



(22) Date de dépôt/Filing Date: 2009/10/21

(41) Mise à la disp. pub./Open to Public Insp.: 2010/04/22

(30) Priorités/Priorities: 2008/10/22 (US12/256,223);  
2009/08/12 (US61/233,241)

(51) Cl.Int./Int.Cl. *C10G 1/00* (2006.01),  
*B01D 21/26* (2006.01), *B03B 9/02* (2006.01)

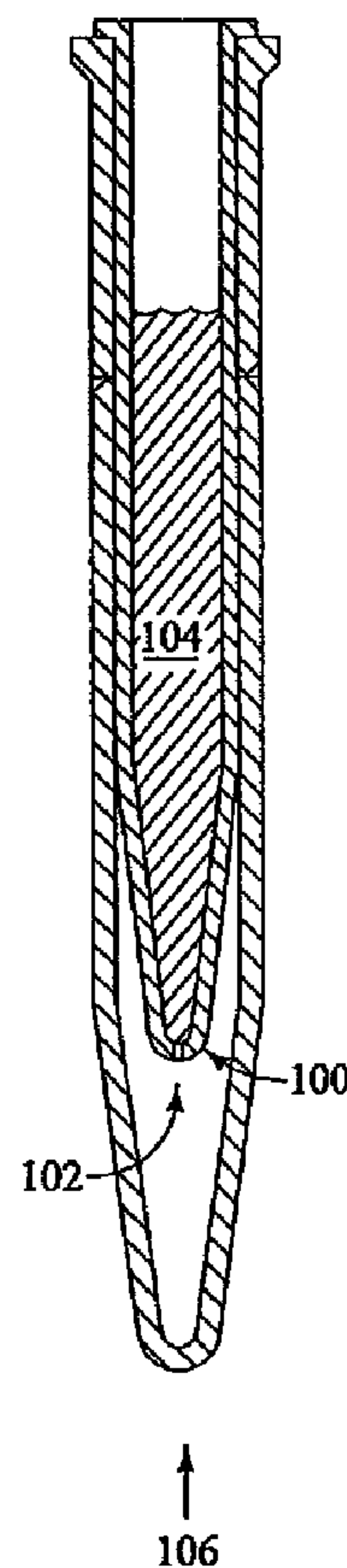
(71) Demandeur/Applicant:  
RTDM ENTERPRISES, LLC, US

(72) Inventeur/Inventor:  
DE MAYO, BENJAMIN, US

(74) Agent: CASSAN MACLEAN

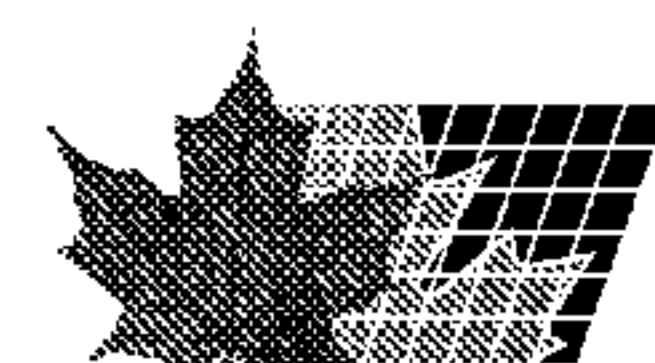
(54) Titre : METHODE ET DISPOSITIF D'EXTRACTION DE LIQUIDES D'UNE MATIERE PARTICULAIRE SOLIDE

(54) Title: METHOD AND DEVICE FOR EXTRACTING LIQUIDS FROM A SOLID PARTICLE MATERIAL



(57) Abrégé/Abstract:

A method, system, and device for separating oil from oil sands or oil shale is disclosed. The method includes heating the oil sands, spinning the heated oil sands, confining the sand particles mechanically, and recovering the oil substantially free of the sand. The



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

method can be used without the addition of chemical extraction agents. The system includes a source of centrifugal force, a heat source, a separation device, and a recovery device. The separation device includes a method of confining the sands while allowing the oil to escape, such as through an aperture.

## ABSTRACT

A method, system, and device for separating oil from oil sands or oil shale is disclosed. The method includes heating the oil sands, spinning the heated oil sands, confining the sand particles mechanically, and recovering the oil substantially free of the sand. The method can be used without the addition of chemical extraction agents. The system includes a source of centrifugal force, a heat source, a separation device, and a recovery device. The separation device includes a method of confining the sands while allowing the oil to escape, such as through an aperture.

## METHOD AND DEVICE FOR EXTRACTING LIQUIDS FROM A SOLID PARTICLE MATERIAL

### BACKGROUND

[0001] Given high oil prices and the finite amount of crude oil available, unconventional petroleum reserves in the form of, for example, oil sands and oil shale are becoming more attractive as an alternative source of hydrocarbons. Oil sands are found in over 60 countries in the world, including the United States. The main deposits occur in Alberta, Canada, and represent the second largest reserves of petroleum in the world, after those in Saudi Arabia.

### BRIEF SUMMARY

[0002] This disclosure relates to a process for extracting liquids, such as bitumen or crude oil, from discrete solid particles, such as sand or shale. The disclosure is particularly applicable to oil sands and oil shale in which oil is present as a highly viscous liquid. The disclosure is also applicable to the cleaning of oil spills.

### BRIEF DESCRIPTION OF THE DRAWINGS

[0003] The physical process for extracting liquid such as oil from the solid-liquid mixture such as oil sands or oil shale involves submitting the heated mixture to centrifugal forces to allow the liquid to mechanically separate from the solid particles and exit the device through small apertures.

[0004] FIG. 1 is a cross-sectional view of a first system.

[0005] FIG. 2 is a cross-sectional view of the first system unassembled.

[0006] FIG. 3 is an exploded detail of the first system.

[0007] FIG. 4 is a diagram illustrating an effect of spinning time.

[0008] FIG. 5 is a diagram illustrating an effect of temperature.

[0009] FIG. 6 is a diagram illustrating an effect of spin rate.

[0010] FIG. 7 is a cross-sectional view of a second system.

[0011] FIG. 8 is a top view of the bottom portion of the second system.

- [0012] FIG. 9 is a perspective view of the top and bottom portions of the second system.
- [0013] FIG. 10 is a cross-sectional view of the second system in an open conformation.
- [0014] FIG. 11 is a cross-sectional view of the second system in a closed conformation.
- [0015] FIG. 12 is a cross-sectional view of the second system in an open conformation.
- [0016] FIG. 13 is a cross-sectional view of the second system in open conformation with a solids-liquids mixture inside.
- [0017] FIG. 14 is a cross-sectional view of a third system.
- [0018] FIG. 15 is a perspective view of the third system.
- [0019] FIG. 16 is a perspective view of the fourth system.
- [0020] FIG. 17 is a perspective view of the fourth system with a top and a bottom.
- [0021] FIG. 18 is a top view of the fourth system.
- [0022] FIG. 19 is an exploded detail of the fourth system.
- [0023] FIG. 20 is an exemplary top view of the spinning and cleaning process of the fourth system.
- [0024] FIG. 21 is a perspective view of a fifth system.
- [0025] FIG. 22 is a cross section view of the fifth system.
- [0026] FIG. 23 is a cross-sectional view of an exemplary separation process in the fifth system.
- [0027] FIG. 24 is a cross-sectional view of a sixth system.
- [0028] FIG. 25 is a cross-sectional view of the sixth system in a closed conformation.
- [0029] FIG. 26 is a cross-sectional view of the sixth system in an open conformation.
- [0030] FIG. 27 is a perspective view of the seventh system in an open conformation.

- [0031] FIG. 28 is a cross-sectional view of the seventh system in a closed conformation.
- [0032] FIG. 29 is a perspective view of a component of the seventh system.
- [0033] FIG. 30 is a cross-sectional view of the seventh system in an open conformation.
- [0034] FIG. 31 is a second cross-sectional view of the seventh system in an open conformation.
- [0035] FIG. 32 is a partial cross-sectional view of the eighth system.
- [0036] FIG. 33 is a first cross-sectional view of the ninth system.
- [0037] FIG. 34 is a second cross-sectional perspective view of the ninth system.
- [0038] FIG. 35 is a third cross-sectional view of the ninth system.
- [0039] FIG. 36 is a fourth cross-sectional view of the ninth system.
- [0040] FIG. 37 is a perspective view of the tenth system.
- [0041] FIG. 38 is a cross-sectional view of the tenth system.
- [0042] FIG. 39 is a perspective view of the eleventh system.
- [0043] FIG. 40 is a first cross-sectional view of the eleventh system.
- [0044] FIG. 41 is a second cross-sectional view of the twelfth system.
- [0045] FIG. 42 is a cross-sectional view of the thirteenth system.

## DETAILED DESCRIPTION

[0046] Oil sands (also referred to as tar sands) are found in over sixty countries in the world, including the United States. Oil sands may include such components as bitumen, water, mineral particles, sand, and clay. Bitumen is a natural, tar-like mixture of hydrocarbons that exists as a solid at room temperature. In nature, bitumen has a density range of 8° to 12° API, and at room temperature its viscosity is greater than 50,000 centipoises.

[0047] Areas such as coastal areas or inland areas may be contaminated by oil oil spills including offshore or land derived oil spills. This disclosure also provides a method applicable to oil spill cleanup.

[0048] The physical process disclosed for separating liquids from solids may use fewer natural resources to produce bitumen from oil sand than the conventional method of separation. The conventional method of separating bitumen from oil sand requires more than 1,000 cubic feet of natural gas to separate one barrel of bitumen from two tons of oil sand, according to the National Energy Board of Canada. However, the physical process disclosed for separating liquids from solids may require less than 190 cubic feet of natural gas and may use no fresh water or other solvents to produce one barrel of bitumen.

[0049] The physical process disclosed may produce a clean effluent. The only significant ingredient in the produced effluent may be sand, from which the oil is removed. On a laboratory scale, approximately over 85% of the available oil may be removed in less than 15 minutes.

[0050] The physical process disclosed may be achieved by a simple mechanical method. The disclosed method may use less than 25% of the energy required of the conventional hot-water process method to separate oil from oil sands. The disclosed physical process may have a small environmental impact.

[0051] As an illustration, the energy needed to heat oil sand may be calculated by multiplying the oil sand specific heat at constant pressure by the mass of the oil sand and the change in temperature. For example, the energy needed to heat two tons (2,000 kg) of oil sand with a specific heat at constant pressure of 1 kJ/kg-K from 0 °C up to 100 °C may equal 200,000 kJ. The specific heat at constant pressure of tested Utah oil sand ranges from 0.67 kJ/kg-K to 1.57 kJ/kg-K in the temperature range of 100 – 350 °C. Converted to the energy units of BTU based on 1.055 kJ per BTU, 200,000 kJ equals 189,574 BTU. Each cubic foot of natural gas contains 1,028 BTU of energy; as a result, 189,574 BTU equals 184 cubic feet of natural gas. Therefore, the physical process disclosed for separating liquids from solids may require less than 190 cubic feet of natural gas to separate one barrel of bitumen from two tons of oil sand, which is 80% less than the 1,000 cubic feet used in the conventional separation method.

[0052] Additionally, the environmental impact from the physical process disclosed for separating liquids from solids may be less than the conventional

separation method because the physical process disclosed does not require any water to separate bitumen from oil sand. Conversely, the conventional separation process requires up to 4 barrels of fresh water to produce one barrel of bitumen from two tons of oil sand. The spent water used in the conventional oil separation process is suspected to cause environmental, wildlife, and health problems. The spent water may contain chemicals used in the conventional separation process and may enter rivers and fresh ground water supplies after leaking from spent water retention ponds. Therefore, the physical process disclosed for separating liquids from solids may be less harmful to the environment than the conventional separation method.

**[0053]** A physical process for separating liquids from solids is disclosed. As a non-limiting example, this physical process may be used to separate liquids, such as oil, from solid particles, such as sand or shale. The process may involve at least the following steps in any order (a) applying heat to a mixture of solids and liquids; (b) rapidly spinning the mixture; and (c) confining the solid particles mechanically.

**[0054]** A first system includes a separation device **90** as shown in FIG. 1. The separation device **90** may be made up of one or more tubes such as test tubes. The separation device **90** may, for example, include a first tube **106** and a second tube **100**. The tubes **106**, **100** of this example are dimensioned such that the second tube **100** fits inside of the first tube **106**, for example, in a nested conformation. The second tube **100** has an aperture **102** at one end. In this example, the aperture may have a diameter of approximately 0.40-1.50 mm, 0.45 – 1.35 mm, 0.80-1.30 mm, or approximately 0.90-1.20 mm. However, the optimal aperture size may vary with other variables, such as the type of solid or liquid being separated or other considerations.

**[0055]** The separation device **90** may be dimensioned as described below and illustrated by FIG. 2. The dimensions are representative of this system but may be varied depending upon, for example the system, production needs, and type of solids and liquids being separated.

[0056] The first tube **106** of this example may be, for example but not limited to, a 15 ml centrifuge tube. The second tube **100** of this example may be, for example but not limited to, a 5 ml centrifuge tube. Again, recognized by those of ordinary skill in the art that dimensions, supply source, and specifications for the first tube **106** and the second tube **100** may be varied to suit the needs of a particular application.

[0057] The second tube **100** may have an aperture **102** at one end. The aperture may facilitate separation by retaining solids, such as sand or shale, within the second tube **100** while allowing liquids, such as oil, to escape. The aperture **102** may be added to a tube, for example, the second tube **100** using a tungsten probe. By way of example, to create an aperture, an area on the second tube **100** may be warmed and bored through with a super-heated tungsten probe. The tungsten probe may be a 1/16 inch tungsten probe which may be filed to a point. Other known methods may also be used to create an aperture **102**.

[0058] The process for removing, for example, oil from sand, may proceed as follows. A solids-liquids mixture **104**, for example oil shale or oil sands, may be heated to approximately 25°C-200°C, 50°C-175°C, 75°C-150°C, 95°C-125°C, 92°C-110°C, or approximately 94°C (e.g., in a water bath). The solids-liquids mixture **104** may be heated prior to loading into the separation device **90**. Alternatively, the solids-liquids mixture may be heated in the separation device, or during spinning. Before or after heating, the solids-liquids mixture may be loaded into the second tube **100**. In this example, the tube may be filled to approximately 3/5 of capacity; however, any amount of solids-liquids mixture **104** may be used. The second tube **100** may be placed inside the first tube **106**, before or after filling, to create a separation device **90**. The separation device **90** including the solids-liquids mixture **104** may then be placed into a centrifuge, for example but not limited to, an LW Scientific Ultra 8 Centrifuge. The separation process may be performed without the addition of chemicals.

[0059] An example of the physical principles of operation is shown in FIG. 3. The separation device **90** may be spun in a centrifuge or similar machine. The optimum range for the spin rate may be 500 rpm to 10,000 rpm. As a result of

centrifugal force 204, the liquid 202 may exit the aperture 102 and may collect in the bottom of the first tube Fig. 1, 106, which may be the outer tube. The solid particles 206 may remain in the second tube Fig. 1, 100, which may be the inner tube. The particles 206 may be retained in the second tube 100 rather than escaping through the aperture 102 because, for example, the centrifugal force 204 causes them to jam up, leaving gaps 208 through which the liquid 202 may move toward the aperture 102 and escape. An optimum time range for spinning in this example may be 15 seconds to 20 minutes.

**[0060]** The aperture 102 size for extracting oil from Athabasca oil sands may be, for example, approximately 0.40-1.50 mm, 0.45-1.35 mm, 0.80-1.30 mm, or approximately 0.85-1.10 mm. In the case of, for example, Athabasca oil sands, an aperture 102 larger than approximately 1.5 mm would let the solid particles 206 escape (e.g., absent the presence of supplementary retaining devices such as a screen). However, the size of the aperture may be optimized to find an appropriate range for different combinations of solids and liquids, including oil sands from other regions, oil shale and including Athabasca oil sands that have different particle sizes.

**[0061]** The following example illustrates performance of the process in one system and also includes exemplary results. This example is merely illustrative of the effect on oil recovery from oil sands of different centrifuge speeds and temperatures. The example also illustrates oil extraction from oil sands without the addition of chemicals.

**[0062]** Athabasca oil sand was purchased from the Alberta Research Council. Materials accompanying the oil sand samples provided an estimated composition of 6-12 weight % bitumen, 5-20 weight % water and the balance sand. The bitumen content was not expressed with certainty, therefore a conservative estimate of 12% bitumen was used to calculate percent oil extracted, unless otherwise noted.

**[0063]** The oil sands were loaded into a separation device 90. The separation device 90 was placed into a boiling water bath at approximately 94°C for

approximately 5 minutes or such time as it takes for the temperature of the sand to reach approximately 94°C.

[0064] At a spin rate of 3300 rpm and at an initial temperature of 94°C, about 90% of the extractable liquid Fig. 3, 202 was recovered in 10 minutes (under the conservative assumption the oil sands contained 12 weight % bitumen). The configuration of the centrifuge used in this experiment caused the oil sands sample to experience a g-force of about 900 g's. At lower temperatures, down to 52°C, longer times were needed to remove smaller portions of oil 202 (~64% at ~72°C and ~35% at ~52°C, respectively) even at maximum rotation speeds (~3300 rpm). (All calculations assume that the oil sands contained 12 weight % bitumen.) See FIG. 5. The separation process was performed without the addition of chemicals.

[0065] The following examples illustrate the effect on recovery of various process variables.

#### **EXAMPLE 1: Effect of Spinning Time**

[0066] The following example is included to illustrate the effect of spinning time on recovery in one system. This example is merely illustrative.

[0067] In this example, the effect of spinning time was investigated. The example was performed in duplicate. For this exemplary experiment two devices 90 were weighed. Each device 90 consisted of a first tube 106 and a second tube 100. The second tube 100 was nested inside of the first tube 106 to form a separation device 90. The second tube 100 included an aperture 102.

[0068] Prior to spinning, the first tube 106 and the second tube 100 of each separation device 90 were weighed. Each device 90 was loaded with an approximately equal amount of solids-liquids mixture 104, which in this example was oil sand. The devices 90 were loaded by inserting the solids-liquids mixture 104, in this case oil sand, into the second tube 100 to a level of approximately 3/5 full. The second tube 100 was then nested into the first tube 106 and the resulting separation device 90 was reweighed to determine sample size (e.g., the difference between the weight of the unloaded assembled separation device versus the weight of the loaded and assembled separation device 90). The weight of the bitumen

present in each sample of oil sand was approximated by assuming that the samples contained 12 weight % bitumen.

[0069] Each loaded separation device 90 was then placed in a constant temperature bath at 94°C until the temperature in each stabilized at 94°C. After heating, each loaded separation device 90 was then placed in the centrifuge and spun for approximately 1 minute at about 3300 rpm.

[0070] After spinning, each loaded separation device 90 was removed from the centrifuge. Each separation device 90 was disassembled by removing the second tube 100 from the first tube 106. The first tube 106 of each device was weighed to determine the amount of liquid 202, in this case oil, was deposited into the first tube 106 (as demonstrated by increased weight) by the spinning. The second tube 100 of each device was weighed to determine the amount of liquid 202 removed from the solids-liquids mixture 104 (as demonstrated by decreased weight) by the spinning.

[0071] After weighing, each separation device 90 was reassembled by inserting the second tube 100 into the first tube 106. Each loaded separation device 90 was then placed in a constant temperature bath at 94°C until the temperature in each stabilized at 94°C. After heating, each loaded separation device 90 was then placed in the centrifuge and spun for approximately 1 minute at about 3300 rpm. After spinning for 1 minute, each separation device 90 was again separated by removing the second tube 100 from the first tube 106. The first tube 106 and second tube 100 were weighed to determine the degree of separation after 2 minutes. This process was repeated for 3 more cycles. The degree of separation at 1, 2, 3, and 4 minutes is illustrated in the following tables and plotted into FIG. 4. Where the X-axis displays the total spin time and the Y-axis shows percent of the oil

[0072] Raw Data Summary

| tubes 2&3 | inner<br>tube<br>sample 1<br>(g) | outer<br>tube<br>sample 1<br>(g) | inner<br>tube<br>sample 2<br>(g) | outer<br>tube<br>sample 2<br>(g) | sample<br>1 outer<br>tube<br>mass | sample<br>2 outer<br>tube<br>mass | tube 1<br>%<br>mass<br>gain* | tube 2<br>%<br>mass<br>gain* |
|-----------|----------------------------------|----------------------------------|----------------------------------|----------------------------------|-----------------------------------|-----------------------------------|------------------------------|------------------------------|
|-----------|----------------------------------|----------------------------------|----------------------------------|----------------------------------|-----------------------------------|-----------------------------------|------------------------------|------------------------------|

|                   |             |        |             |        |             |             |      |      |
|-------------------|-------------|--------|-------------|--------|-------------|-------------|------|------|
|                   |             |        |             |        | gain<br>(g) | gain<br>(g) |      |      |
| initial,<br>empty | 10.493      | 15.649 | 10.632      | 15.492 |             |             |      |      |
| w/oil sand        | 13.107      |        | 13.526      |        |             |             |      |      |
| oil sand          |             | 2.614  |             | 2.896  |             |             |      |      |
| spin 1 min        | 12.958      | 15.791 | 13.35       | 15.661 | 0.142       | 0.169       | 45.3 | 48.6 |
| spin 2 min        | 12.911      | 15.835 | 13.331      | 15.678 | 0.186       | 0.186       | 59.3 | 53.5 |
| spin 3 min        | 12.901      | 15.85  | 13.32       | 15.688 | 0.201       | 0.196       | 64.1 | 56.4 |
| spin 4 min        | 12.889      | 15.853 | 13.313      | 15.693 | 0.204       | 0.201       | 65.0 | 57.8 |
| hole size<br>(mm) | Sample<br>1 | 0.79   | Sample<br>2 | 0.93   |             |             |      |      |

\* percent gains based on oil fraction of 12% weight percent

Sample 1 Summary, aperture size 0.79mm

|       | Oil Sand (g)       | Oil (g)      | % Extracted |
|-------|--------------------|--------------|-------------|
| Start | <b>2.614</b>       | <b>0.314</b> |             |
| 1 min | (0.149)<br>(0.142) | 0.146        | 46 %        |
| 2 min | (0.196)<br>(0.186) | 0.191        | 61 %        |
| 3 min | (0.206)<br>(0.201) | 0.204        | 65 %        |
| 4 min | (0.218)<br>(0.204) | 0.211        | 67 %        |

Sample 2 Summary, aperture size 0.93mm

|       | Oil Sand (g)       | Oil (g)      | % Extracted |
|-------|--------------------|--------------|-------------|
| Start | <b>2.896</b>       | <b>0.348</b> |             |
| 1 min | (0.176)<br>(0.169) | 0.173        | 50 %        |
| 2 min | (0.195)<br>(0.186) | 0.191        | 55 %        |
| 3 min | (0.206)<br>(0.196) | 0.201        | 58 %        |
| 4 min | (0.213)<br>(0.201) | 0.207        | 59 %        |

All data is calculated based on an assumed, conservative value of 12 weight % oil per oil sand sample. Actual percent extraction is likely higher.

[0073] The combination of heating, spinning and an appropriate aperture size is highly effective at separating oil from oil sands, even in the absence of chemical extraction agents.

[0074] As illustrated in FIG. 4, when the liquid is oil and the solid-liquid mixture is oil sands, the oil is removed rather quickly and in a large proportion to the amount available at 94°C and 3300 rpm. These results are expected to vary, depending upon the nature of the device used and the starting materials.

## **EXAMPLE 2: Effect of Temperature**

[0075] The following example is included to illustrate the effect of temperature on recovery. This example is merely illustrative.

