wire of suitable drainage layer 24 is placed on the base pipe 10 which has previously been drilled with holes, coated and threaded. Then, the filtration layer 26 is wrapped at an angle over the top of the drainage layer 24. The filtration enhancement layer 32 is placed over the top of the filtration layer 26. Then, the outer shroud 34 is placed over the filtration enhancement layer 32 and the total package is run through a set of dies that swages or forces all components to vigorously contact each other.

The filter assembly A has the advantage of superior performance, whether it is expanded downhole or not. If it is not expanded, it can be gravel packed in the known manner. Figures 3 and 4 illustrate a unique step-wise expansion technique. In a first step, the expander 20 which may be a fixed cone or a cone with variable diameter is moved downwardly through the filter assembly A to achieve about a 15% expansion. At the lower end of the filter assembly A, a cone latch 42 engages a fixed or variable diameter expander or cone 22 to increase the overall expansion to as much as 50%. As previously stated, more expansion steps can be used and different degrees of step-wise expansion and overall expansion can be obtained with this technique. It should be noted that the second expansion does not necessarily have to proceed in a direction opposite the first expansion.

There are many applications of the filter assembly of the present invention. In horizontal open hole completions there are usually more than 1,000 feet of contact with the productive formation, sometimes in excess of 9,000 feet. Because there is so much contact, the amount of production per foot is very low. In most cases if the theoretical production per foot was traveling into a screen directly opposite of the formation then the velocity would be too low to transport sand from unconsolidated

formations or cause erosion. There are many wells in which erosion is taking place and sand is being produced. Presently there are a couple of theories that explain this occurrence. First the formations may be so unconsolidated that they simply fall apart when the pressure in the well bore used to control the well during drilling and completing the well is removed. This is referred to as hole or formation collapse. A second possibility is that fluid flows along the path of least resistance. This may be on the inside of a screen that is in place or along the outside. As the flow proceeds towards the beginning of the open hole section, the accumulative effects of production means the velocity is much higher towards the top section (beginning) of the open hole. This velocity (accumulated flow) can be high enough on the outside of the screen to transport sand and erode the formation and screen.

By expanding screen in an open hole horizontal well the annulus between the screen and the formation can be greatly reduced or even eliminated. Reduction of the annulus means greater resistance to flow and therefore, production flow is reduced on the exterior of the screen and increased on the interior. The reduction in exterior flow means lower velocities near the well bore and therefore, less sand transportability and less erosion effects.

Expansion can also aid in formation stability by physically supporting the formation if the screen is expanded until it is touching the formation. This support in turn could prevent the collapsing of the formation when the pressure in the well bore is reduced.

In cased hole applications filter assembly A offers the advantage of a large inside diameter for remedial work below its installation. Another advantage is that in frac packs and gravel packs all that is necessary to do is to place the proppant or sand in the perforation tunnels and formation fractures. Annular packs between the screen and the casing, which are often difficult to achieve, are not necessary since expanding screen removes this annulus. The filter assembly A could also be used in conjunction with a frac pack or gravel pack and subsequently expanded to back fill any voids in the annulus pack or perforations not filled.

Turning now to Figures 6 to 18 embodiments of expandable screens are shown. In Figure 6, an inner layer 110 is fed off a reel 112 in sheet form into a sintering furnace 114. A filter layer 116 is fed off reel 118 into the furnace 114 above

inner layer 110. An outer layer 120 is fed off of reel 122 into the sintering furnace 114. The three layers 110, 116, and 120 come off in a sheet and get initially compressed together through rollers 124 before the furnace 114 and rollers 126 after the furnace 114. A take-up reel 128 collects the sintered together assembly of the layers 110, 116, and 120 onto itself. Other techniques of joining layers are also within the scope of the invention such as welding or fusing.

Referring to Figure 7, the material off of reel 128 is placed into a tubular form which can have alternatively either a longitudinal joint or can be spirally wound into a tubular shape and then spirally welded so that it presents a long tube, a cut-away of which is shown in Figure 7. The inner layer 110 is preferably .09 inches thick with .125 inch diameter holes and having a 30 to 40% open area. In this preferred as well as the other embodiments the holes or openings can be round, somewhat out of round, triangular, oval, elliptical, square or polygonal to name some shapes. Openings should preferably not be slots. The openings need not be in a particular pattern and do not need overlap longitudinally. These openings can be formed in a number of ways such as perforating, drilling, milling or water jetting. The filtering layer 116 is preferably .031 inches thick and comprises a mesh weave. The outer layer is 120 is preferably .060 inches thick with .125 diameter holes with 30 to 40% open area. The assembly shown in Figure 7 may be expanded diametrically 25% ± 10% minimizing the stress on the filtering layer 116 because the layers 110, 116, and 120 are connected together and expand together. By virtue of having run the three layers 110, 116 and 120 through the sintering furnace and rollers 124 and 126, a stronger structure is presented which has greater collapse strength than pervious known designs. Relative movement of the layers does not occur as in the past as shown in the U.S. Patent No. 6,012,522 because of the sintering process. Figure 9 illustrates that an end connection 130 can be attached with a weld 132. The end connection 130 can be put at one or both ends of each tube so that one tube or a series of tubes can be connected together and made part of a completion assembly in a manner known in the art.

The mechanical properties of the screen would be such to allow for easy expansion. There are several methods that may be used to expand the described screen. One method is to mechanically expand the screen using a cone shaped

apparatus that has a larger outside diameter (OD) than the screen inside diameter (ID) and push this apparatus through the screen (see Figures 12 and 13). A variation of this would be to place the cone expanding apparatus on the bottom of the screen. A length of tubing would be connected (latched) to the cone and pull the cone through the screen (see Figure 14).

Another method of screen expansion would utilize hydraulic force by means of a bladder 145. The bladder 145 would be placed inside the screen and fluid inflated to a pressure that would expand the screen outward. Once the section of screen in which the bladder 145 was inflated had expanded, the bladder could be deflated and moved to the next section of screen to be expanded (see Figures 15 and 16). A variation of this method would be to have hydraulic actuated arms that would be extended to the ID of the screen and with sufficient force expand the screen. After expanding the screen, the hydraulic pressure would be released, collapsing the arms and, the tool moved to a section of screen that needed expanding.

