

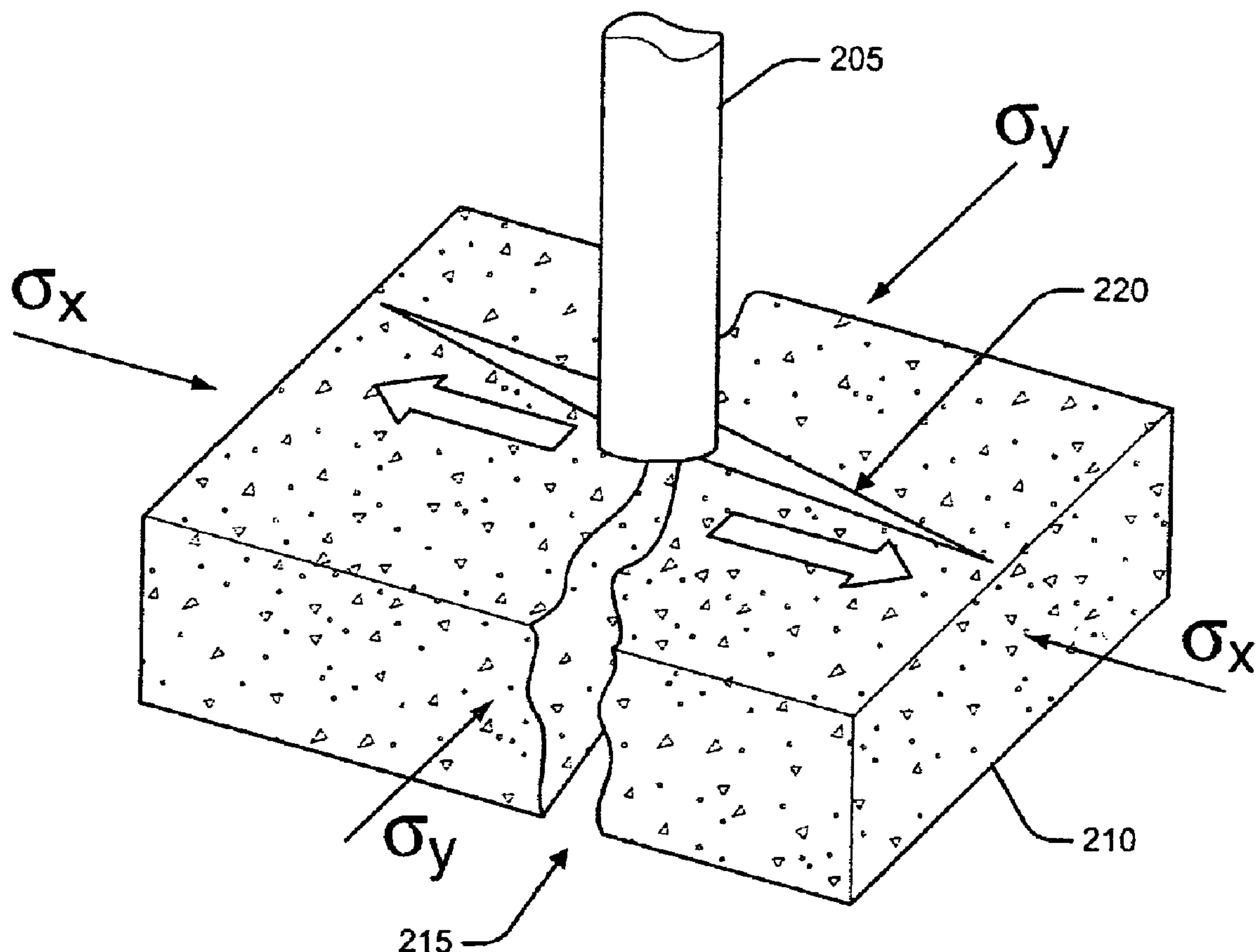


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(54) Title: METHODS AND SYSTEMS FOR WELL STIMULATION USING MULTIPLE ANGLED FRACTURING



(57) Abrégé/Abstract:

Methods, systems, and apparatus for inducing fractures in a subterranean formation and more particularly methods and apparatus to place a first fracture with a first orientation in a formation followed by a second fracture with a second angular orientation in the

(57) **Abrégé(suite)/Abstract(continued):**

formation are disclosed. The first and second fractures are initiated at about a fracturing location. The initiation of the first fracture is characterized by a first orientation line. The first fracture temporarily alters a stress field in the subterranean formation. The initiation of the second fracture is characterized by a second orientation line. The first orientation line and the second orientation line have an angular disposition to each other.

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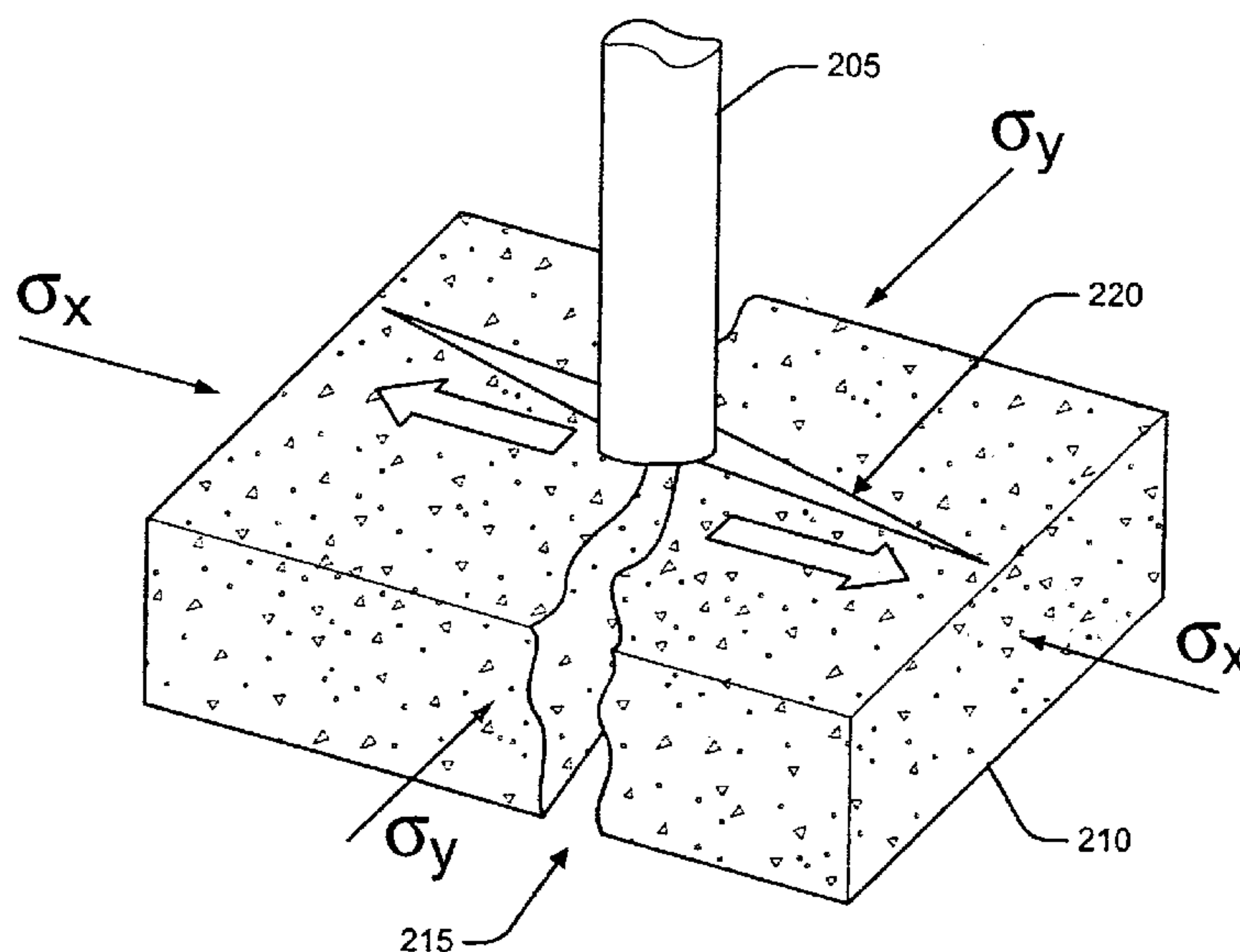
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(54) Title: METHODS AND SYSTEMS FOR WELL STIMULATION USING MULTIPLE ANGLED FRACTURING



(57) Abstract: Methods, systems, and apparatus for inducing fractures in a subterranean formation and more particularly methods and apparatus to place a first fracture with a first orientation in a formation followed by a second fracture with a second angular orientation in the formation are disclosed. The first and second fractures are initiated at about a fracturing location. The initiation of the first fracture is characterized by a first orientation line. The first fracture temporarily alters a stress field in the subterranean formation. The initiation of the second fracture is characterized by a second orientation line. The first orientation line and the second orientation line have an angular disposition to each other.

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## **METHODS AND SYSTEMS FOR WELL STIMULATION USING MULTIPLE ANGLED FRACTURING**

**[0001]** The present invention relates generally to methods, systems, and apparatus for inducing fractures in a subterranean formation and more particularly to methods and apparatus to place a first fracture with a first orientation in a formation followed by a second fracture with a second angular orientation in the formation.

**[0002]** Oil and gas wells often produce hydrocarbons from subterranean formations. Occasionally, it is desired to add additional fractures to an already-fractured subterranean formation. For example, additional fracturing may be desired for a previously producing well that has been damaged due factors such as fine migration. Although the existing fracture may still exist, it is no longer effective, or less effective. In such a situation, stress caused by the first fracture continues to exist, but it would not significantly contribute to production. In another example, multiple fractures may be desired to increase reservoir production. This scenario may be also used to improve sweep efficiency for enhanced recovery wells such water flooding steam injection, etc. In yet another example, additional fractures may be created to inject with drill cuttings.