[0076] In this example, the effect of temperature on recovery was investigated. The example was performed at three exemplary temperatures, 94 °C, 72 °C, and 52°C. For this exemplary experiment three separation devices 90 were prepared, each of which consisted of a first tube 106 and a second tube 100. The second tube 100 was nested inside of the first tube 106 to form a separation device 90. The second tube 100 included an aperture 102 as described above. Each separation device 90 was weighed prior to loading. The weight amount of the bitumen present in each sample of oil sand was approximated by assuming that the samples contained 12 weight % bitumen.

[0077] After weighing, each separation device 90 was loaded with an approximately equal amount of solids-liquids mixture 104, which in this example was oil sand. The devices 90 were loaded by inserting the solids-liquids mixture 104, in this case oil sand, into the second tube 100 to a level of approximately 3/5 full. The second tube 100 was then nested into the first tube 106 and the resulting separation device 90 was reweighed to determine sample size.

[0078] Each loaded separation device 90 was then placed in a constant temperature bath. In this example, each of the three separation devices 90 was warmed to a different temperature. One separation device 90, represented in FIG. 5 as a triangle, was warmed in a constant temperature bath at approximately 94°C

until the temperature in the separation device **90** stabilized at approximately 94°C. A second separation device **90**, represented in FIG.5 as a circle, was warmed in a constant temperature bath at approximately 72°C until the temperature in the separation device **90** stabilized at approximately 72°C. A third separation device **90**, represented in FIG. 5 as a square, was warmed in a constant temperature bath at approximately 52°C until the temperature in the separation device **90** stabilized at approximately 52°C.

[0079] After heating, each loaded separation device **90** was then placed in the centrifuge and spun for approximately 1 minute at about 3300 rpm. After spinning for one minute, each loaded separation device **90** was removed from the centrifuge. The separation device **90** was disassembled by removing the second tube **100** from the first tube **106**. The first tube **106** of each separation device **90** was weighed to determine the amount of liquid **202**, in this case oil, deposited into the first tube **106** (as demonstrated by increased weight) by the spinning. The second tube **100** of each separation device **90** was weighed to determine the amount of liquid **202** removed from the solids-liquids mixture **104** (as demonstrated by decreased weight) by the spinning.

[0080] After weighing, each separation device **90** was reassembled by inserting the second tube **100** into the first tube **106**. Each loaded separation device **90**, represented by a triangle, circle, and square, was then placed back into a constant temperature bath at approximately 94°C, 72 °C, or 52 °C, respectively until the temperature in each stabilized at approximately 94°C, 72 °C, or 52 °C, respectively. After heating, each loaded separation device **90** was then placed in the centrifuge and spun for approximately 5 minutes at about 3300 rpm. After spinning for approximately 5 minutes, each separation device **90** was again separated by removing the second tube **100** from the first tube **106**. The first tube **106** and second tube **100** were weighed to determine the degree of separation after 5 minutes.

[0081] After weighing, each separation device **90** was reassembled by inserting the second tube **100** into the first tube **106**. Each loaded separation device **90**, represented by a triangle, circle, and square, was then placed back into a constant

temperature bath at approximately 94°C, 72 °C, or 52 °C, respectively until the temperature in each stabilized at approximately 94°C, 72 °C, or 52 °C, respectively. After heating, each loaded separation device **90** was then placed in the centrifuge and spun for approximately 10 minutes at about 3300 rpm. After spinning for 10 minutes, each separation device **90** was again separated by removing the second tube **100** from the first tube **106**. The first tube **106** and second tube **100** were weighed to determine the degree of separation after 10 minutes.

[0082] The degree of separation for each separation device **90** at three temperatures 94°C, 72 °C, or 52 °C was plotted in FIG. 5. The degree of separation at each temperature and at each of 1, 5, and 16 minutes is plotted.

[0083] As illustrated in FIG. 5, even in the absence of chemical agents, the extraction percentage of oil from oil sands on laboratory scale at approximately 94°C and approximately 3300 rpm levels off at about 10 minutes spinning time. These results are expected to vary depending upon the nature of the device and the starting materials.

### **EXAMPLE 3: Effect of Spin Rate on Recovery**

[0084] The following example is included to illustrate the effect of spin rate on recovery in a laboratory scale system. This example is merely illustrative and not meant to be limiting.

[0085] In this example, the effect of spin rate on recovery was investigated. The example was performed at two exemplary spin rates, 3300 rpm and 2000 rpm. All other variables were identical between the two samples. For this exemplary experiment two separation devices **90** were prepared, each of which consisted of a first tube **106** and a second tube **100**. The second tube **100** was nested inside of the first tube **106** to form a separation device **90**. The second tube **100** included an aperture **102**. Each separation device **90** was weighed prior to loading.

[0086] After weighing, each device **90** was loaded with an approximately equal amount of solids-liquids mixture **104**, which in this example was oil sand. The separation devices **90** were loaded by inserting the solids-liquids mixture **104**, in

this case oil sand, into the second tube **100** to a level of approximately 3/5 full. The second tube **100** was then nested into the first tube **106** and the resulting separation device **90** was reweighed to determine sample size.

[0087] Each loaded separation device **90** was then placed in a constant temperature bath. In this example, each separation device **90**, was warmed in a constant temperature bath at 94°C until the temperature in the separation device **90** stabilized at 94°C.

[0088] After heating, each loaded separation device **90** was then placed in the centrifuge and spun for approximately 1 minute. One separation device **90** represented in FIG. 6 by the letter B, was spun at about 3300 rpm. A second separation device **90** represented in FIG. 6 by the letter E, was spun at about 2000 rpm. After spinning each separation device **90** at its respective speeds for one minute, each loaded separation device **90** was removed from the centrifuge. Each separation device **90** was disassembled by removing the second tube **100** from the first tube **106**. The first tube **106** of each device was weighed to determine the amount of liquid **202**, in this case oil, deposited into the first tube **106** (as demonstrated by increased weight) by the spinning. The second tube **100** of each device was weighed to determine the amount of liquid **202** removed from the solids-liquids mixture **104** (as demonstrated by decreased weight) by the spinning. The weight amount of the bitumen present in each sample of oil sand was approximated by assuming that the samples contained 12 weight % bitumen.

[0089] After weighing, each separation device **90** was reassembled by inserting the second tube **100** into the first tube **106**. Each loaded separation device **90**, represented by a B or an E, was then placed back into a constant temperature bath at approximately 94°C until the temperature in each stabilized at approximately 94°C. After heating, each loaded separation device **90**, represented by a B or an E, was then placed in the centrifuge and spun for approximately 1 minute at about 3300 rpm and 2000 rpm, respectively. After spinning for 1 minute, each separation device **90** was again separated by removing the second tube **100** from the first tube **106**. The first tube **106** and second tube **100** were weighed to

determine the degree of separation after 1 minute at about 3300 rpm and 2000 rpm, respectively.

[0090] After weighing, each separation device **90** was reassembled by inserting the second tube **100** into the first tube **106**. The cycle of heating, spinning, and weighing was repeated and results were plotted on FIG. 6 for each device **90** at 1, 2, 3, 4, and 5 minutes. FIG. 6 illustrates that percent extraction begins to converge at longer spin times.

[0091] The underlying data is included in the charts below:

| Samples B & E                                | inner tube Sample B (g) | outer tube Sample B (g) | inner tube Sample E (g) | outer tube Sample E (g) | Sample B mass gain (g) | Sample E mass gain (g) | Sample B % gain* | Sample E % gain* |
|----------------------------------------------|-------------------------|-------------------------|-------------------------|-------------------------|------------------------|------------------------|------------------|------------------|
| initial, empty                               | 10.542                  | 15.384                  | 10.389                  | 15.253                  |                        |                        |                  |                  |
| w/oil sand                                   | 13.576                  |                         | 13.435                  |                         |                        |                        |                  |                  |
| oil sand                                     |                         | 3.034                   |                         | 3.046                   |                        |                        |                  |                  |
| spin 1 min                                   | 13.512                  | 15.452                  | 13.405                  | 15.277                  | 0.068                  | 0.024                  | 21.7             | 6.9              |
| spin 2 min                                   | 13.429                  | 15.533                  | 13.335                  | 15.35                   | 0.149                  | 0.097                  | 47.5             | 27.9             |
| spin 3 min                                   | 13.382                  | 15.577                  | 13.282                  | 15.398                  | 0.193                  | 0.145                  | 61.5             | 41.7             |
| spin 4 min                                   | 13.348                  | 15.609                  | 13.271                  | 15.408                  | 0.225                  | 0.155                  | 71.7             | 44.6             |
| spin 5 min                                   | 13.338                  | 15.621                  | 13.255                  | 15.421                  | 0.237                  | 0.168                  | 75.6             | 48.3             |
| hole size (mm)                               | tube 5                  | 0.9906                  | tube 6                  | 0.889                   |                        |                        |                  |                  |
| * percent gains based on oil fraction of 12% |                         |                         |                         |                         |                        |                        |                  |                  |

[0092] Summary Sample B

Hole size 0.99mm

|       | Oil Sand (g)       | Oil (g)     | % Extracted |
|-------|--------------------|-------------|-------------|
| Start | <b>3.034</b>       | <b>0.36</b> |             |
| 1 min | (0.064)<br>(0.068) | 0.066       | 18 %        |
| 2 min | (0.147)<br>(0.149) | 0.148       | 41 %        |

|       |                    |       |      |
|-------|--------------------|-------|------|
| 3 min | (0.194)<br>(0.193) | 0.194 | 54 % |
| 4 min | (0.228)<br>(0.225) | 0.227 | 63 % |
| 5 min | (0.238)<br>(0.237) | 0.238 | 66 % |

**[0093]** Summary Sample E

Hole size 0.89mm

|       | Oil Sand (g)       | Oil (g)     | % Extracted |
|-------|--------------------|-------------|-------------|
| Start | <b>3.046</b>       | <b>0.37</b> |             |
| 1 min | (0.030)<br>(0.024) | 0.027       | 7 %         |
| 2 min | (0.100)<br>(0.097) | 0.099       | 27 %        |
| 3 min | (0.153)<br>(0.145) | 0.149       | 40 %        |
| 4 min | (0.164)<br>(0.155) | 0.160       | 43 %        |
| 5 min | (0.180)<br>(0.168) | 0.174       | 47 %        |

**[0094]** For another example, the following calculations may be helpful in the evaluation and description of the spin rate.

$$a_c = rw^2 \quad (1)$$

$$g_c = \frac{a_c}{g_o} \quad (2)$$

$$g_c = \frac{rw^2}{g_o} \quad (3)$$

$a_c$  = centripetal acceleration (m/s<sup>2</sup>)

$r$  = radius (m)

$w$  = angular velocity (rpm)

$g_o$  = gravitational acceleration at Earth's surface (9.8 m/s<sup>2</sup>)

$g_c$  = G force (g)

**[0095]** FIGS. 7-13 illustrate a second system **300** of a separation device. The second system may have a clam shell-like formation which may further have a

first portion 302 and a second portion 304. The first portion 302 and the second portion 304, depending on the orientation of the device, may be the top and the bottom of the separation system 300. In FIG. 7, the first portion 302 and the second portion 304 of the second system fit together with the aid of, for example, an aligning pivot 305. The first portion 304 may have cavities 306, wherein each cavity 306 may form an aperture 308 where the first portion 302 and second portion 304 of the second system come together.

[0096] FIGS. 8 and 9 illustrates how the cavities 306 may align radially. For example, the cavities 306 may be roughly semi conical with an opening that is wider toward the center 402 of the second portion 304 of the second system 300 and narrows as it reaches the perimeter 404. While the cavities 306 are illustrated as semi conical in FIGS. 8 and 9, other shapes may be used.

[0097] The second system 300 may also include a liquid collector FIG. 11, 706, which may be cylindrical, or any other shape. For example, the liquid collector may or may not approximate the shape of the second system separation system 300. The liquid collector 706 may include a gutter 707 which may collect and funnel the liquid to a collection reservoir. The gutter 707 may be located on the lower edge of the liquid collector, or may be located in any other location. The liquid collector 706 may be arranged with the second system separation system 300 such that the second system separation system 300 may be raised and lowered into position with the liquid collector 706 as the separation process proceeds.

[0098] FIGS. 10-13 illustrate how the process for extracting liquids from solid particles might be adapted for the second system 300 separation device described above. The solids-liquids mixture 602 may be placed inside the cavities 306 in the second system 300. In FIG. 10 the solids-liquids mixture 602 may be heated before loading, during loading, or after loading into the system 300. The second system 300 may be lowered into a liquid collector 706 and may be spun as shown in FIG. 11. Spinning may cause the liquid 702 to separate from the solid particles 704. The liquid 702 may exit apertures 308, and may accumulate, for example, on the liquid collector 706, and/or in a gutter 707. The solid particles 704 may remain inside the closed second system 300.

[0099] After separation has been accomplished, the liquid collector 706 may be raised, and the second system 300 may be opened as shown in FIG. 12. The first portion 302 and second portion 304 may be spun such that the solid particles are spun out of the cavities 306. A solid particles collector 802 may be used to catch the solid particles 704.

[00100] The second system 300 may then be reused. A new load of heated or unheated solids-liquids mixture 602 may be inserted into the second system 300 and the liquid collector 706 may be replaced into a position that will allow it to capture extracted liquids. The second system 300 may be closed and respun, as shown in FIG. 13, continuing the cycle. Alternatively, the cycle may terminate after one use. The optimal aperture 308 size for removing oil from Athabasca oil sands is approximately 0.40-1.50 mm, 0.45-1.35 mm, 0.80-1.30 mm, or approximately 9.90-1.20 mm. However, other sizes may be used.

[00101] FIG. 14 is a cross-sectional view of a third system, which may have a cyclone formation 1010. The third system 1010 may be approximately conical in shape and may have baffles 1020 located along the interior. The baffles 1020 may be arranged in a screw-thread-like fashion along the interior of the third system 1010. The walls 1018 of the third system 1010 may include small apertures or capillaries 1022. An exploded exemplary view of a wall 1018 including capillaries 1022 is illustrated in FIG. 14a. The third system 1010 may further include a coaxial piston, 1014 and a central shaft 1011 which may be supported by a bearing 1012 and a feed tube 1016. The third system 1010 may also include a liquid collector 1026 which may be cylindrical or any other shape.

[00102] FIGS. 14-15 illustrate how the process for extracting liquids from solid particles might be adapted for the third system 1010 described above. The solids-liquids mixture 602, for example, oil sands, may be heated prior to loading or may be heated during loading or, alternatively, in the third system 1010. For example, the solids-liquids mixture 602 may be heated in the feed tube, in the cyclone, or in a retaining tank attached to the feed tube, and etc.; alternatively, it may be heated prior to being loaded into the feed tube.

**[00103]** The heated or unheated solids-liquids mixture **602** may be loaded into the third system **1010** by a feed tube **1016**. The feed tube **1016** may be centrally located. A coaxial piston **1014** may push an amount of a heated solids-liquids mixture **602** down a central feed tube **1016** and out the bottom of the central feed tube **1016** into the centrifuge wall **1018**, rotating co-axially as shown in FIG. 15. The heated solids-liquids mixture **602** may be centrifugally forced outward and upward along the baffles **1020**. The liquid **702** may escape through the small apertures **1022**, which may have a diameter of approximately 0.40-1.50 mm, 0.45-1.35 mm, 0.80-1.30 mm or about 0.90-1.20 mm. Solid particles **704** may be centrifugally pushed upward and eventually go over the top **1024** of the third system **1010** where it may be collected and recycled, disposed of or otherwise. The liquid **702** that is extracted may be collected by the oil collector **1026**, for example, by accumulating at the bottom **1028**. This may be a continuous process by which the feed tube **1016** continually feeds solids-liquids mixture **602** into the third system **1010** to replace the liquid and solids that are removed.

**[00104]** FIG. 16 shows a fourth system which may be formed of rotating planes. The fourth system may have a chamber **1202**. This device may be self-cleaning. As shown in FIG. 17, the rotating planes system may have a top plate **1205** and a bottom plate **1207**, which may be coaxially mounted with a main shaft **1204** so that the top plate **1205** can be raised and the bottom plate **1207** can be lowered. The chamber may be formed of multiple chamber walls **1206**. The chamber walls may have apertures or capillaries **1402** through which liquid may be extracted from the liquids-solid mixture. The chamber **1202** can take many shapes depending on the number of walls **1206**, such as a hexagonal shape as shown in FIGS. 16-20. Each of the walls **1206** may be centrally pivoted **1208**. The rotating planes separator **1202** may have at least two configurations, for example, a closed configuration (see, e.g., FIGS. 16, 17, 20a, 20c, 20e) and an open configuration (see, e.g., FIGS. 20b, 20d). In the closed configuration, the walls **1206** may be sealed by outer **1304** and inner **1306** splines as shown in FIG. 19. The apertures **1402** in the chamber walls **1206** may have a diameter of

approximately 0.40-1.50 mm, 0.45-1.35 mm, 0.80-1.30 mm, or about 0.90-1.20 mm. In the open configuration, the walls 1206 may be rotated on their pivot point such that they are no longer in contact. (See, e.g., FIGS. 20b, 20d)

[00105] In operation, heated solids-liquids mixture 602 may be placed in the chamber and the chamber may be spun, as shown in the top view in FIG. 20a. The liquid 702 separates from the solid particles 704 and may be collected by a liquid collector 1504 surrounding the chamber. The liquid collector 1504 may be, for example, cylindrical or may otherwise approximate the shape of the fourth system 1202. Alternatively, the liquid collector 1504 may be of any other shape or format. When separation has been completed and rotation has stopped, the bottom plate may be lowered. The top plate may be raised and the fourth system 1504 may be raised even more, so that its bottom is above the top of the chamber walls 1206, which are rotated as shown in the second step in FIG. 20b.

[00106] Next, the chamber walls 1206 may be locked by the splines at for example 180° so that the apertures face toward the center of the chamber. The separation device 1202 may be spun to cleanse the remaining solid particles 704. The solid particles 704 removed from the chamber may be caught by a solid-particle collector 1506 as shown in the third step in FIG. 20c.

[00107] After cleaning, the separator 1202 may be stopped; the solid-particle collector 1506 may be lowered away from the separator 1202. The separator may be returned to a closed position by rotating the walls 1206, for example, 180° as shown in the fourth step in FIG. 20d. The bottom plate may rise to complete the closed conformation. At that point, more solids-liquids mixture 602 may be placed inside the chamber, and the top may be lowered and the liquid collector 1504 raised into conformation for the next round of processing.

[00108] FIG. 21 shows a fifth system 1600 which may be a double piston type of a separator. The fifth system 1600 may have a rotating main shaft 1602. The rotating main shaft 1602 may further have an attached a top piston 1604 and a bottom piston 1606. The fifth system 1600 may also include a filtering portion 1607 which may have a top band 1608, a bottom band 1610 and a screen 1612.

**[00109]** The screen **1612** may be made of any material and may be of sufficient strength to withstand centrifugal force and retain the solid particles. The screen may be supported by bands **1608** and **1610** as illustrated in FIG. 21 and band **1609** as illustrated in FIG. 22. The screen **1612** may have openings or apertures, which may be dimensioned to retain the solid particles **704** and let the liquid **702** through, as shown in FIG. 22. For separation of oil from Athabasca oil sands, the aperture may have a diameter of approximately 0.40-1.50 mm, 0.45-1.35 mm, 0.80-1.30 mm, or about 0.90-1.20 mm. As stated above, the aperture size may vary depending on the properties of the liquid-solid material and the efficiency of the separation may vary as a function of aperture size.

**[00110]** The attached top piston **1604** and bottom piston **1606** may be separated by a distance such that, in the closed position, the top piston **1604** is even with the top band **1608** of the filtering portion **1607**, and the bottom piston **1606** is even with the bottom band **1610** of the filtering portion **1607**.

**[00111]** In operation, the top **1604** and bottom **1606** pistons may be raised enough to introduce the solids-liquids mixture **602** as shown in the first step in FIG. 23. The pistons may be lowered and aligned with the filtering portion **1607**. The apparatus may be spun, as shown in the second step **1802** in FIG. 23b. Heat may be applied to the mixture prior to loading or the apparatus may be heated before or during spinning.

**[00112]** During spinning the solid particles **704** may be restrained by the screen **1612**; the liquid **702** may pass through the screen **1612** and may be captured by the liquid collector **1804**.

**[00113]** After the spinning is completed and extraction has concluded, the apparatus may be cleaned as follows. The pistons may be lowered until the bottom edge of the top of the piston **1604** is even with the bottom edge of bottom band **1610**, as shown in the third step in FIG. 23c. The solid particles **704** may be removed from the piston by spinning such that the solid particles **704** leave the fifth system **1600** and are collected by a solid-particle collector **1806**.

[00114] After cleaning, the process may be repeated. For example, a new batch of heated or unheated solids-liquids mixture **602** may be inserted into the double piston system, as shown in the fourth step in FIG. 23d.

[00115] While various systems of the disclosure have been described, it will be apparent to those of ordinary skill in the art that many more systems and implementations are possible that are within the scope of the disclosure.

[00116] FIG. 21 shows a cross sectional view of a sixth system **2100**, which may be a centrifugal type of separator. The sixth system **2100** may have a rotor **2104**. The rotor **2104** may spin a separation device **2102**, which may be a tube. The sixth system **2100** may include multiple separation devices **2102** depending on the size of the separation device **2102** and the rotor **2104**. The separation device **2102**, may include multiple parts. For example, the separation device **2102** may have a first part **2216** and a second part **2118**. The multiple parts may be connected, such as by a hinge **2114** or otherwise. When the first part **2116** and the second part **2118** are in contact, they may form a separation device **2102**. The separation device **2102** may include an aperture **2106** at one end. The aperture **2106** may facilitate separation of liquids, such as oil or water, from solids, such as sand or shale, by retaining solids within the separation device **2102**. The sixth system **2100** may also include an extractor **2108**. As shown in FIG. 24, the extractor **2108** may remove the separation device **2102** from the rotor **2104**, may split the separation device **2102** into its first part **2116** and second part **2118**, and may spin the separation device **2102** to remove the solid particles.

[00117] The sixth system **2100** may include a liquid collector **2202**, as shown in FIG. 25, which may be any shape capable of containing the liquid, such as a cylinder, rectangle, or hexagon.

[00118] The process for extracting liquids from solid particles may be adapted for the sixth system **2100**, described above, by placing a solids-liquids mixture in the separation device **2102**, which may be placed in the rotor **2104**. The solids-liquids mixture may be heated before, during, or after placement in the separation device **2102**. The solids-liquids mixture, for example oil shale or oil sands, may be heated to approximately 25°C-200 °C, 50 °C-175 °C, 75 °C-150 °C,

95 °C-125 °C, and approximately 92 °C-110 °C and approximately 94 °C (e.g., in a water bath). The separation device **2102** may be inserted into the rotor **2104** and spun perpendicular to the long axis of the separation device **2102**. The separation device **2102** may be spun to approximately 500 rpm to 10,000 rpm. Spinning may cause the liquid to separate from the solid particles. The separation device **2102** may be spun for approximately 15 seconds to 20 minutes. The liquid may exit the aperture **2106** and may accumulate, for example, on the liquid collector **2202**. The optimum aperture **2106** size for extracting oil from Athabasca oil sands may be, for example, approximately 0.40-1.50 mm, 0.45-1.35 mm, 0.80-1.30 mm, or approximately 0.85-1.10mm. The sixth system **2100** may then be reused with a new solids-liquids mixture.