An alternative to the technique shown in Figure 6 involves just running layers 110 and 116 through the sintering furnace 114 and forming just those two layers into a tube by rolling them into a longitudinal joint or spirally rolling the sheet to make a spiral joint which can be welded to create the desired diameter in a tubular structure. The assembly of the layers 110 and 116 is then inserted into a pre-made tube of outer layer 120. When assembled as shown in Figure 8, the look of the product is virtually identical to running all three layers through the furnace 114 as shown in Figures 6 and 7. Some clearance needs to be provided so that when rolled into a tube, layers 110 and 116 will slide readily into the outer layer 120 which has been preformed into a tube. Upon initiation of expansion, the filter layer 116 very quickly contacts the outer layer 120 as the entire assembly is diametrically expanded in a manner known in the art. A wide choice of material is available for all of these layers. The open area of the inner and outer layers of 110 and 120 can be varied and the material of construction of the outer layer which basically protects the filter layer 116 can also be varied. The nature of the openings in the outer layer 120 can be perforations or punchouts which deflect the incoming flow in a manner well known in the art. The attachment of layers 110 and 116 in the furnace 114 also serves to increase the collapse resistance over prior designs. The technique shown in Figure 6 where all

three layers are attached to each other by going through the rollers 124 and 126 as well as the furnace 114 presents the design that has the greatest collapse resistance as between the two designs so far described.

Layers 110 and 120 can be perforated punched with louvers or any combination of the above techniques. The filter layer can be any number of different materials such as woven metal which further includes Dutch weave, twill Dutch weave, square weave, and centered multi-layer metal weaves. The filter layer 116 can also be made from PEEK* woven material or from foamed metal.

As an alternative, the outer layer 120 and the filter layer can be sintered together in the furnace 114 and then mounted over the inner layer 110 which has been previously fashioned into a tube.

By adopting the construction designs as described above, the burst collapse and tensile strength of such an assembly is in some instances sufficient to alleviate the need for use of a base pipe. However, if additional strength is required a perforated base pipe can be inserted in the finished structure shown in Figures 7 or 8 and the two structures welded together at the ends to further increase the structural of the final assembly.

When sintering layers 110 and 116 together and inserting them through a pre-made tube, the pre-made tube may be plastic such as PVC which has perforation. Alternatively, the outer layer 120 now made into a tube can be of the same material as the underlying layers. Regardless of how many layers are run through the furnace 114, a base pipe can be optionally inserted through the finished assembly which is welded or spiral wound into a tubular shape with end welds to further improve the strength of the completed structure.

Referring now to Figure 10, a completely different approach is illustrated. A base pipe 134 is perforated to have a bout 30 to 40 % open area. Its outer surface comprises a thread 136 which is interrupted by the perforations 138 which extend from the inside of the base pipe 134 to its outer surface where the thread 136 is machined on to it. Wound inside the thread is a wire 140 which is attached to the base pipe 134 at either and optionally, at intermediate locations. The opening size for filtration is a factor of the thread pitch and the wire diameter wound inside between the thread peaks. The opening shape can be as previously described. The entire

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assembly can be surrounded with an outer shroud 142 which can be perforated, punched, or made in any other way so as to have preferably 20 to 40% open area. The advantage to this design is its structural strength as well as the reliability of the dimensions of the openings for filtration. Diametric expansion in the order of 25 ± 10% is possible with very minor, if any, deviation in the opening size. The reason this occurs is that as diametric expansion is occurring, the diameter of the wrapped wire inside the thread is decreasing. However, diametric expansion of the base pipe 134 reduces its longitudinal length and brings the thread pitches together. The bringing together of the thread pitches compensates for the decrease in diameter of the wire which is extending in the thread between its peaks. The net result is that the opening size for filtration purposes remains relatively constant. The advantages in increased strength to resist collapse are apparent. Additionally, the reliability of the structure after dramatic expansions diametrically is also a significant advantage of this design technique.

Another alternative design is shown in Figure 11. This design incorporates three layers similar to the previous designs however the top layer covers the filtration media completely but only partially covers the bottom layer 148. Likewise, the filtration layer 146 would only partially cover the bottom layer 148. Both the top 144 and bottom 148 layers are constructed of fully annealed 316L stainless steel or a material of similar properties which is perforated with holes or openings, as previously described to yield 10-30% open area. The three layers are sintered together to form a ridged plate (see Figure 11) which would be formed into a half tube. The two half tubes of the sintered layers would be welded together to form an expandable screen cartridge tube. This tube would then be placed over a tube 147 that has been perforated or has openings of the shapes previously described only under the filtration media (see Figure 17). When expanding the complete screen assembly the holes 150 in the bottom layer of the filtration cartridge would bend open between the sections of the multiple layers. This phenomenon is akin to expanding a stent in blood vessel. This requires much less force than yielding the combination of the outer layer, filtration layer and the bottom layer. By only bending the area between the filtration media a small amount of force is needed to expand the screen and the opening size of the filtration media is not affected (see Figure 18).

Accordingly, the various embodiments have described techniques for constructing screens which can be expanded as much as about 35% diametrically while still providing high collapse resistance and reliability of the filter medium.

Those skilled in the art will appreciate that modifications of the above-described preferred embodiments can be made without departing from the spirit of the invention whose scope is defined in the claims which appear below.

What is claimed is:

1. An expandable filter assembly for downhole use, comprising:

a base pipe having an inside surface, a longitudinal axis, and a plurality of openings;

at least one filtration layer mounted over said base pipe; and

an expander capable of multi-stage expansion of said base pipe and said at least one filtration layer.

2. The assembly of claim 1, wherein:

said base pipe is expanded in stages up to about 30% above its original dimension.

3. The assembly of claim 1, wherein:

said at least one filtration layer and said base pipe are annealed to facilitate subsequent expansion downhole;

said at least one filtration layer and said base pipe are swaged together and said annealing further comprises solution annealing at up to about 1800 degrees F.