**[0003]** Conventional methods for initiating additional fractures typically induce the additional fractures with near-identical angular orientation to previous fractures. While such methods increase the number of locations for drainage into the wellbore, they may not introduce new directions for hydrocarbons to flow into the wellbore. Conventional method may also not account for, or even more so, utilize, stress alterations around existing fractures when inducing new fractures.

**[0004]** Thus, a need exists for an improved method for initiating multiple fractures in a wellbore, where the method accounts for tangential forces around a wellbore.

### **SUMMARY**

**[0005]** The present invention relates generally to methods, systems, and apparatus for inducing fractures in a subterranean formation and more particularly to methods and apparatus to place a first fracture with a first orientation in a formation followed by a second fracture with a second angular orientation in the formation.

**[0006]** An example method of the present invention is for fracturing a subterranean formation. The subterranean formation includes a wellbore having an axis. A first fracture is induced in the subterranean formation. The first fracture is initiated at about a fracturing location. The initiation of the first fracture is characterized by a first orientation line. The first fracture temporarily alters a stress field in the subterranean formation. A second fracture is induced in the subterranean formation. The second fracture is initiated at about the fracturing location. The initiation of the second fracture is characterized by a second

orientation line. The first orientation line and the second orientation line have an angular disposition to each other.

[0007] An example fracturing tool according to present invention includes a tool body to receive a fluid, the tool body comprising a plurality of fracturing sections, wherein each fracturing section includes at least one opening to deliver the fluid into the subterranean formation at an angular orientation; and a sleeve disposed in the tool body to divert the fluid to at least one of the fracturing sections while blocking the fluid from exiting another at least one of the fracturing sections.

[0008] An example system for fracturing a subterranean formation according to the present invention includes a downhole conveyance selected from a group consisting of a drill string and coiled tubing, wherein the downhole conveyance is at least partially disposed in the wellbore; a drive mechanism configured to move the downhole conveyance in the wellbore; a pump coupled to the downhole conveyance to flow a fluid through the downhole conveyance; and a computer configured to control the operation of the drive mechanism and the pump.

[0009] The fracturing tool includes tool body to receive the fluid, the tool body comprising a plurality of fracturing sections, wherein each fracturing section includes at least one opening to deliver the fluid into the subterranean formation at an angular orientation and a sleeve disposed in the tool body to divert the fluid to at least one of the fracturing sections while blocking the fluid from exiting another at least one of the fracturing sections.

[0010] The features and advantages of the present invention will be apparent to those skilled in the art. While numerous changes may be made by those skilled in the art, such changes are within the spirit of the invention.

### **BRIEF DESCRIPTION OF THE DRAWINGS**

[0011] These drawings illustrate certain aspects of some of the embodiments of the present invention, and should not be used to limit or define the invention.

[0012] Figure 1 is a schematic block diagram of a wellbore and a system for fracturing.

[0013] Figure 2A is a graphical representation of a wellbore in a subterranean formation and the principal stresses on the formation.

Figure 2B is a graphical representation of a wellbore in a subterranean formation that has been fractured and the principal stresses on the formation.

[0014] Figure 3 is a flow chart illustrating an example method for fracturing a formation according to the present invention.

[0015] Figure 4 is a graphical representation of a wellbore and multiple fractures at different angles and fracturing locations in the wellbore.

[0016] Figure 5 is a graphical representation of a formation with a high-permeability region with two fractures.

[0017] Figure 6 is a graphical representation of drainage into a horizontal wellbore fractured at different angular orientations.

[0018] Figures 7A, 7B, and 7C illustrate a cross-sectional view of a fracturing tool showing certain optional features in accordance with one example implementation.

[0019] Figure 8 is a graphical representation of the drainage of a vertical wellbore fractured at different angular orientations.

[0020] Figure 9 is a graphical representation of a fracturing tool rotating in a horizontal wellbore and fractures induced by the fracturing tool.

Figure 10 is a graph of the stress profile around the wellbore for a net pressure of 1000 psi.

Figure 11 is a graph illustrating the tangential stress profile in the first quadrant of the creation of two fractures.

### **DETAILED DESCRIPTION**

[0021] The present invention relates generally to methods, systems, and apparatus for inducing fractures in a subterranean formation and more particularly to methods and apparatus to place a first fracture with a first orientation in a formation followed by a second fracture with a second angular orientation in the formation. Furthermore, the present invention may be used on cased well bores or open holes.

[0022] The methods and apparatus of the present invention may allow for increased well productivity by the introduction of multiple fractures introduced at different angles relative to one another in the a wellbore.

[0023] Figure 1 depicts a schematic representation of a subterranean well bore 100 through which a fluid may be injected into a region of the subterranean formation surrounding well bore 100. The fluid may be of any composition suitable for the particular injection operation to be performed. For example, where the methods of the present invention are used in accordance with a fracture stimulation treatment, a fracturing fluid may be injected into a subterranean formation such that a fracture is created or extended in a

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region of the formation surrounding well bore 12 and generates pressure signals. The fluid may be injected by injection device 105 (e.g., a pump). At wellhead 115, a downhole conveyance device 120 is used to deliver and position a fracturing tool 125 to a location in the wellbore 100. In some example implementations, the downhole conveyance device 120 may include coiled tubing. In other example implementations, downhole conveyance device 120 may include a drill string that is capable of both moving the fracturing tool 125 along the wellbore 100 and rotating the fracturing tool 125. The downhole conveyance device 120 may be driven by a drive mechanism 130. One or more sensors may be affixed to the downhole conveyance device 120 and configured to send signals to a control unit 135. The control unit 135 is coupled to drive unit 130 to control the operation of the drive unit. The control unit

135 is coupled to the injection device 105 to control the injection of fluid into the wellbore 100. The control unit 135 includes one or more processors and associated data storage.

[0024] Figure 2 is an illustration of a wellbore 205 passing through a formation 210 and the stresses on the formation. In general, formation rock is subjected by the weight of anything above it, *i.e.*  $\sigma_z$  overburden stresses. By Poisson's rule, these stresses and formation pressure effects translate into horizontal stresses  $\sigma_x$  and  $\sigma_y$ . In general, however, Poisson's ratio is not consistent due to the randomness of the rock. Also, geological features, such as formation dipping and tectonic stresses may cause other stresses. Therefore, in most cases,  $\sigma_x$  and  $\sigma_y$  are different.

[0025] Figure 2B is an illustration the wellbore 205 passing through the formation 210 after a fracture 215 is induced in the formation 210. Assuming for this example that  $\sigma_x$  is smaller than  $\sigma_y$ , the fracture 215 will extend into the y direction. The orientation of the fracture is, however, in the x direction. As used herein, the orientation of a fracture is defined to be a vector perpendicular to the fracture plane.

[0026] As fracture 215 opens fracture faces to be pushed in the x direction. Because formation boundaries cannot move, the rock becomes more compressed, increasing both  $\sigma_x$  and  $\sigma_y$  however to different degrees. Over time, the fracture will tend to close as the rock moves back to its original shape due to the increased  $\sigma_x$ . The change in the two horizontal stresses will change the hoop stress (tangential stress around the wellbore) While the fracture is closing however, the stresses in the formation will cause a subsequent fracture to propagate in a new direction shown by projected fracture 220. The method, system, and apparatus according to the present invention are directed to initiating fractures, such as projected fracture 220, while the stress field in the formation 210 is temporarily altered by an earlier fracture, such as fracture 215.

[0027] If the existing fracture is prevented from taking any more fluid (by chemical or mechanical means) the new hoop stress will favor the initiation of a fracture at angle to the first fracture. The minimum tangential stress will be between 0 and 90 degrees. This value will depend on the magnitude of the minimum and maximum horizontal stresses, the fracture width, and net stress reached during creation of the first fracture. The tangential stress will not be 90 degrees even if the initial horizontal stresses are equal.

[0028] The foregoing is illustrated by the following example. The general equation for the distribution of the tangential (hoop) stress is given below:

$$\sigma_{\theta} = \frac{1}{2}(\sigma_y + \sigma_x) \left( 1 + \left( \frac{r}{r_w} \right)^2 \right) - \frac{1}{2}(\sigma_y - \sigma_x) \left( 1 + 3 \left( \frac{r}{r_w} \right)^4 \right) \cos(2\theta)$$

[0029] The tangential stress forms a profile around the wellbore. The minimum value occurs at angle,  $\theta$ , of zero. The value of the tangential stress is at maximum at the wellbore surface. It declines quickly to a value equal to perpendicular principal stress within a few radii from the wellbore. The axial stress on the other hand is equal to zero at the wellbore.

[0030] The hoop stress before and after the creation of the first fracture given the reservoir data set forth in the Table I below is illustrated in Figure 10.

Table 1 – Input parameters for example

| parameter             | value | Parameter           | value |
|-----------------------|-------|---------------------|-------|
| $\sigma_{\min}$ , psi | 6000  | Pore pressure, psi  | 5000  |
| $\sigma_{\max}$ , psi | 6500  | Net pressure, psi   | 500   |
| $\sigma_v$ , psi      | 7000  | Wellbore radius, ft | 0.25  |

From Figure 10, it is clear that the following has happened:

- The magnitude of the tangential stress all around the well bore has increased. The largest increase occurred right near where the first fracture was created.
- The location of the minimum tangential stress has moved from angle Theta of zero to angle Theta of  $+38^\circ$  and  $-38^\circ$ .
- There are two preferred orientations for the second fracture. Presence of perforation / jetting will determine which orientation would be the actual orientation of the fracture.

[0031] Lithological heterogeneity may also play a part in the determining the fracture orientation. It is highly desirable to orient the second fracture in the preferred orientation to minimize tortiousity. The technique used in creating the first fracture will apply when creating the second fracture.