**[00119]** FIGS. 27-32 show a seventh system **2400** which may be a centrifugal type of separator. The seventh system **2400** may have a rotor with multiple parts. The first part of the rotor **2404** may attach to a power generator or other source of power. The first part of the rotor **2404** may have an axial opening **2506**. The second part of the rotor **2504** may constrain the movement of a separation device **2402** within the first part of the rotor **2404**, as shown in FIG. 28, a cross-sectional view. The rotor **2404**, **2504** may spin a separation device **2402**, which may be a tube. The seventh system **2400** may include multiple separation devices **2402** depending on the size of the separation device **2402** and the rotor **2404**, **2504**. The separation device **2402** may include one open end **2502**, as shown in FIG. 28. The separation device **2402** may include a smaller aperture **2408** at the other end. The aperture **2408** may facilitate separation of liquids, such as oil or water, from solids, such as sand or shale, by retaining solids within the separation device **2402**. The separation device **2402** may also include a pivot point **2410**, such as an axle, along the length of the separation device **2402** that may be perpendicular to the separation device length, as shown in FIG. 29.

**[00120]** The seventh system **2400** may include a liquid collector **2702**, as shown in FIG. 30 and FIG. 31, which may be any shape capable of containing the liquid, such as a cylinder, rectangle, or hexagon.

**[00121]** The process for extracting liquids from solid particles may be adapted for the seventh system **2400**, described above, by placing a solids-liquids mixture in the separation device **2402**, which may be placed in the first part of the rotor **2404** and secured in place by the second part of the rotor **2504**. The solids-liquids mixture may be heated before, during, or after placement in the separation device **2402**. The solids-liquids mixture, for example oil shale or oil sands, may be heated to approximately 25°C-200 °C, 50 °C-175 °C, 75 °C-150 °C, 95 °C-125 °C, and approximately 92 °C-110 °C and approximately 94 °C (e.g., in a water bath). The separation device **2402** may be inserted into the first part of the rotor **2404**, as shown in FIG. 30, and spun perpendicular to the long axis of the separation device **2402**. The separation device **2402** may be spun to approximately 500 rpm to 10,000 rpm. The separation device **2402** may be spun for approximately 15 seconds to 20 minutes. Spinning may cause the liquid to separate from the solid particles. The liquid may exit the aperture **2408** and may accumulate, for example, on the liquid collector **2702**. The optimum aperture **2408** size for extracting oil from Athabasca oil sands may be, for example, approximately 0.40-1.50 mm, 0.45-1.35 mm, 0.80-1.30 mm, or approximately 0.85-1.10mm. Once the liquid has left the separation device **2402**, the second part of the rotor **2504** may be moved to allow the separation device **2402** to pivot along the pivot point **2410**. If the separation device **2402** is spun, the remaining solid particles may exit the open end **2502** of the separation device **2402**, as shown in FIG. 31. The collector **2702** may be changed to collect the solid particles. The seventh system **2400** may then be reused with a new solids-liquids mixture.

**[00122]** FIG. 32 shows an eighth system **2900**, which may be a centrifugal type of separator. The eighth system **2900** may include a rotor **2904**. The rotor **2904** may spin a separation device **2902**, which may be a tube. The eighth system **2900** may include multiple separation devices **2902** depending on the size of the separation device **2902** and the rotor **2904**. The separation device **2902** may be open on one end **2910** and may include a smaller aperture **2906** at the other end. The aperture **2906** may facilitate separation of liquids, such as oil or water, from solids, such as sand or shale, by retaining solids within the separation device **2902**.

The separation device **2902** may include a lockable pivot point **2908**, such as a geared axle, along the length of the separation device **2902** that may be perpendicular to the separation device **2902** length.

[00123] The eighth system **2900** may include a liquid collector **2912**, as shown in FIG. 32, which may be any shape capable of containing the liquid, such as a cylinder, rectangle, or hexagon.

[00124] The process for extracting liquids from solid particles may be adapted for the eighth system **2900**, described above, by placing a solids-liquids mixture in the separation device **2902**, which may be positioned within the rotor **2904** and secured in place by the lockable pivot point **2908**. The solids-liquids mixture may be heated before, during, or after placement in the separation device **2902**. The solids-liquids mixture, for example oil shale or oil sands, may be heated to approximately 25°C-200 °C, 50 °C-175 °C, 75 °C-150 °C, 95 °C-125 °C, and approximately 92 °C-110 °C and approximately 94 °C (e.g., in a water bath). The rotor **2904** may spin the separation device **2902** perpendicular to the long axis of the separation device **2902**. The separation device **2902** may be spun to approximately 500 rpm to 10,000 rpm. The separation device **2902** may be spun for approximately 15 seconds to 20 minutes. Spinning may cause the liquid to separate from the solid particles. The liquid may exit the aperture **2906** and may accumulate, for example, on the liquid collector **2912**. The optimum aperture **2906** size for extracting oil from Athabasca oil sands may be, for example, approximately 0.40-1.50 mm, 0.45-1.35 mm, 0.80-1.30 mm, or approximately 0.85-1.10mm. Once the liquid has left the separation device **2902**, the lockable pivot point **2908** may allow the separation device **2902** to pivot such that the remaining solid particles may exit the open end of the separation device **2902** if it is spun. The collector **2912** may be changed to collect the remaining solid particles. The eighth system **2900** may then be reused with a new solids-liquids mixture.

[00125] FIG. 33 shows a ninth system **3000**, which may be a centrifugal type of separator. An exemplary cross-sectional perspective view of the ninth system **3000** is shown in FIG. 34. The ninth system **3000** may include a

separation device **3002**. The separation device **3002** may be open on one end **3010**. The separation device **3002** may include a smaller aperture **3008** at the other end. The aperture **3008** may facilitate separation of liquids **3304**, such as oil or water, from solids **3306**, such as sand or shale, by retaining solids **3306** within the separation device **3002** if it is spun. The ninth system **3000** may include a disk **3004**. The disk **3004** may be contained within the separation device **3002**. The disk **3004** may be held in place such that the disk **3004** is perpendicular to the length of the separation device **3002**, as shown in FIG. 33 and FIG. 34. The disk **3004** may also be moved by rods **3006** such that the disk **3004** is parallel to the length of the separation device **3002**, as shown in the front view in FIG. 35a and in the side view in FIG. 35b.

[00126] The process for extracting liquids **3304** from solid particles **3306** may be adapted for the ninth system **3000**, described above, by placing a solids-liquids mixture **3302** in the separation device **3002** with the disk **3004** positioned parallel to the length of the separation device **3002**, as shown in front view in FIG. 36a and inside view in FIG. 36b. The solids-liquids mixture **3302** may be heated before, during, or after placement in the separation device **3002**. The solids-liquids mixture **3302**, for example oil shale or oil sands, may be heated to approximately 25°C-200 °C, 50 °C-175 °C, 75 °C-150 °C, 95 °C-125 °C, and approximately 92 °C-110 °C and approximately 94 °C (e.g., in a water bath). Spinning the separation device **3002** perpendicular to the long axis of the separation device **3002** may cause the liquid **3304** to separate from the solid particles **3306**. The separation device **3002** may be spun to approximately 500 rpm to 10,000 rpm. The separation device **3002** may be spun for approximately 15 seconds to 20 minutes. The liquid **3304** may exit the aperture **3008** for collection later. The optimum aperture **3008** size for extracting oil from Athabasca oil sands may be, for example, approximately 0.40-1.50 mm, 0.45-1.35 mm, 0.80-1.30 mm, or approximately 0.85-1.10mm. Once the liquid **3304** has left the separation device **3002**, the disk **3004** may be repositioned perpendicular to the length of the separation device **3002** and removed from the separation device **3002**, as shown in FIG. 36c, extracting the remaining solid particles **3306** as it is

removed. The ninth system **3000** may then be reused with a new solids-liquids mixture **3302**, as shown in FIG. 36d.

[00127] FIGS. 37-40 show a tenth system **3400**, which may have a cylindrical formation. The tenth system **3400** may include a shaft **3406**. The shaft **3406** may be placed within a first cylinder **3402**. The shaft **3406** may be angled to allow the movement of a solids-liquids mixture **3504** down the inside of the first cylinder **3402** by gravity. The first cylinder **3402** may include apertures **3416**. An exploded exemplary view of the first cylinder **3402** including apertures **3416** is illustrated in FIG. 38a. The apertures **3416** may facilitate the separation of liquids **3502**, such as oil or water, from solids, such as sand or shale, by retaining solids **3506** within the first cylinder **3402**. The first cylinder **3402** may be placed within a second cylinder **3404**. As shown in FIG. 37, the second cylinder **3404** may include a protrusion **3412**. The protrusion **3412** may collect and direct the liquid **3502** to a collection point **3414**.

[00128] The process for extracting liquids **3502** from solid particles **3506** may be adapted for the tenth system **3400**, described above, by placing a solids-liquids mixture **3504** on the inside of the spinning first cylinder **3402** and allowing it to travel along the surface of the first cylinder **3402** by gravity. The solids-liquids **3504** mixture may be heated before, during, or after placement in the first cylinder **3402**. The solids-liquids mixture **3504**, for example oil shale or oil sands, may be heated to approximately 25°C-200 °C, 50 °C-175 °C, 75 °C-150 °C, 95 °C-125 °C, and approximately 92 °C-110 °C and approximately 94 °C (e.g., in a water bath). Spinning the first cylinder **3402** may cause the liquid **3502** to separate from the solid particles **3506**. The first cylinder **3402** may be spun to approximately 500 rpm to 10,000 rpm. The first cylinder **3402** may be spun for approximately 15 seconds to 20 minutes. The liquid **3502** may exit the first cylinder **3402** through the apertures **3416**. The optimum aperture **3416** size for extracting oil from Athabasca oil sands may be, for example, approximately 0.40-1.50 mm, 0.45-1.35 mm, 0.80-1.30 mm, or approximately 0.85-1.10mm. The liquid **3502** may accumulate on the second cylinder **3404** and may be contained by the protrusion **3412** and drained at the collection point **3414**. Adjustments may be

made to adjust the angle of the first cylinder **3402**, the rotational rate of the first cylinder **3402**, and the feed rate of the solids-liquids mixture **3504** such that a majority of the liquid **3502** may be removed by the time the solids-liquids mixture **3504** reaches the lower end of the first cylinder **3402**. The tenth system **3400** may be used in a continuous process.

**[00129]** FIGS. 39-40 show an eleventh system **3600**, which may have a cylindrical formation. The eleventh system **3600** may include a rotating screw shaft **3606**. The rotating screw shaft **3606** may be placed within a first cylinder **3602**. The rotating screw shaft **3606** may facilitate the separation of liquids **3702**, such as oil or water, from solids **3704**, such as sand or shale, by retaining solids **3704** within the first cylinder **3602**. The first cylinder **3602** may include apertures **3614**. An exploded exemplary view of the first cylinder **3602** including apertures **3614** is illustrated in FIG. 40a. The apertures **3614** may facilitate the separation of liquids **3702**, such as oil or water, from solids **3704**, such as sand or shale, by retaining solids **3704** within the first cylinder **3602**. The first cylinder **3602** may be placed within a second cylinder **3604**. As shown in FIG. 40, the second cylinder **3604** may include a protrusion **3610**. The protrusion **3610** may collect and direct the liquid to a collection point **3612**.

**[00130]** The process for extracting liquids **3702** from solid particles **3704** may be adapted for the eleventh system **3600**, described above, by placing a solids-liquids mixture **3608** on the inside of the spinning first cylinder **3602** and using the rotating screw **3606** to move the solids-liquids mixture **3608** along the inner surface of the first cylinder **3602**. The solids-liquids mixture **3608** may be heated before, during, or after placement in the first cylinder **3602**. The solids-liquids mixture **3608**, for example oil shale or oil sands, may be heated to approximately 25°C-200 °C, 50 °C-175 °C, 75 °C-150 °C, 95 °C-125 °C, and approximately 92 °C-110 °C and approximately 94 °C (e.g., in a water bath). Spinning the first cylinder **3602** may cause the liquid **3702** to separate from the solid particles **3704**. The first cylinder **3602** may be spun to approximately 500 rpm to 10,000 rpm. The first cylinder **3602** may be spun for approximately 15 seconds to 20 minutes. The liquid **3702** may exit the first cylinder **3602** through

the apertures **3614**. The optimum aperture **3614** size for extracting oil from Athabasca oil sands may be, for example, approximately 0.40-1.50 mm, 0.45-1.35 mm, 0.80-1.30 mm, or approximately 0.85-1.10mm. The liquid **3702** may accumulate on the second cylinder **3604** and may be contained by the protrusion **3610** and drained at the collection point **3612**. Adjustments may be made to adjust the rotational rate of the screw **3606**, the feed rate of the solids-liquids mixture **3608**, and the rotational rate of the first cylinder **3602** such that a majority of the liquid **3702** may be removed by the time the solids-liquids **3608** mixture reaches the end of the first cylinder **3602**. The eleventh system **3600** may be used in a continuous process.

[00131] FIG. 41 shows a cross sectional view of a twelfth system **3800**, which may which may have a cyclone formation. The twelfth system **3800** may include a first cone **3802** and a second cone **3804**, placed concentrically around a shaft **3806**. The second cone **3804** may include baffles **3810**. The baffles **3810** may be arranged in a screw-thread-like fashion on the first wall of the second cone **3804**, in the space between the first cone **3802** and the second cone **3804**. The second cone **3804** may include apertures **3818**. An exploded exemplary view of the second cone **3804** including apertures **3818** is illustrated in FIG. 41a. The apertures **3818** may facilitate the separation of liquids **3812**, such as oil or water, from solids **3814**, such as sand or shale, by retaining solids **3814**, within the second cone **3804**. The twelfth system **3800** may also include a liquid collector **3808**. The liquid collector **3808** may surround the second cone **3804**.

[00132] The process for extracting liquids **3812** from solid particles **3814** may be adapted for the twelfth system **3800**, described above, by placing a solids-liquids mixture **3816** within the cavity of the first cone **3802** and feeding it into the space **3820** between the first cone **3802** and second cone **3804**. The solids-liquids **3816** mixture may be heated before, during, or after placement in the first cone **3802**. The solids-liquids mixture **3816**, for example oil shale or oil sands, may be heated to approximately 25°C-200 °C, 50 °C-175 °C, 75 °C-150 °C, 95 °C-125 °C, and approximately 92 °C-110 °C and approximately 94 °C (e.g., in a water bath). The process to feed the solids-liquids mixture **3816** into the space between the first

cone 3802 and second cone 3804 may include, by way of example, gravity, compressed air, an auger, a piston, and a plunger. The solids-liquids mixture 3816 may travel up the inside surface of the spinning second cone 3804 by centrifugal force, by the action of the baffles 3810, or by suction force. Spinning the second cone 3804 may cause the liquid 3812 to separate from the solid particles 3814. The second cone 3804 may be spun to approximately 500 rpm to 10,000 rpm. The second cone 3804 may be spun for approximately 15 seconds to 20 minutes. The liquid 3812 may exit the second cone 3804 through the apertures 3818 and may be collected on the liquid collector 3808. The optimum aperture 3818 size for extracting oil from Athabasca oil sands may be, for example, approximately 0.40-1.50 mm, 0.45-1.35 mm, 0.80-1.30 mm, or approximately 0.85-1.10mm. The remaining solid particles 3814 may exit space 3822 between the first cone 3802 and second cone 3804 near the top of the second cone 3804. Adjustments may be made to adjust the angle of the first cone 3802 and second cone 3804, the rotational rate of the second cone 3804, the feed rate of the solids-liquids mixture 3816, and the placement of the baffles 3810 such that a majority of the liquid 3812 may be removed by the time the solids-liquids mixture 3816 reaches the top of the second cone 3804. The twelfth system 3800 may be used in a continuous process.

[00133] FIG. 42 shows a cross sectional view of a thirteenth system 3900, which may include a cylindrical formation. The thirteenth system may include a vertical first cylinder 3902 and a vertical second cylinder 3904, placed concentrically around a shaft 3906. The first cylinder 3902 and second cylinder 3904 may include baffles 3910. The baffles 3910 may be positioned in the space between the first cylinder 3902 and the second cylinder 3904. The baffles 3910 may control the movement of a solids-liquids mixture 3912. The second cylinder 3904 may include apertures 3918. An exploded exemplary view of the second cylinder 3904 including apertures 3918 is illustrated in FIG. 42a. The apertures 3918 may facilitate the separation of liquids 3914, such as oil or water, from solids 3916, such as sand or shale, by retaining solids 3916 within the second cylinder 3904. The twelfth system may also include a liquid collector 3908. The liquid collector 3908 may surround the second cylinder 3904.

[00134] The process for extracting liquids 3914 from solid particles 3916 may be adapted for the thirteenth system 3900, described above, by placing a solids-liquids mixture 3912 in the space 3920 between the rotating first cylinder 3902 and rotating second cylinder 3904. The solids-liquids mixture 3912 may be heated before, during, or after placement in the space between the first cylinder 3902 and second cylinder 3904. The solids-liquids mixture 3912, for example oil shale or oil sands, may be heated to approximately 25°C-200 °C, 50 °C-175 °C, 75 °C-150 °C, 95 °C-125 °C, and approximately 92 °C-110 °C and approximately 94 °C (e.g., in a water bath). The size and placement of the baffles 3910 may adjust the movement of the solids-liquids mixture 3912. Spinning the first cylinder 3902 and second cylinder 3904 may cause the liquid 3914 to separate from the solid particles 3916. The first cylinder 3902 and second cylinder 3904 may be spun to approximately 500 rpm to 10,000 rpm. The second cylinder 3904 may be spun for approximately 15 seconds to 20 minutes. The liquid 3914 may exit the second cylinder 3904 through the apertures 3918 and may be collected on the liquid collector 3908. The optimum aperture 3918 size for extracting oil from Athabasca oil sands may be, for example, approximately 0.40-1.50 mm, 0.45-1.35 mm, 0.80-1.30 mm, or approximately 0.85-1.10mm. The remaining solid particles 3916 may exit the space 3922 between the first cylinder 3902 and second cylinder 3904 near the bottom of the second cylinder 3904. The space 3922 between the first cylinder 3902 and the second cylinder 3904 that may allow the solid particles to exit may be continuous. Adjustments may be made to adjust the rotational rate of the first cylinder 3902 and second cylinder 3904, the feed rate of the solids-liquids mixture 3912, and the placement of the baffles 3910 such that a majority of the liquid 3914 may be removed by the time the solids-liquids mixture 3912 reaches the bottom of the second cylinder 3904. The thirteenth system 3900 may be used in a continuous process.

[00135] Through a simple mechanical method, the physical process disclosed for separating liquids from solids uses no water or other solvents and less than 190 cubic feet of natural gas to produce one barrel of bitumen. Minimizing the environmental impact, the disclosed process produces a clean

affluent with the sole ingredient of sand. In comparison to the conventional method, the physical process disclosed requires fewer natural resources and less than 25 % of the energy of the amount required in the conventional hot-water process to separate oil from oil sands. Further, on a laboratory scale, the disclosed method effectively separates over 85 % of the available oil in less than 15 minutes.

[00136] While various systems of the disclosure have been described, it will be apparent to those of ordinary skill in the art that many more systems and implementations are possible that are within the scope of the disclosure.

**I CLAIM:**

1. A method for separating oil from oil sands comprising:  
heating the oil sands;  
spinning the heated oil sands;  
confining mechanically sand particles present in the oil sands away  
from the oil, and  
recovering the oil substantially free of the sand.
2. The method of claim 1 wherein the oil sands are heated to  
approximately 25-200°C.
3. The method of claim 1 wherein the oils sands are heated to  
approximately 92°C - 110°C.
4. The method of claim 1 wherein the particles are confined away from  
the oil by an aperture.
5. The method of claim 4 wherein the aperture is about 0.40 to about  
1.5 mm in diameter.
6. The method of claim 4 wherein the aperture is about 0.80 to about  
1.20 mm in diameter.
7. The method of claim 1 wherein the oil sands are subjected to  
centrifugal force.
8. The method of claim 1 wherein the oil is extracted from the oil  
sands without the use of chemicals.
9. A separation device for separating liquids from a solid particulate  
material, the separation device comprising:  
a structure for confining sand particles;  
a structure for recovering the oil; and wherein

the separation device is subjected to centrifugal force.

10. The separation device of claim 9 wherein:
- the structure for confining sand particles comprises a first tube and a second tube;
  - the first tube and the second tube being dimensioned such that the first tube fits inside the second tube;
  - the first tube including at least one aperture sized smaller than the oil sand;
  - the first tube for confining the sand particles mechanically; and
  - the second tube for recovering the oil.

11. The separation device of claim 9, wherein the structure for confining the particles has a clam shell formation comprising:
- a first portion and a second portion;
  - the first portion and the second portion being dimensioned to fit together with an aligning pivot;
  - the first portion including at least one cavity;
  - the second portion including at least one cavity that mirrors the cavity of the first portion; and
  - wherein, when the first portion and the second portion are fit together, the cavity in the first portion and the cavity in the second portion align to form one cavity; and
  - the cavities terminate to form an aperture through which oil escapes;
  - and
  - the aperture is dimensioned to confine the sand particles within the cavity.

12. The device of claim 11 wherein the aperture is about 0.40 to about 1.5 mm in diameter.

13. The device of claim 11 wherein the aperture is about 0.80 to about 1.20 mm in diameter.

14. The separation device of claim 9, wherein the structure for confining the particles has a conical formation comprising:  
one or more walls;  
the walls including apertures;  
the walls also including baffles located along the interior of the conical separator;  
the baffles being continuous and arranged radially; and  
wherein the separation device further comprises a structure for recovering the oil.

15. The device of claim 14 wherein the aperture is about 0.40 to about 1.5 mm in diameter.

16. The device of claim 14 wherein the aperture is about 0.80 to about 1.20 mm in diameter.

17. The separation device of claim 9, wherein the structure for confining the particles comprises:  
three or more planes;  
the planes being freely rotatable about a central axis;  
the central axis having a pivot;  
the planes being oriented so that they form walls of a closed chamber when rotated to a closed formation;  
the planes further including apertures through which oil escapes;  
and  
a structure for recovering the oil.

18. The device of claim 17 wherein the aperture is about 0.80 to about 1.20 mm in diameter.

19. The separation device of claim 9, the separation device wherein the structure for confining the particles comprises:
- a rotating main shaft;
  - a top piston and a bottom piston removably attached to the main shaft;
  - a filtering portion;
  - the filtering portion having a top band, a bottom band, and a screen;
  - the screen having apertures through which oil escapes;
  - the screen, the top piston, and the bottom piston being arranged such that the pistons may be raised or lowered out of the plane of the screen.
20. A system for separating oil from oil sands comprising:
- a source of centrifugal force;
  - a heat source;
  - a separation device; and
  - a recovery device.