4. The assembly of claim 3, wherein:

said at least one filtration layer comprises a weave having weft and warp wires and wherein one of said weft and warp wires is disposed at an angle of about 10-80 degrees with respect to the longitudinal axis of said base pipe.

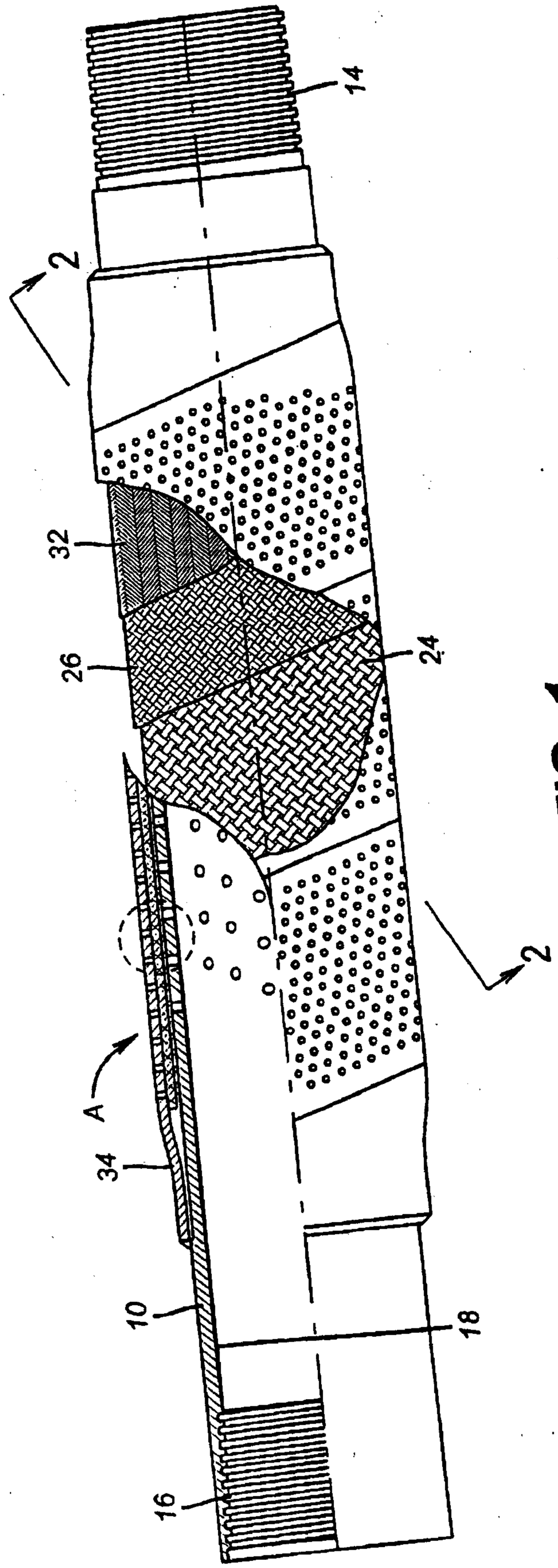


FIG. 1

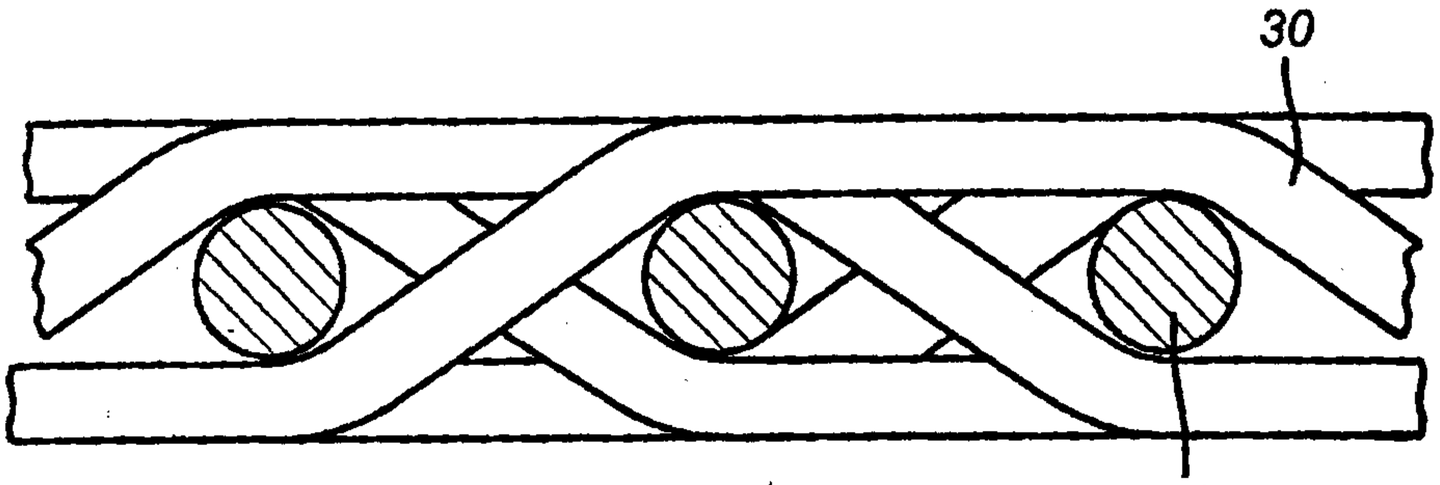

30
28

FIG. 2

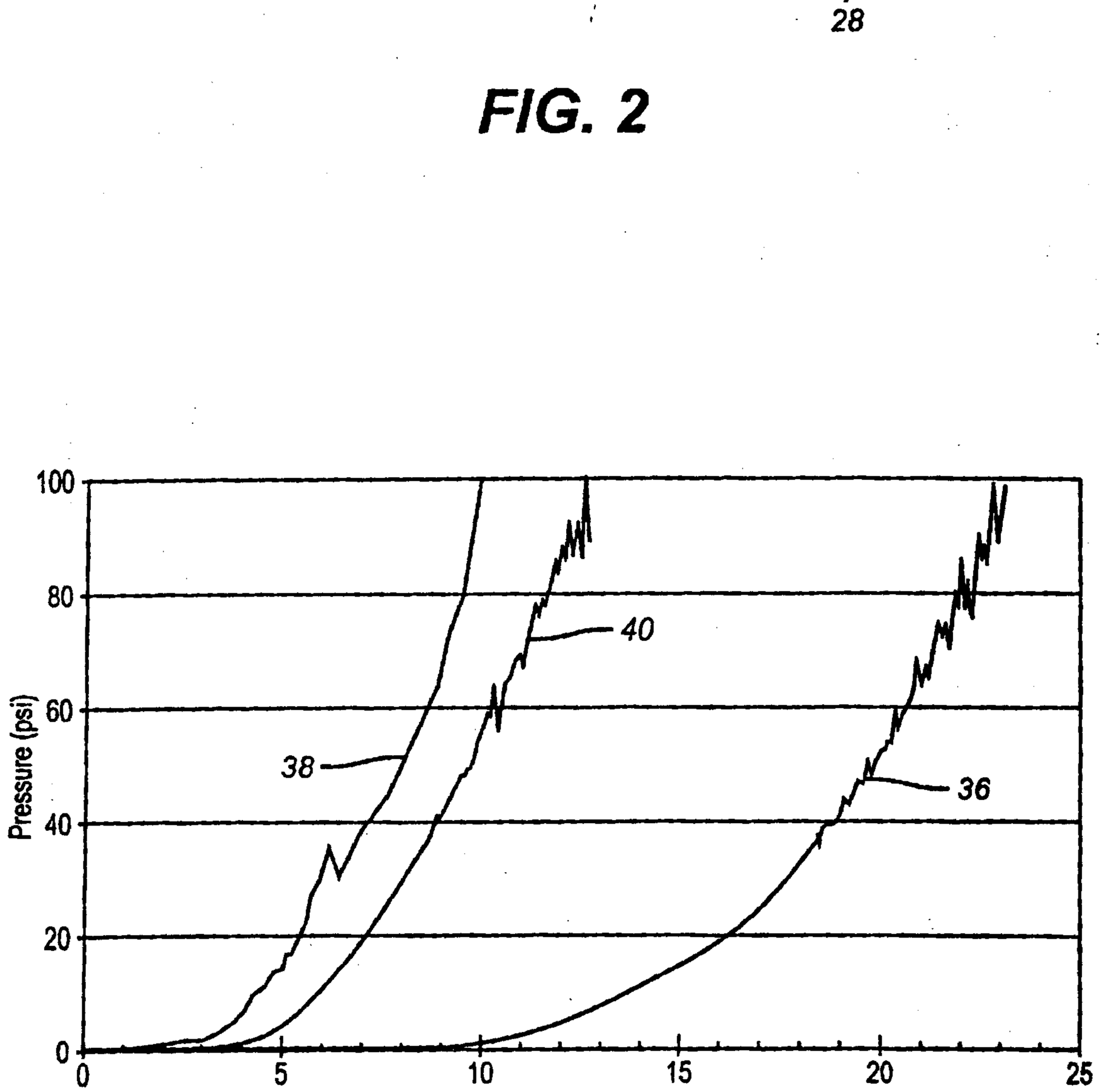

100
80
60
40
20
0
Pressure (psi)
0
5
10
15
20
25
Time (mins)