[0032] After the creation of a second fracture, it would be expected that the tangential stress changes would be even more significant in the orientation of a third or subsequent fracture. In addition the symmetry of the system would be lost. Figure 11 illustrates the tangential stress profile in the first quadroon for the condition give in Figure 10 after creating two fractures. The minimum tangential stress would occur at about 52 degrees and at a value slightly more than 4700 psi.

[0033] The tangential stress after creating the first fracture was calculated first by calculating the increase in stress due to the presence of the fracture. Assuming that the width of the fracture is too small to affect the circular shape of the well, the tangential pressure may

be calculated using conventional methods. A more accurate method is to do this calculation using a numerical simulator. However the potential change in angle will most probably too small to be of significant effect under real operational conditions.

[0034] This invention may also be used to create multiple longitudinal fractures intersecting a horizontal well. If the horizontal well is drilled in the direction of maximum stress a longitudinal fracture is usually expected. This longitudinal fracture may be created in situations involving open hole fracturing, cased hole with perforations and slotted casing. The preferred way is to create the perforation or slot or other means of communication along the top and bottom of the well. One method to create the means of communication is by hydrojetting.

[0035] Figure 3 is a flow chart illustration of an example implementation of one method of the present invention, shown generally at 300. The method includes determining one or more geomechanical stresses at a fracturing location in step 305. In some implementations, step 305 may be omitted. In some implementations, this step includes determining a current minimum stress direction at the fracturing location. In one example implementation, information from tilt meters or micro-seismic tests performed on neighboring wells is used to determine geomechanical stresses at the fracturing location. In some implementations, geomechanical stresses at a plurality of possible fracturing locations are determined to find one or more locations for fracturing. Step 305 may be performed by the control unit 305 by computer with one or more processors and associated data storage.

[0036] The method 300 further includes initiating a first fracture at about the fracturing location in step 310. The first fracture's initiation is characterized by a first orientation line. In general, the orientation of a fracture is defined to be a vector normal to the fracture plane. In this case, the characteristic first orientation line is defined by the fracture's initiation rather than its propagation. In certain example implementations, the first fracture is substantially perpendicular to a direction of minimum stress at the fracturing location in the wellbore.

[0037] The initiation of the first fracture temporarily alters the stress field in the subterranean formation, as discussed above with respect to figures 2A and 2B. The duration of the alteration of the stress field may be based on factors such as the size of the first fracture, rock mechanics of the formation, the fracturing fluid, and subsequently injected proppants, if any. Due to the temporary nature of the alteration of the stress field in the

formation, there is a limited amount of time for the system to initiate a second fracture at about the fracturing location before the temporary stresses alteration has dissipated below a level that will result in a subsequent fracture at the fracturing being usefully reoriented. Therefore, in step 315 a second fracture is initiated at about the fracturing location before the temporary stresses from the first fracture have dissipated. In some implementations, the first and second fractures are initiated within 24 hours of each other. In other example implementations, the first and second fractures are initiated within four hours of each other. In still other implementations, the first and second fractures are initiated within an hour of each other.

**[0038]** The initiation of the second fracture is characterized by a second orientation line. The first orientation line and second orientation lines have an angular disposition to each other. The plane that the angular disposition is measured in may vary based on the fracturing tool and techniques. In some example implementations, the angular disposition is measured on a plane substantially normal to the wellbore axis at the fracturing location. In some example implementations, the angular disposition is measured on a plane substantially parallel to the wellbore axis at the fracturing location.

**[0039]** In some example implementations, step 315 is performed using a fracturing tool 125 that is capable of fracturing at different orientations without being turned by the drive unit 130. Such a tool may be used when the downhole conveyance 120 is coiled tubing. In other implementations, the angular disposition between the fracture initiations is caused by the drive unit 130 turning a drillstring or otherwise reorienting the fracturing tool 125. In general there may be an arbitrary angular disposition between the orientation lines. In some example implementations, the angular orientation is between  $45^\circ$  and  $135^\circ$ . More specifically, in some example implementations, the angular orientation is about  $90^\circ$ . In still other implementations, the angular orientation is oblique.

**[0040]** In step 320, the method includes initiating one or more additional fractures at about the fracturing location. Each of the additional fracture initiations are characterized by an orientation line that has an angular disposition to each of the existing orientation lines of fractures induced at about the fracturing location. In some example implementations, step 320 is omitted. Step 320 may be particularly useful when fracturing coal seams or diatomite formations.

[0041] The fracturing tool may be repositioned in the wellbore to initiate one or more other fractures at one or more other fracturing locations in step 325. For example, steps 310, 315, and optionally 320 may be performed for one or more additional fracturing locations in the wellbore. An example implementation is shown in Figure 4. Fractures 410 and 415 are initiated at about a first fracturing location in the wellbore 405. Fractures 420 and 425 are initiated at about a second fracturing location in the wellbore 405. In some implementations, such as that shown in figure 4, the fractures at two or more fracturing locations, such as fractures 410-425, and each have initiation orientations that angularly differ from each other. In other implementations, fractures at two or more fracturing locations have initiation orientations that are substantially angularly equal. In certain implementations, the angular orientation may be determined based on geomechanical stresses about the fracturing location.

[0042] Figure 5 is an illustration of a formation 505 that includes a region 510 with increased permeability, relative to the other portions of formation 505 shown in the figure. When fracturing to increase the production of hydrocarbons, it is generally desirable to fracture into a region of higher permeability, such as region 510. The region of high permeability 510, however, reduces stress in the direction toward the region 510 so that a fracture will tend to extend in parallel to the region 510. In the fracturing implementation shown in figure 5, a first fracture 515 is induced substantially perpendicular to the direction of minimum stress. The first fracture 515 alters the stress field in the formation 505 so that a second fracture 520 can be initiated in the direction of the region 510. Once the fracture 520 reaches the region 510 it may tend to follow the region 510 due to the stress field inside the region 510. In this implementation, the first fracture 515 may be referred to as a sacrificial fracture because its main purpose was simply to temporarily alter the stress field in the formation 505, allowing the second fracture 520 to propagate into the region 510.

[0043] Figure 6 illustrates fluid drainage from a formation into a horizontal wellbore 605 that has been fractured according to method 100. In this situation, the effective surface area for drainage into the wellbore 605 is increased, relative to fracturing with only one angular orientation. In the example shown in figure 6, fluid flow along planes 610 and 615 are able to enter the wellbore 605. In addition, flow in fracture 615 does not have to enter the wellbore radially, which causes a constriction to the fluid. Fig. 6 also shows flow entering the fracture 615 in a parallel manner; which then flows through the fracture 615 in a parallel

fashion into fracture 610. This scenario causes very effective flow channeling into the wellbore.

[0044] In general, additional fractures, regardless of their orientation, provide more drainage into a wellbore. Each fracture will drain a portion of the formation. Multiple fractures having different angular orientations, however, provide more coverage volume of the formation, as shown by the example drainage areas illustrated in figure 8. The increased volume of the formation drained by the multiple fractures with different orientations may cause the well to produce more fluid per unit of time.

[0045] A cut-away view of an example fracturing tool 125, shown generally at 700, that may be used with method 300 is shown in figures 7A-7C. The fracturing tool 700 includes at least two fracturing sections, such as fracturing sections 705 and 710. Each of sections 705 and 710 are configured to fracture at an angular orientation, based on the design of the section. In one example implementation, fluid flowing from section 710 may be oriented obliquely, such as between  $45^{\circ}$  to  $90^{\circ}$ , with respect to fluid flowing from section 705. In another implementation fluid flow from sections 705 and 710 are substantially perpendicular.

[0046] The fracturing tool includes a selection member 715, such as sleeve, to activate or arrest fluid flow from one or more of sections 705 and 710. In the illustrated implementation selection member 715 is a sliding sleeve, which is held in place by, for example, a detent. While the selection member 715 is in the position shown in Fig. 7A, fluid entering the tool body 700 exits through section 705.

[0047] A valve, such as ball valve 725 is at least partially disposed in the tool body 700. The ball valve 725 includes an actuating arm allowing the ball valve 725 to slide along the interior of tool body 700, but not exit the tool body 700. In this way, the ball valve 725 prevents the fluid from exiting from the end of the fracturing tool 125. The end of the ball valve 725 with actuating arm may be prevented from exiting the tool body 700 by, for example, a ball seat (not shown).

[0048] The fracturing tool further comprises a releasable member, such as dart 720, secured behind the sliding sleeve. In one example implementation, the dart is secured in place using, for example, a J-slot.

[0049] In one example implementation, once the fracture is induced by sections 705, the dart 720 is released. In one example implementations, the dart is released by quickly and

briefly flowing the well to release a j-hook attached to the dart 725 from a slot. In other example implementations, the release of the dart 720 may be controlled by the control unit 135 activating an actuator to release the dart 720. As shown in Figure 7B, the dart 720 causes the selection member 715 to move forward causing fluid to exit through section 710.

**[0050]** As shown in Figure 7C, the ball valve 725 with actuating arm may reset the tool by forcing the dart 720 back into a locked state in the tool body 700. The ball valve 725 also may force the selection member 715 back to its original position, before fracturing was initiated. The ball valve 725 may be forced back into the tool body 700 by, for example, flowing the well.

**[0051]** Another example fracturing tool 125 is shown in Figure 9. Tool body 910 receives fracturing fluid through a drill string 905. The tool body has an interior and an exterior. Fracturing passages pass from the interior to the exterior at an angle, causing fluid to exit from the tool body 910 at an angle, relative to the axis of the wellbore. Because of the angular orientation of the fracturing passages, multiple fractures with different angular orientations may be induced in the formation by reorienting the tool body 810. In one example implementation, the tool body is rotated to reorient the tool body to 810 to fracture at different orientations and create fractures 915 and 920. For example, the tool body may be rotated about 180°. In the example implementation shown in Figure 9 where the fractures 915 and 920 are induced in a horizontal or deviated portion of a wellbore, the drill string 805 may be rotated more than the desired rotation of the tool body 910 to account for friction.