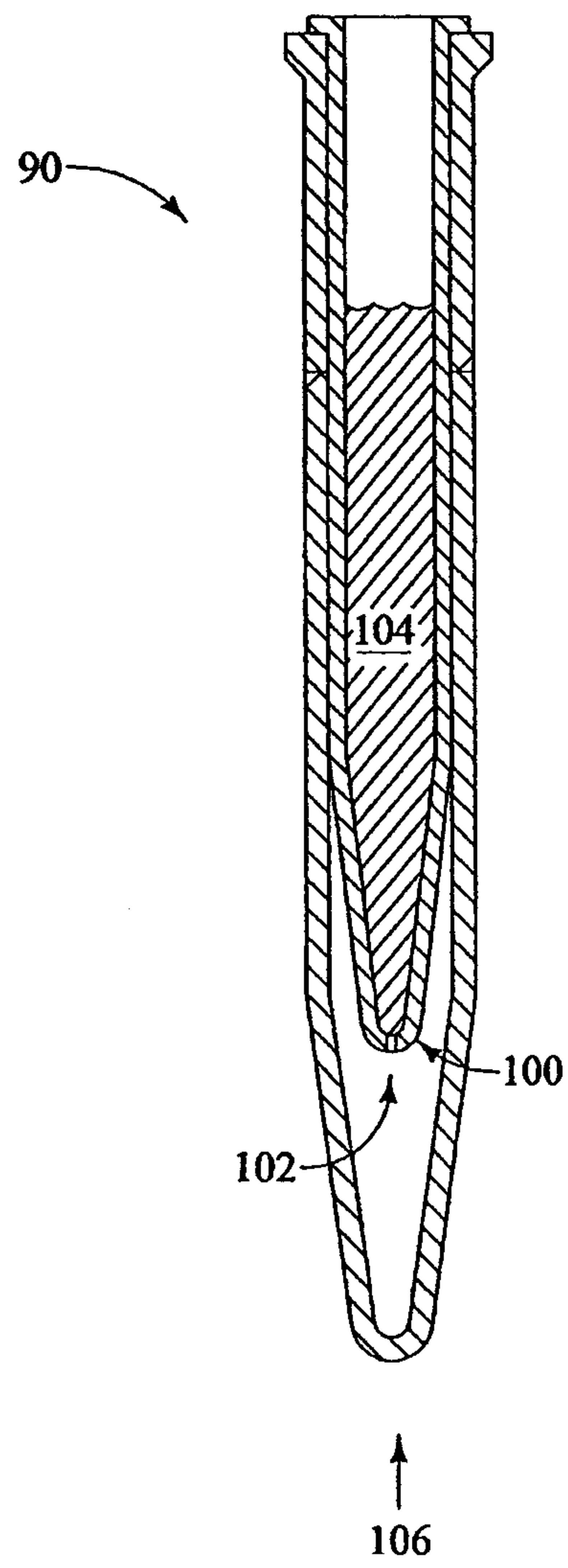


FIG. 1

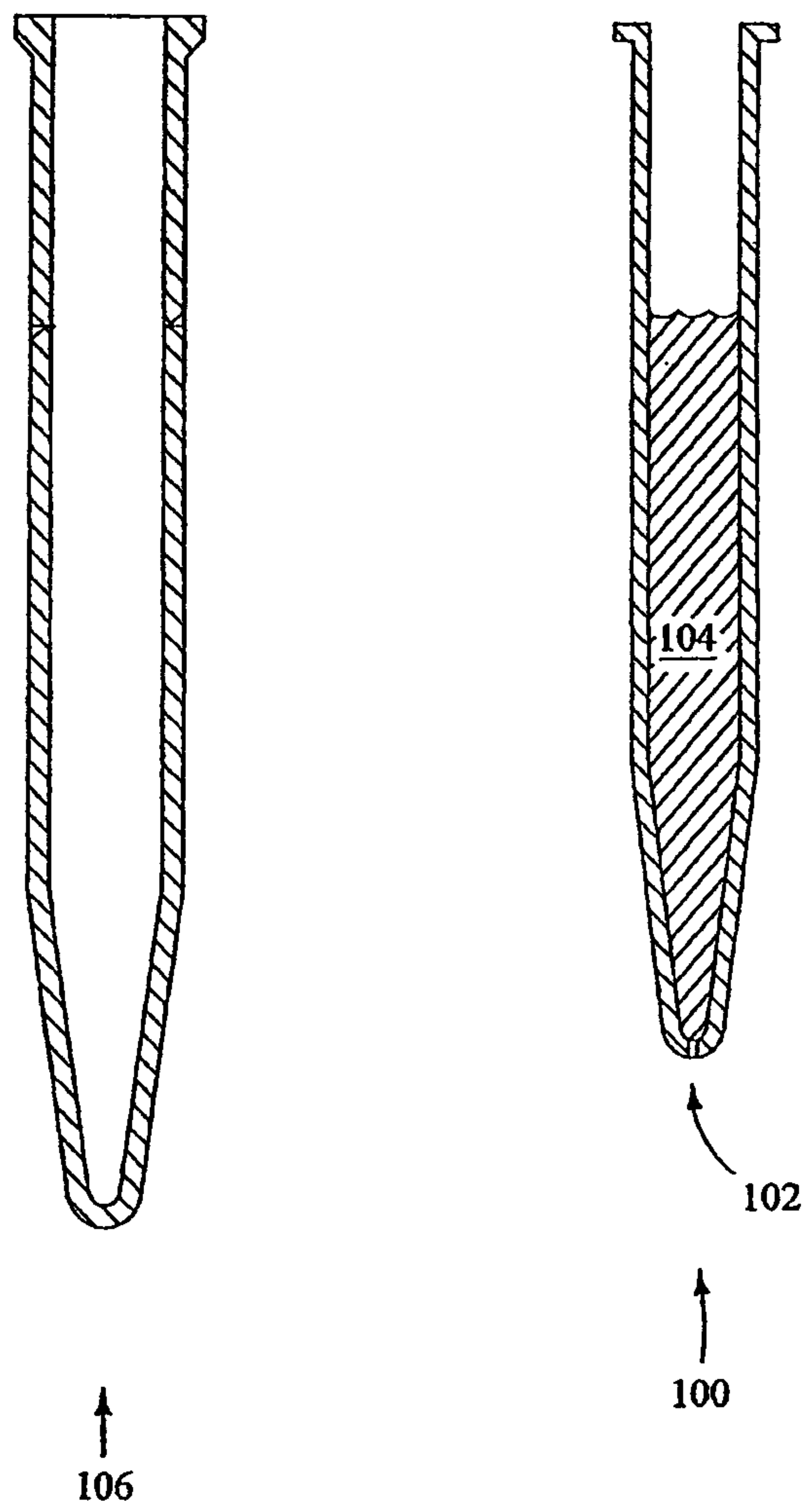


FIG. 2

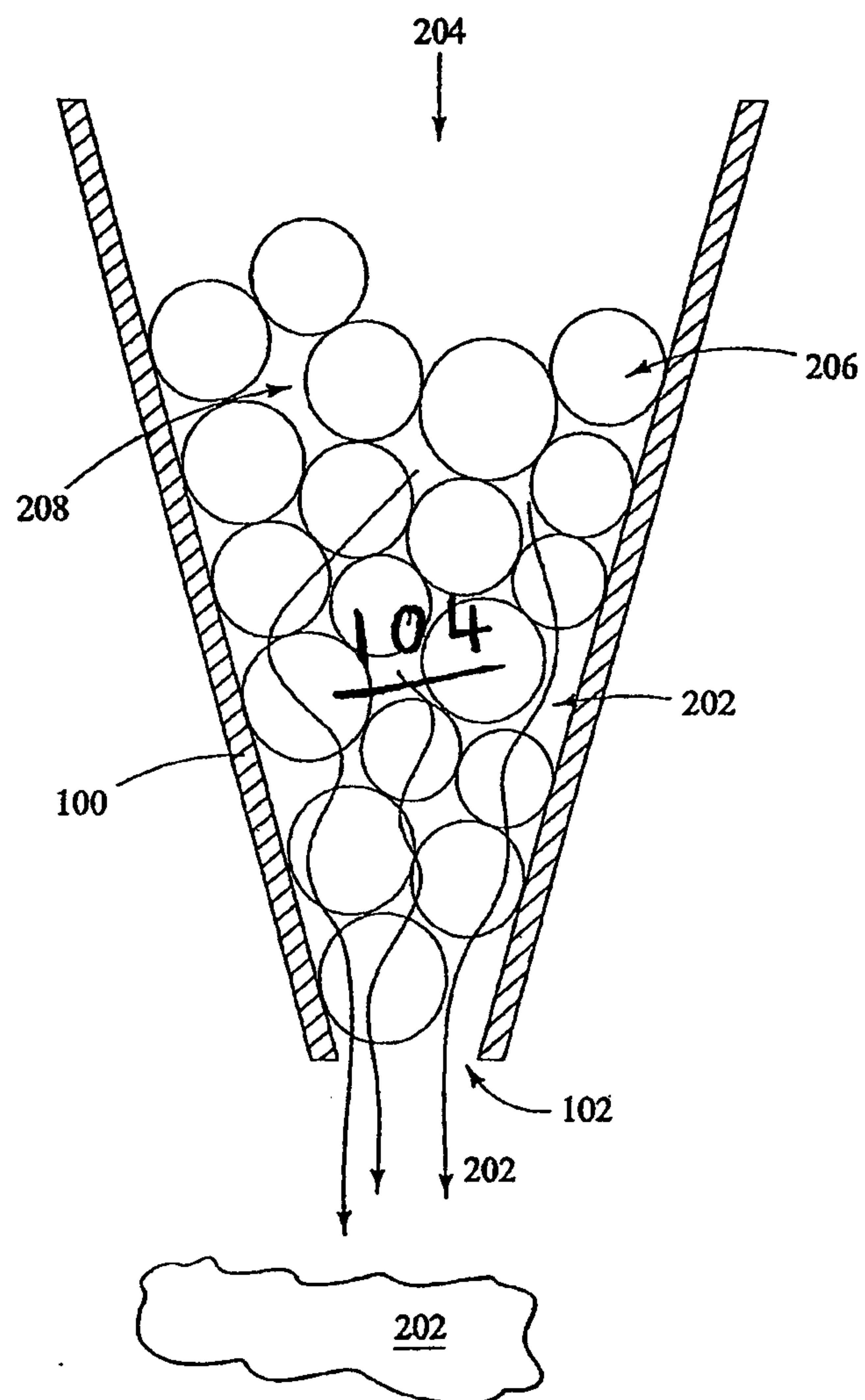
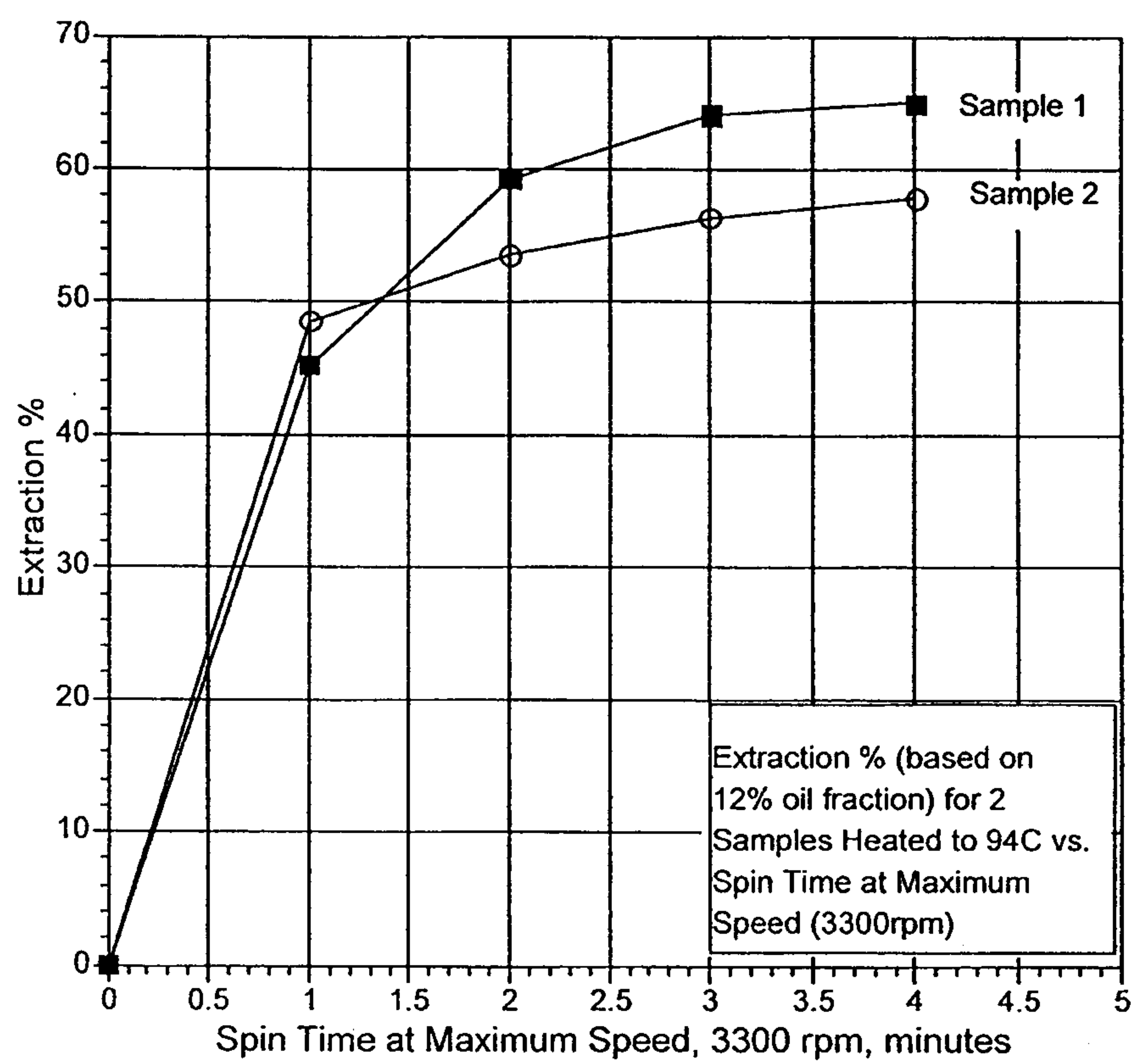
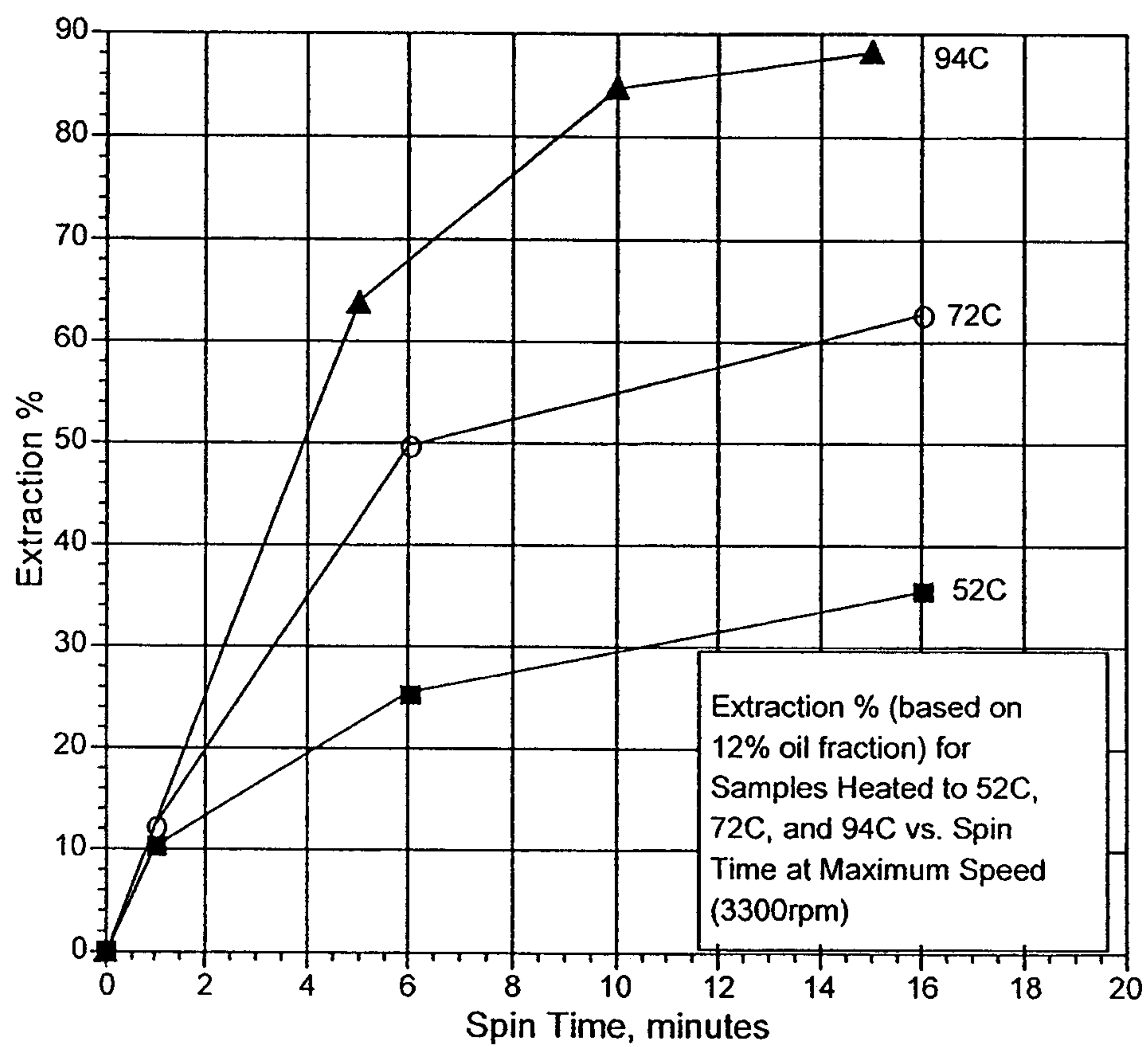
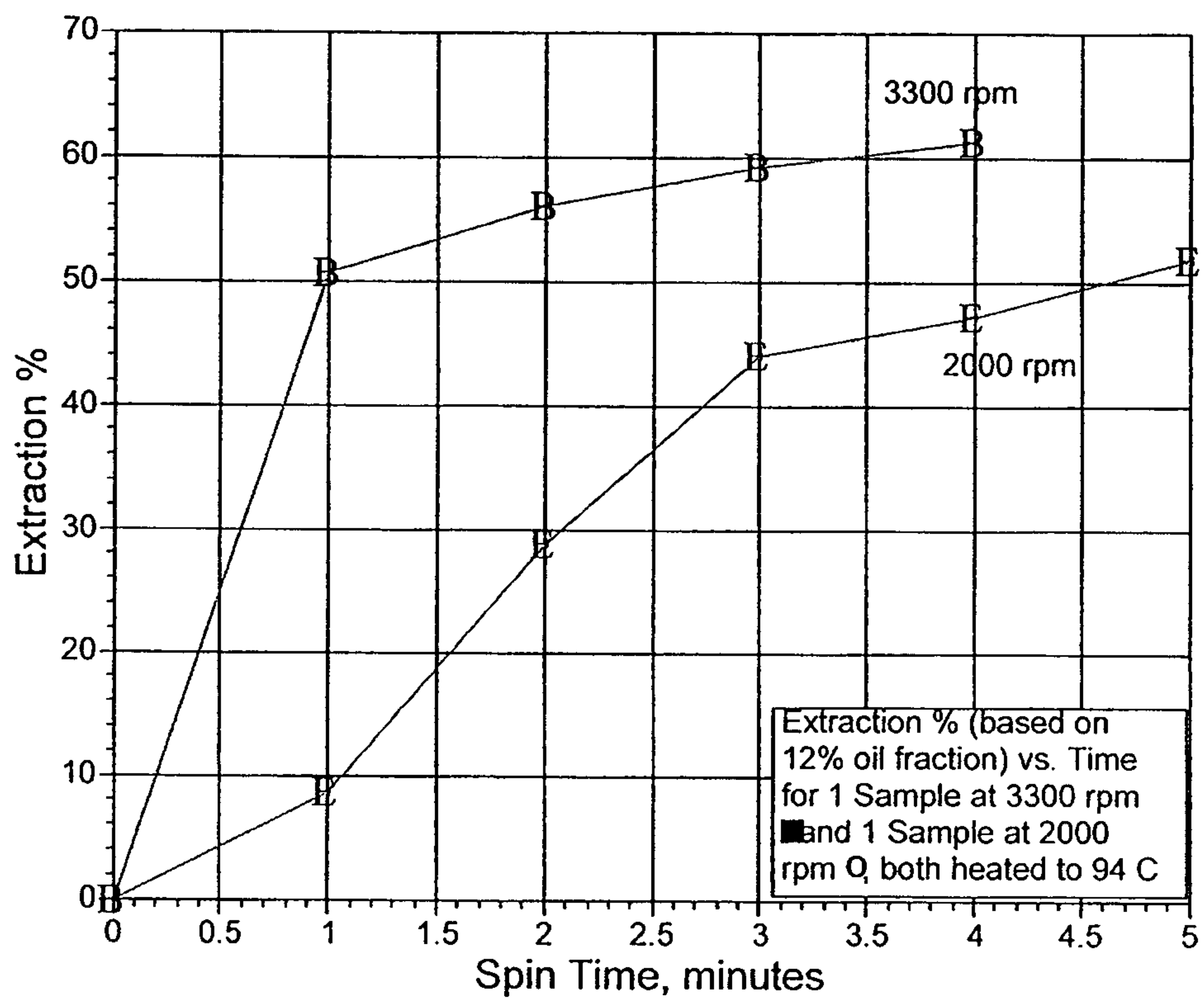