38
40
36

FIG. 5

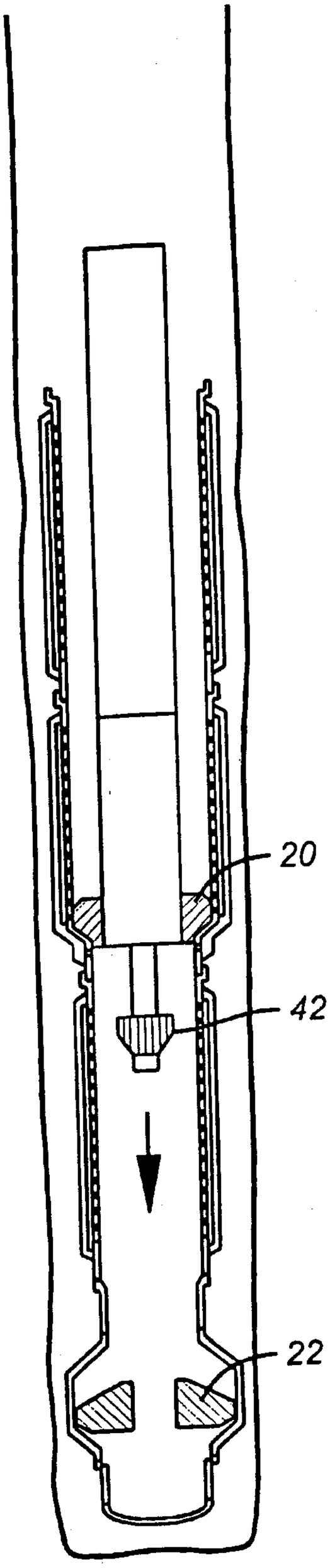


FIG. 3

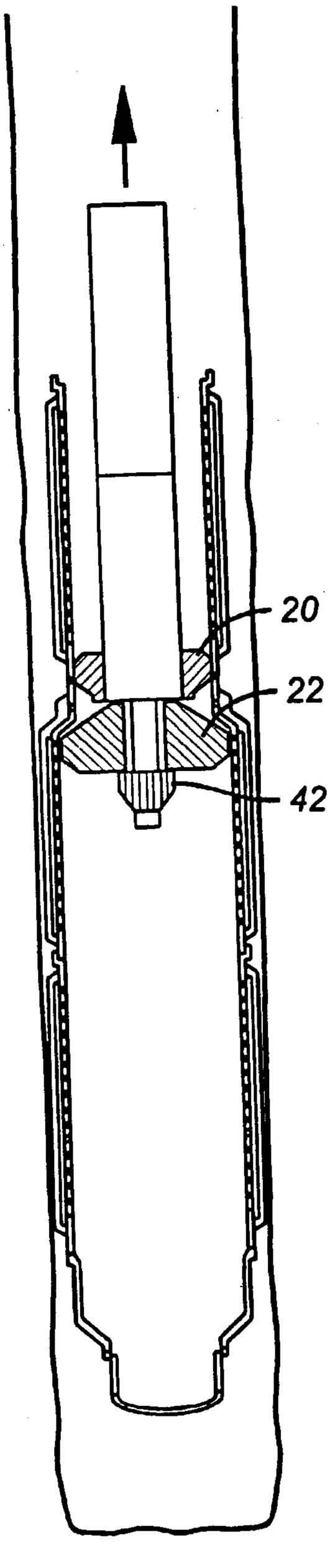


FIG. 4

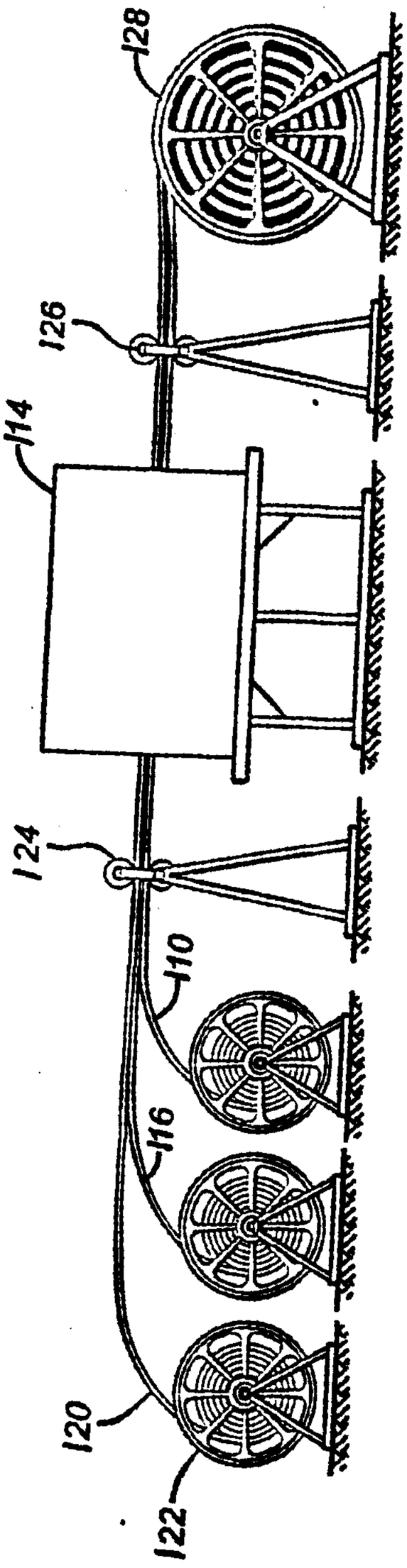


FIG. 6

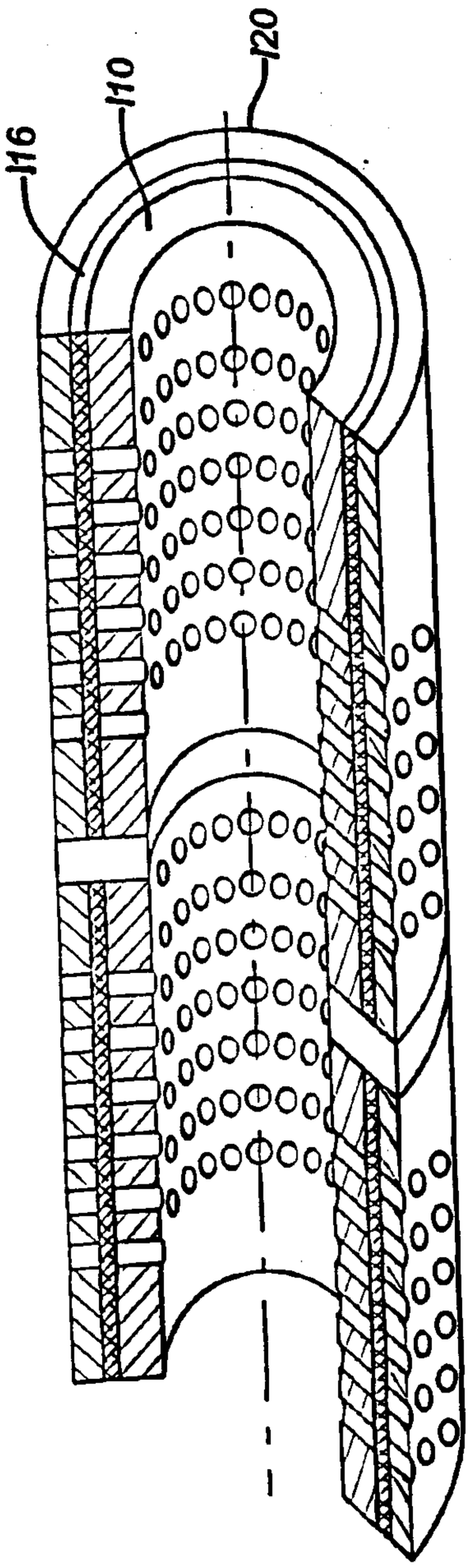


FIG. 7