**[0052]** Therefore, the present invention is well adapted to attain the ends and advantages mentioned as well as those that are inherent therein. The particular embodiments disclosed above are illustrative only, as the present invention may be modified and practiced in different but equivalent manners apparent to those skilled in the art having the benefit of the teachings herein. Furthermore, no limitations are intended to the details of construction or design herein shown, other than as described in the claims below. Also, the terms in the claims have their plain, ordinary meaning unless otherwise explicitly and clearly defined by the patentee.

## WHAT IS CLAIMED IS:

1. A method for fracturing a subterranean formation at a fracturing location along a wellbore comprising:

determining at least one angle of minimum tangential stress about the wellbore, based at least in part on the geomechanical stresses at the fracturing location along the well bore;

creating a first fracture at the fracturing location such that the first fracture temporarily alters the geomechanical stresses at the fracturing location and determining an angle of minimum tangential stress after the first fracture is created;

sealing the first fracture; and then,

initiating a second fracture in the subterranean formation, where the second fracture is oriented about an angle of minimum tangential stress after the first fracture is initiated and wherein the second fracture is created before the temporarily altered geomechanical stresses at the fracturing location from the first fracture have dissipated.

2. The method of claim 1, wherein determining at least one angle of minimum tangential stress about the wellbore is further based, at least in part, on the geomechanical stresses before the first fracture is created.

3. The method of claim 1, wherein before the first fracture is created there is an existing fracture at the fracturing location along the wellbore that propagates substantially perpendicular to a minimum horizontal stress before the first fracture is created.

4. The method of claim 1 wherein the second fracture is initiated within 24 hours of the first fracture.

5. The method of claim 1, wherein after the step of initiating a second fracture,

sealing the second fracture; and then,

initiating a third fracture in the subterranean formation, where the third fracture is oriented at about the at least one angle of minimum tangential stress and

wherein the third fracture is created before the temporarily altered geomechanical stresses at the fracturing location from the first fracture have dissipated.

6. The method of claim 1 wherein the first fracture is oriented at a first orientation line and the second fracture is oriented at a second orientation line and wherein the angular disposition between the first orientation line and the second orientation line is between 45 degrees and 135 degrees.

7. The method of claim 1 wherein the first fracture is oriented at a first orientation line and the second fracture is oriented at a second orientation line and wherein the angular disposition between the first orientation line and the second orientation line is about 90 degrees.

8. The method of claim 1 wherein the first fracture is oriented at a first orientation line that is substantially perpendicular to the angle of minimum tangential stress.

9. A system for fracturing a subterranean formation at a fracturing location along a wellbore comprising:

at least one processor configured to:

determine a set of geomechanical stresses at the fracturing location along the well bore, wherein the geomechanical stresses include at least a tangential stress distribution about the wellbore and an angle of minimum tangential stress; and,

a fracturing tool configured to:

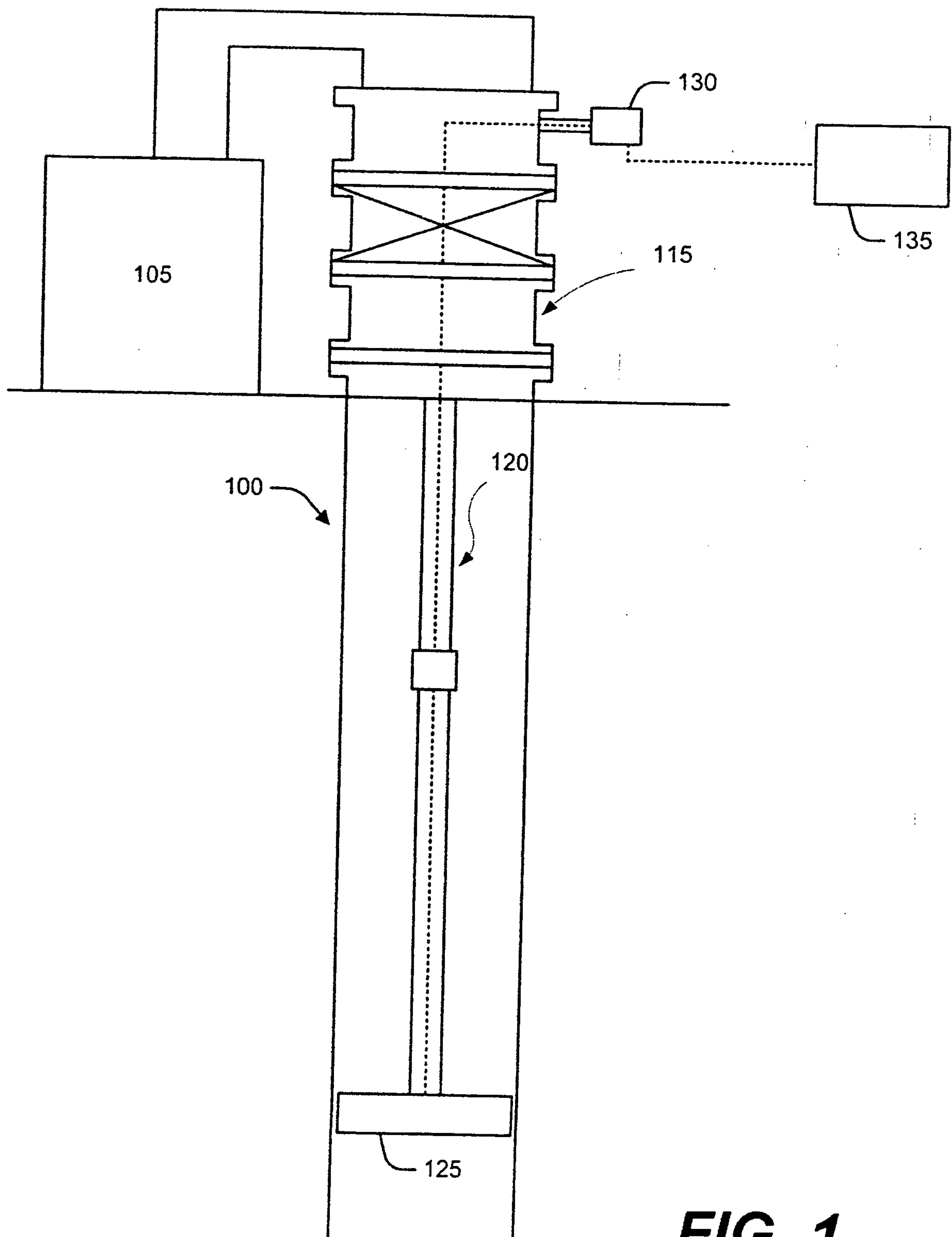
initiate a first fracture in the subterranean formation, and

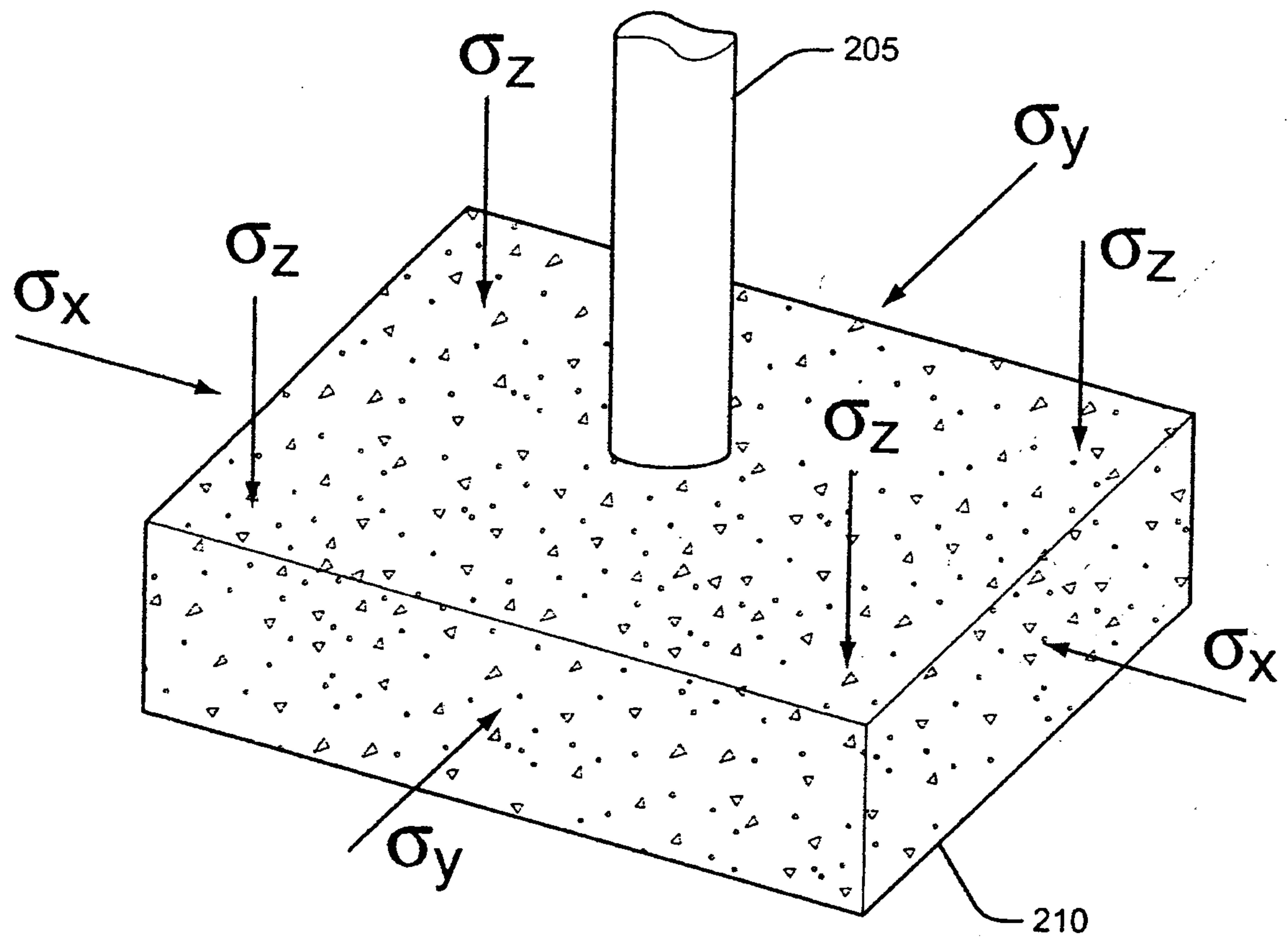
initiate a second fracture which is oriented about an angle of minimum tangential stress calculated after the first fracture is initiated, wherein the first fracture is sealed before initiating the second fracture, and wherein the second fracture is created before the temporarily altered geomechanical stresses at the fracturing location from the first fracture have dissipated.