FIG. 3

**FIG. 4**

**FIG. 5**

**FIG. 6**

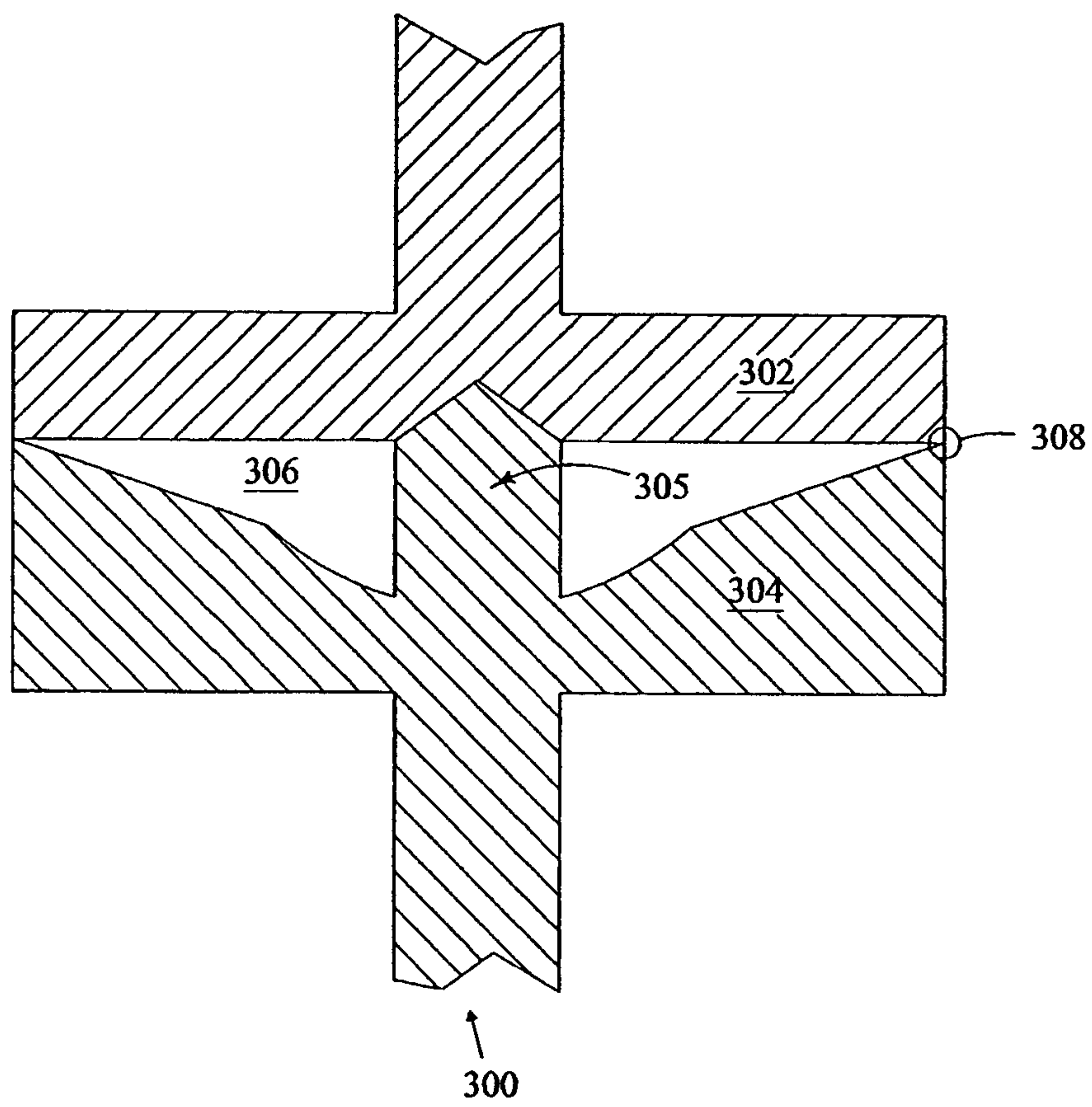


**FIG. 7**

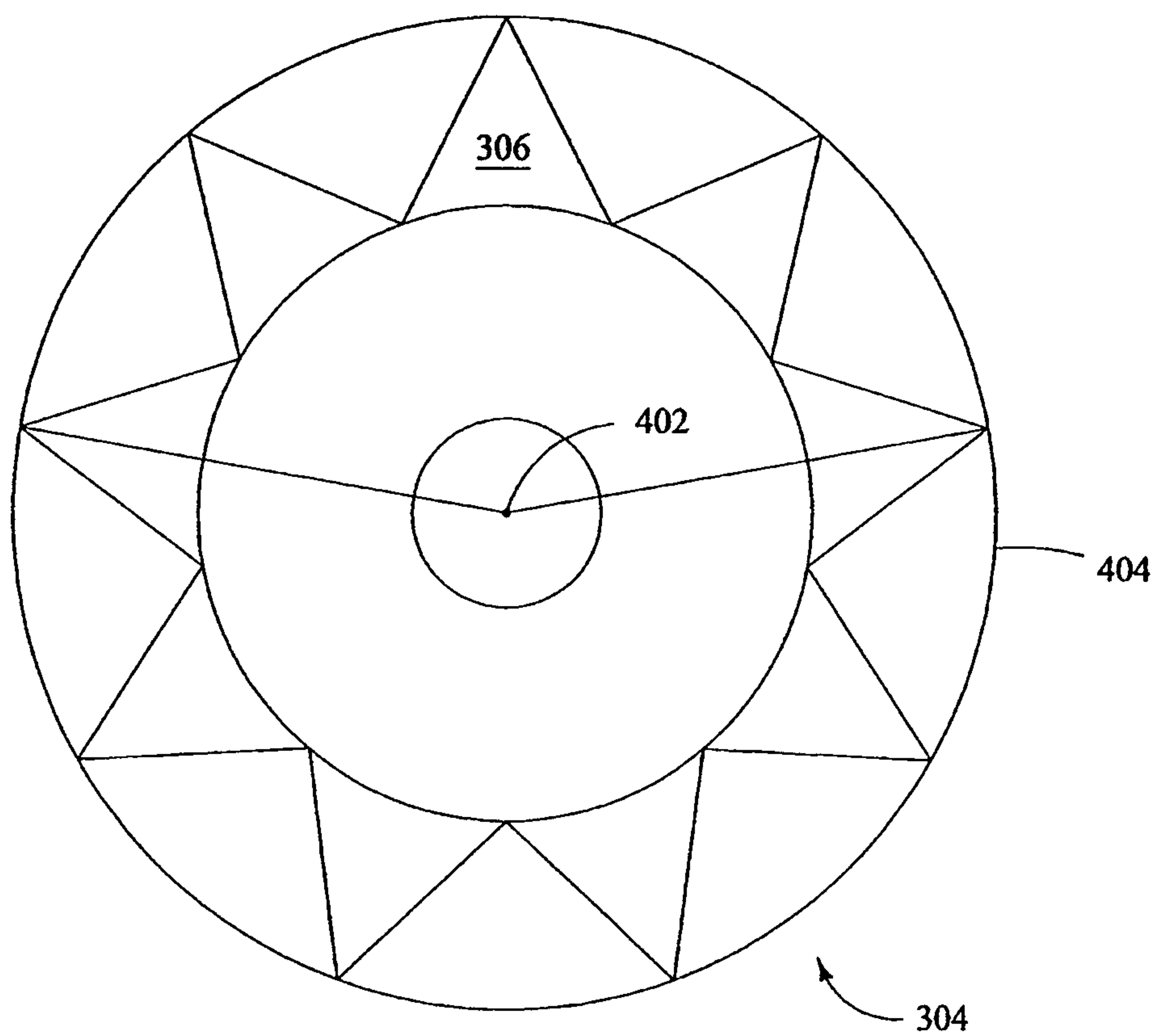


**FIG. 8**

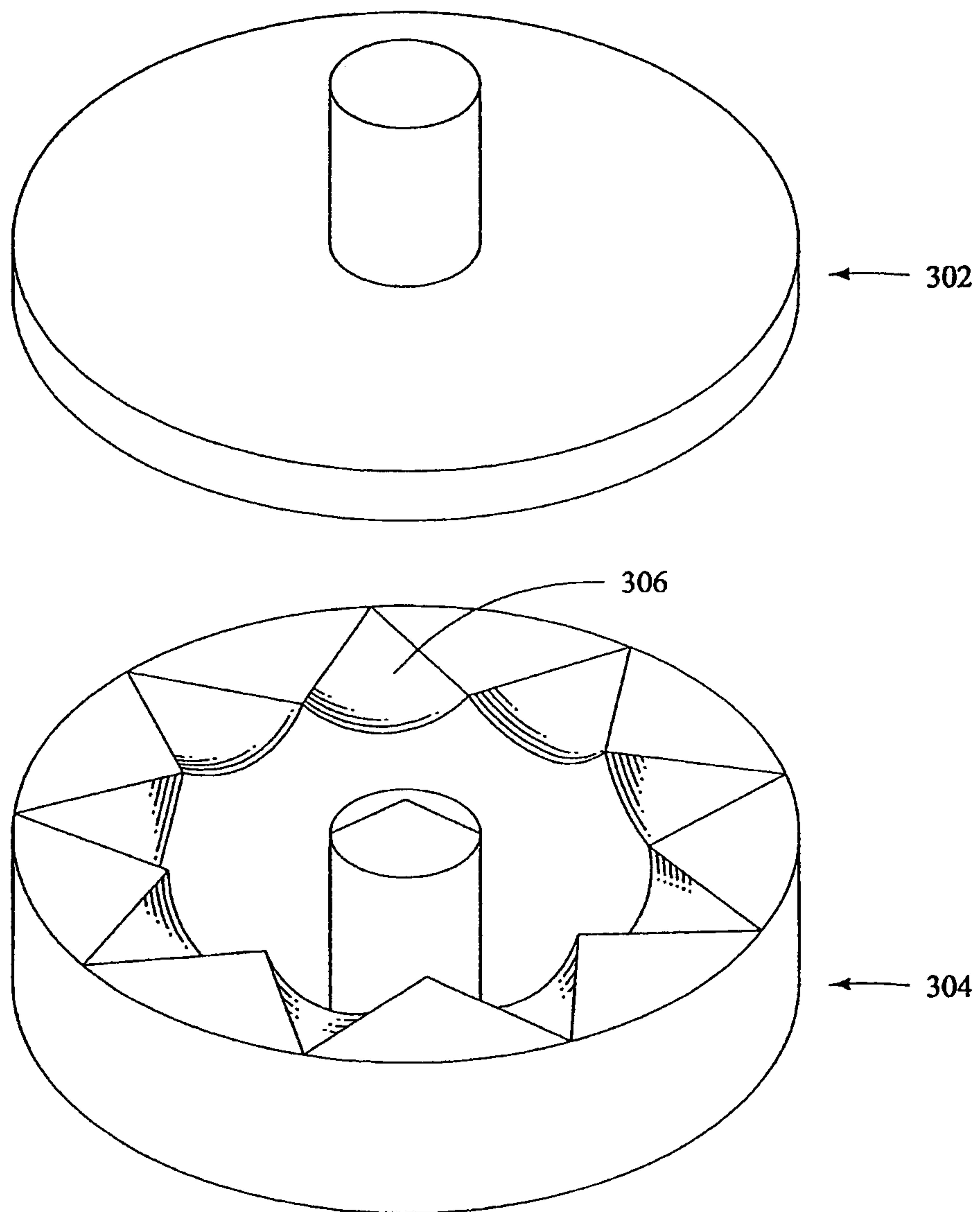


**FIG. 9**

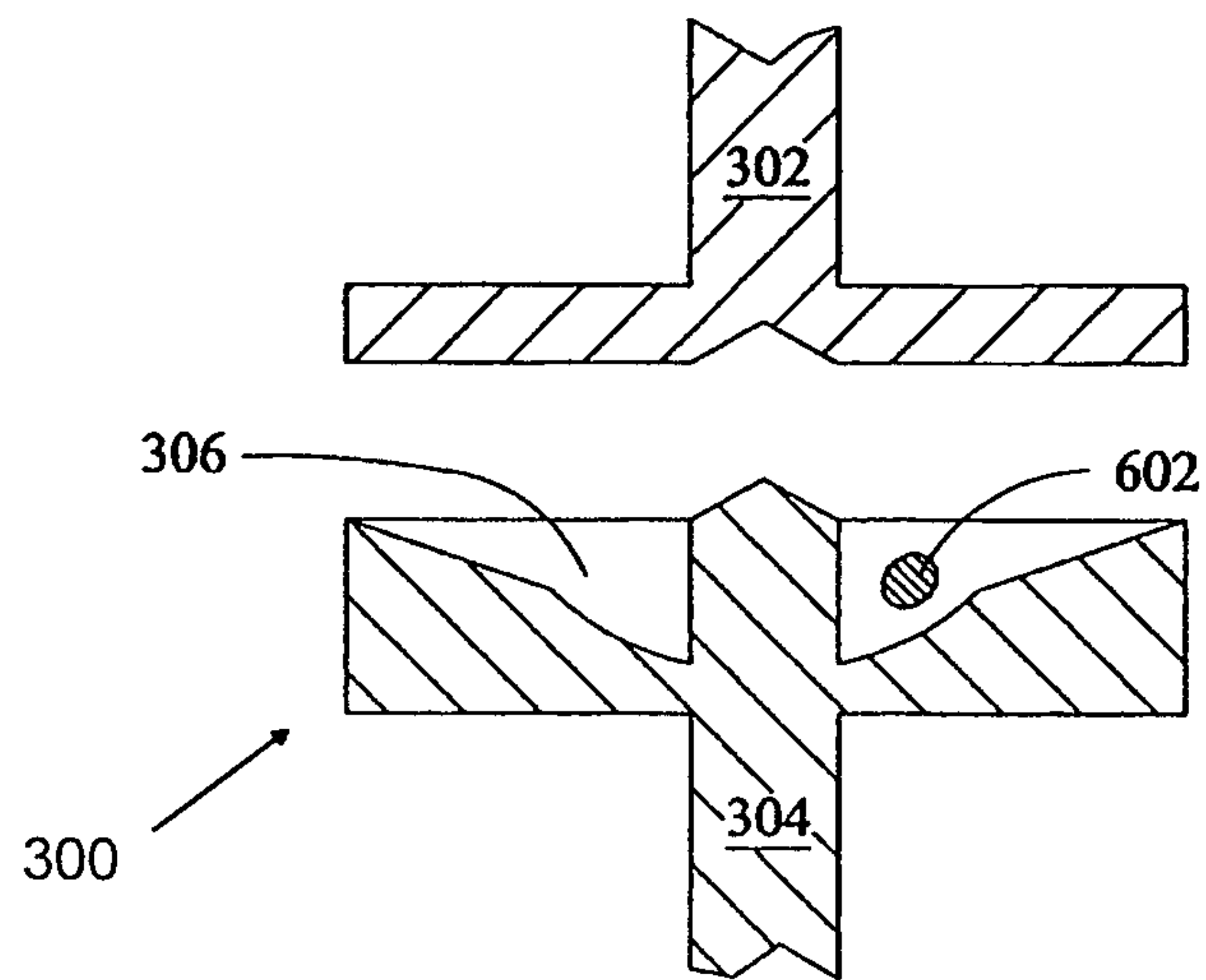


**FIG. 10**

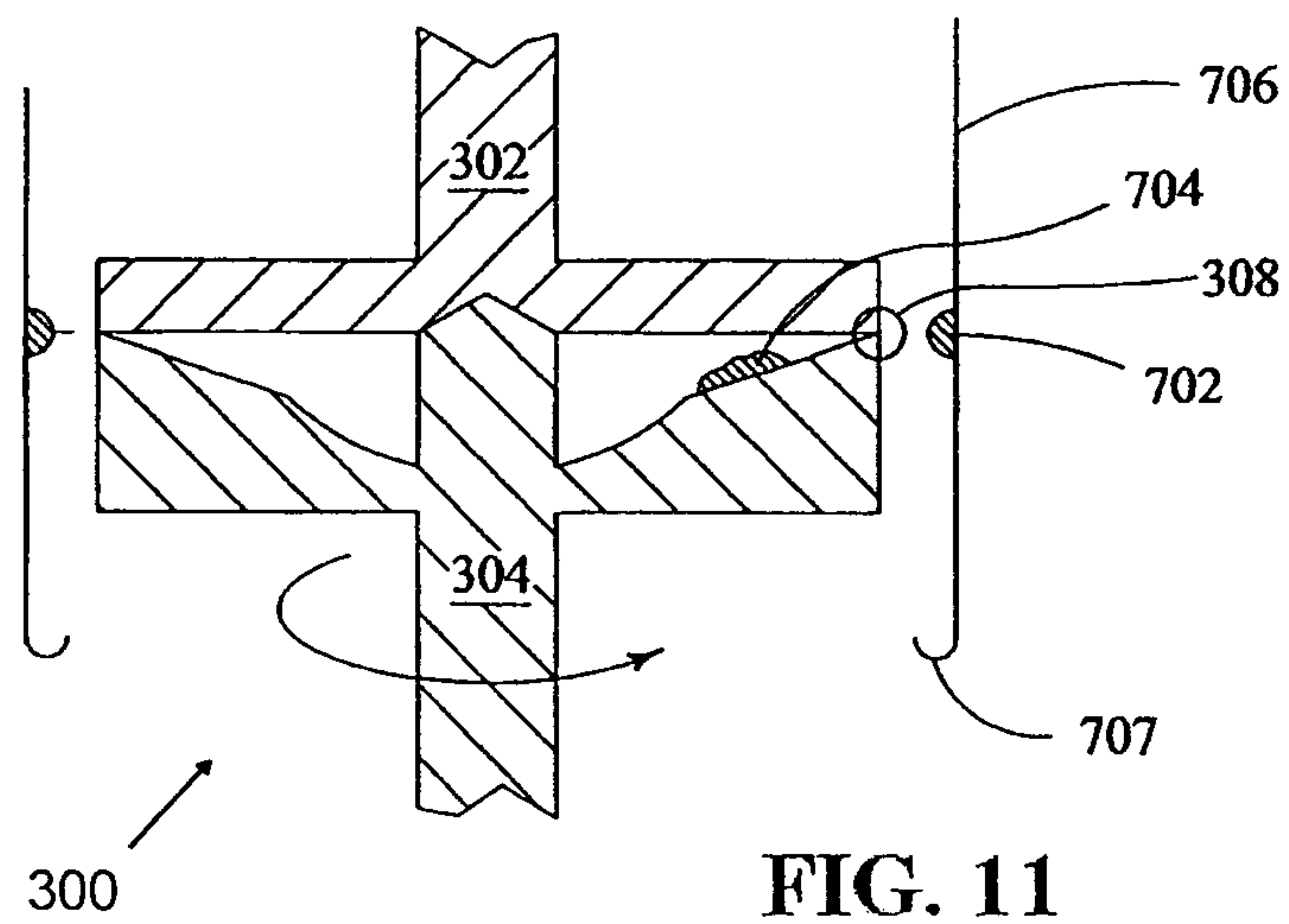


**FIG. 11**

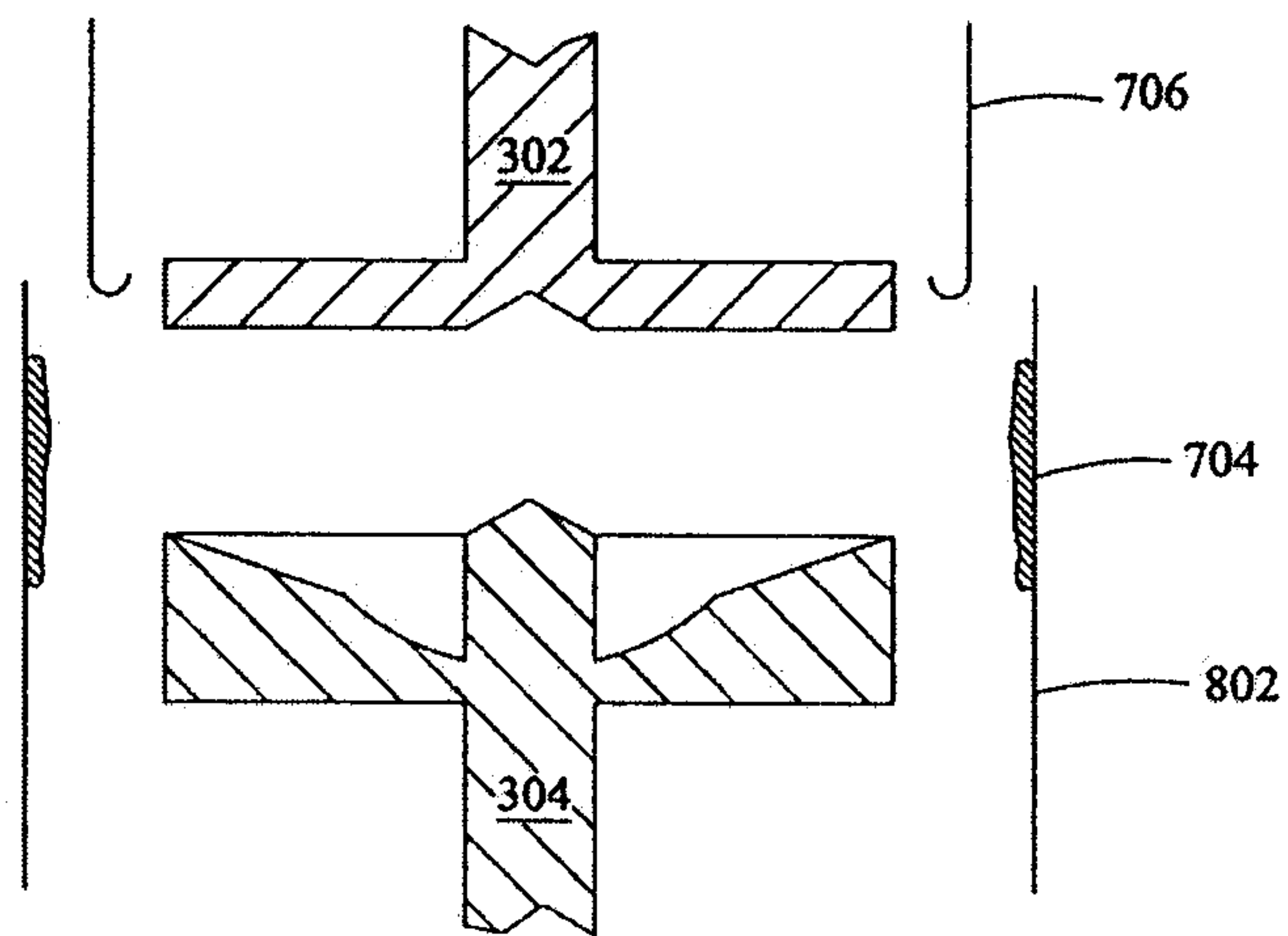


