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Abass et al.

(54) **FORMATION OF FRACTURES WITHIN HORIZONTAL WELL**

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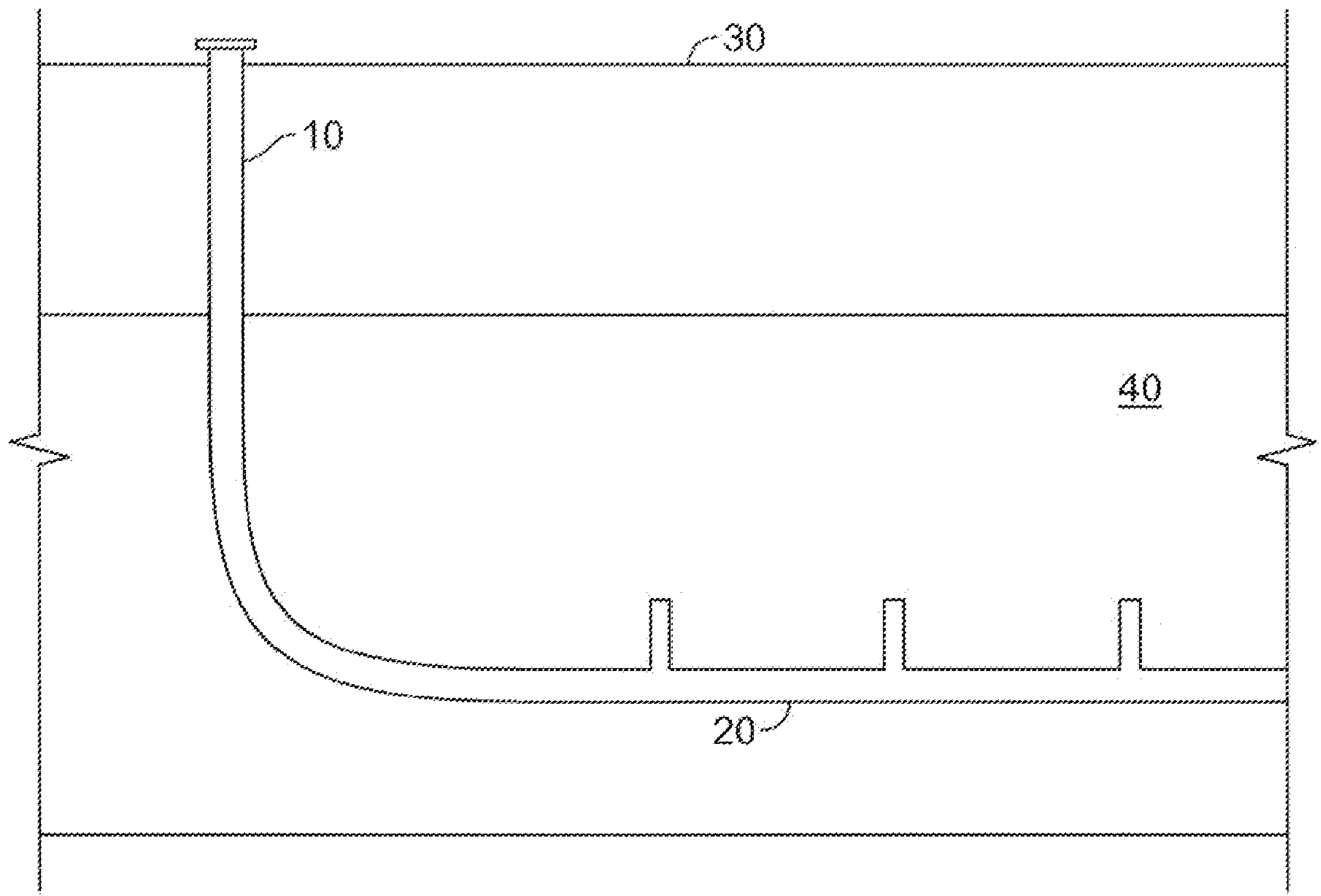
(57) **ABSTRACT**

Producing transverse fractures in a horizontal well may be achieved at a relatively lower fracturing pressure by forming one or more tunnels extending from the horizontal wellbore. One or more tunnels may be formed at each location along the horizontal wellbore where a transverse fracture is desired. The tunnel(s) may be formed mechanically, optically, or hydraulically. Further, fracturing may be formed at a lower pressure than would otherwise be required to form transverse fractures from a horizontal wellbore. According to some implementations, the transverse fractures may be formed without isolating a portion of the horizontal wellbore.