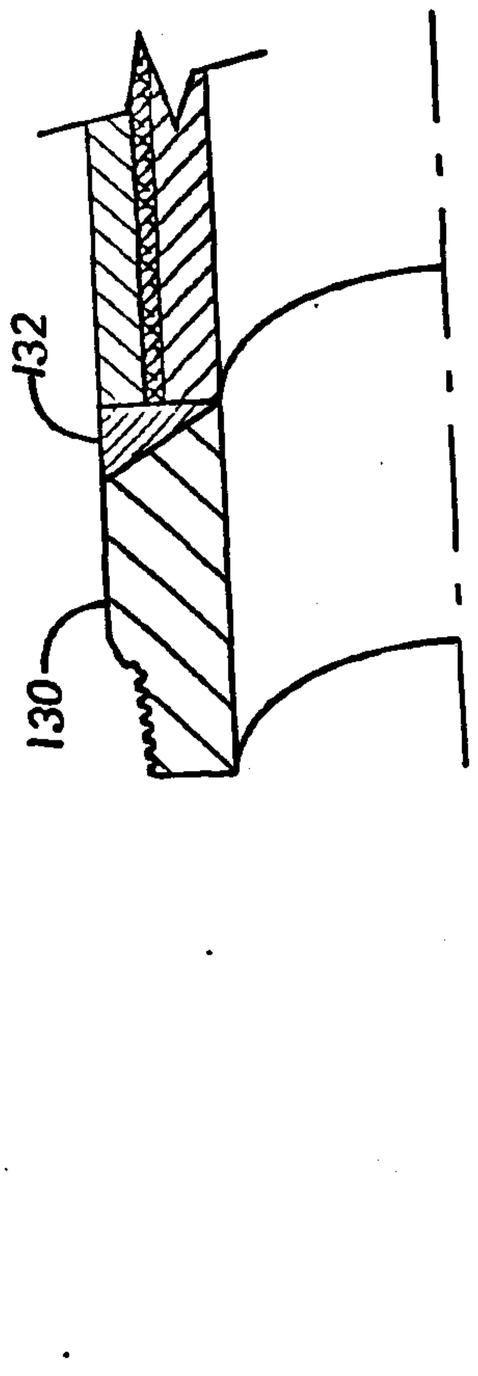


FIG. 9

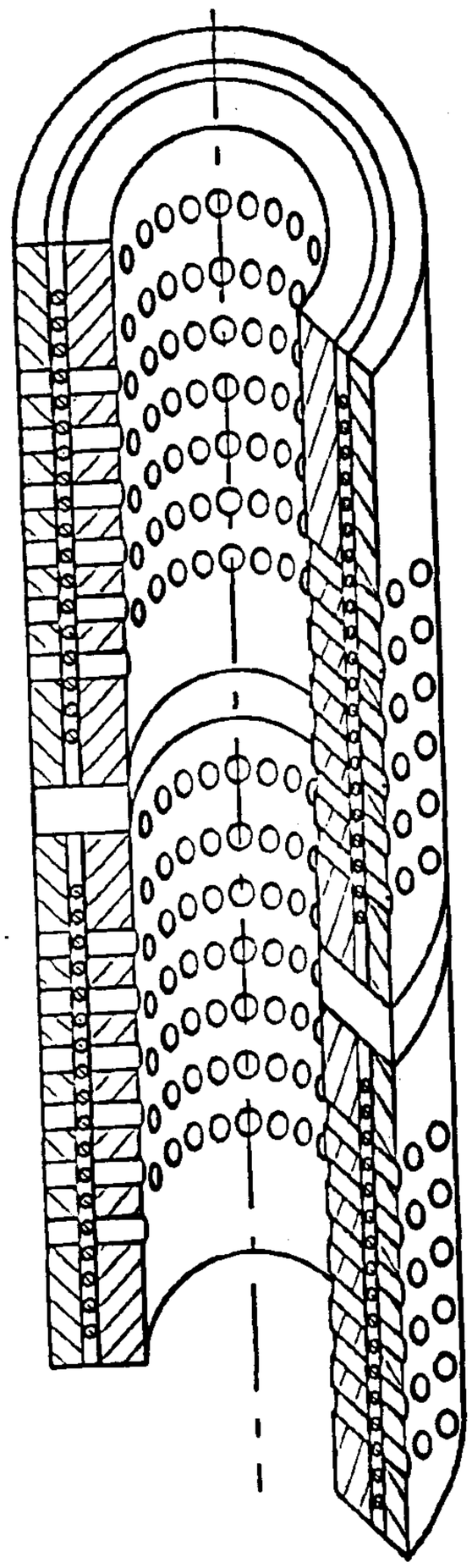


FIG. 8

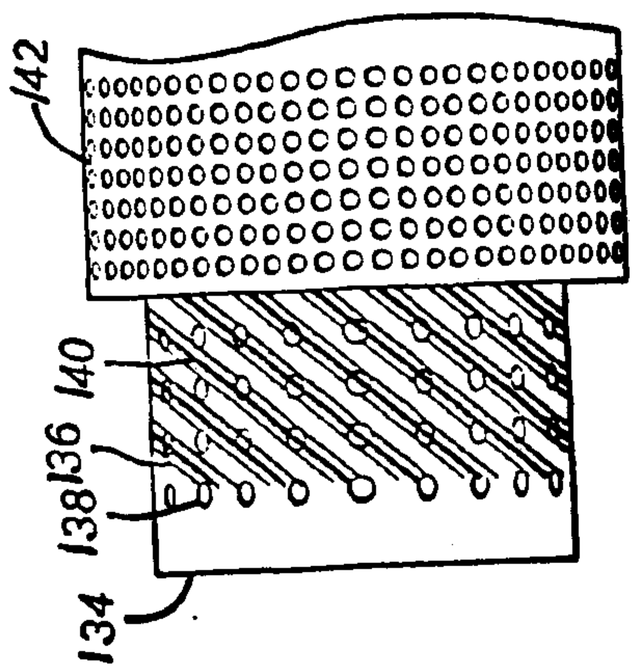


FIG. 10

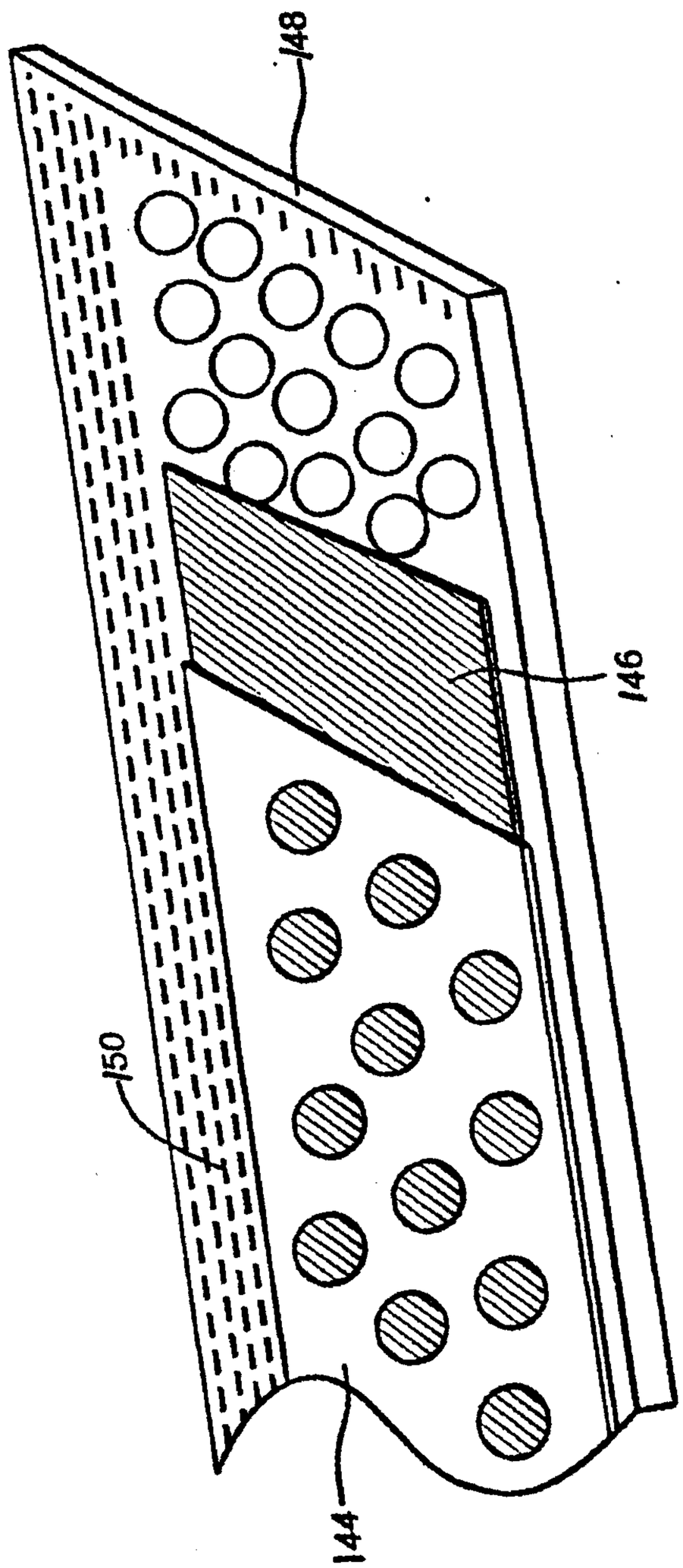


FIG. 11

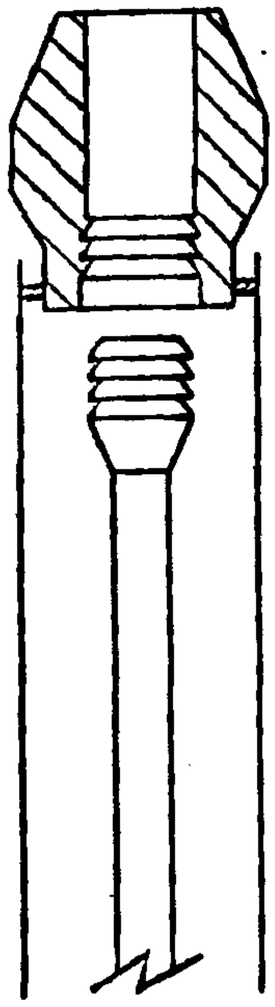