FIG. 12

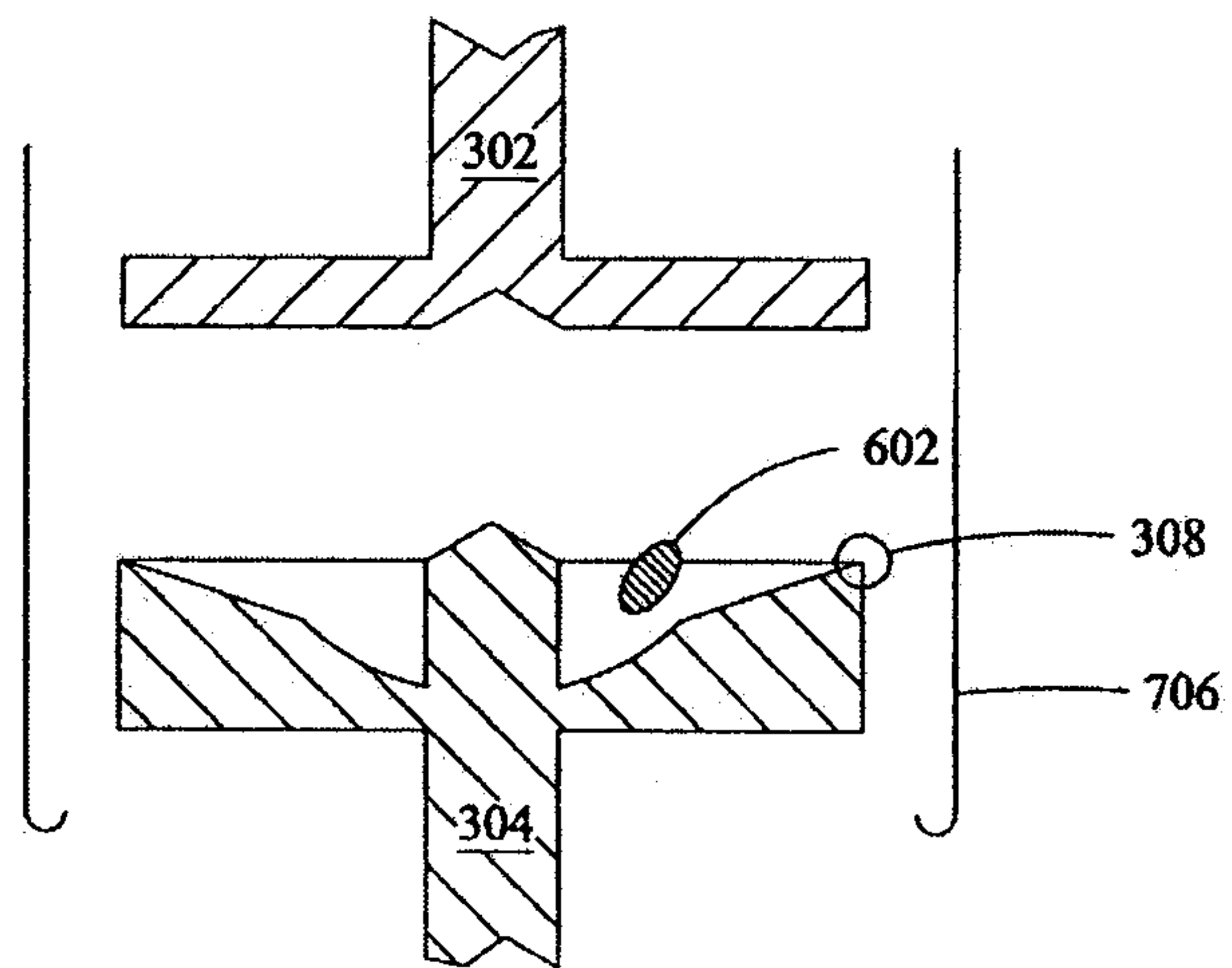


FIG. 13

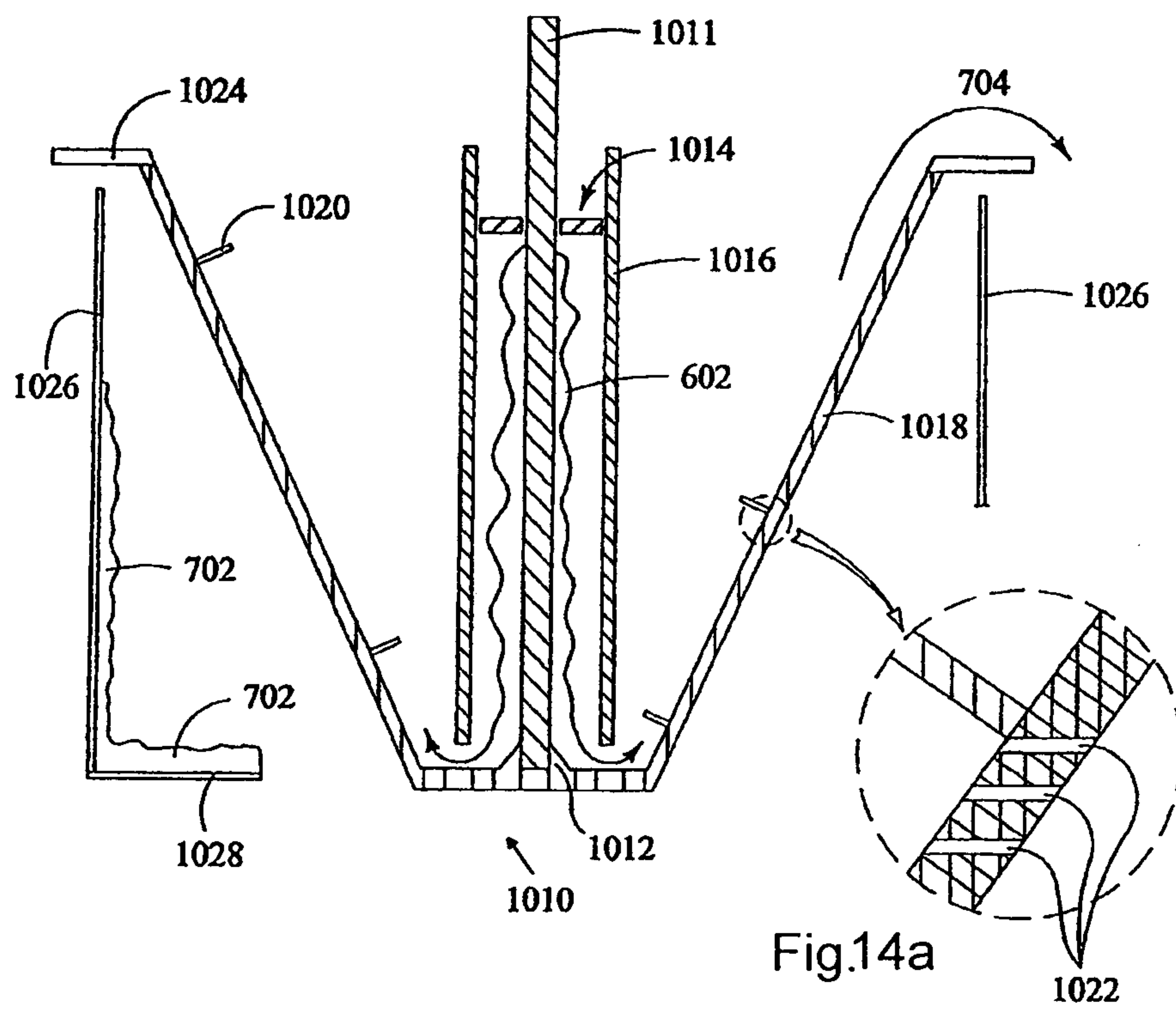


FIG. 14

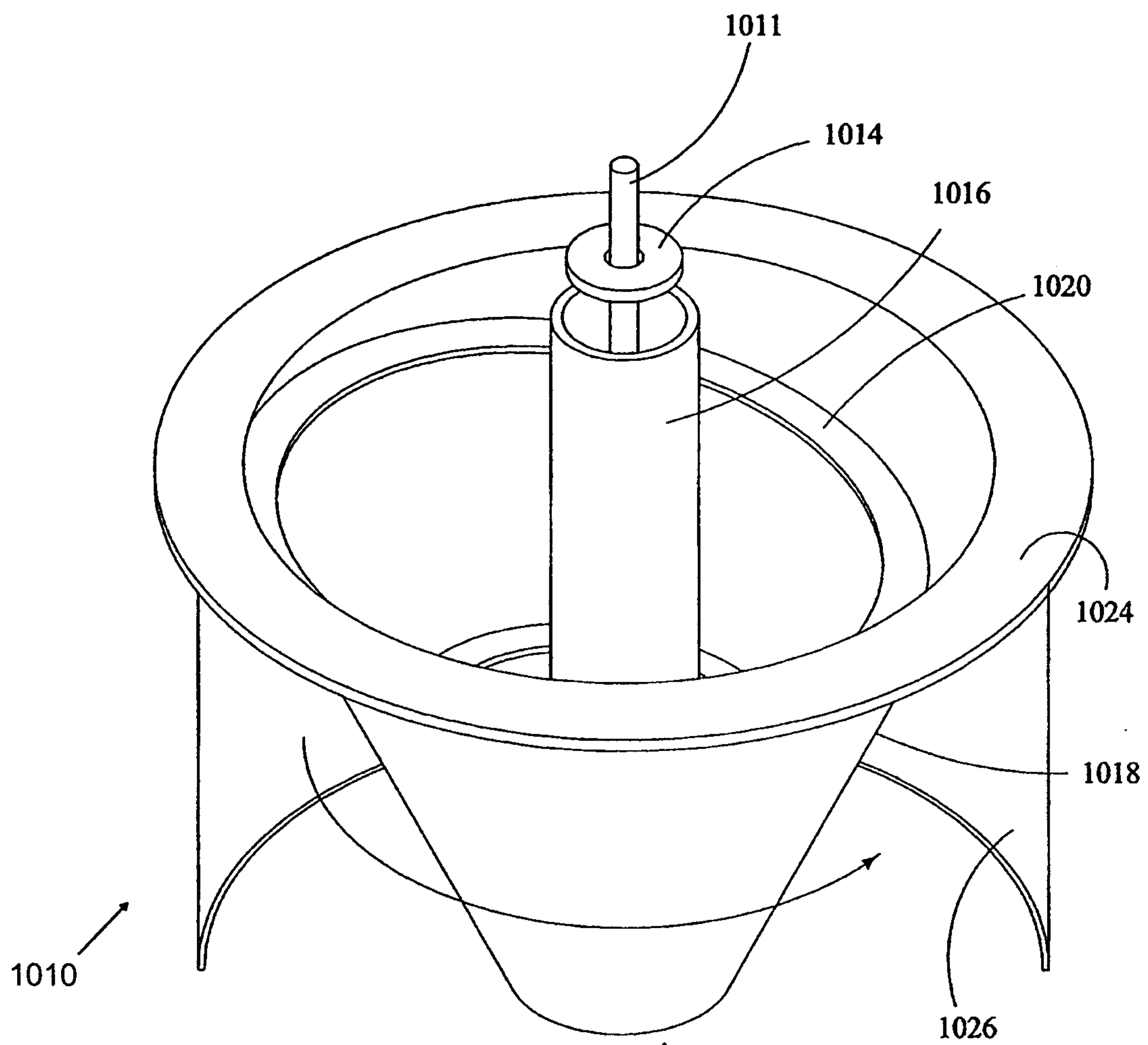


FIG. 15

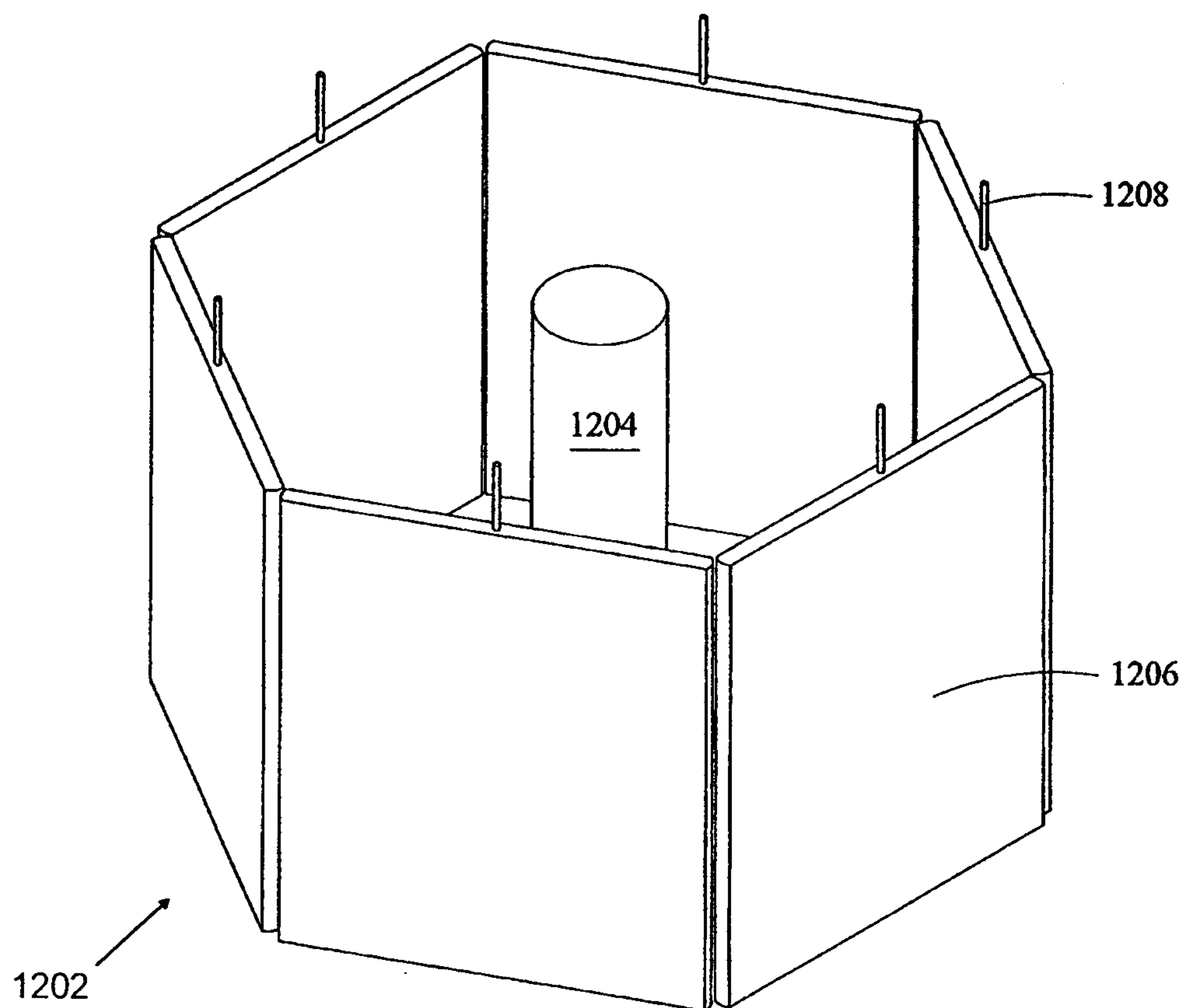


**FIG. 16**

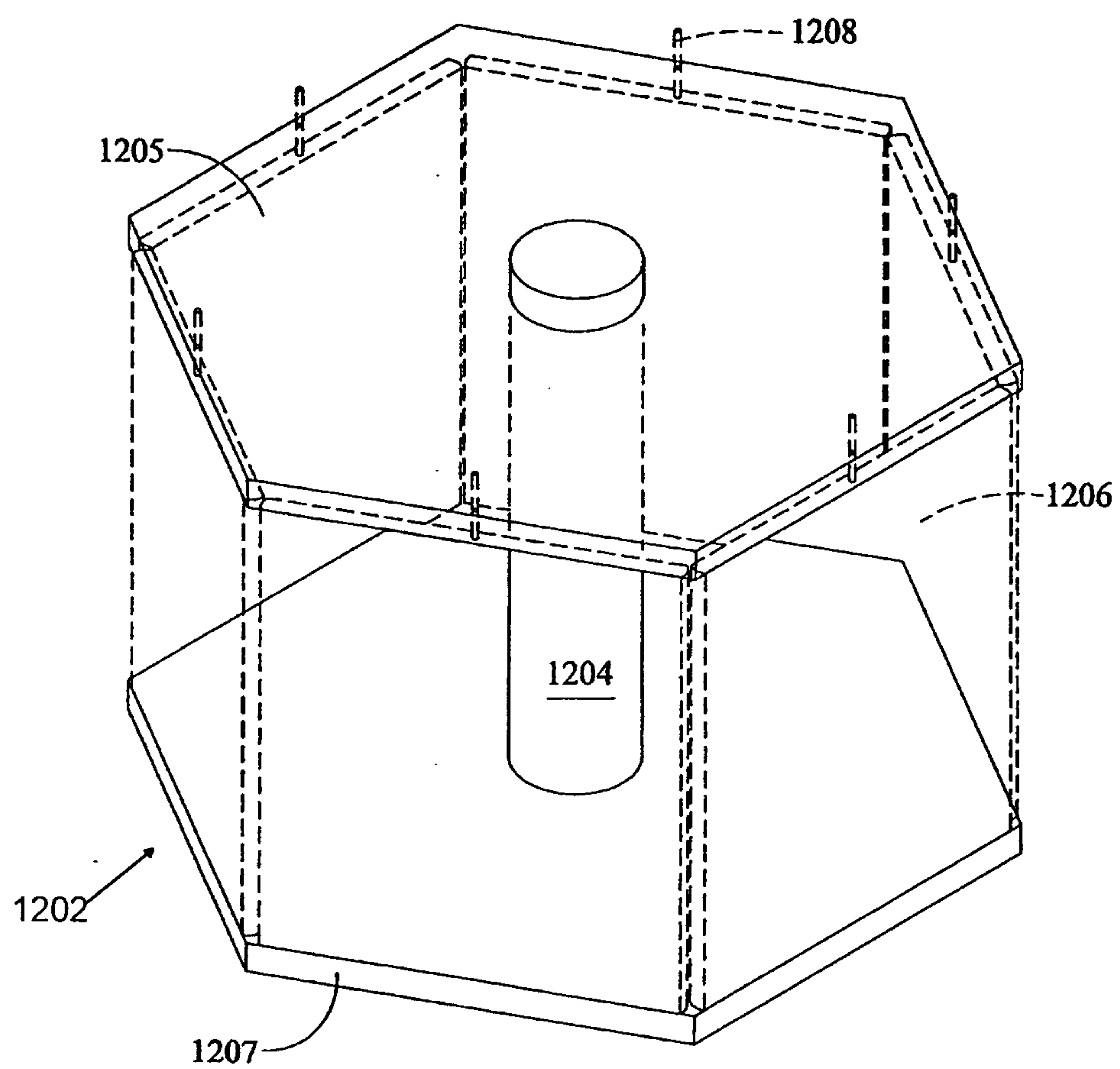


FIG. 17

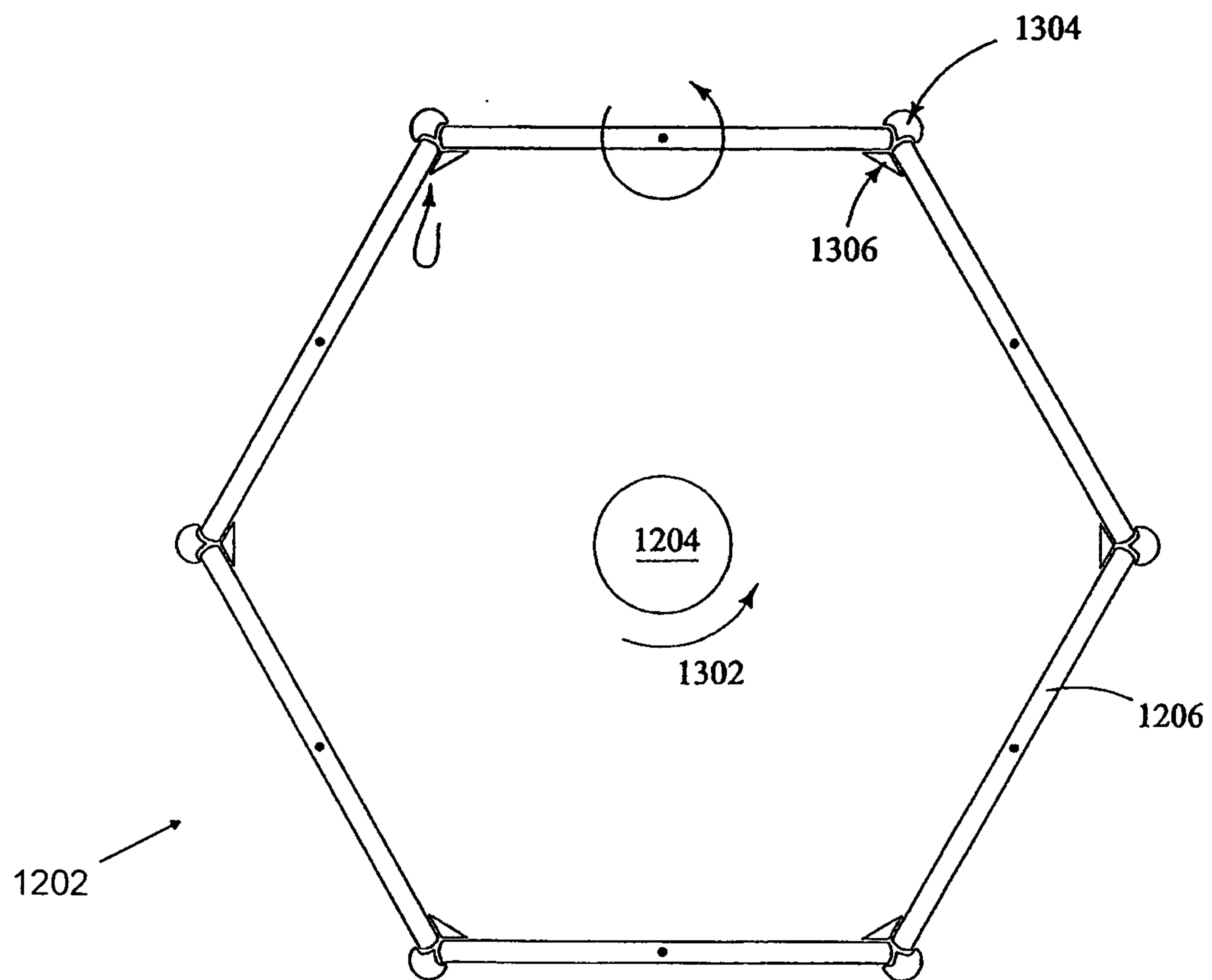


**FIG. 18**

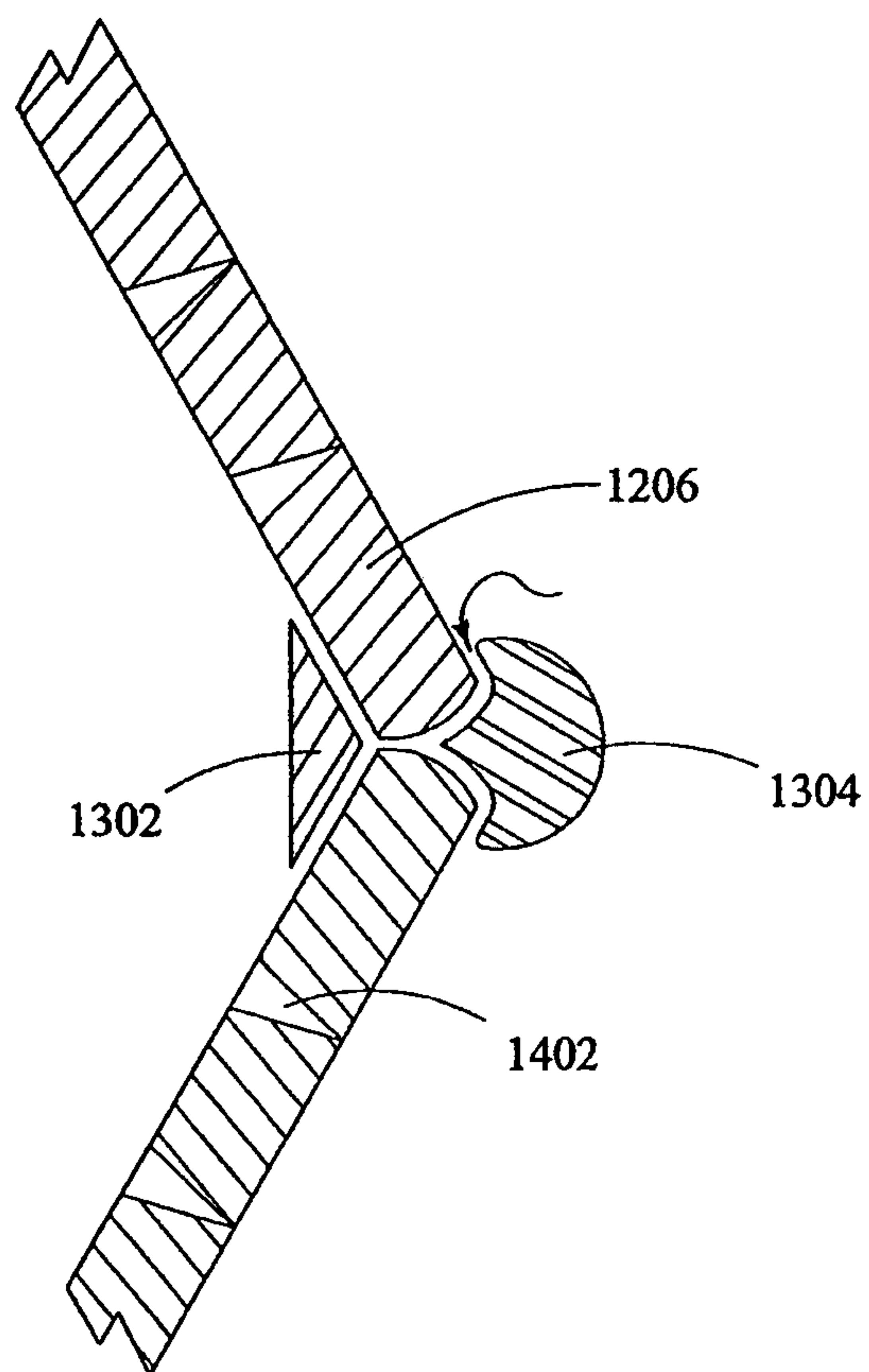