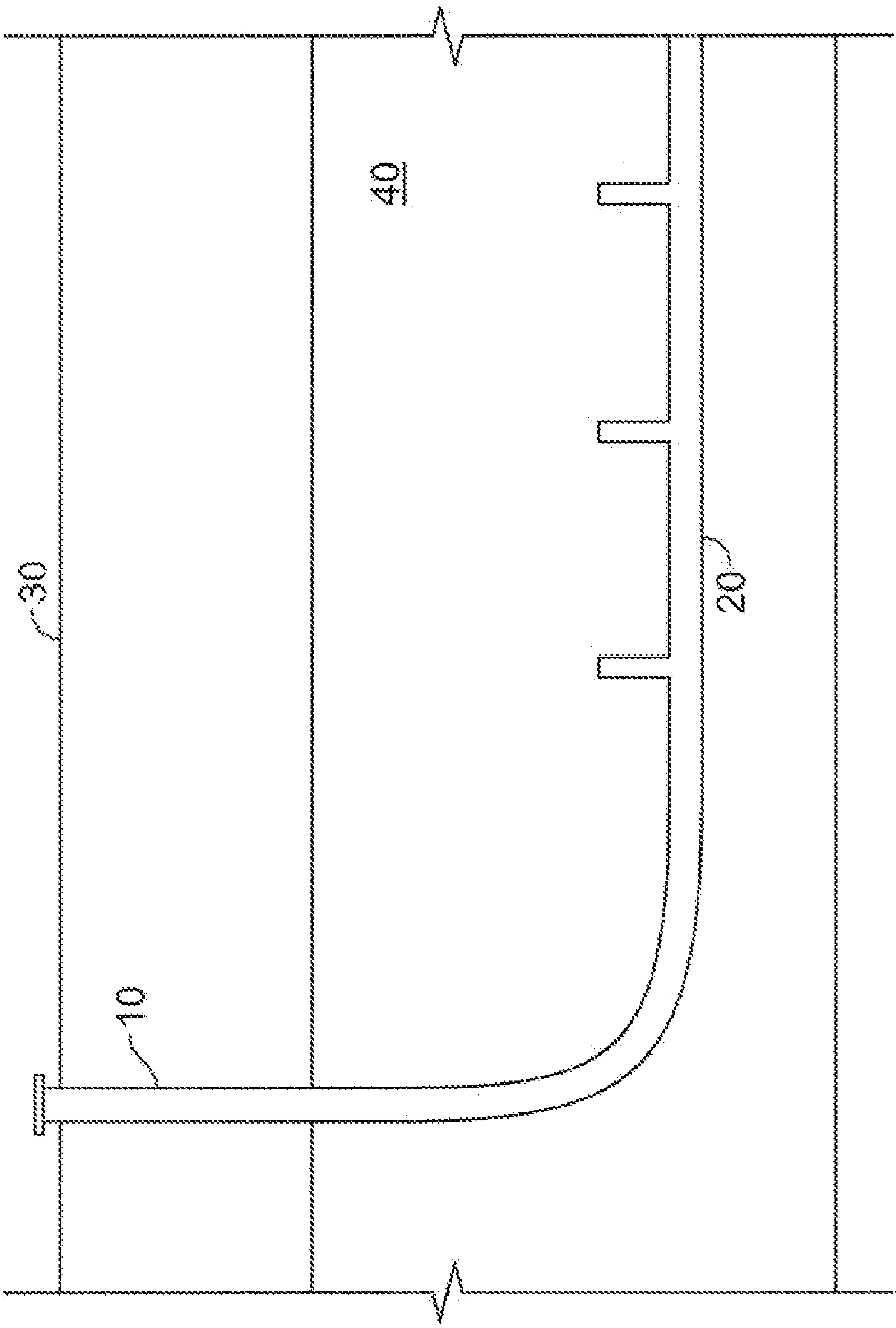


FIG. 1

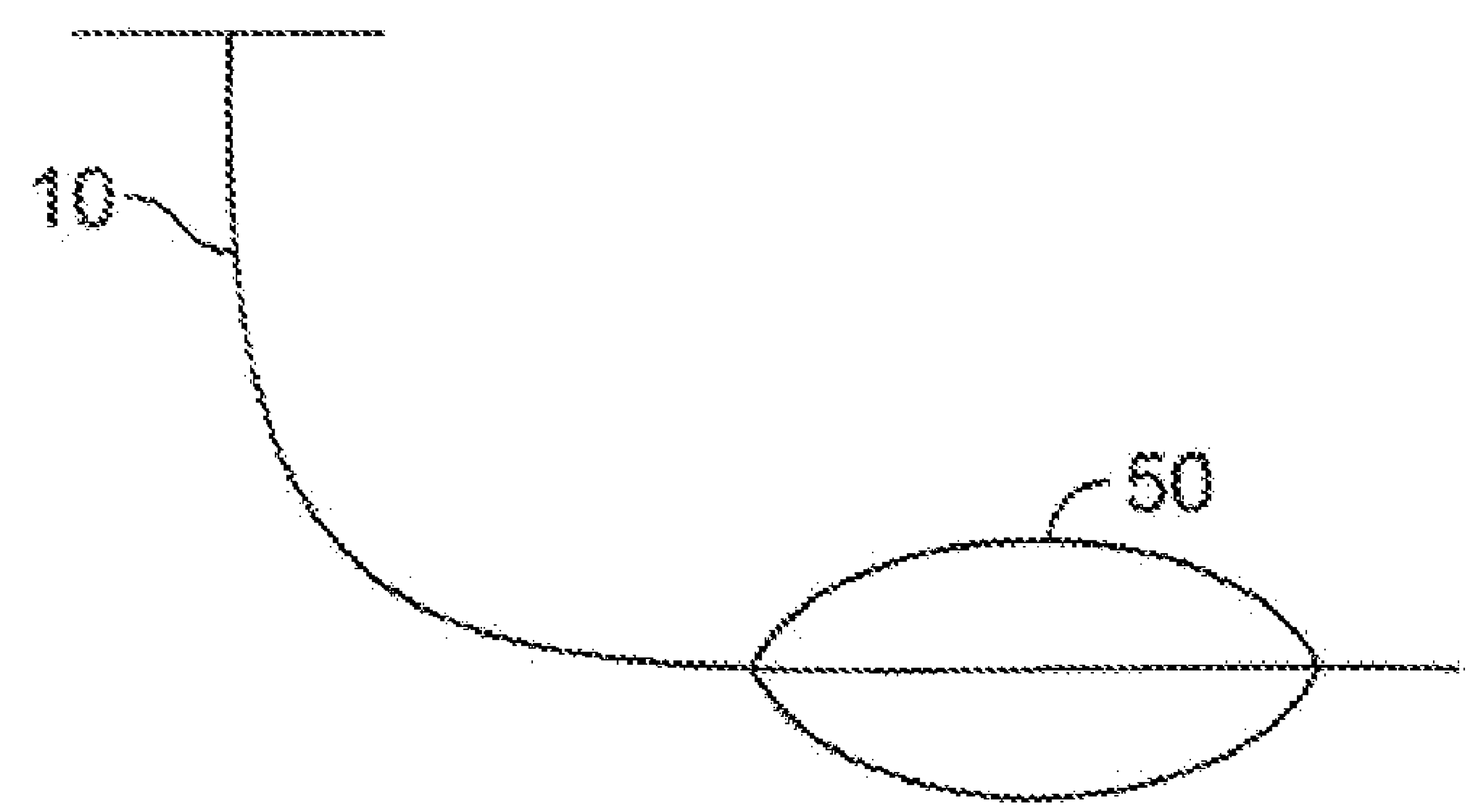


FIG. 2

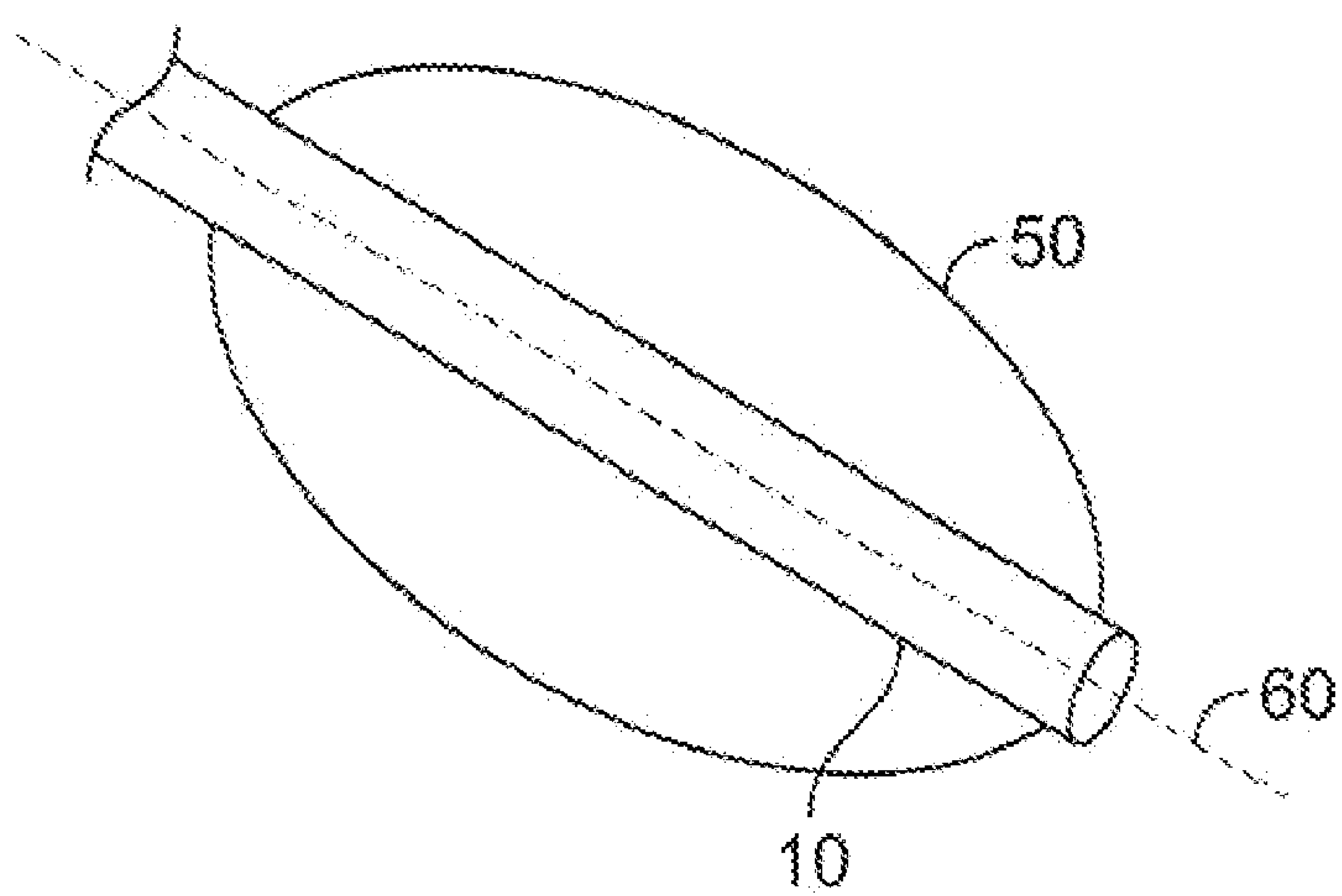


FIG. 3

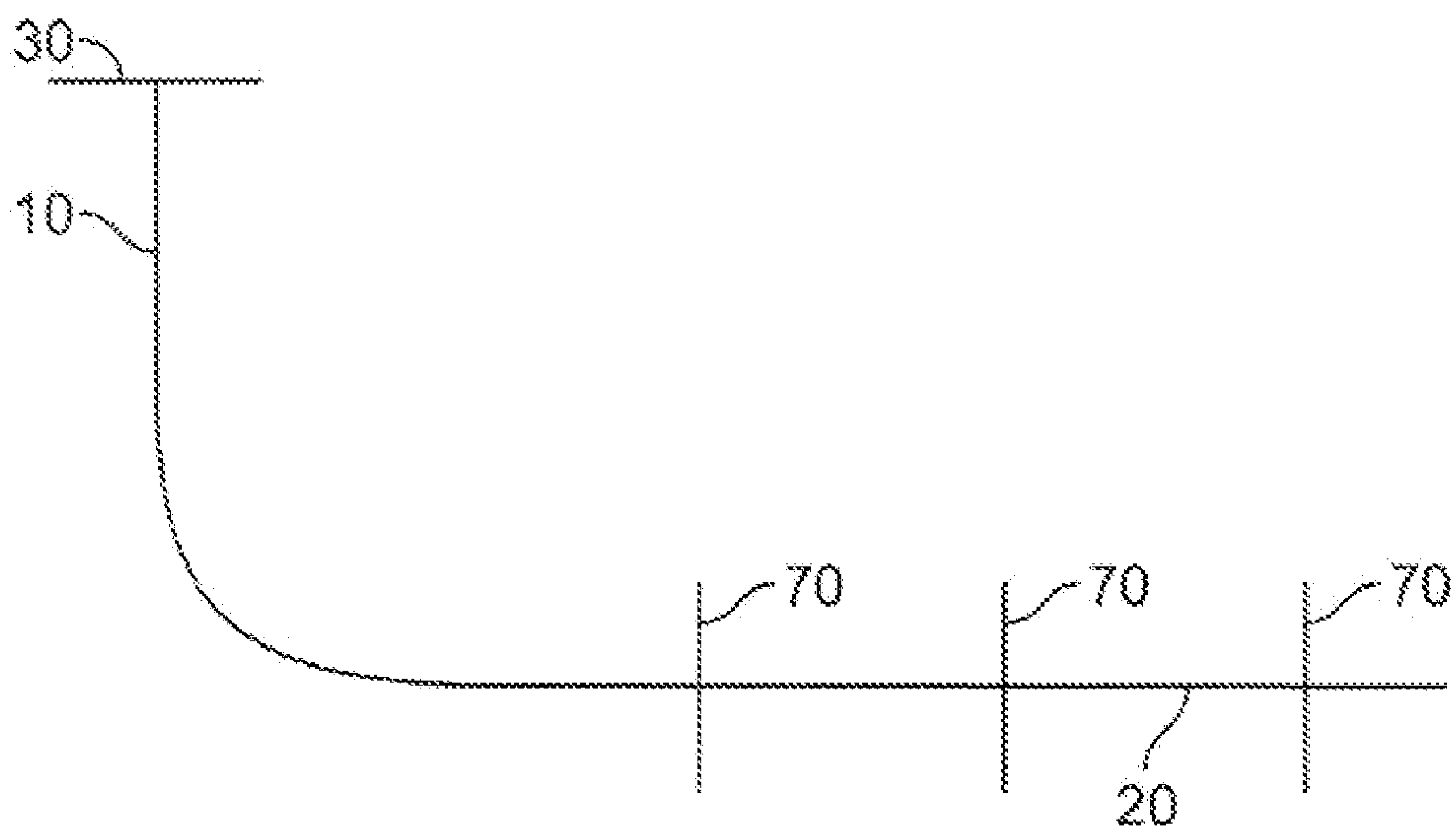


FIG. 4

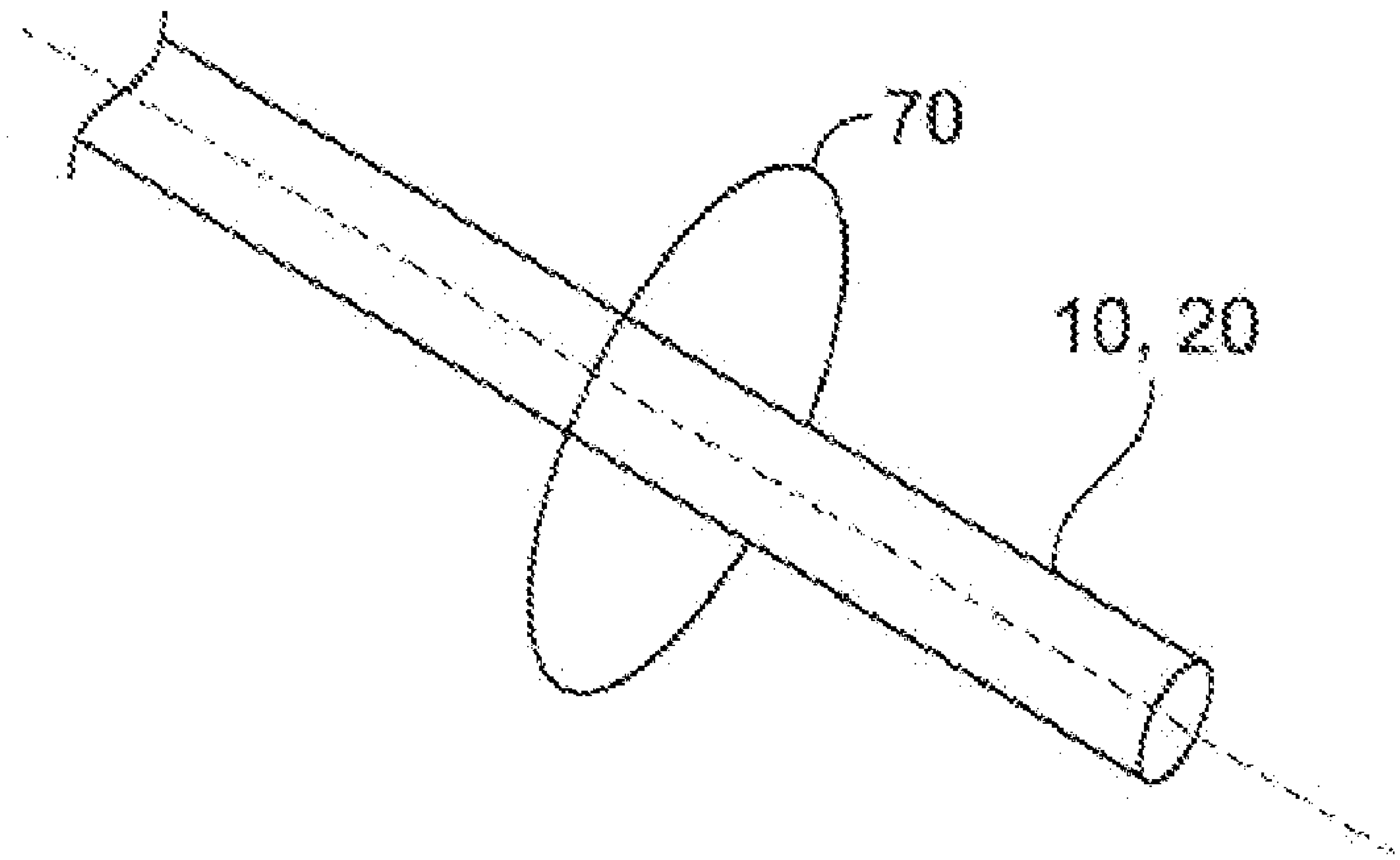


FIG. 5

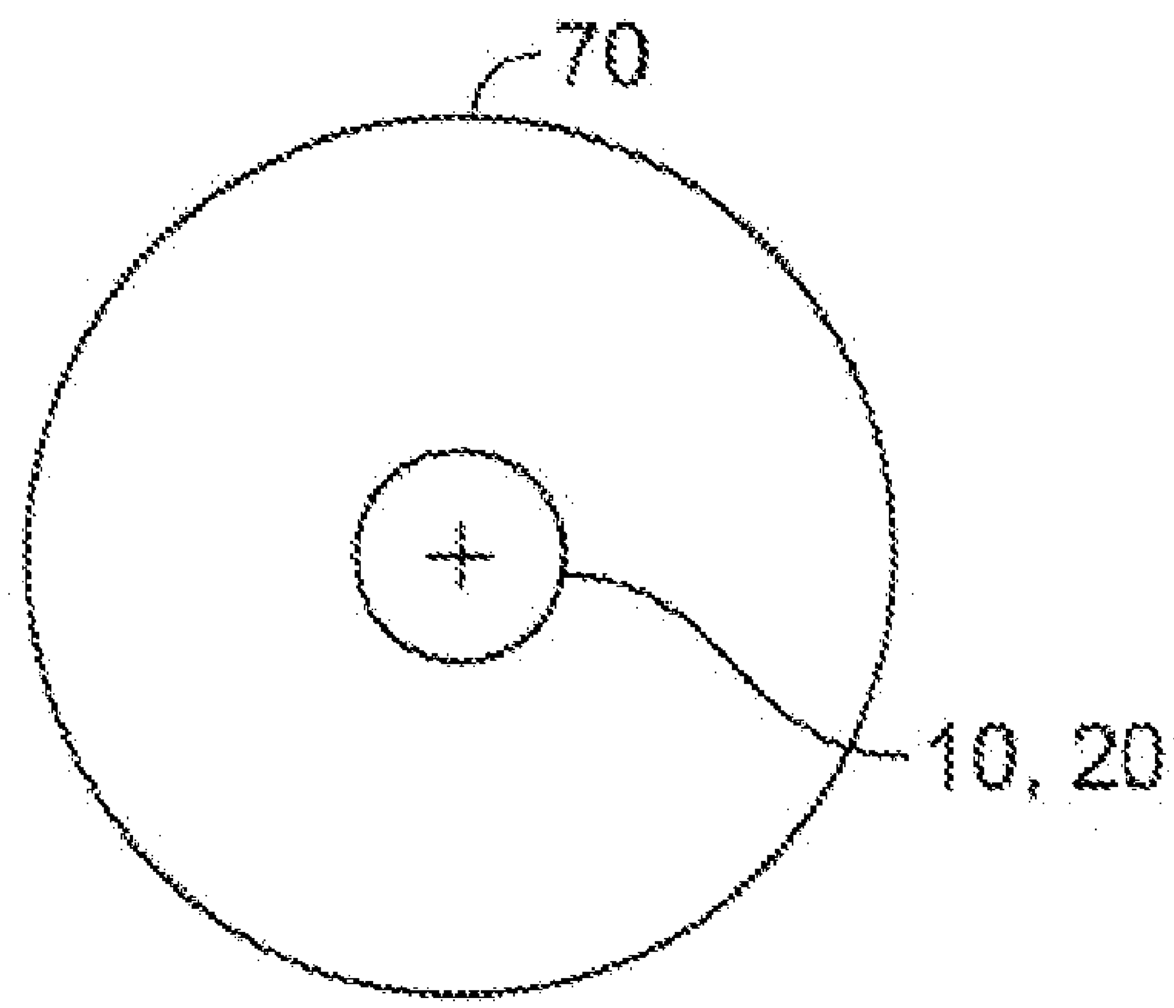


FIG. 6

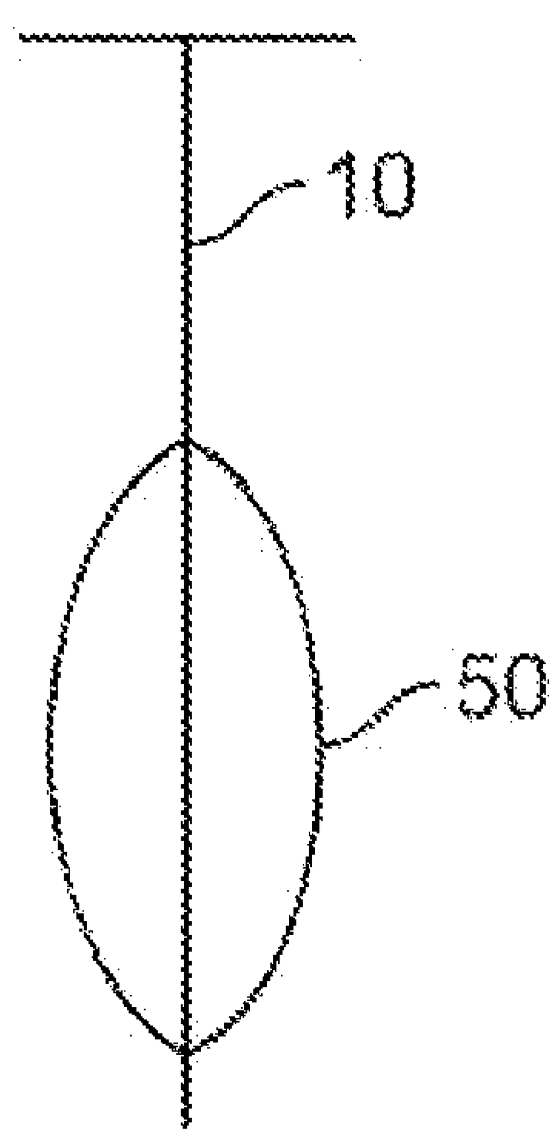


FIG. 7

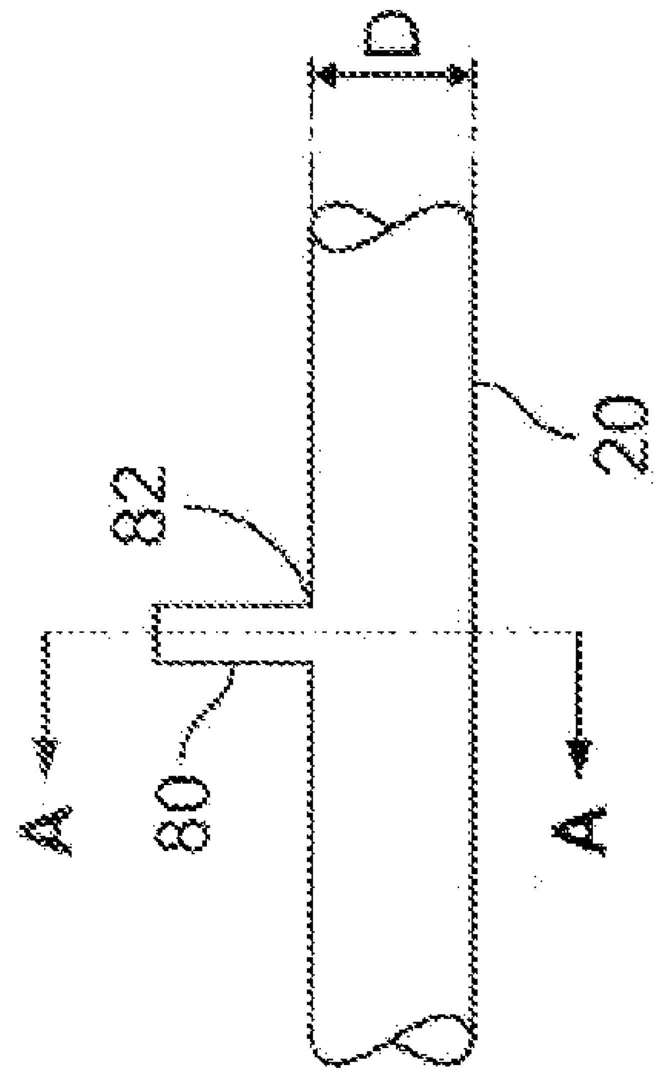


FIG. 8

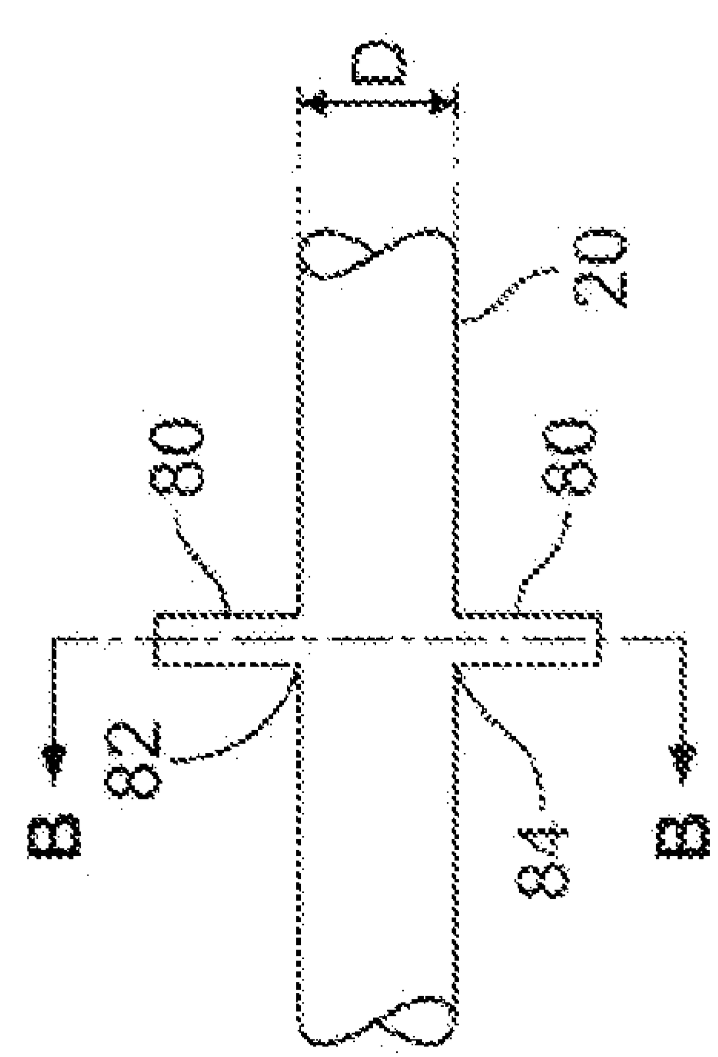


FIG. 9

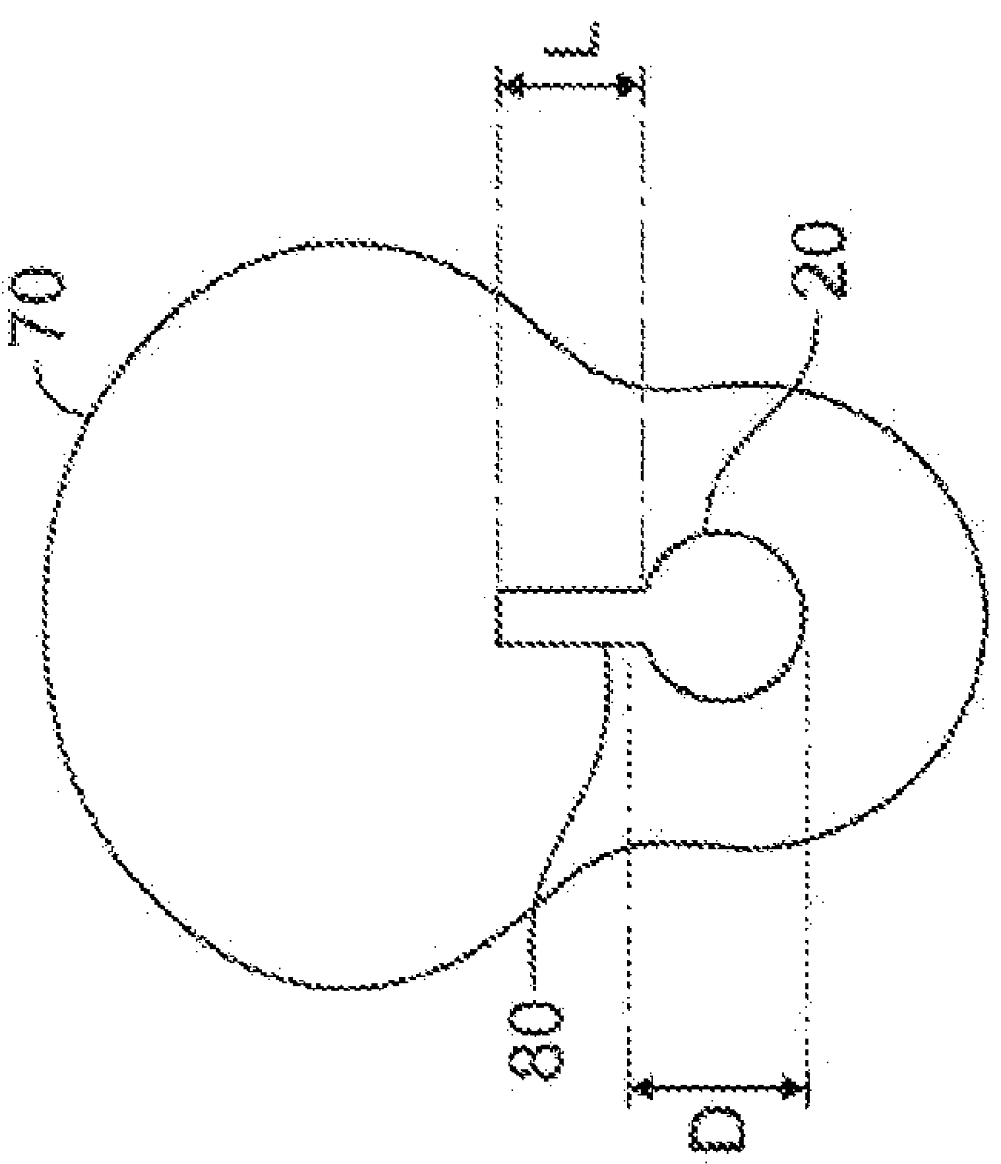