FIG. 14

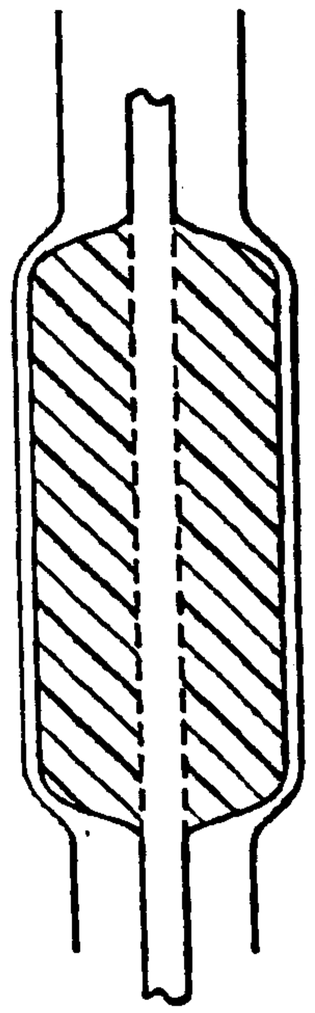


FIG. 16

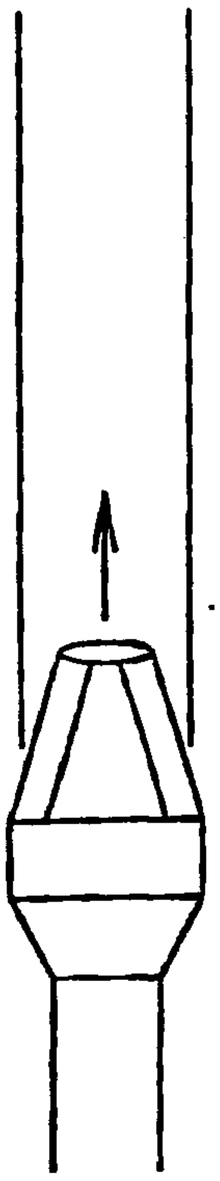


FIG. 12

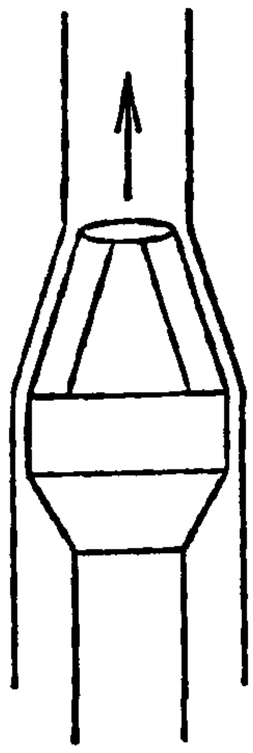


FIG. 13

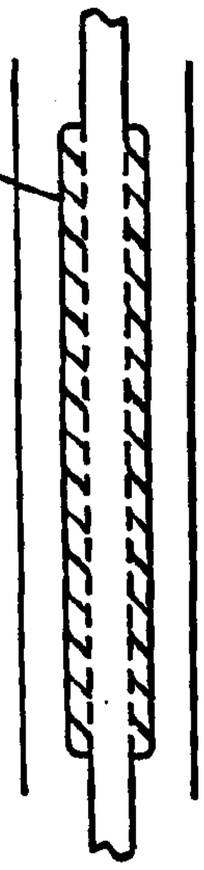


FIG. 15