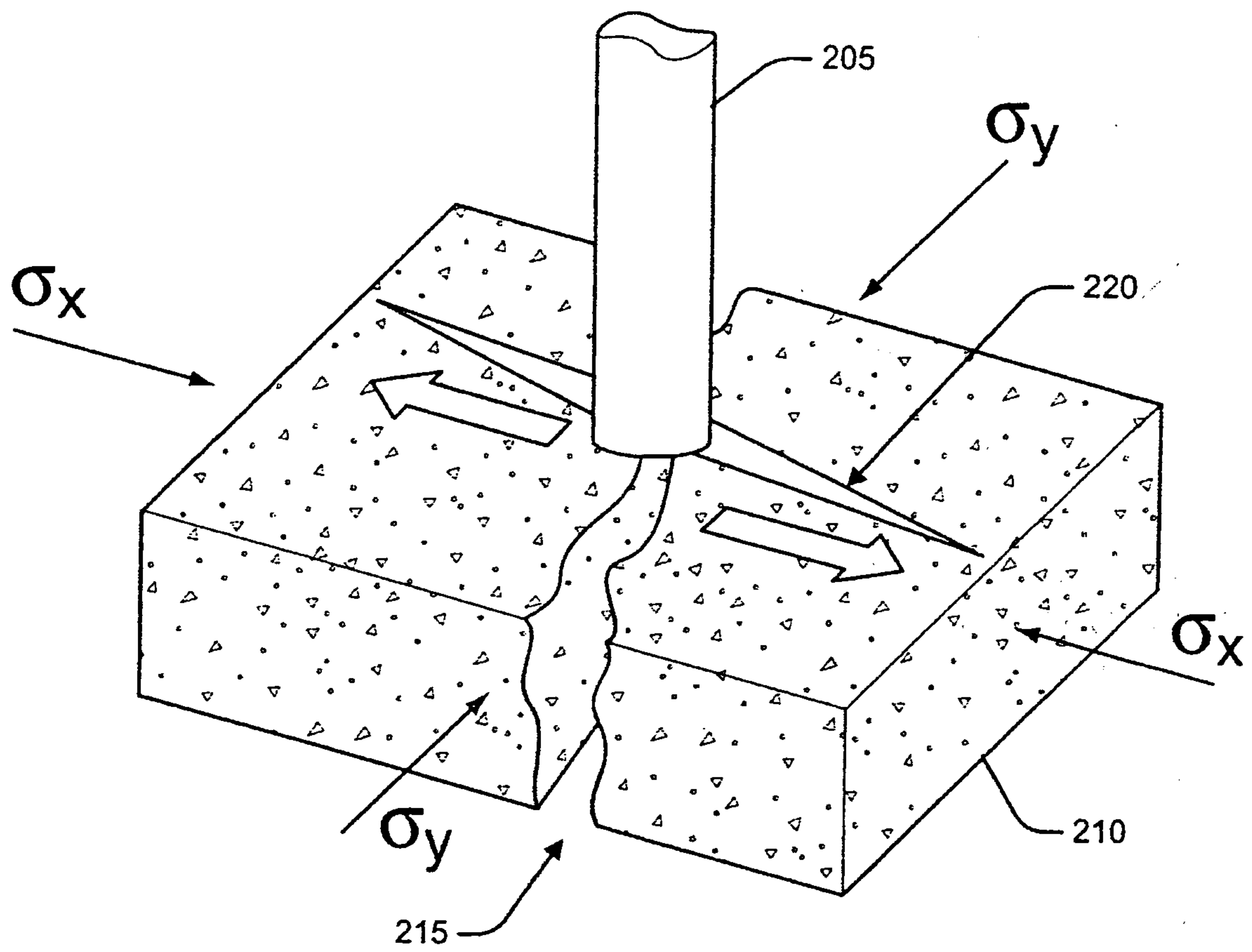
10. The system of claim 9, wherein determining at least one angle of minimum tangential stress about the wellbore is further based, at least in part, on an initial stress field before the first fracture is initiated.

11. The system of claim 9, wherein the fracturing tool is further configured to:  
initiate the first fracture propagating substantially perpendicular to a minimum horizontal stress wherein the minimum horizontal stress is measured before the first fracture is created.
12. The system of claim 9 wherein the second fracture is initiated within 24 hours of the first fracture.
13. The system of claim 9, wherein after initiating a second fracture, the second fracture is sealed and the tool is configured to then:  
initiate a third fracture in the subterranean formation, where the third fracture is oriented at about the at least one angle of minimum tangential stress and wherein the third fracture is created before the temporarily altered geomechanical stresses at the fracturing location from the first fracture have dissipated.
14. The system of claim 9 wherein the first fracture is oriented at a first orientation line and the second fracture is oriented at a second orientation line and wherein the angular disposition between the first orientation line and the second orientation line is between 45 degrees and 135 degrees.
15. The system of claim 9 wherein the first fracture is oriented at a first orientation line and the second fracture is oriented at a second orientation line and wherein the angular disposition between the first orientation line and the second orientation line is about 90 degrees.
16. The system of claim 9 wherein the first fracture is oriented at a first orientation line that is substantially perpendicular to the angle of minimum tangential stress.