FIG. 10

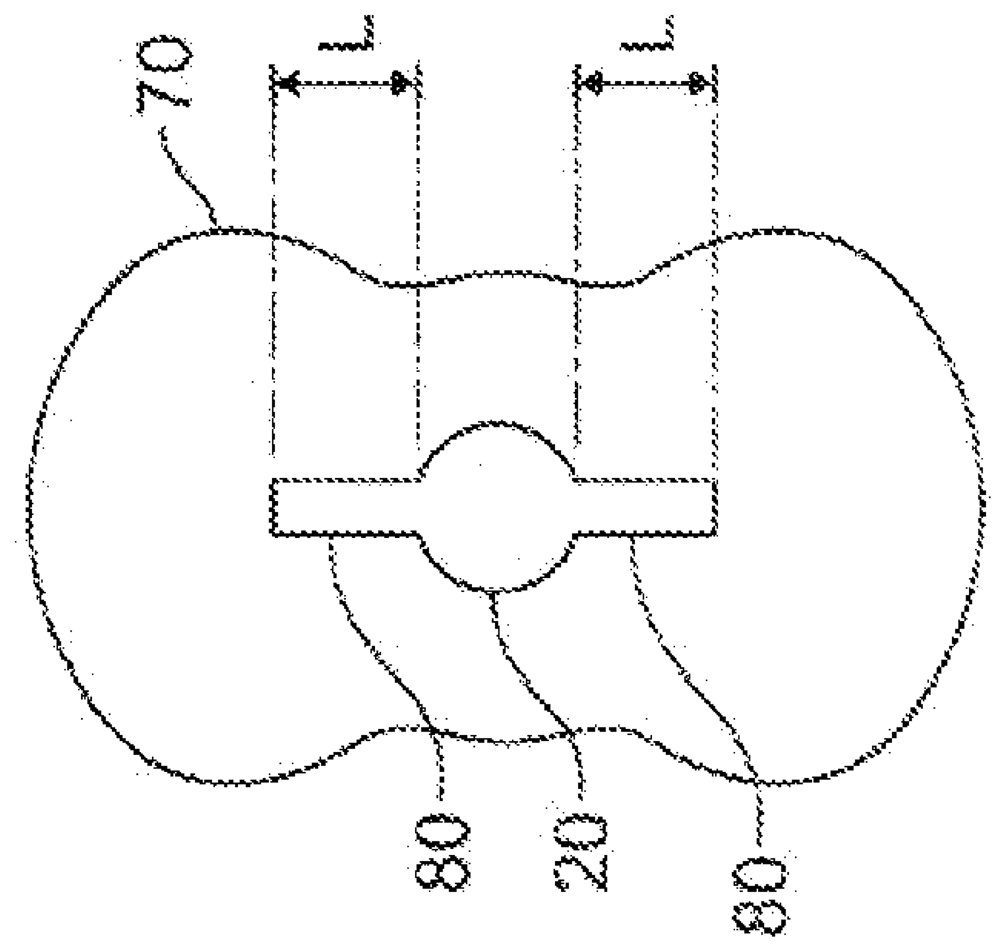


FIG. 11

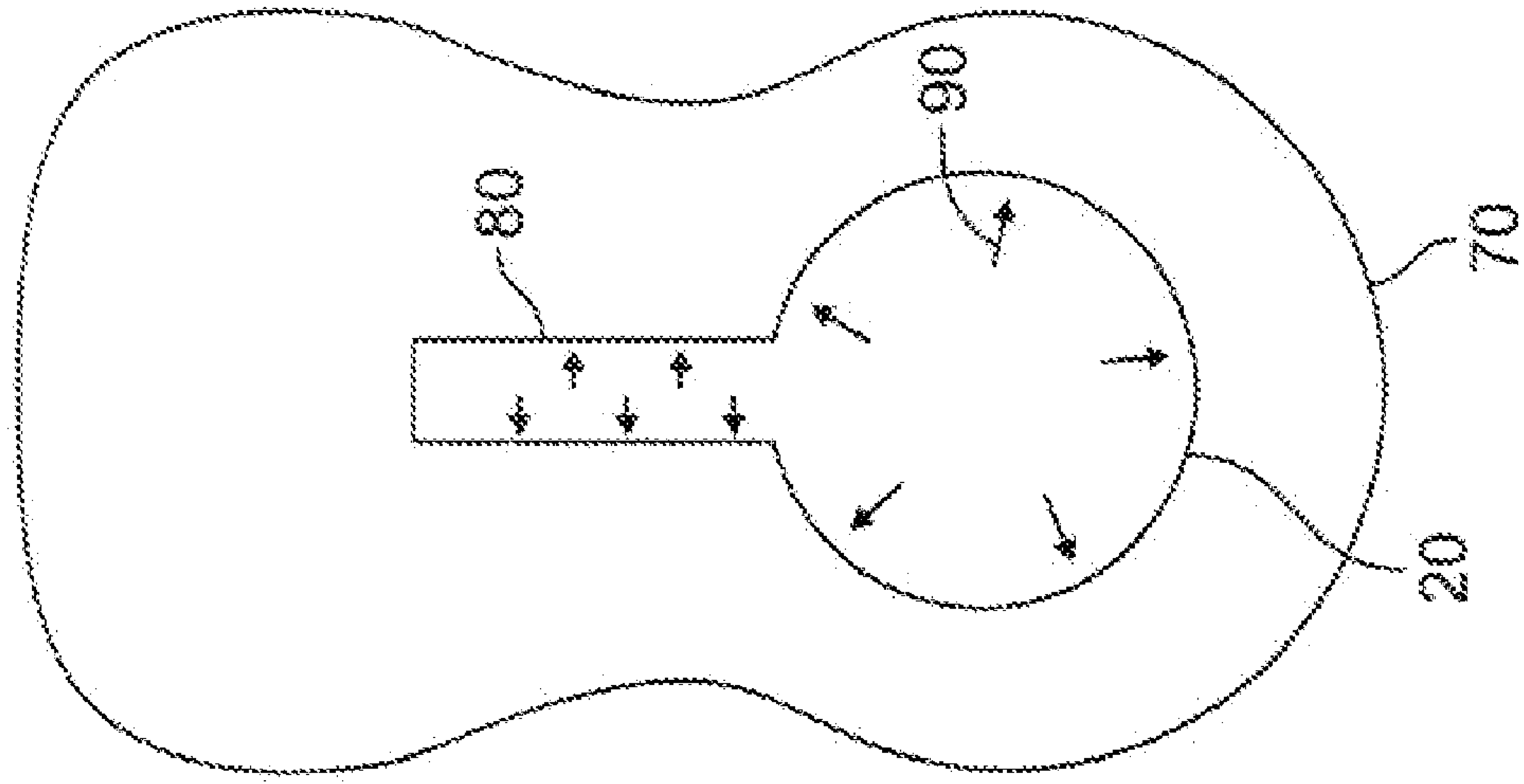


FIG. 14

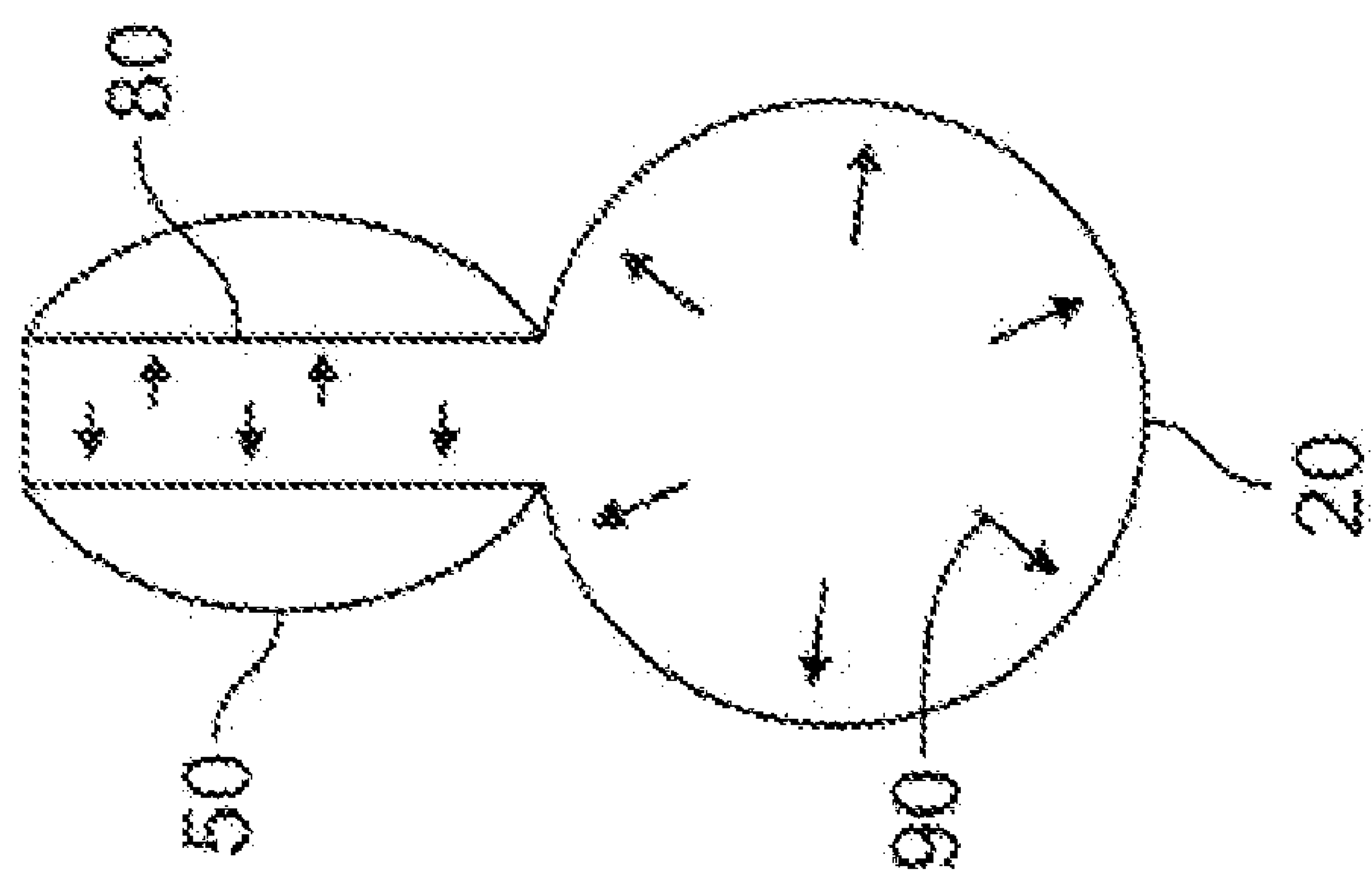


FIG. 13

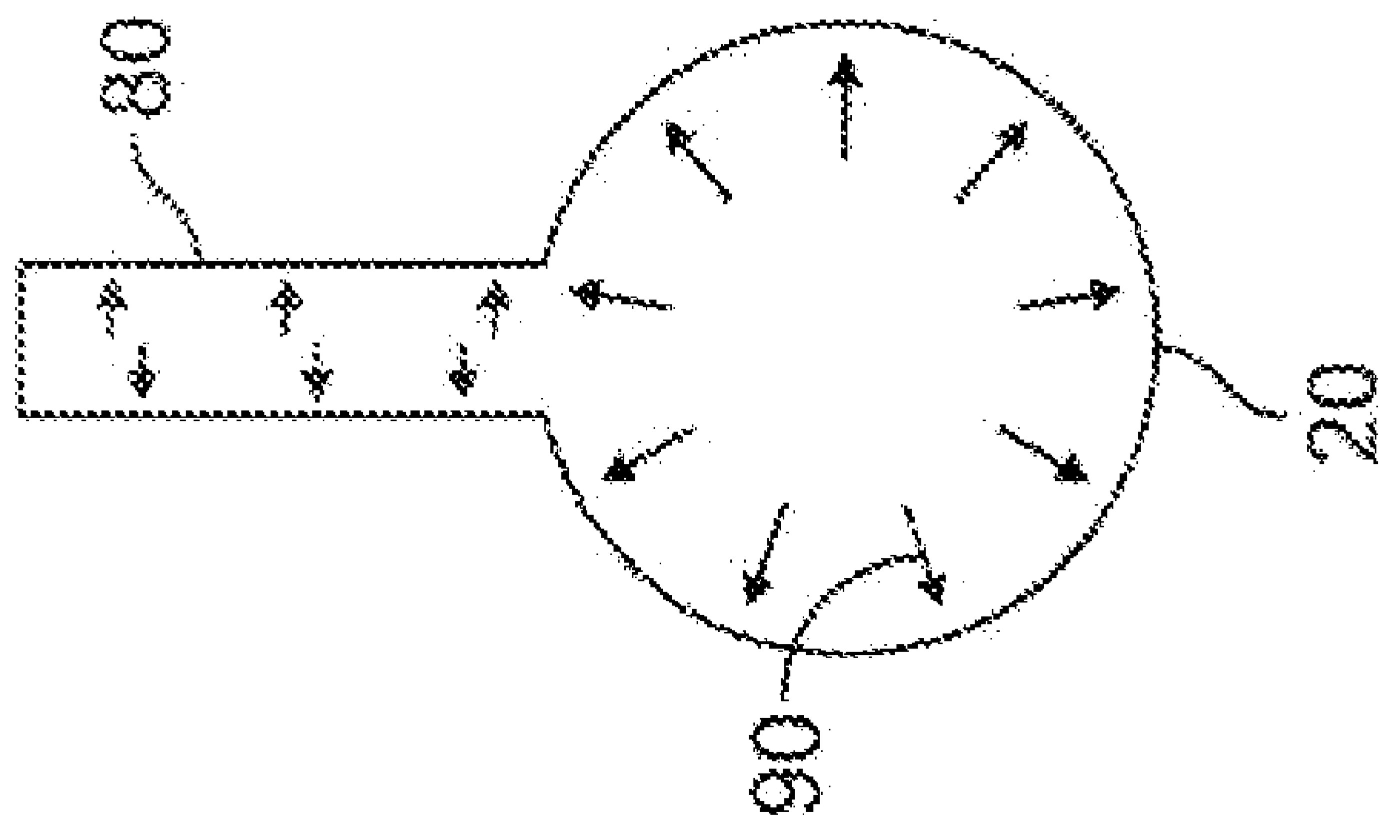


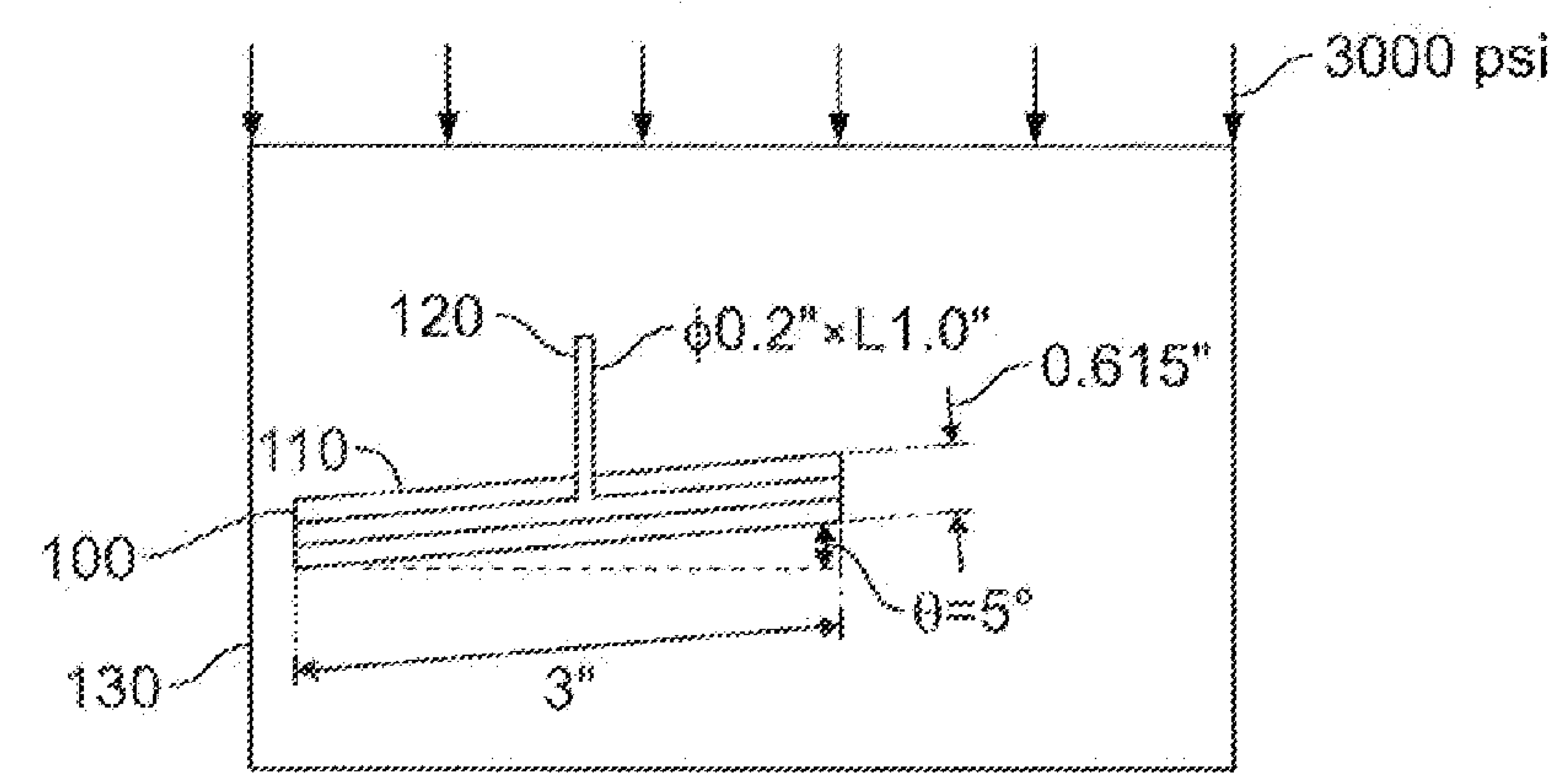
FIG. 12

Experimentation Results

Test	Bore Angle Relative to Horizontal (°)	Bore Diameter (in.)	Bore Length (in.)	Bore Orientation Relative to Minimum Stress	Vertical Tunnel Present (Y/N)	Vertical Tunnel Dimensions		Breakdown Pressure (psi)	Fracture Type	Fracture Orientation Relative to Minimum Stress
						Diameter (in.)	Length (in.)			
1	5	0.615	3	Perpendicular	Y	0.2	1	3323	Transverse	Perpendicular
2	5	0.615	3	Perpendicular	Y	0.3	1.5	2889	Transverse	Perpendicular
3	5	0.615	3	Perpendicular	N	--	--	3903	Longitudinal	Perpendicular
4	5	0.615	3	Parallel	Y	0.3	1.5	3596	Transverse	Perpendicular
5	5	0.615	3	Perpendicular	N	--	--	3525	Longitudinal	Perpendicular
6	90	0.615	3	Perpendicular	N	--	--	2726	Longitudinal	Perpendicular