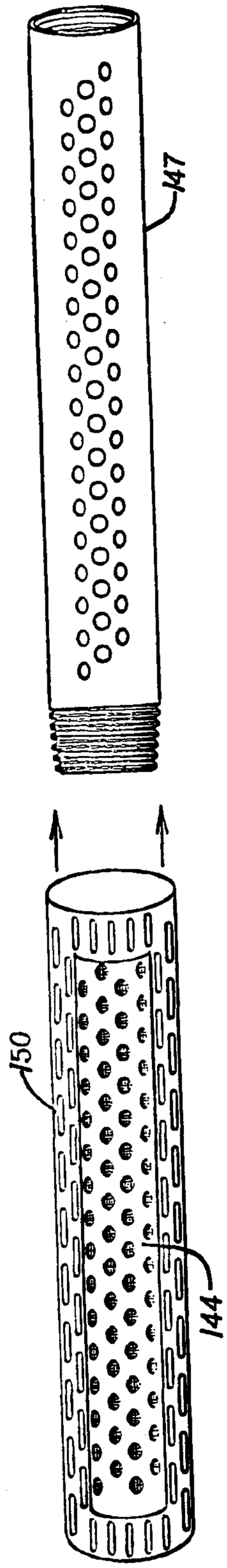


FIG. 17

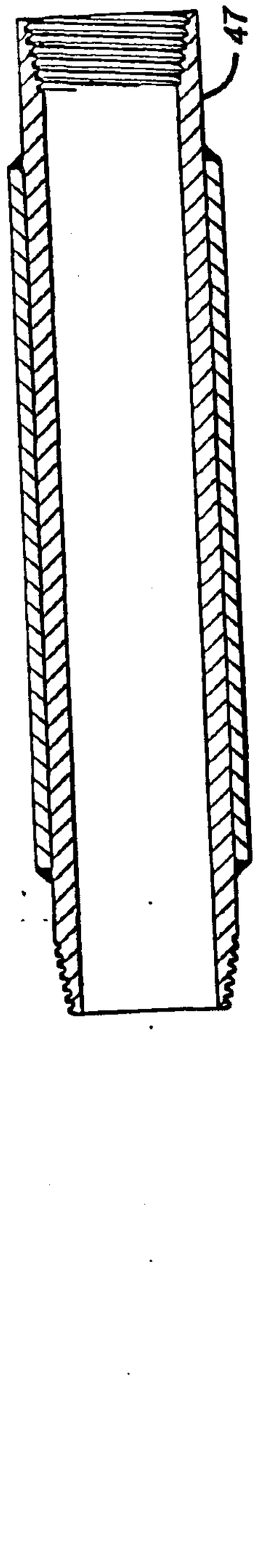
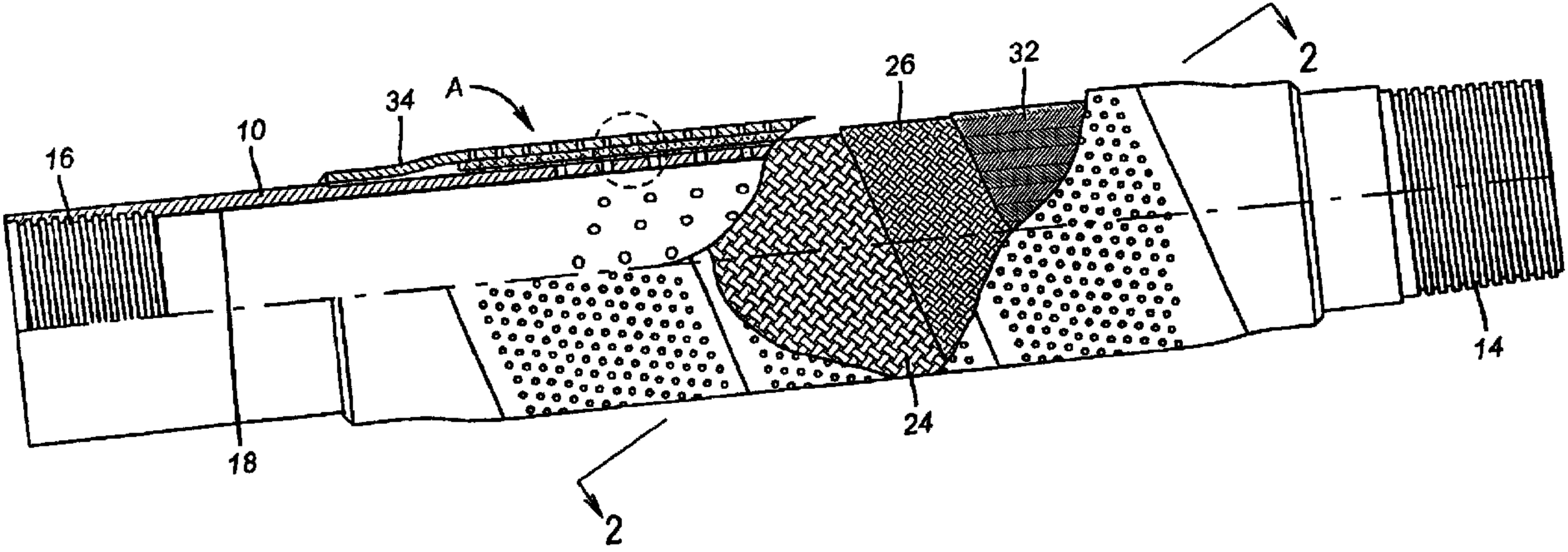


FIG. 18


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A
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