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**FIG. 1**

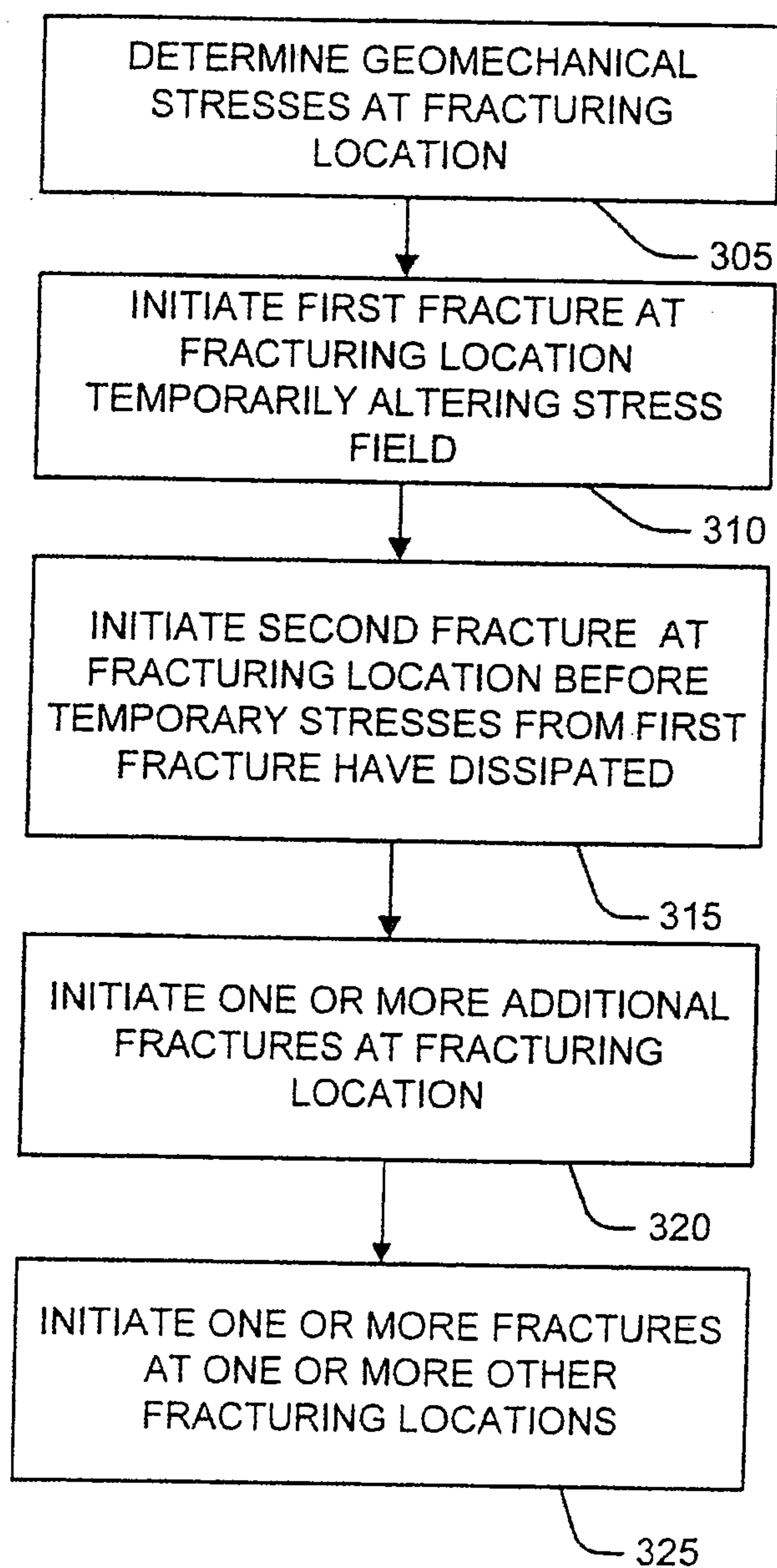
**FIG. 2A**

**FIG. 2B**

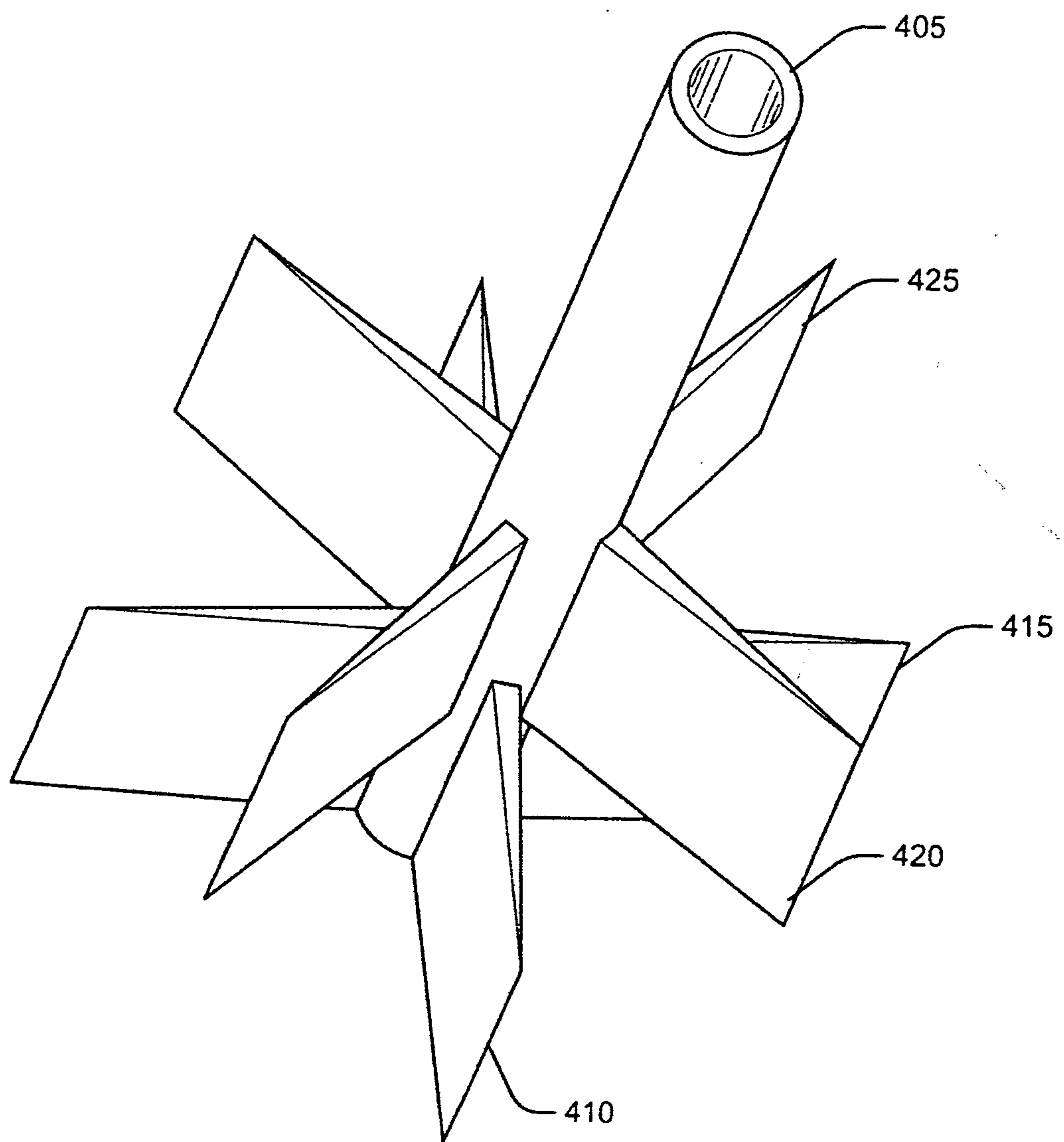
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FIG. 3

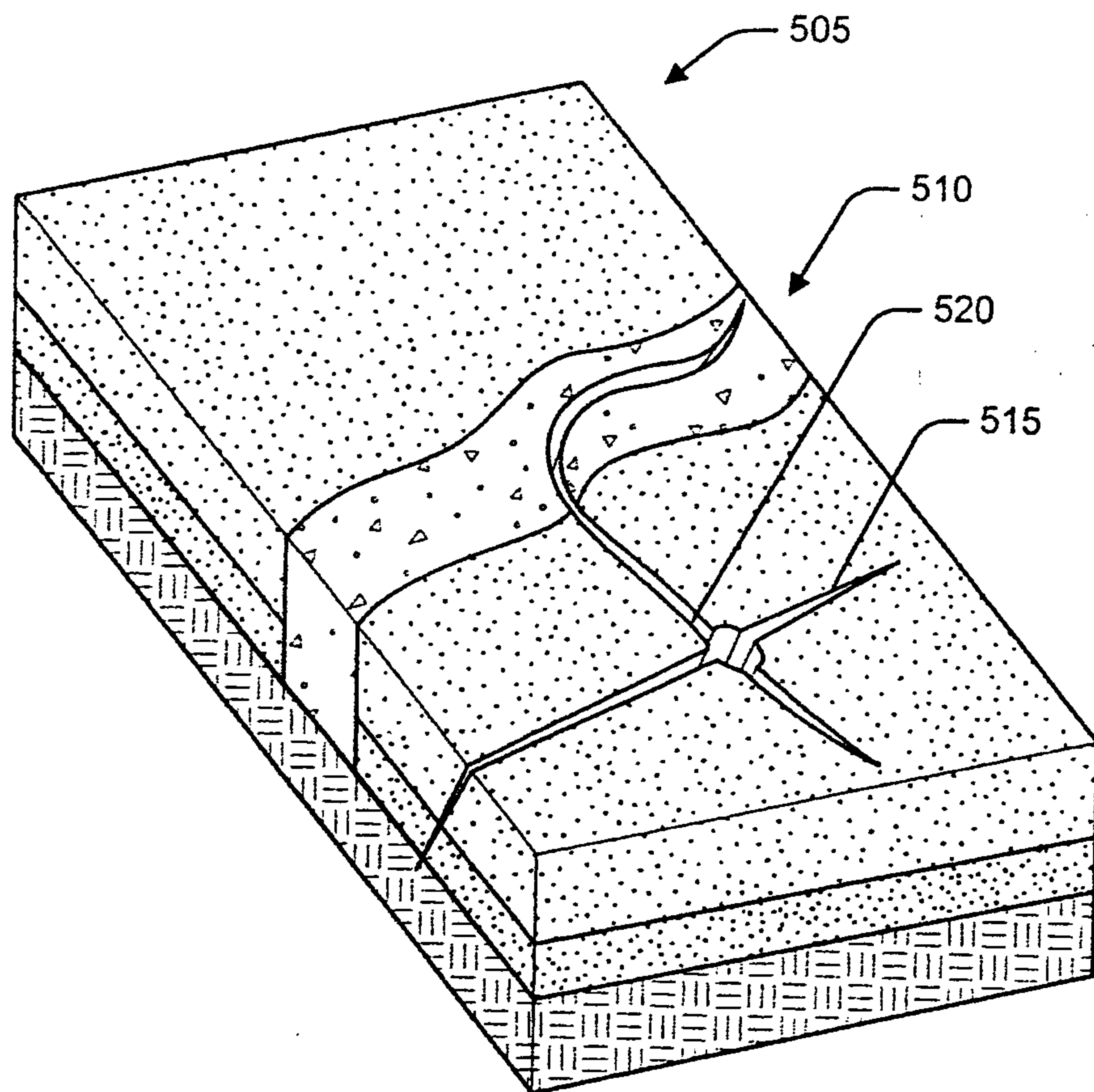
300



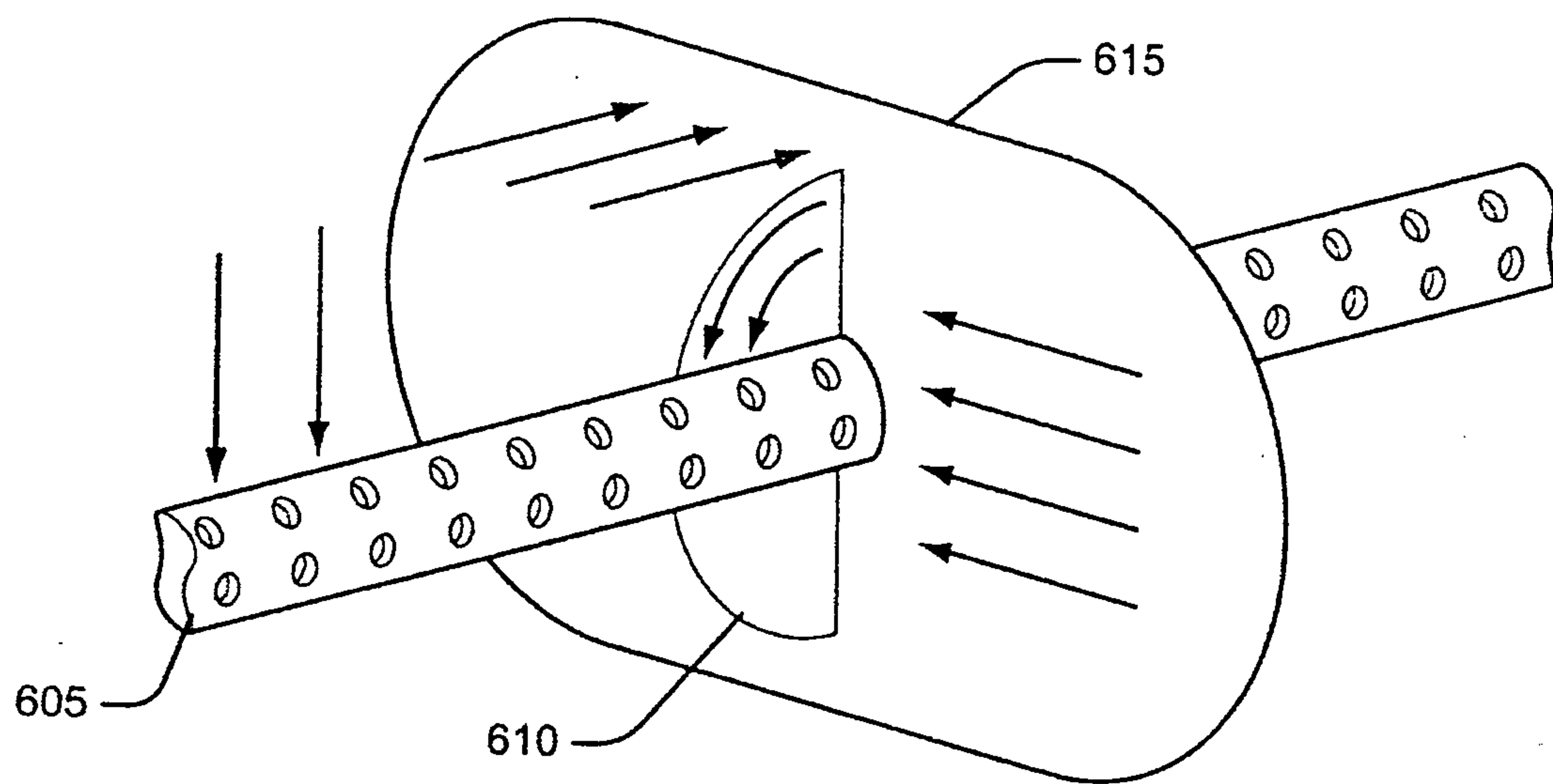
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**FIG. 4**