FIG. 15

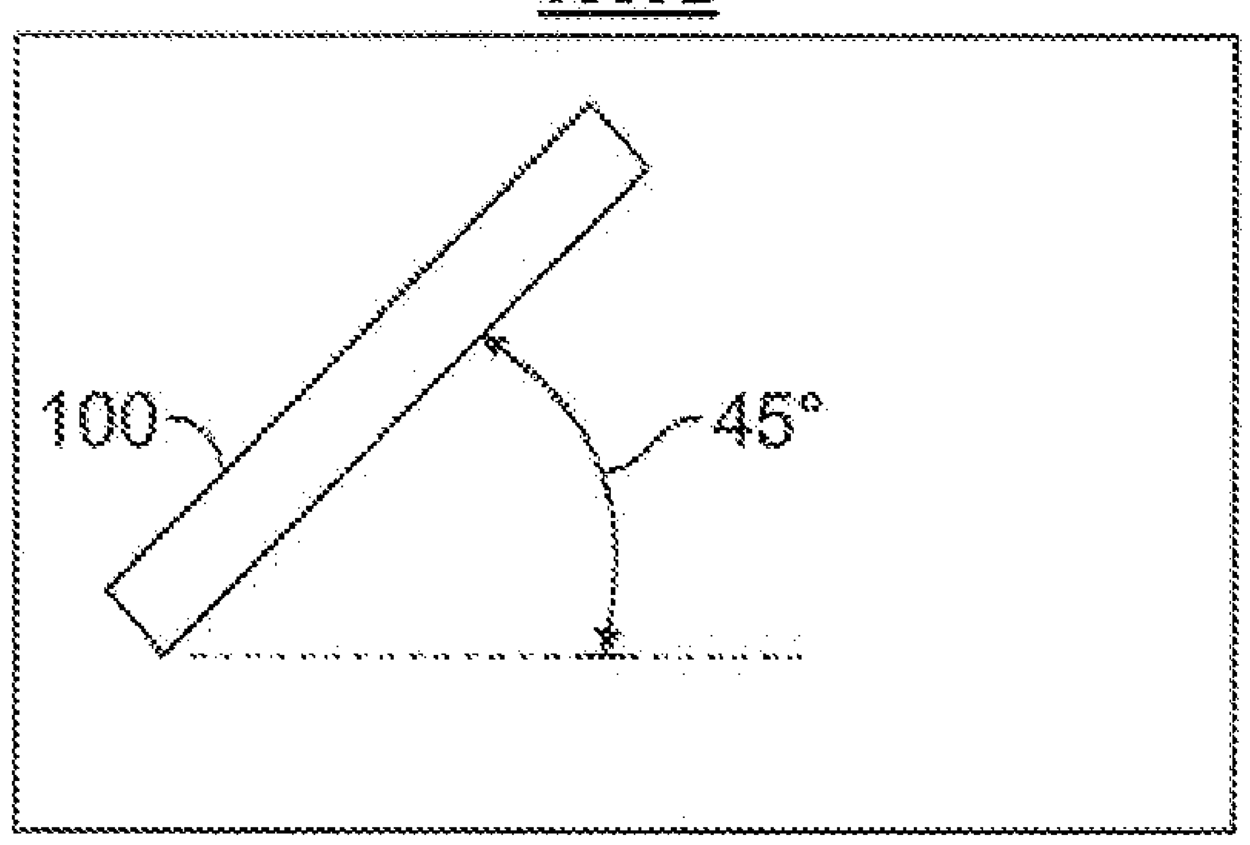
Test 1



Elevation View

FIG. 16

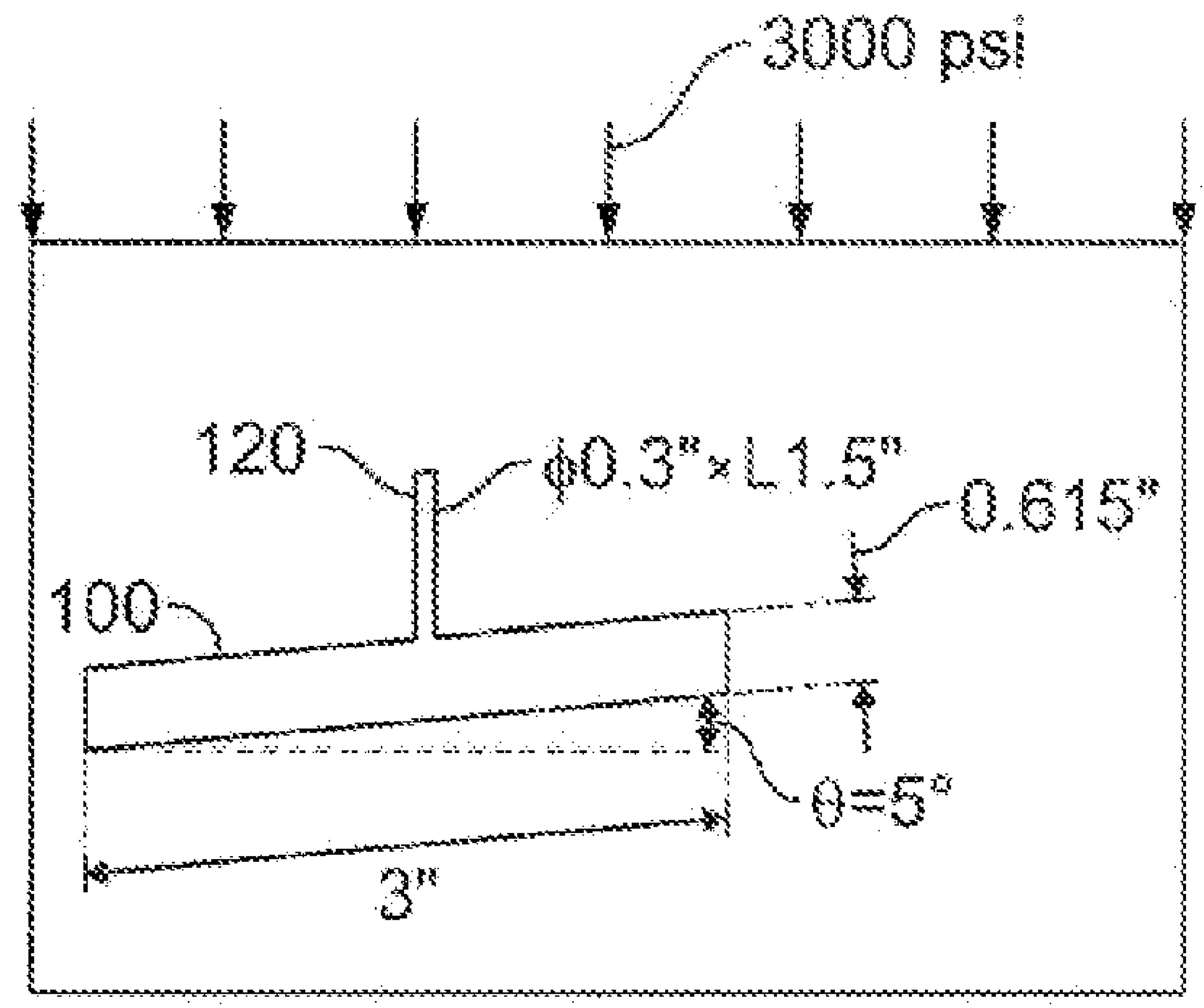
Test 2



Plan View

FIG. 17

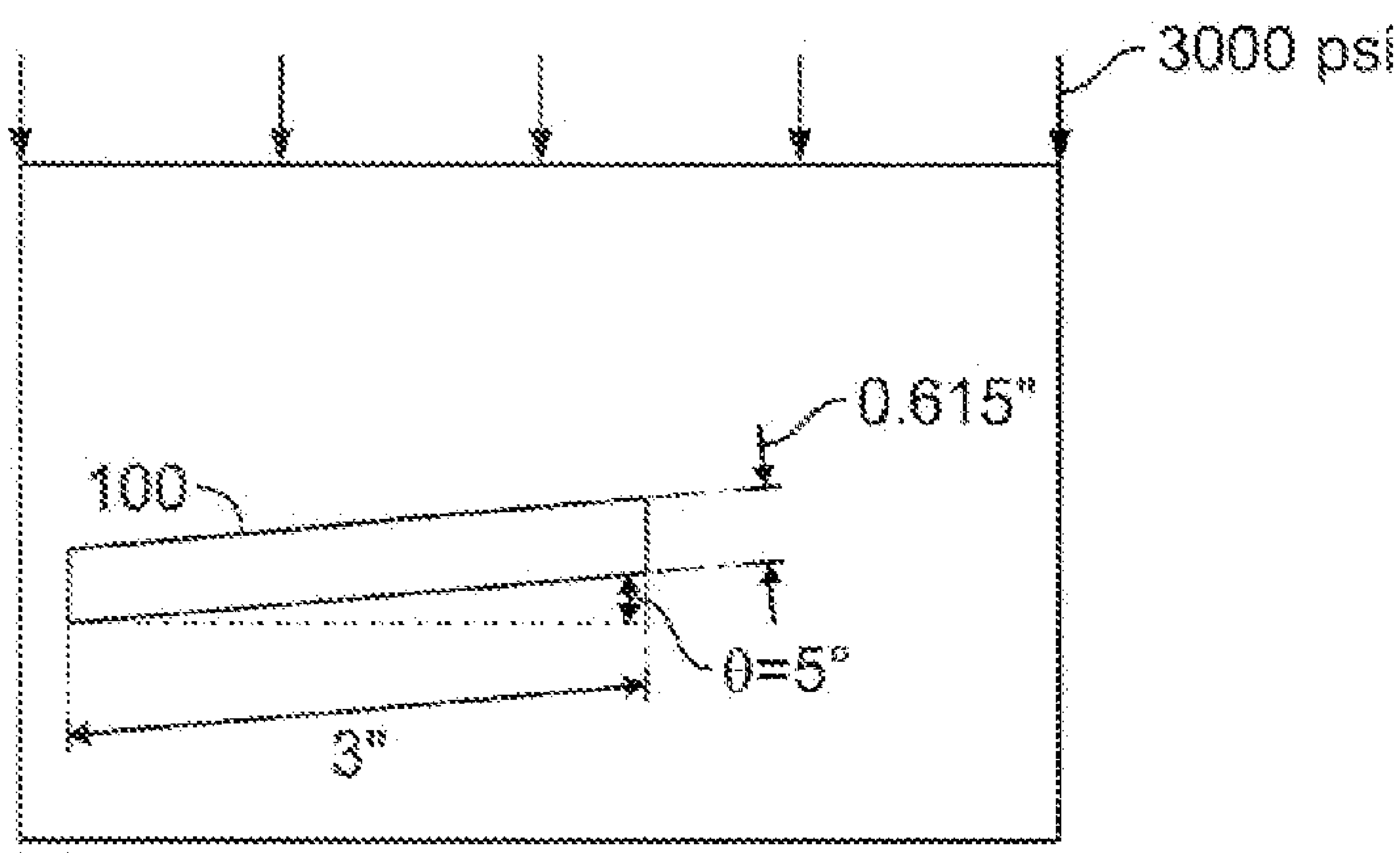
Test 2



Elevation View

FIG. 18

Test 3



Elevation View

FIG. 19

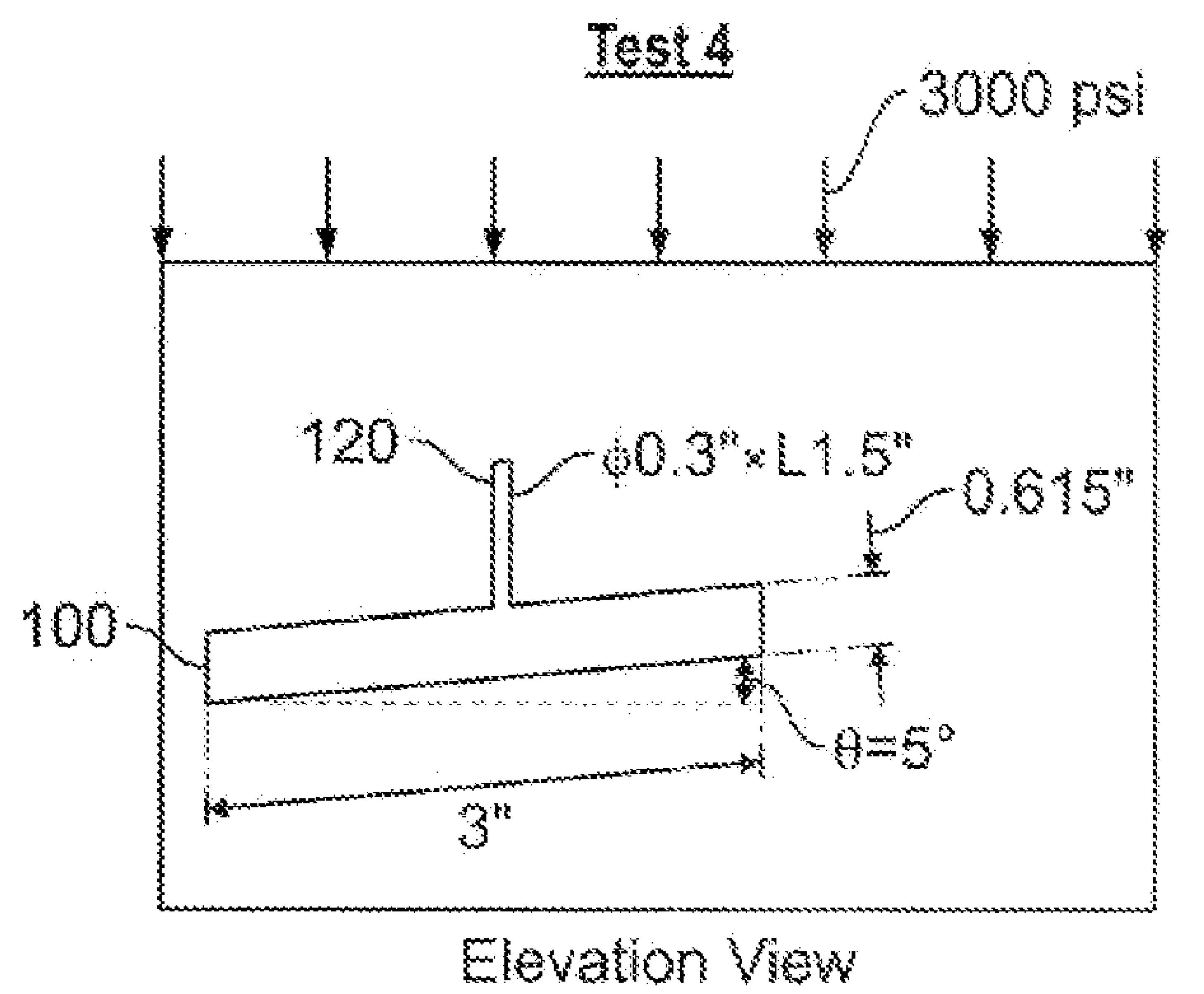


FIG. 20

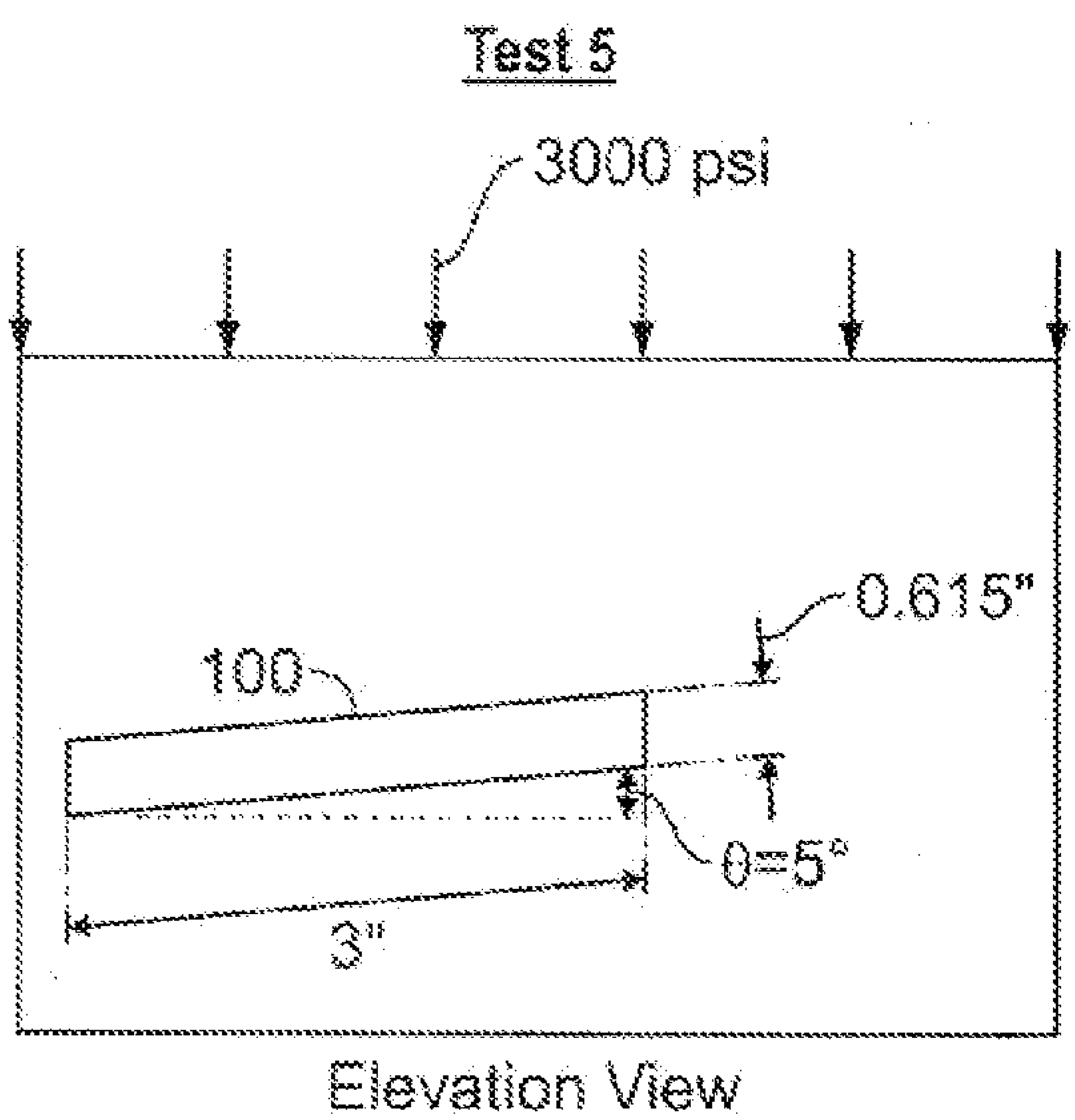


FIG. 21

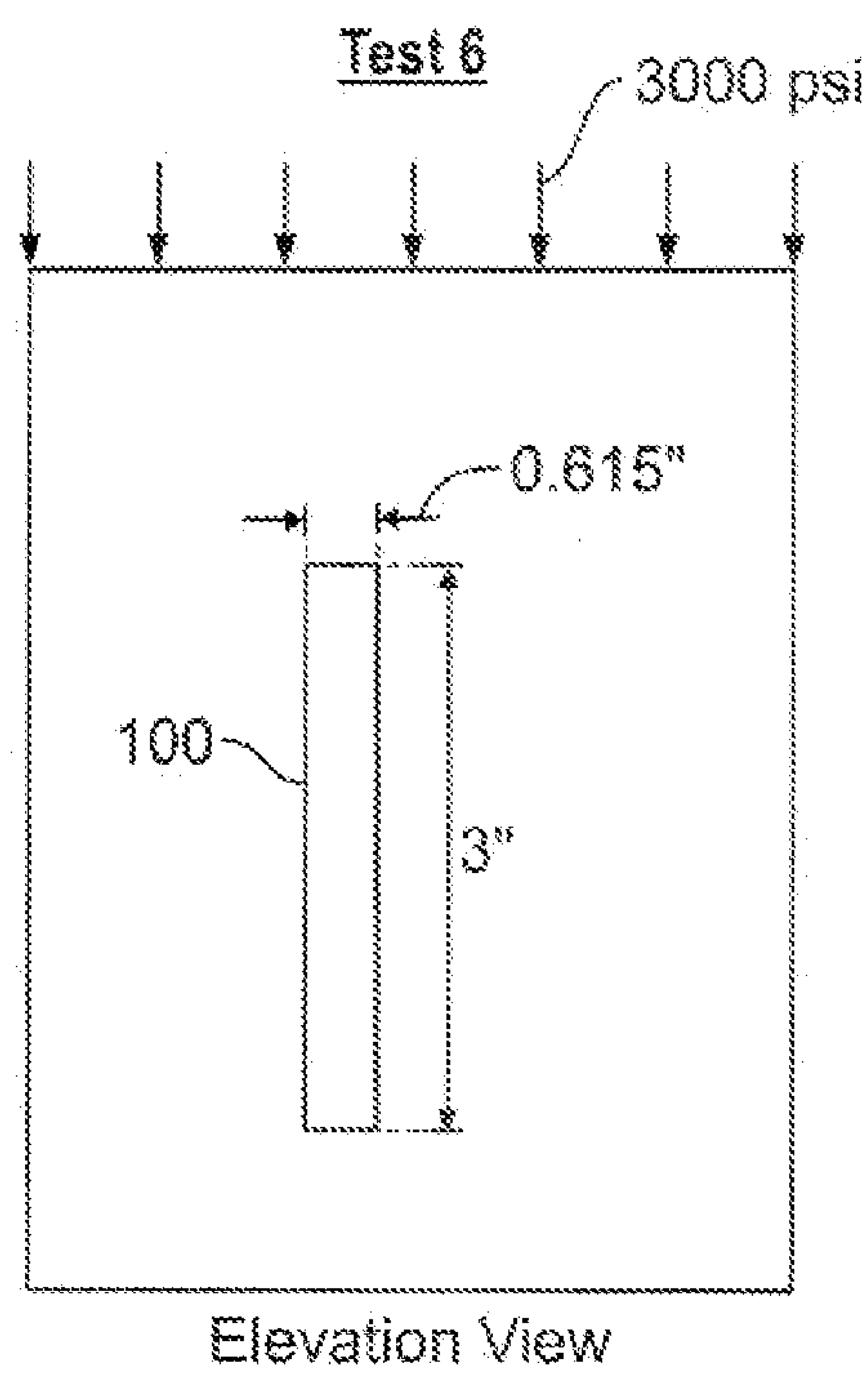


FIG. 22

FORMATION OF FRACTURES WITHIN HORIZONTAL WELL

TECHNICAL FIELD

[0001] This disclosure relates to forming transverse fractures into a subterranean zone from a horizontal well and more particularly to using a tunnel extending from the horizontal wellbore as a transverse fracture initiation location.

BACKGROUND

[0002] Reservoir stimulation may be used to enhance recovery of reservoir fluids from a subterranean reservoir or zone. An example reservoir stimulation is hydraulic fracturing (interchangeably referred to as "fracturing") in which fluid is pumped into a wellbore at an elevated pressure to form one or more fractures in the subterranean reservoir bordering the wellbore. The fractures formed during fracturing provide flow conduits emanating from the wellbore, providing flowpaths for the reservoir fluid to collect in the wellbore and subsequently be produced to the surface.

SUMMARY

[0003] One aspect of the present disclosure is directed to a method of forming transverse fractures extending from a horizontal wellbore. The method may include forming a wellbore having a horizontal wellbore portion within a subterranean zone and forming a tunnel extending from the horizontal wellbore portion into the subterranean zone towards the overburden. The tunnel may be formed with a length adapted to initiate a fracturing extending from the tunnel along a longitudinal axis thereof being influenced insignificantly by the horizontal wellbore portion. The method may also include applying fluid pressure to an interior of the horizontal wellbore portion at a location proximate the tunnel to form a fracture extending from the tunnel along a longitudinal axis thereof and propagating the initiated fracture to encompass the horizontal wellbore portion.

[0004] A second aspect is directed to a wellbore system including a horizontal wellbore extending through a subterranean zone and at least one tunnel extending from the horizontal wellbore into the subterranean zone towards the overburden. The at least one tunnel may have a length adapted to form transverse fractures relative to the horizontal wellbore.