**FIG. 19**

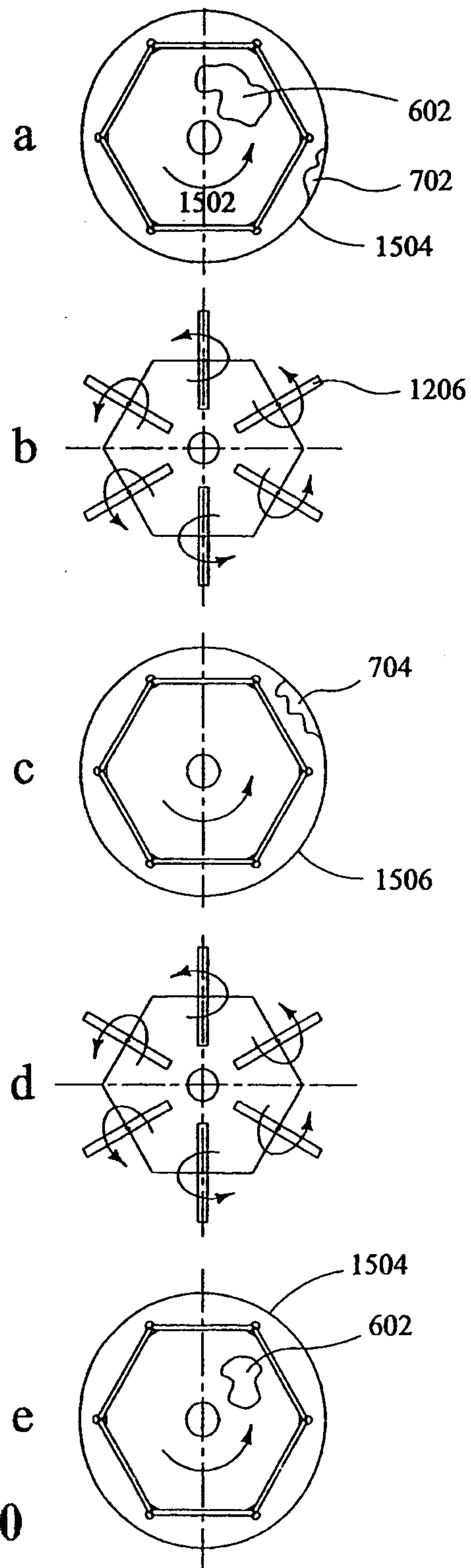


**FIG. 20**

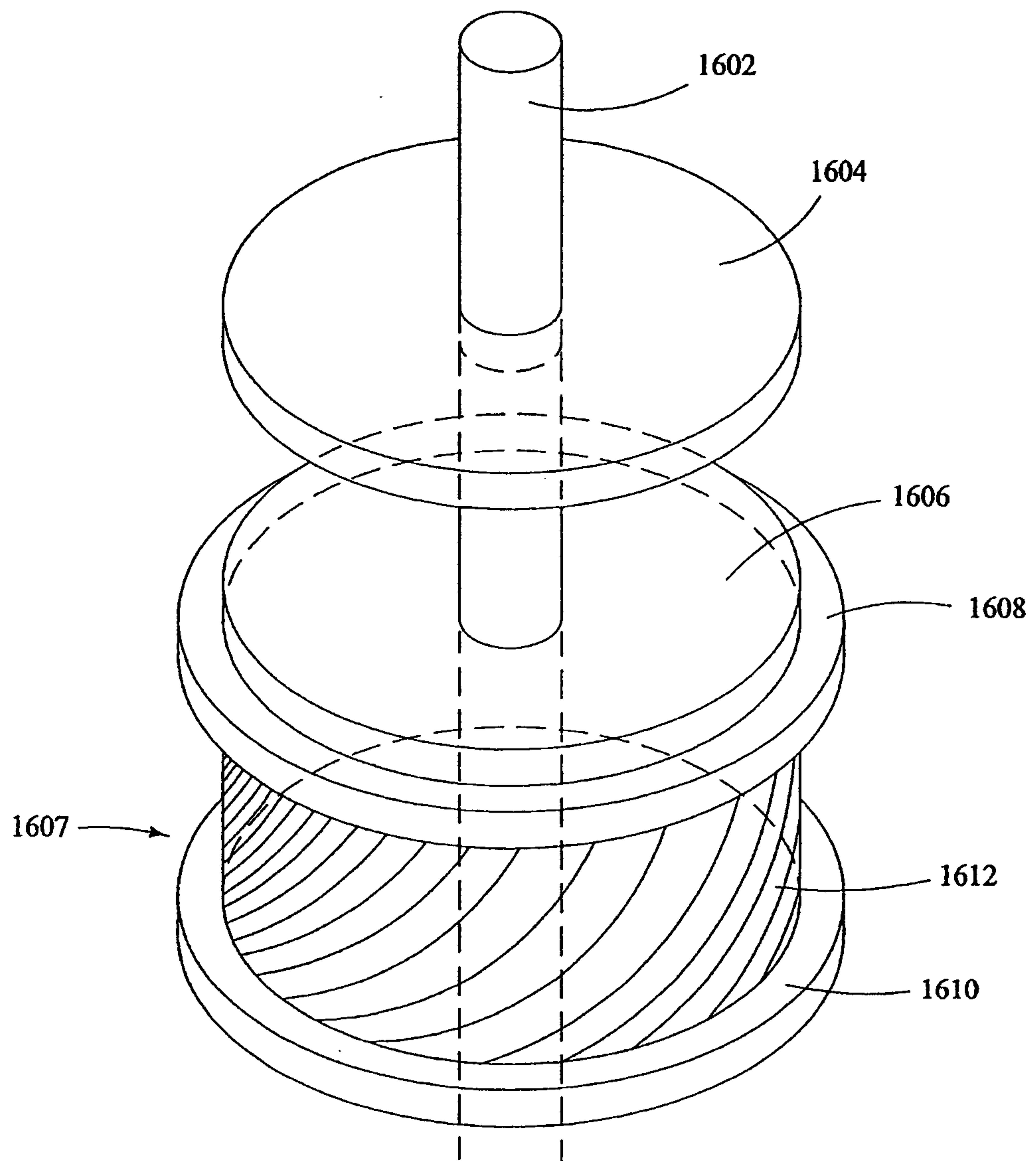


**FIG. 21**

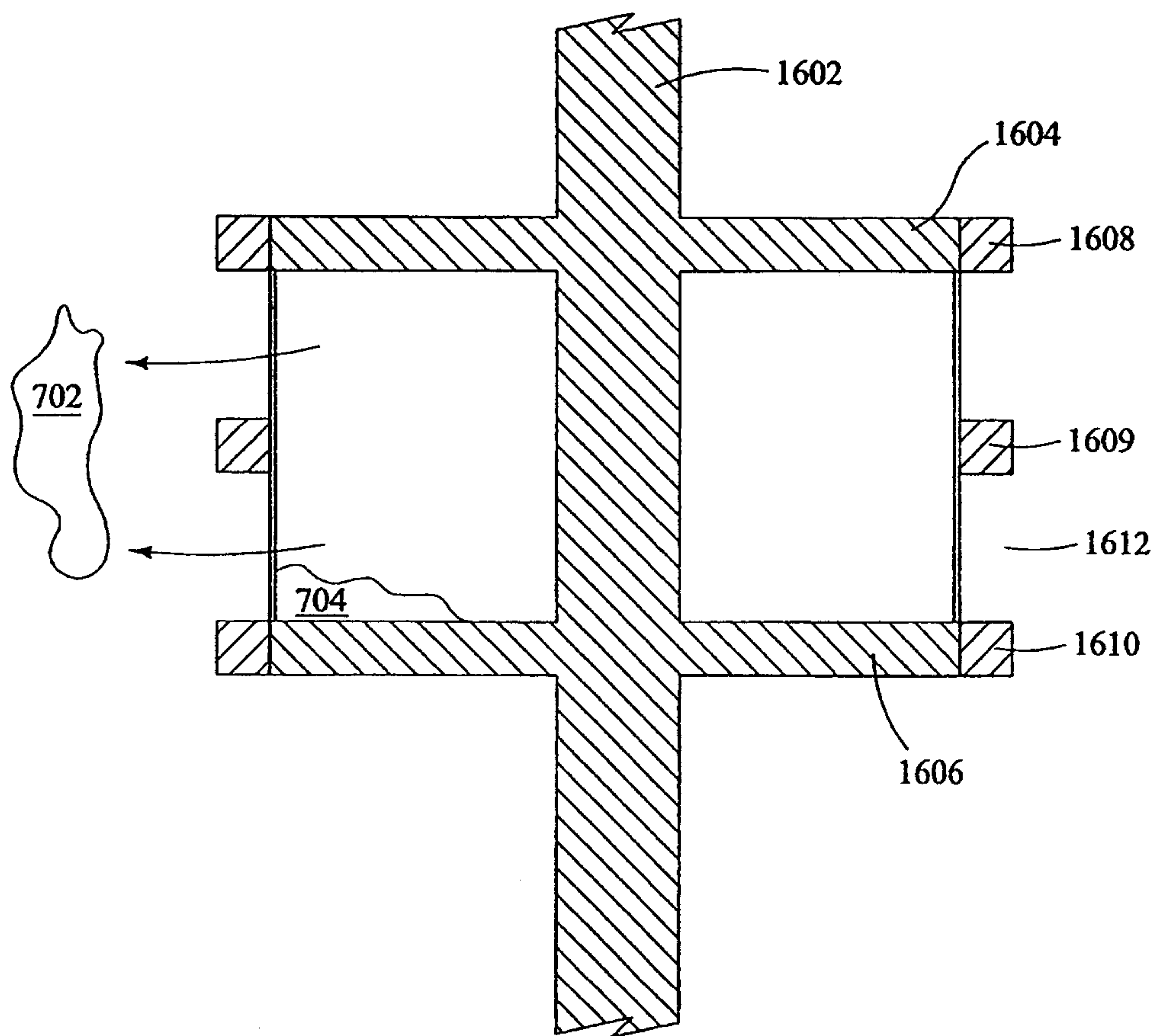


**FIG. 22**

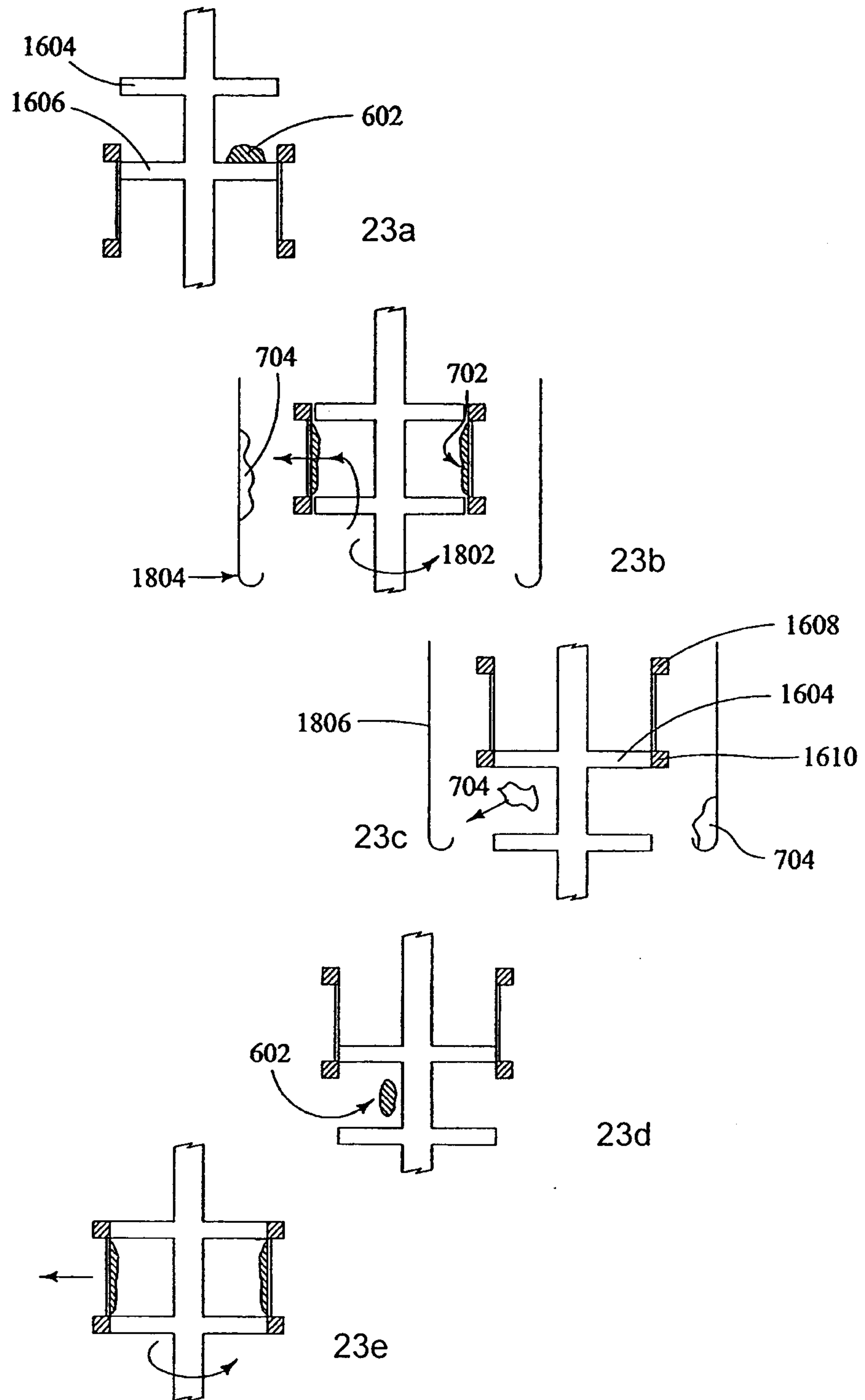


FIG. 23

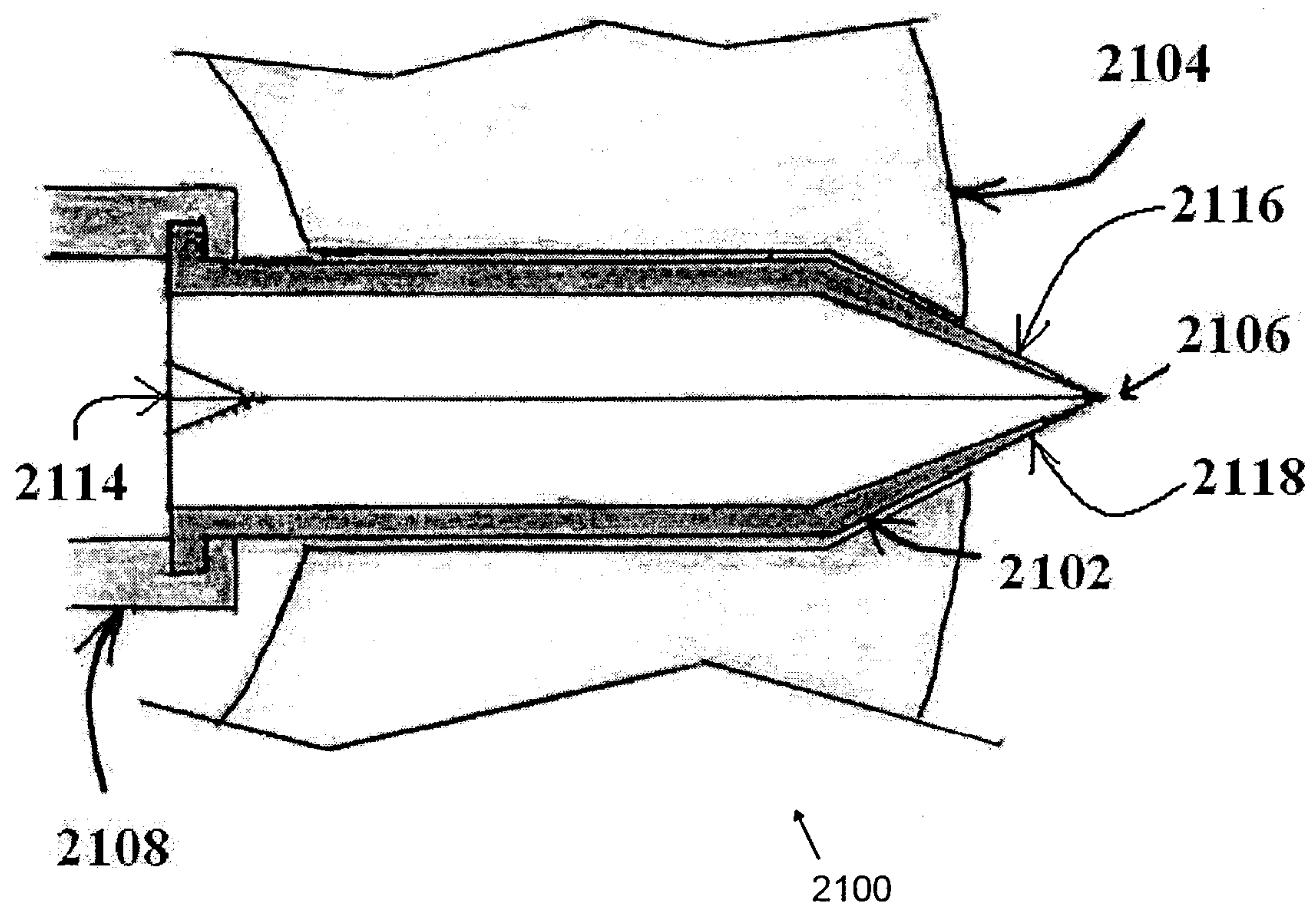


FIG. 24

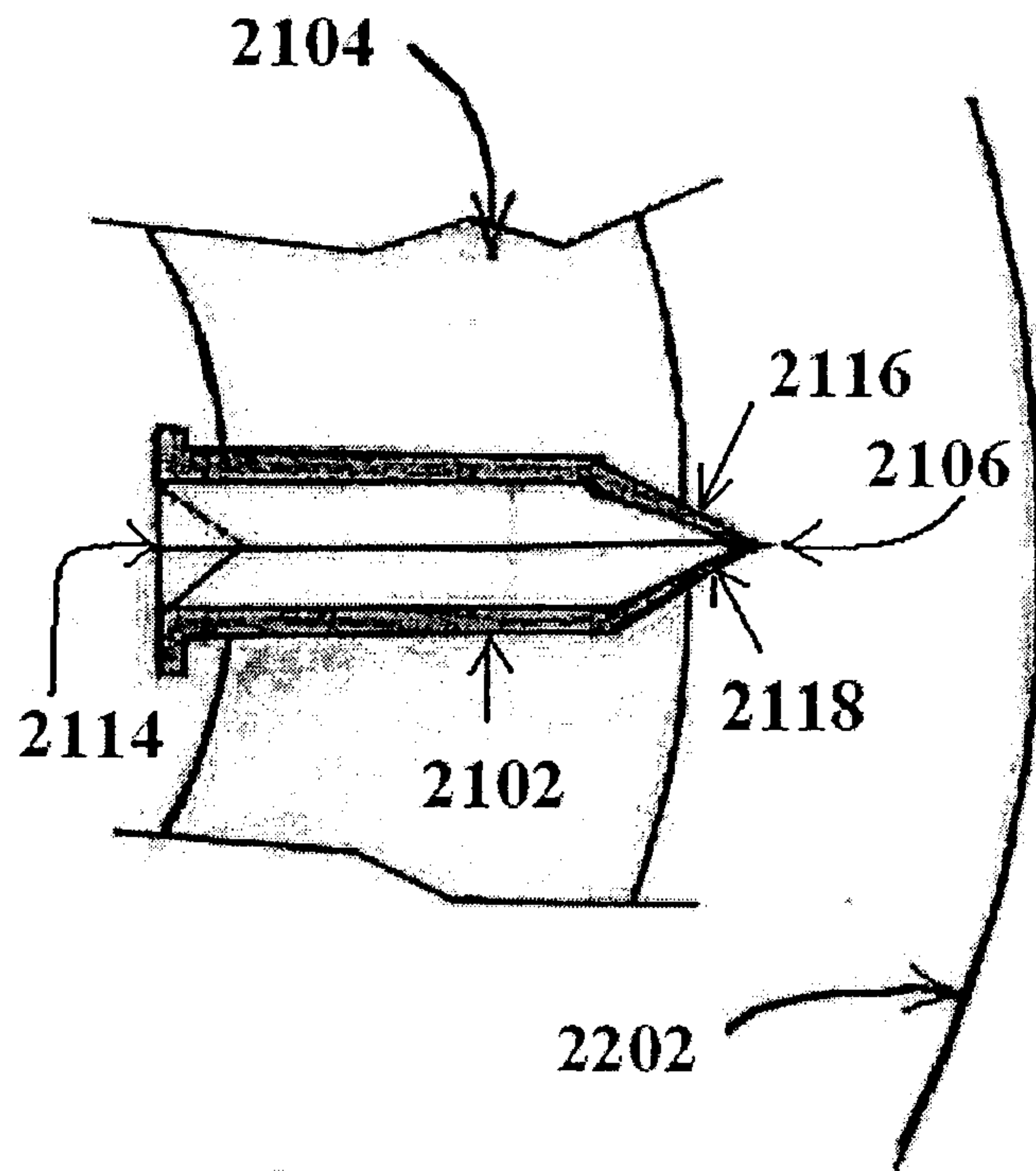


FIG. 25