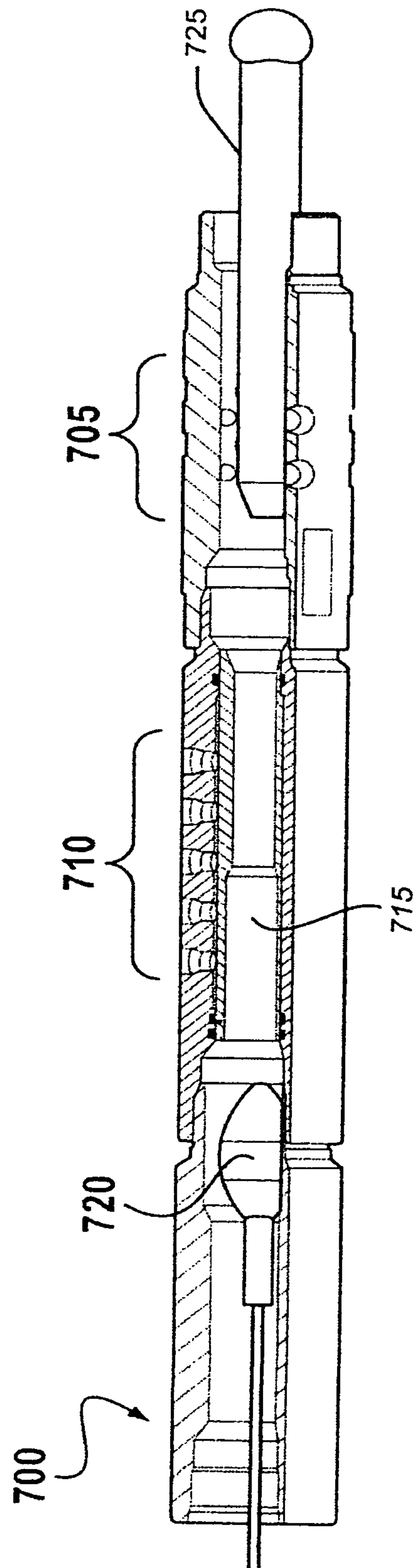
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**FIG. 5**

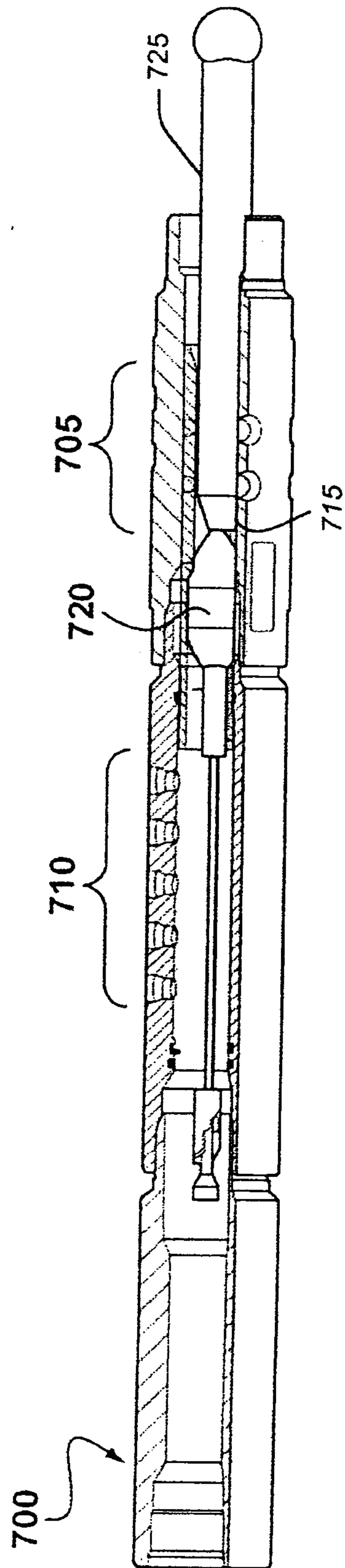
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**FIG. 6**

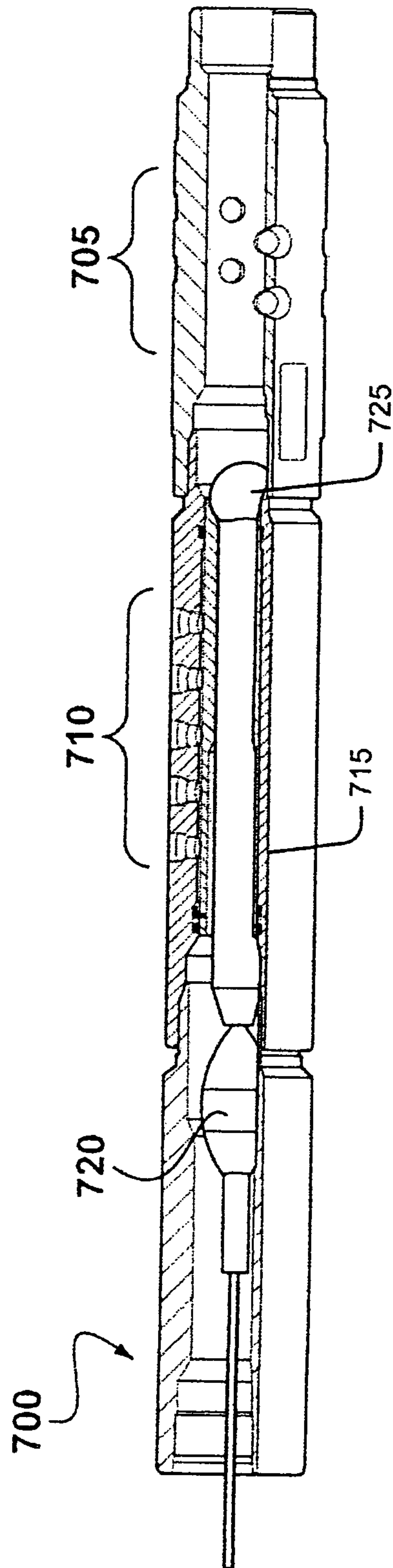
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**FIG. 7A**

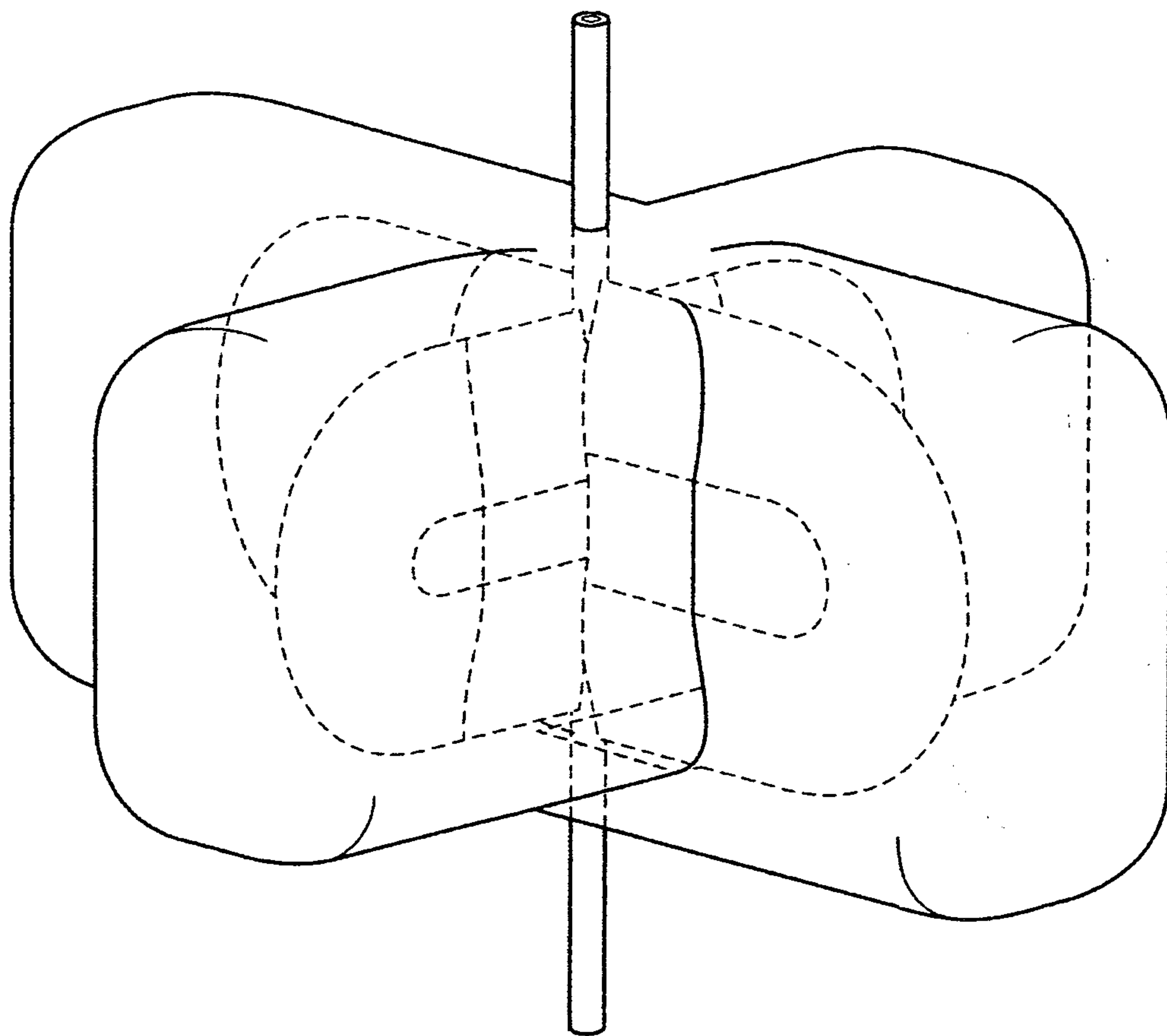
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**FIG. 7B**