[0005] A third aspect is directed to a method of forming fractures transverse to a horizontal wellbore including forming a wellbore having a horizontal wellbore portion within a subterranean zone and forming a tunnel extending from the horizontal wellbore portion into the subterranean zone towards the overburden. The tunnel may be formed with a length such that the horizontal wellbore portion has insignificant effects on formation of a fracture extending from the tunnel along a longitudinal axis thereof The method may also include applying fluid pressure to an interior of the horizontal wellbore portion at a location proximate the tunnel to form the fracture extending from the tunnel along the longitudinal axis thereof and propagating the initiated fracture to encompass the horizontal wellbore portion.

[0006] One or more of the aspects may include one or more of the following features. Forming a tunnel extending from the horizontal wellbore portion into the subterranean zone towards the overburden may include inserting a tool in the horizontal wellbore portion and orienting the tool into a desired orientation to form the tunnel. Forming a tunnel extending from the horizontal wellbore portion into the subterranean zone towards the overburden may include forming a first tunnel extending from a first portion of the horizontal wellbore portion and forming a second tunnel extending from a second portion of the horizontal wellbore portion opposite the first portion. Forming a tunnel extending from the horizontal wellbore portion into the subterranean zone towards the overburden may include forming the tunnel with one of a hydrajet, a laser, or a drilling tool. Forming the tunnel with a hydrajet may include disposing a hydrajet into the horizontal wellbore portion at a desired location therein, orienting the hydrajet to form the tunnel, and operating the hydrajet to impinge a fluid flow onto a surface of the horizontal wellbore portion to form the tunnel. Forming the tunnel with a laser may include disposing a laser into the substantially horizontal wellbore portion, orienting the laser to form the tunnel, and operating the laser to form the tunnel. Forming the tunnel with a drilling tool may include disposing a drilling tool into the substantially horizontal wellbore portion, orienting the drilling tool to form the tunnel, and operating the drilling tool to form the tunnel.

[0007] One or more of the aspects may also include one or more of the following features. Forming a tunnel extending from the horizontal wellbore portion into the subterranean zone towards the overburden may include forming a tunnel extending from the horizontal wellbore portion into the subterranean zone towards the overburden at two or more different locations along an axial length of the horizontal wellbore portion. A portion of the horizontal wellbore may be isolated at a location of the tunnel before applying the fluid pressure. Forming a tunnel extending from the horizontal wellbore portion into the subterranean zone towards the overburden may include forming the tunnel with a length of at least one and a half (1.5) times a radius of the horizontal wellbore portion. Forming a tunnel extending from the horizontal wellbore portion into the subterranean zone towards the overburden may include forming the tunnel with a length of at least three (3) times a radius of the horizontal wellbore portion. Forming a tunnel extending from the horizontal wellbore portion into the subterranean zone towards the overburden may include forming the tunnel with a length of at least six (6) times a radius of the horizontal wellbore portion.

[0008] One or more of the aspects may additionally include one or more of the following features. At least a portion of the horizontal wellbore may include a slanted portion, and the tunnel may extend from the slanted portion of the horizontal wellbore. The at least one tunnel extending from the horizontal wellbore into the subterranean zone towards the overburden may include a first substantially vertical tunnel extending from a first portion of the horizontal wellbore and a second substantially vertical tunnel extending from a second portion of the horizontal wellbore along a perimeter thereof opposite the first portion. The at least one tunnel having a length adapted to form transverse fractures relative to the horizontal wellbore may include a tunnel having a length of at least one and a half (1.5) times a radius of the horizontal wellbore, a tunnel having a length of at least three (3) times a radius of the horizontal wellbore, or a tunnel having a length of at least six (6) times a radius of the horizontal wellbore.

[0009] One or more of the aspects may further include one or more of the following features. Forming a tunnel extending from the horizontal wellbore portion into the subterranean zone towards the overburden may include forming the tunnel with a length of at least one and a half (1.5) times a radius of

the horizontal wellbore portion, forming the tunnel with a length of at least three (3) times a radius of the horizontal wellbore portion, or forming the tunnel with a length of at least six (6) times a radius of the horizontal wellbore portion. Forming a tunnel extending from the horizontal wellbore portion into the subterranean zone towards the overburden may include inserting a tool in the horizontal wellbore portion and orienting the tool into a desired orientation to form the tunnel. Forming a tunnel extending from the horizontal wellbore portion into the subterranean zone towards the overburden may include forming the tunnel with one of a hydrajet, a laser, or a drilling tool. Forming a tunnel extending from the horizontal wellbore portion into the subterranean zone towards the overburden may include forming a tunnel at two or more different locations along an axial length of the horizontal wellbore portion. A portion of the horizontal wellbore portion may be isolated at a location of the tunnel before applying the fluid pressure.

[0010] The details of one or more implementations are set forth in the accompanying drawings and the description below. Other features, objects, and advantages will be apparent from the description and drawings, and from the claims.

DESCRIPTION OF DRAWINGS

[0011] FIG. **1** shows a wellbore extending from a terranean surface into a subterranean zone.

[0012] FIG. **2** shows a longitudinal fracture extending from a horizontal portion of a wellbore.

[0013] FIG. **3** shows a longitudinal fracture extending from a horizontal wellbore.

[0014] FIG. **4** shows transverse fractures extending from a horizontal portion of a wellbore.

[0015] FIG. **5** shows a transverse fracture extending from a horizontal wellbore.

[0016] FIG. **6** is a view along an axis of a horizontal wellbore in which a transverse fracture extends from the horizontal wellbore.

[0017] FIG. **7** shows a longitudinal fracture extending from a vertical wellbore.

[0018] FIG. **8** shows a tunnel extending from a portion of a horizontal wellbore.

[0019] FIG. **9** shows first and second tunnels extending vertically from opposite locations along a perimeter of a horizontal wellbore.

[0020] FIG. **10** is a cross-sectional view along A-A in FIG. **8** showing a transverse fracture surrounding the horizontal wellbore that was initiated from the tunnel.

[0021] FIG. **11** is a cross-sectional view along B-B in FIG. **9** showing a transverse fracture surrounding the horizontal wellbore that was initiated from the tunnel.

[0022] FIGS. **12-14** illustrate the formation of a transverse fracture relative to a horizontal wellbore.

[0023] FIG. **15** is a summary table of experimentation data.

[0024] FIGS. **16-22** are schematic diagrams illustrating the configuration of the bores extending through various test samples.

DETAILED DESCRIPTION

[0025] Producing transverse fractures in a horizontal well is described. FIG. **1** shows a wellbore **10** having a substantially horizontal portion (hereinafter referred to as "horizontal wellbore") **20**. The wellbore **10** extends from a terranean surface **30** and extends into a subterranean zone **40**. During the producing life of the wellbore **10**, such as after formation of the wellbore **10** or at one or more occasions after the wellbore **10** has been producing reservoir fluids, the subterranean zone **40** may be subjected to a fracturing operation to enhance production of the reservoir fluids.

[0026] Previously, fracturing was performed, for example, by isolating a relatively small section of the wellbore **10** (such as with one or more packers) and injecting a fluid into the isolated section at high pressure. The high pressure fluid increased the stress state of the subterranean zone **40** resulting in the formation of fractures extending into the subterranean zone. However, controlling the orientation of the produced fracturing with respect to the wellbore **10** using this fracturing method was difficult, resulting in high friction pressure and sometimes creating axial fractures (also referred to herein as longitudinal fractures). In some instances, as the axially fractures propagated, the axial fractures would become re-oriented so as to be perpendicular to the minimum stress of the subterranean zone **40**. The re-orientation of these fractures may lead to a sand out. That is, the fracture is unable to accept additional proppant during the fracturing operation and only the carrier fluid is injected into the formation through these fractures. FIGS. **2** and **3** illustrate longitudinal fractures **50** extending longitudinally along an axis **60** of the horizontal wellbore **20**. Longitudinal fractures, though, are not optimum and generally result in reduced production in comparison to transverse fractures formed in a horizontal wellbore. FIGS. **4-6** illustrate transverse fractures **70** formed in the subterranean zone **40** bordering the horizontal wellbore **20**. Further, longitudinal fractures are generally more likely to result when fracturing a horizontal wellbore.

[0027] Longitudinal fractures are also more likely to be formed in vertical wellbores at lower fluid pressures. That is, longitudinal fractures are formed from a vertical wellbore at a lower breakdown pressure. FIG. **7** illustrates longitudinal fractures **50** extending from a vertical well. This characteristic can be utilized to promote formation of transverse fractures in a horizontal well. Particularly, one or more bores or tunnels **80** may be extended from a horizontal wellbore **20** and used to promote the formation of a transverse fracture about the horizontal wellbore **20**. The one or more tunnels **80** may extend towards the overburden. Generally, this means that the one or more tunnels **80** extend vertically or substantially vertically from the horizontal wellbore **20**. For the purposes of this disclosure, forming the one or more tunnels **80** towards the overburden is described as being formed vertical or substantially vertical. However, it is understood that the tunnels **80** may be formed in a direction other than vertical or substantially vertical in situations where the overburden is not at a location vertically offset from the horizontal wellbore **20**. Further, the one or more tunnels **80** may deviate from vertical or substantial vertical by 15°. The tunnels **80** promote the initiation and propagation of fractures that are independent of influences associated with horizontal and vertical orientations aspects of the well.

[0028] FIG. **8** shows a single tunnel **80** extending substantially vertically from a first portion **82** of the horizontal wellbore **20**, while FIG. **9** shows a pair of tunnels **80** extending from the horizontal wellbore **20**. In FIG. **9**, one of the tunnels **80** extends from the first portion **82** of the horizontal wellbore **20**, and the second tunnel **80** extends from a second portion **84** of the horizontal wellbore **20**, opposite the first portion **82**. Further, both tunnels **80** are oriented vertically or substantially vertically so as to promote the formation of the transverse fracture relative to the horizontal wellbore **20**.

[0029] The horizontal wellbore **20** may also include numerous tunnels **80** formed along the length of the horizontal wellbore **20**. Particularly, a tunnel **80** may be included on the horizontal wellbore **20** at any location where a transverse fracture is desired. Thus, the number of tunnels **80** formed into the subterranean zone **40** from the horizontal wellbore **20** may be dependent upon the number of transverse fractures **70** desired. Consequently, the number of tunnels may be determined according to the design of the stimulation activity.

[0030] FIGS. **10** and **11** show cross-sectional views of the horizontal wellbore **20** along lines A-A and B-B, respectively. FIGS. **10** and **11** show example transverse fractures **70** extending into the subterranean zone **40** that were initiated at the tunnels **80**.

[0031] The tunnels **80** may be formed in any number of different ways. For example, one or more of the tunnels **80** may be formed mechanically, such as by drilling into the reservoir from the horizontal wellbore **20**. According to other implementations, one or more of the tunnels **80** may be formed using one or more lasers. A laser device may be included on a tubing string extending into the horizontal wellbore **20** and used to form the tunnels **80** therefrom. According to still other implementations, one or more of the tunnels **80** may be formed with a stream of pressurized fluid, e.g., by hydrajetting, which forces a concentrated jet of fluid at elevated pressures towards a point within a wellbore. Example hydrajets that may be used are described in U.S. Pat. No. 5,361,856 and U.S. Pat. No. 5,494,103, each of which is incorporated herein by reference in their entirety. A pressurized fluid is then introduced into the horizontal well **20** to form the transverse fracture **70**.

[0032] Unlike perforations formed in a wellbore, the tunnel **80** has a better defined elongated shape with less damage to the surrounding subterranean zone **40**. This damage provides leak-off paths for the fracturing fluid to flow off into the subterranean zone **40**, thereby reducing the effective pressure exerted on the subterranean zone **40** to form the fractures therein, i.e., the damage to the surrounding subterranean zone **40** may cause an increase in the breakdown pressure required to fracture the subterranean zone **40**. Further, during a perforating operation, a plurality of perforations are formed in the subterranean zone **40**. These multiple perforations also act to lessen the effect of the pressurized fluid, because the multiple perforations require more pressure and fluid flow.

[0033] Additionally, perforating a wellbore with a hydrajet expels a plurality of fluid streams through respective nozzles. The fluid streams form a plurality of openings into the subterranean formation from the wellbore. However, the effect of using the plurality of fluid streams results in enlarging the openings into an enlarged cavity formed in the subterranean zone surrounding the wellbore. Thus, when the pressurized fluid is introduced into the wellbore for fracturing, the enlarged cavity reduces the effectiveness of concentrating the pressurized fluid to initiate and propagate a fracture in a controlled manner. Further, present hydrajets for perforating a subterranean zone are also deficient in that the nozzles expelling the fluid streams are not capable of being aligned with a particular orientation within the wellbore and are, thus, incapable of aligning openings formed by the hydrajet with a desired orientation.

[0034] Once the one or more tunnels **80** are formed, the subterranean zone **40** may then be fractured. According to some implementations, the pressurized fluid may be introduced into the horizontal wellbore **20** via a concentrated stream at or near the location of the tunnel(s) **80**. Alternately, a portion of the horizontal wellbore **20** including the tunnel(s) **80** is isolated according to any desired manner, and the pressurized fluid is introduced into the isolated portion of the horizontal wellbore **20** to form the transverse fracture **70**.

[0035] It is believed that the introduced pressurized fluid works on the tunnel **80** to form a longitudinal fracture extending therefrom. As this longitudinal fracture extends, the fracture encompasses the horizontal wellbore **20**, resulting in a transverse fracture with respect to the horizontal wellbore **20**. FIGS. **12**-**14** illustrate the progression of the fracture believed to occur at a location along a horizontal wellbore **20** having a tunnel **80**. In FIG. **12**, the pressurized fluid (represented by the plurality of arrows **90**) is introduced into the horizontal wellbore **20**. In FIG. **13**, the longitudinal fracture **50** is formed extending from the tunnel **80**. The initiated longitudinal fracture **50** extends and expands to encompass the horizontal wellbore **20**, thereby resulting in a transverse fracture **70** extending into the subterranean zone **40**, as shown in FIG. **14**.

[0036] The one or more tunnels **80** may have any desired length L. However, as the length L of the tunnel **80** increases, influences from the horizontal wellbore **20** during fracturing are reduced, resulting in a greater likelihood that a transverse fracture with respect to the horizontal wellbore **20** will result. These influences include how the horizontal wellbore **20** affects the stress state of the subterranean zone **40** surrounding the tunnels **80** during fracturing. Moreover, for a tunnel **80** having a length L of three (3) times the diameter D or six (6) times the radius of the horizontal wellbore, the influences from the horizontal wellbore **20** are negligible. In fact, the influences from the horizontal wellbore **20** are also small with respect to tunnels **80** having lengths L smaller than three times the diameter D of the horizontal wellbore **20**. For example, a horizontal wellbore **20** may have substantially inconsequential effects on a tunnel **80** having a length of three times the radius or more (e.g., three, three and a half, four, four and a half, five, and five and half times the radius of the horizontal wellbore). A tunnel **80** having a length less than three times the radius of the horizontal wellbore **20**, such as two and a half, two, and even one and a half times the radius of the horizontal wellbore **20**, may also form transverse fractures notwithstanding the larger, though non-detrimental, effects on the formation of the transverse fractures associated with these smaller lengths.

[0037] A further benefit of using one or more tunnels **80** is that the size of any isolated portion of the wellbore that may be used can be larger than conventionally isolated portions. In still other implementations, the pressurized fluid may be introduced into the horizontal wellbore **20** at or near the tunnel(s) **80** without isolating a portion of the horizontal wellbore **20**. The manner of injecting the pressurized fluid into the horizontal wellbore **20** may be selected based on conditions associated with the wellbore **10**, the subterranean zone **40**, and/or any number of different considerations. For example, porosity of the subterranean zone **40**, the stress condition of the subterranean zone **40**, properties of the reservoir fluids, and/or any other considerations may affect the manner chosen for introducing the pressurized fluid into the horizontal wellbore **20**.