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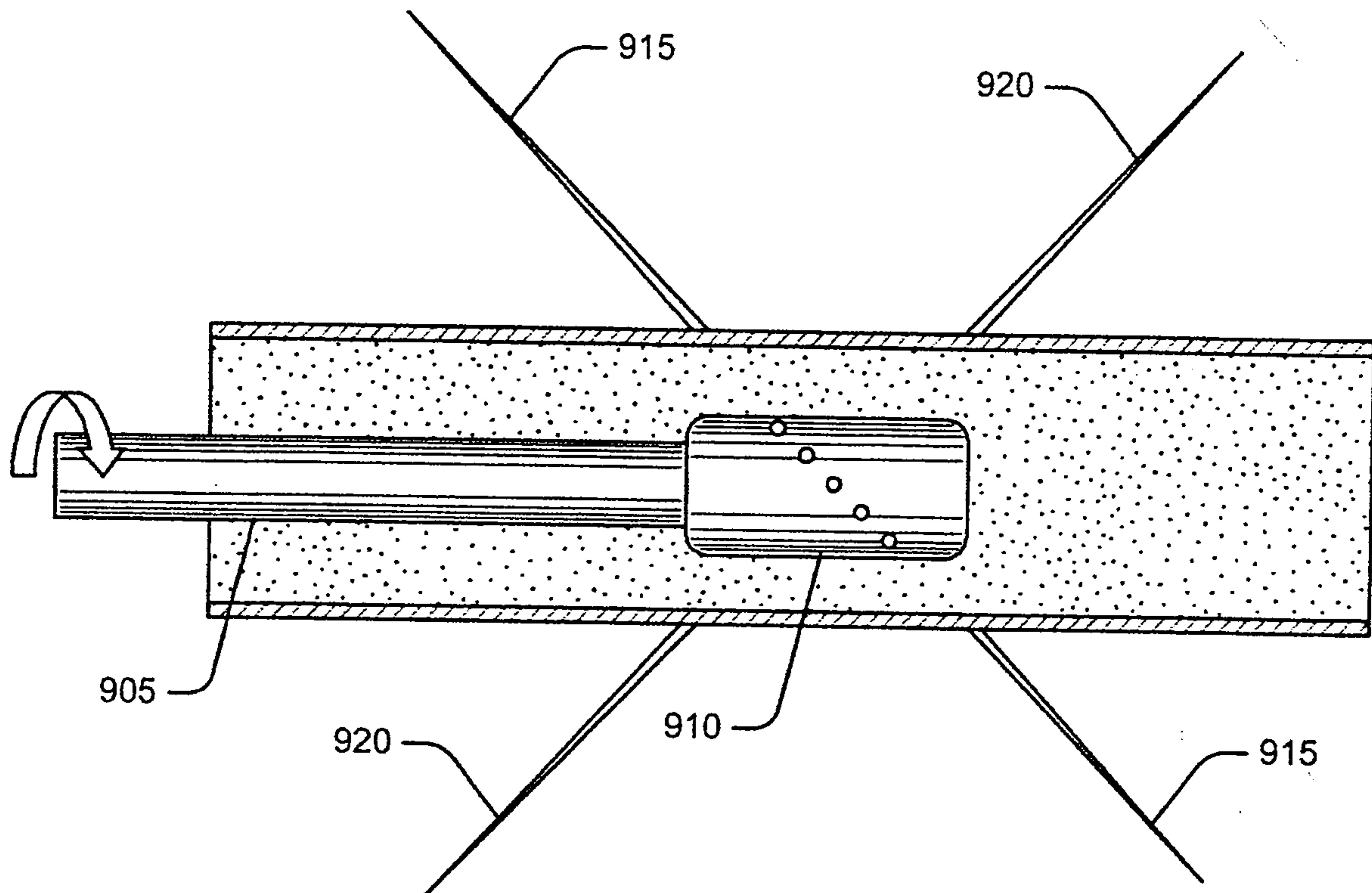
**FIG. 7C**

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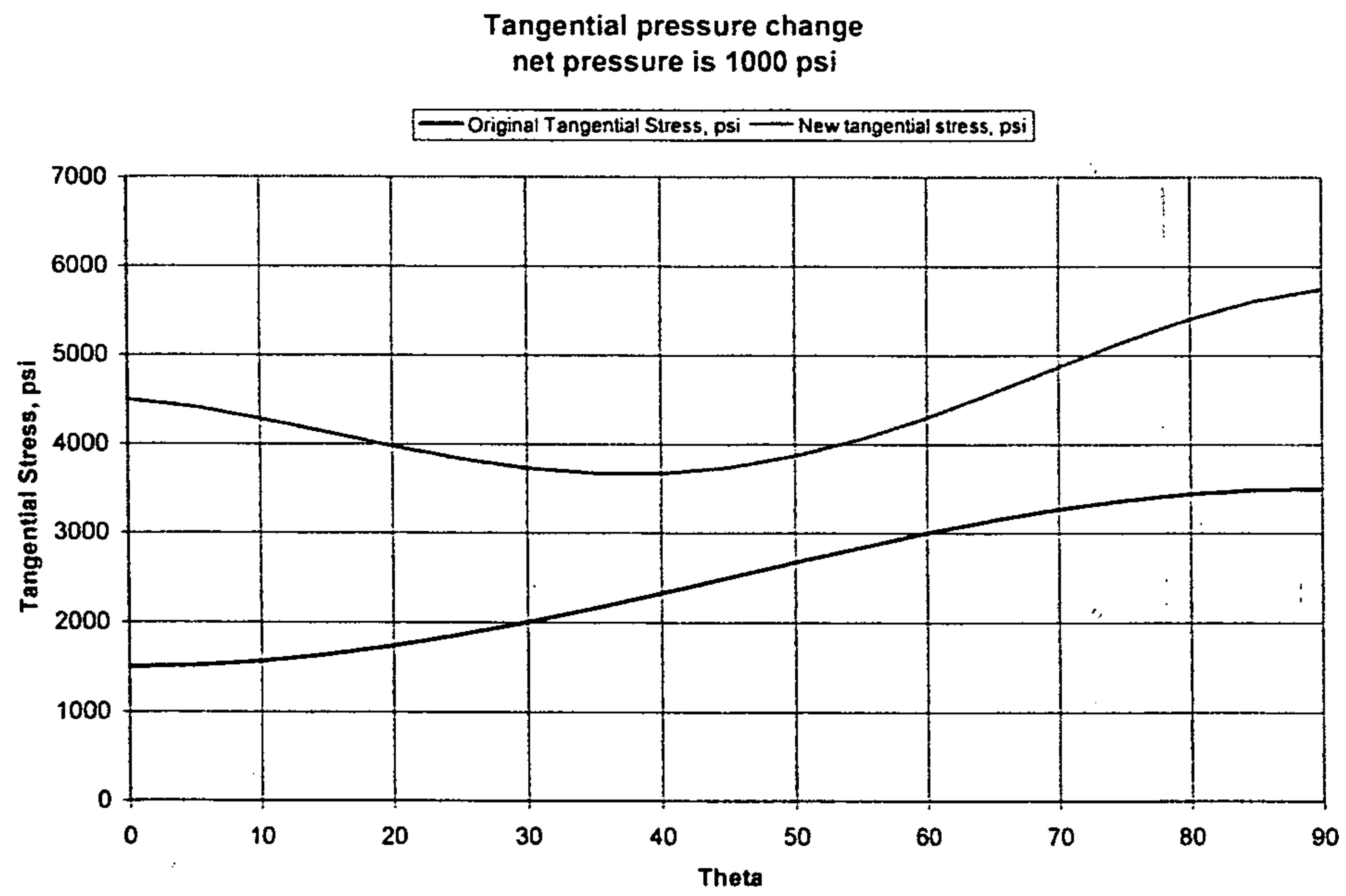
**FIG. 8**

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**FIG. 9**

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Figure 10 – Stress profile around the wellbore for net pressure of 1000 psi



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Figure 11 - Stress profile around the wellbore after creating two fractures