[0038] As mentioned above, the tunnel **80** represents a vertical well, and, during fracturing of a vertical well, a longitudinal fracture more readily forms at a lower pressure. A longitudinal fracture extending from a vertical wellbore more readily occurs because of the stress state of the subterranean zone. Fractures propagate perpendicular to the minimum principal stress in the subterranean zone. Generally, the minimum principal stress is oriented horizontally. Thus, for a vertical wellbore, longitudinal fractures are more likely to form and form more readily at lower breakdown pressures. Thus, it is believed that by including the tunnel **80** along the horizontal wellbore **20**, the tunnel **80** acts as a fracture initiation location for a longitudinal fracture with respect to the tunnel **80**. The fracture propagates to the horizontal wellbore perpendicular to the minimum principal stress of the subterranean zone.

[0039] Further, it is believed that the initiated fracture intersects the horizontal wellbore **20** irrespective of the orientation thereof. That is, the horizontal wellbore **20** may be oriented horizontally or substantially horizontally, or may be slanted within the subterranean zone **40**, and the fracture initiated at the tunnel **80** still extends to the horizontal wellbore **20** to form a transverse fracture relative thereto. For example, some horizontal wellbores may be slanted at one or more locations so as to follow a particular formation within a subterranean reservoir. A wellbore extending through a subterranean zone, such as subterranean zone **40**, that is horizontal, substantially horizontal, or that is at least partially slanted is considered horizontal within the scope of this disclosure. Thus, the longitudinal fracture **50** formed from the tunnel **80** represents a transverse fracture with respect to the horizontal wellbore **20**. Consequently, forming the tunnel **80** permits the formation of a transverse fracture along the horizontal wellbore **20** using fluid at a lower fluid pressure than would otherwise be required to form a transverse fracture along a horizontal wellbore. Use of the tunnel **80** also allows consistent formation of a transverse fracture **70** relative to the horizontal wellbore **20**. Further, depending on the downhole conditions, the pressurized fluid may be introduced without the need for isolating one or more portions of the well. Therefore, use of the tunnel **80** has lower associated fracturing costs. Moreover, the tunnel **80** is also believed to essentially eliminate the formation of multiple fractures and fracture tortuosity that may result during a fracturing operation.

[0040] Experimentation, described below, has been performed demonstrating the effectiveness of a tunnel extending from a horizontal wellbore in forming a fracture transverse to the horizontal wellbore at a relatively low fracturing pressure. FIG. **15** shows test summary data for six test samples. Each of the test samples were performed by casting a bore and, in some of the experiments, a vertical or substantially vertical tunnel extending therefrom in hydrostone, a gypsum cement. The hydrostone was prepared having a ratio of 30 parts of water per 100 parts of hydrostone. FIGS. **16-22** show schematic diagrams of the configuration of the bores and, optionally, the tunnels within the hydrostone. Each of the test samples were subjected to a 3000 psi pressure on a top surface (as shown in the figures), which resulted in the following stress state: vertical stress=3000 psi, minimum horizontal stress=1800 psi, and maximum horizontal stress=2500 psi. It is noted that, although some of the tests described in FIGS. **15-22** include a wellbore slanted relative to horizontal (e.g., some wellbores have a slant of 5° relative to horizontal), the wellbores may have a slant of greater than or less than 5° and still be within the scope of the disclosure. For example, in some instances, the wellbore may have a slant of 15° or greater and a tunnel extending therefrom may still be operable to produce a transverse fracture at a relatively low fracture pressure.

[0041] FIG. **16** is an elevation view of a schematic of test sample **1**. Test sample **1** was formed having a bore **100** having a casing **110**. A tunnel **120** extends vertically or substantially vertically from the bore **100**. (Dimensions of the bore **100** and tunnel **120** are provided in the table of FIG. **15**.) The bore **100** was formed at approximately 5° from horizontal. An interior of the tunnel was in communication with an interior of the bore via an opening formed in the casing **110**. As a result of the casing **110**, fluid pressure introduced into the bore **100** was exerted on the hydrostone (formation **130**) via the tunnel **120**. As a result, a fracture initiated at a fluid pressure of 3323 psi transverse to the bore **100**. The fracture is believed to have initiated from the tunnel **120** and extended to encompass the bore **100**. The fracture extended transverse to the minimum horizontal stress.

[0042] FIGS. **17** and **18** are schematic plan and elevation views, respectively, of test sample **2**. Test sample **2** included an uncased bore **100** formed at approximately 5° from horizontal. The bore **100** was also formed at approximately 45° within a horizontal plane, as shown in the plan view of FIG. **17**. The bore **100** of test sample **2** was not cased but did include a tunnel **120** extending vertically or substantially vertically from the bore **100**. A fracture transverse to the bore **100** was initiated in the test sample at 2889 psi. The fracture is believed to have initiated at the tunnel **120** and extended to encompass the bore **100**. The resulting fracture extended past the bore **100** without causing multiple fractures.

[0043] FIG. **19** shows a schematic view of test sample **3**. Test sample **3** included a bore **100** that was not cased and did not include a tunnel, and the bore **100** was formed at an angle of 5° from horizontal. A fracture extending longitudinally along the bore **100** was formed at a fluid pressure of 3903 psi introduced into the bore **100**.

[0044] FIG. **20** shows a schematic elevation view of test sample **4**. Test sample **4** included an uncased bore **100** formed at an angle of 5° from horizontal. A vertical or substantially vertical tunnel **120** extended from the bore **100**. Fluid pressure was introduced into the interior of the bore **100** and the tunnel **120**, which caused a fracture transverse to the bore **100** at a fluid pressure of 3596 psi. The fracture is believed to have initiated in the tunnel and propagated to encompass the bore **100**.

[0045] FIG. **21** shows a schematic elevation view of test sample **5**. Test sample **5** included an uncased bore **100** formed at an angle of 5° from horizontal. The bore **100** did not include a tunnel extending therefrom. The bore **100** was subjected to an internal fluid pressure which, at a fluid pressure of 3525 psi, caused a fracture extending longitudinally along the bore **100**.

[0046] FIG. **22** shows a schematic elevation view of test sample **6**, which includes a vertical or substantially vertical uncased bore **100**. Fluid pressure was introduced into the bore **100**, resulting in a fracture extending longitudinally along the bore **100** at a fluid pressure of 2726 psi. Test sample **6** illustrates the tendency to forming fractures extending longitudinally along a vertical bore under stress conditions similar to those in an earth formation.

[0047] In each of the experiments, the resulting fractures propagated perpendicular to the minimum stress state. Further, the results show that, for the bores including vertical or substantially vertical tunnels extending therefrom, a fracture transverse to the bore was formed at a fluid pressure approximately the same as or lower than pressures forming a fracture longitudinal to those bores that did not include a vertical or substantially vertical tunnel extending therefrom.

[0048] A number of implementations have been described. Nevertheless, it will be understood that various modifications may be made without departing from the spirit and scope of the disclosure. Accordingly, other implementations are within the scope of the following claims.

What is claimed is:

1. A method of forming transverse fractures extending from a horizontal wellbore comprising:

forming a wellbore within a subterranean zone, the wellbore having a horizontal wellbore portion;

forming a tunnel extending from the horizontal wellbore portion into the subterranean zone towards the overburden, the tunnel formed with a length adapted to initiate a fracturing extending from the tunnel along a longitudinal axis thereof being influenced insignificantly by the horizontal wellbore portion;

applying fluid pressure to an interior of the horizontal wellbore portion at a location proximate the tunnel to form a fracture extending from the tunnel along a longitudinal axis thereof; and

propagating the initiated fracture to encompass the horizontal wellbore portion.

2. The method of claim **1**, wherein forming a tunnel extending from the horizontal wellbore portion into the subterranean zone towards the overburden comprises:

inserting a tool in the horizontal wellbore portion; and

orienting the tool into a desired orientation to form the tunnel.

3. The method of claim **1**, wherein forming a tunnel extending from the horizontal wellbore portion into the subterranean zone towards the overburden comprises:

forming a first tunnel extending from a first portion of the horizontal wellbore portion; and

forming a second tunnel extending from a second portion of the horizontal wellbore portion opposite the first portion.

4. The method of claim **1**, wherein forming a tunnel extending from the horizontal wellbore portion into the subterranean zone towards the overburden comprises forming the tunnel with one of a hydrajet, a laser, or a drilling tool.

5. The method of claim **4**, wherein forming the tunnel with a hydrajet comprises:

disposing a hydrajet into the horizontal wellbore portion at a desired location therein;

orienting the hydrajet to form the tunnel; and

operating the hydrajet to impinge a fluid flow onto a surface of the horizontal wellbore portion to form the tunnel.

6. The method of claim **4**, wherein forming the tunnel with a laser comprises:

disposing a laser into the substantially horizontal wellbore portion;

orienting the laser to form the tunnel; and

operating the laser to form the tunnel.

7. The method of claim **4**, wherein forming the tunnel with a drilling tool comprises:

disposing a drilling tool into the substantially horizontal wellbore portion;

orienting the drilling tool to form the tunnel; and

operating the drilling tool to form the tunnel.

8. The method of claim **1**, wherein forming a tunnel extending from the horizontal wellbore portion into the subterranean zone towards the overburden comprises forming a tunnel extending from the horizontal wellbore portion into the subterranean zone towards the overburden at two or more different locations along an axial length of the horizontal wellbore portion.

9. The method of claim **1** further comprising isolating a portion of the horizontal wellbore at a location of the tunnel before applying the fluid pressure.

10. The method of claim **1**, wherein forming a tunnel extending from the horizontal wellbore portion into the subterranean zone towards the overburden comprises forming the tunnel with a length of at least one and a half (1.5) times a radius of the horizontal wellbore portion.

11. The method of claim **1**, wherein forming a tunnel extending from the horizontal wellbore portion into the subterranean zone towards the overburden comprises forming the tunnel with a length of at least three (3) times a radius of the horizontal wellbore portion.

12. The method of claim **1**, wherein forming a tunnel extending from the horizontal wellbore portion into the subterranean zone towards the overburden comprises forming the tunnel with a length of at least six (6) times a radius of the horizontal wellbore portion.

13. A wellbore system comprising:

a horizontal wellbore extending through a subterranean zone; and

at least one tunnel extending from the horizontal wellbore into the subterranean zone towards the overburden, the at least one tunnel having a length adapted to form transverse fractures relative to the horizontal wellbore.

14. The wellbore system of claim **13**, wherein at least a portion of the horizontal wellbore comprises a slanted portion and wherein the tunnel extends from the slanted portion of the horizontal wellbore.

15. The wellbore system of claim **13**, wherein the at least one tunnel extending from the horizontal wellbore into the subterranean zone towards the overburden comprises:

a first substantially vertical tunnel extending from a first portion of the horizontal wellbore; and

a second substantially vertical tunnel extending from a second portion of the horizontal wellbore along a perimeter thereof opposite the first portion.

16. The wellbore system of claim **13**, wherein the at least one tunnel having a length adapted to form transverse fractures relative to the horizontal wellbore comprises a tunnel having a length of at least one and a half (1.5) times a radius of the horizontal wellbore.

17. The wellbore system of claim **13**, wherein the at least one tunnel having a length adapted to form transverse fractures relative to the horizontal wellbore comprises a tunnel having a length of at least three (3) times a radius of the horizontal wellbore.

18. The wellbore system of claim **13**, wherein the at least one tunnel having a length adapted to form transverse fractures relative to the horizontal wellbore comprises a tunnel having a length of at least six (6) times a radius of the horizontal wellbore.

19. A method of forming fractures transverse to a horizontal wellbore comprising:

forming a wellbore having a horizontal wellbore portion within a subterranean zone;

forming a tunnel extending from the horizontal wellbore portion into the subterranean zone towards the overburden, the tunnel formed with a length such that the horizontal wellbore portion has insignificant effects on formation of a fracture extending from the tunnel along a longitudinal axis thereof;

applying fluid pressure to an interior of the horizontal wellbore portion at a location proximate the tunnel to form the fracture extending from the tunnel along the longitudinal axis thereof; and

propagating the initiated fracture to encompass the horizontal wellbore portion.

20. The method of claim **19**, wherein forming a tunnel extending from the horizontal wellbore portion into the subterranean zone towards the overburden comprises forming the tunnel with a length of at least one and a half (1.5) times a radius of the horizontal wellbore portion.

21. The method of claim **19**, wherein forming a tunnel extending from the horizontal wellbore portion into the subterranean zone towards the overburden comprises forming the tunnel with a length of at least three (3) times a radius of the horizontal wellbore portion.

22. The method of claim **19**, wherein forming a tunnel extending from the horizontal wellbore portion into the subterranean zone towards the overburden comprises forming the tunnel with a length of at least six (6) times a radius of the horizontal wellbore portion.

23. The method of claim **19**, wherein forming a tunnel extending from the horizontal wellbore portion into the subterranean zone towards the overburden comprises:

inserting a tool in the horizontal wellbore portion; and

orienting the tool into a desired orientation to form the tunnel.

24. The method of claim **19**, wherein forming a tunnel extending from the horizontal wellbore portion into the subterranean zone towards the overburden comprises forming the tunnel with one of a hydrajet, a laser, or a drilling tool.

25. The method of claim **19**, wherein forming a tunnel extending from the horizontal wellbore portion into the subterranean zone towards the overburden comprising forming a tunnel at two or more different locations along an axial length of the horizontal wellbore portion.

26. The method of claim **19** further comprising isolating a portion of the horizontal wellbore portion at a location of the tunnel before applying the fluid pressure.

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