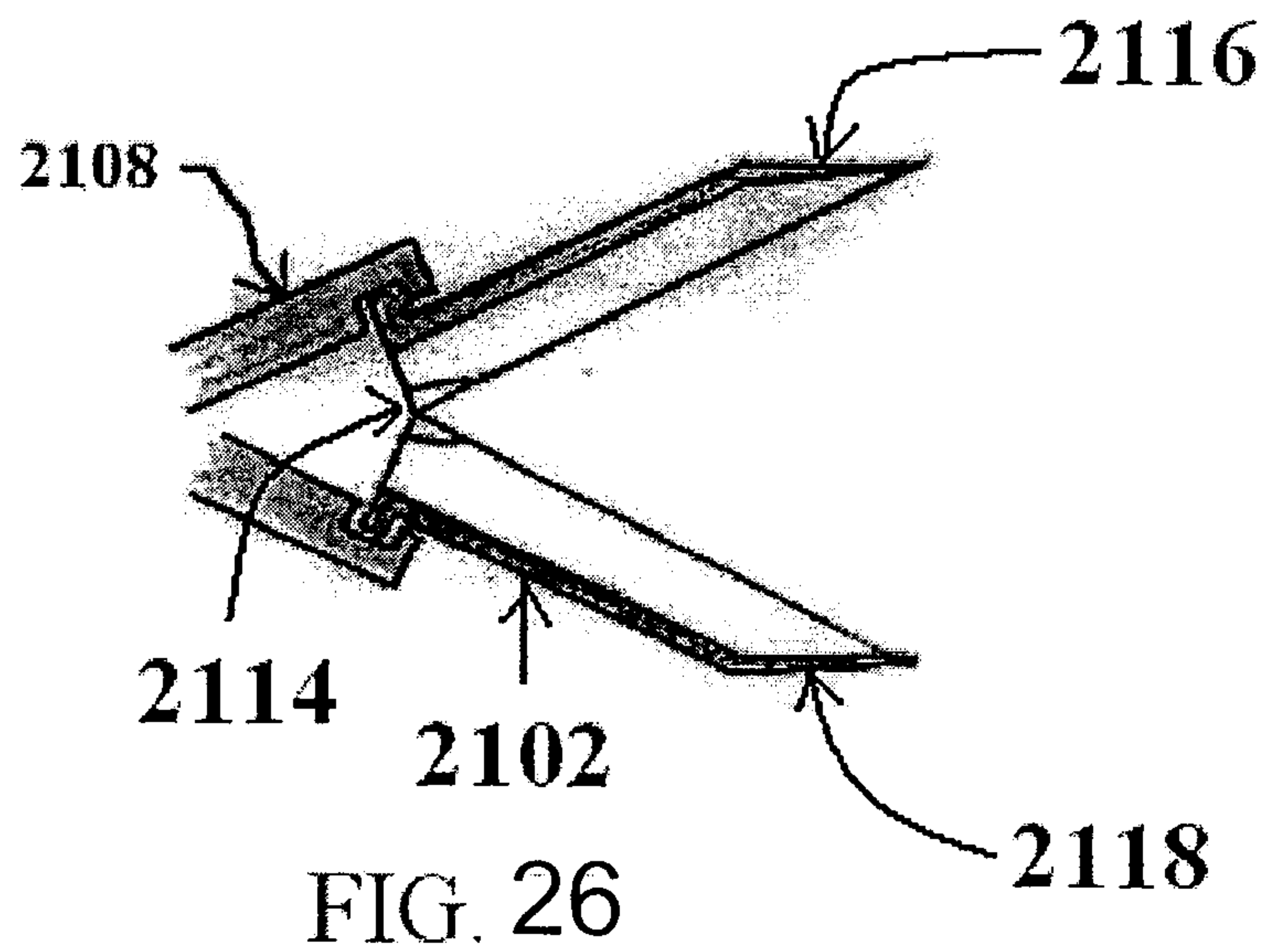


FIG. 26

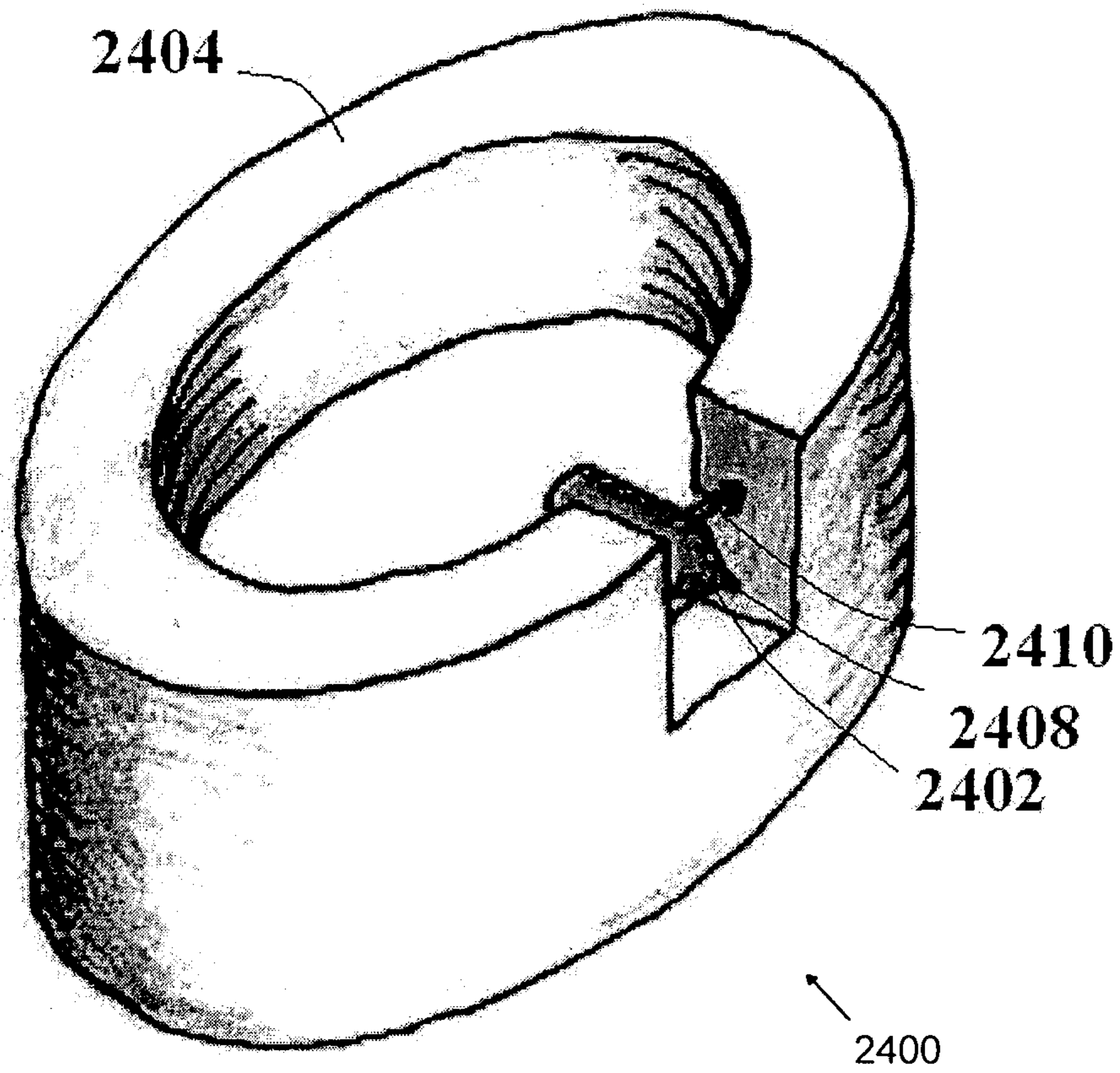


FIG. 27

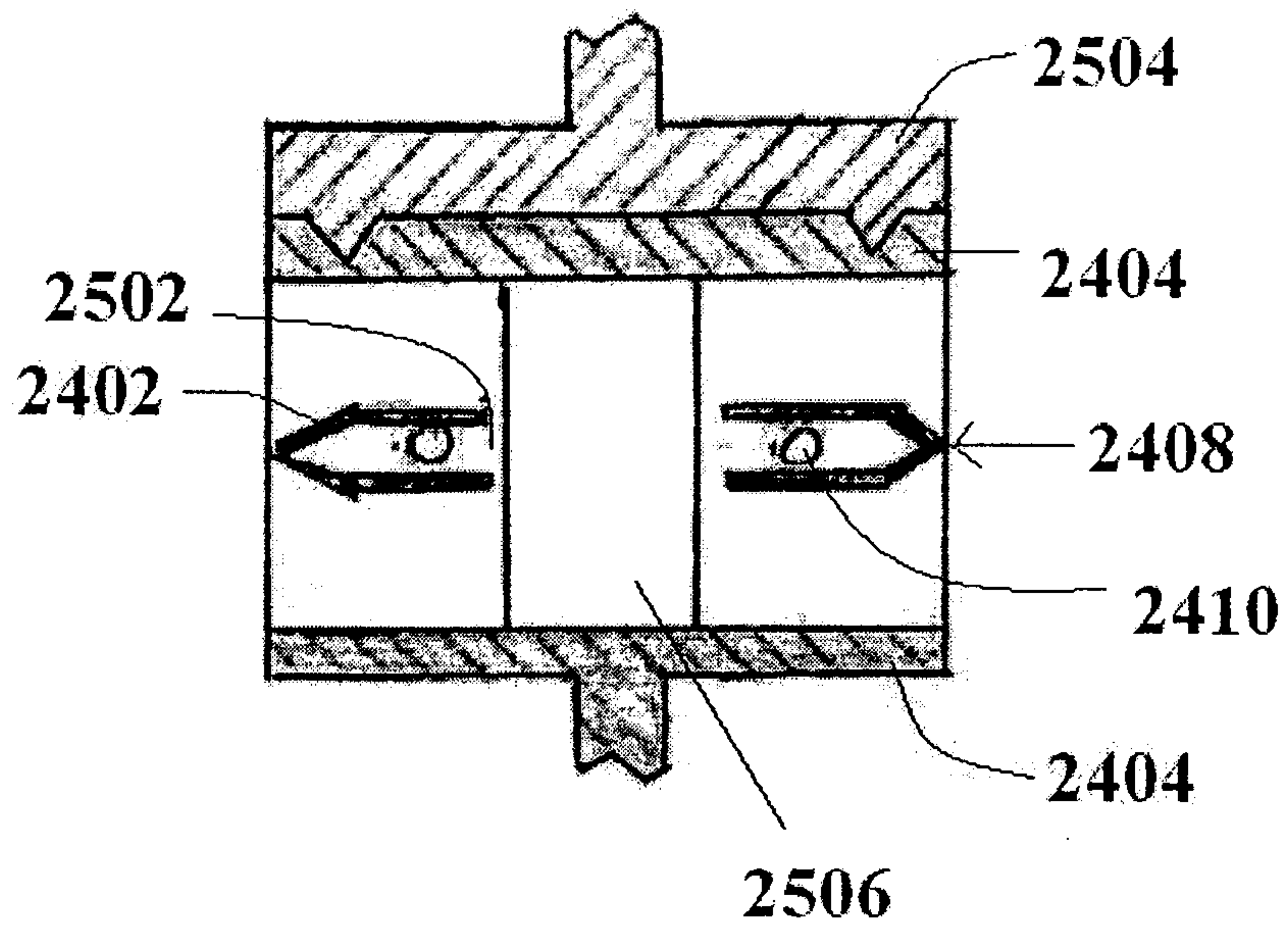


FIG. 28

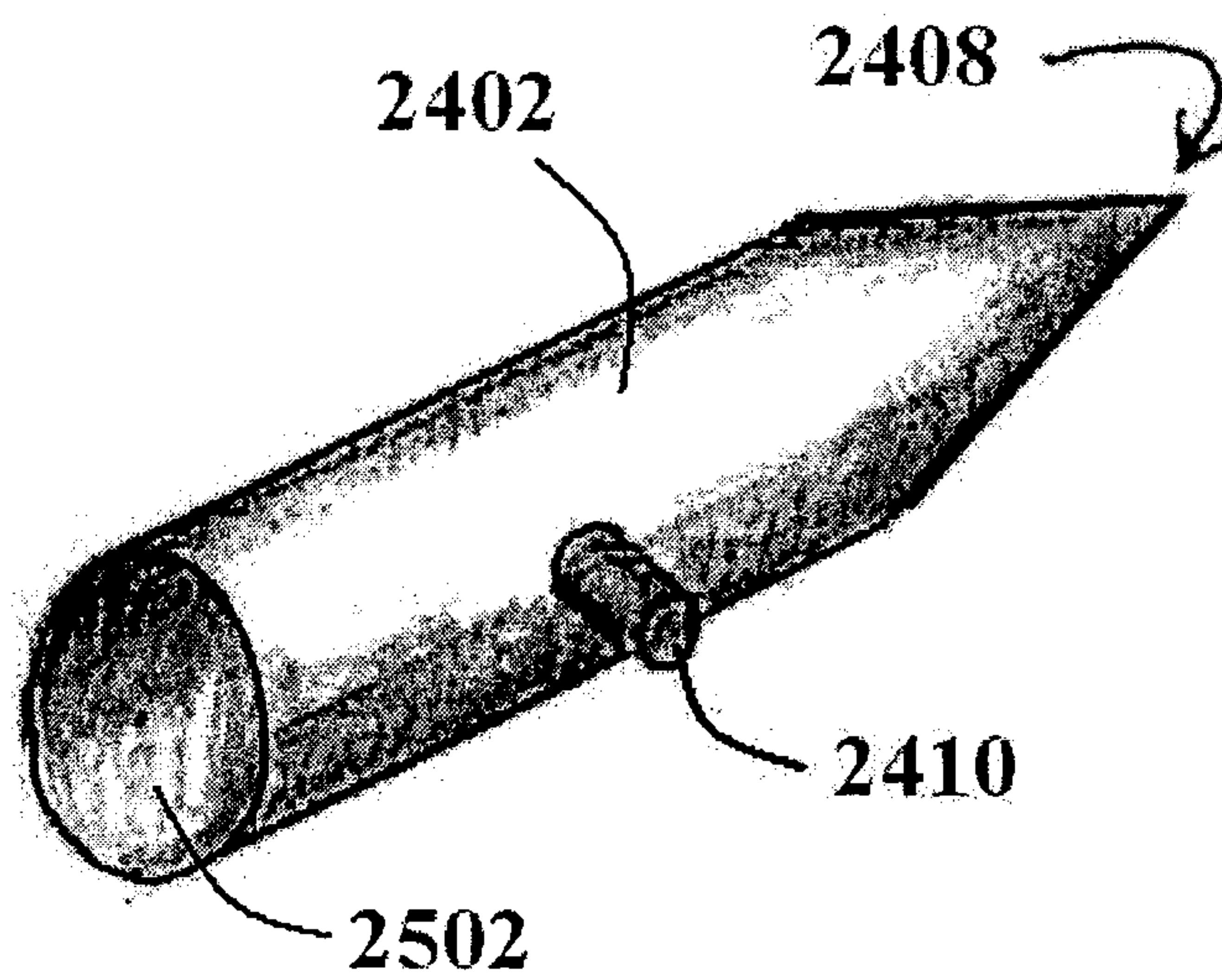


FIG. 29

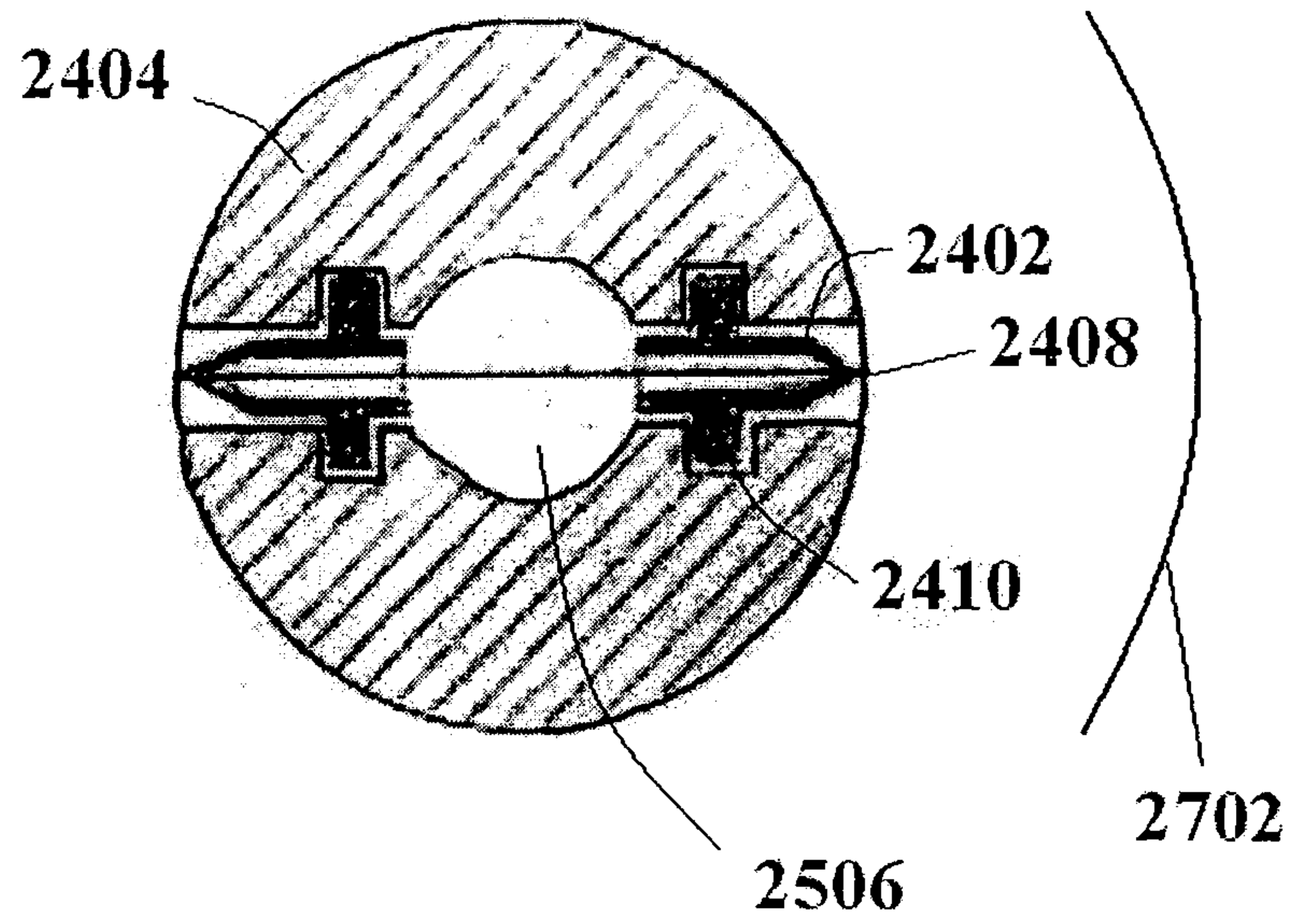


FIG. 30

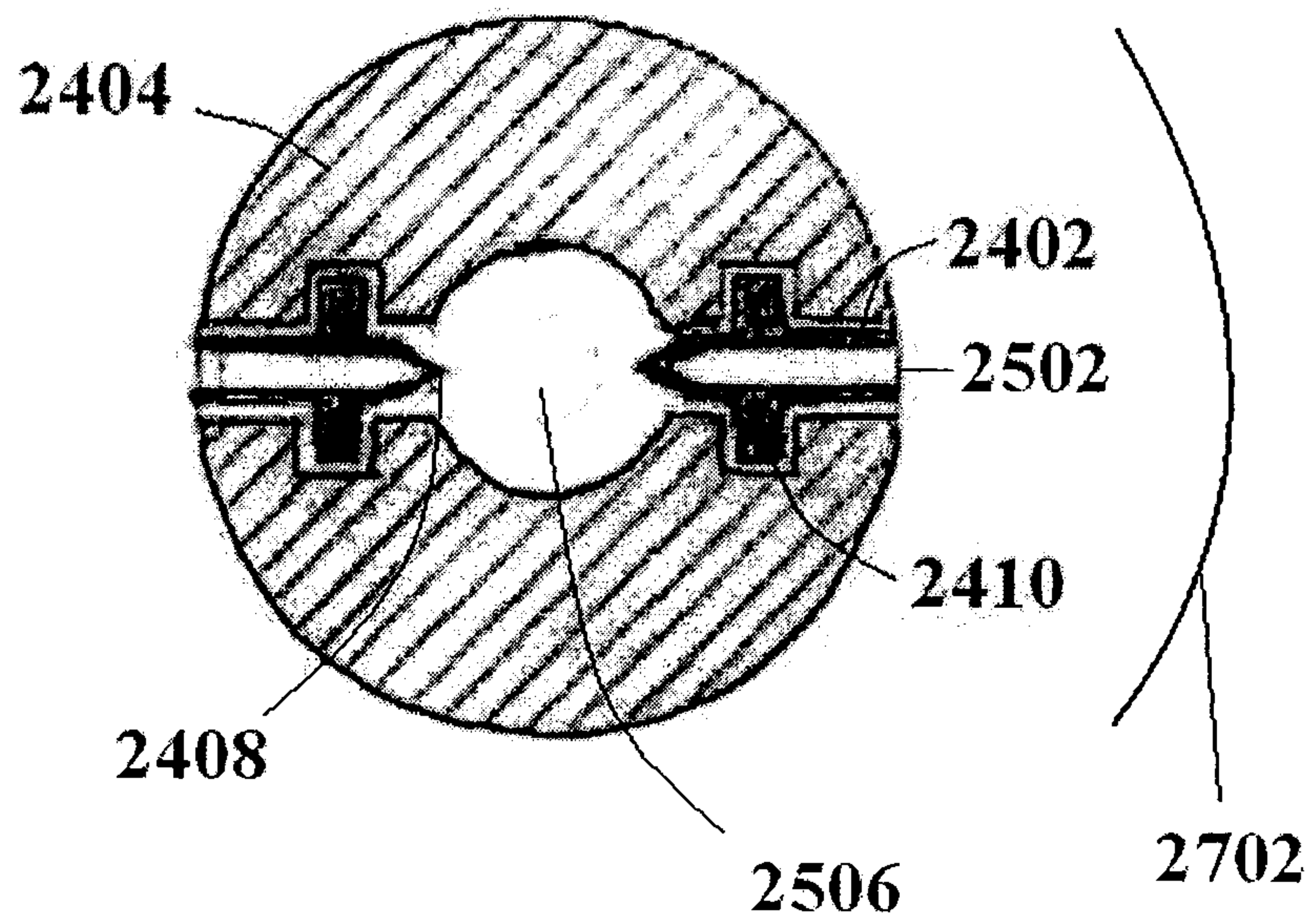


FIG. 31

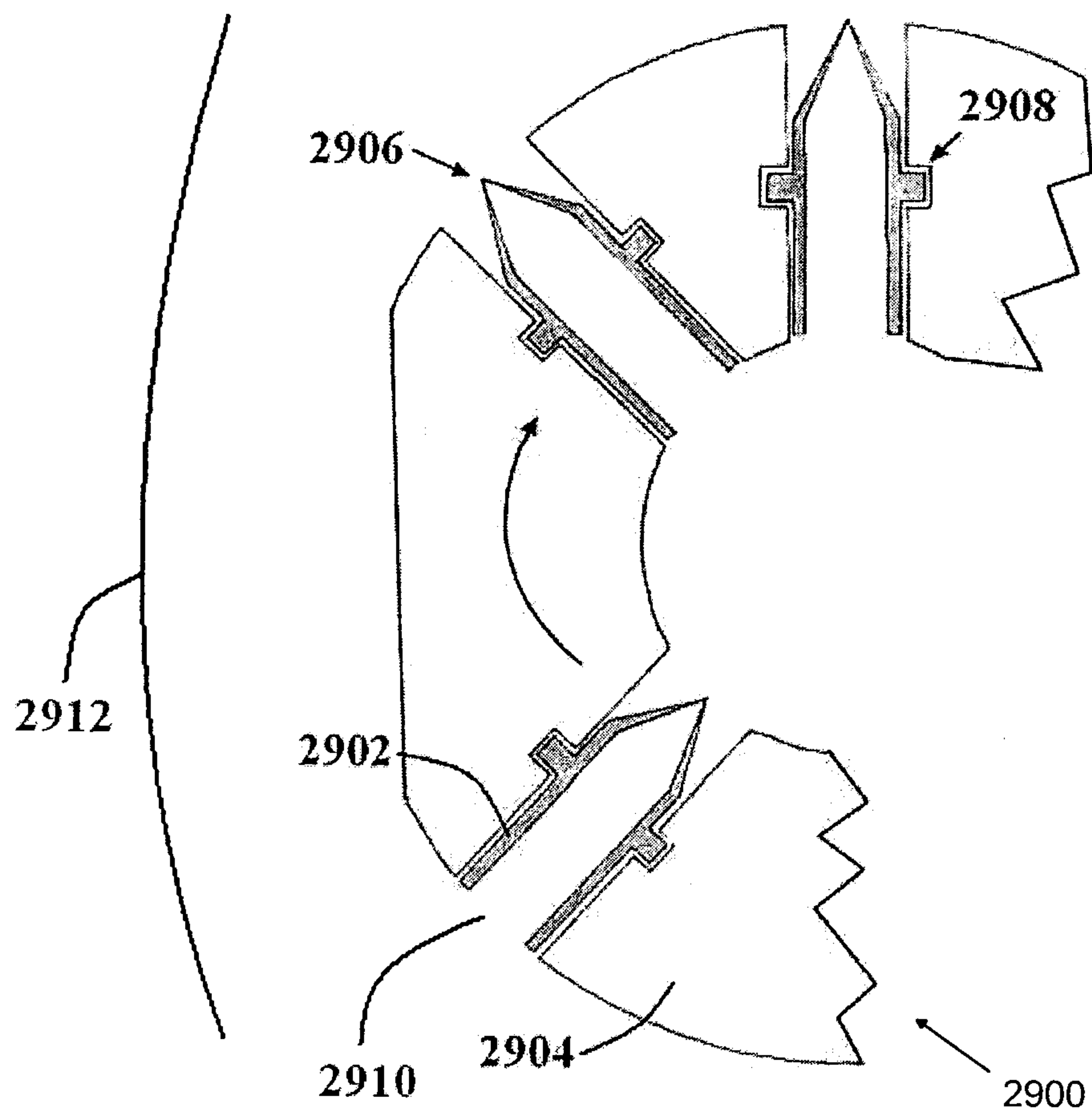


FIG. 32

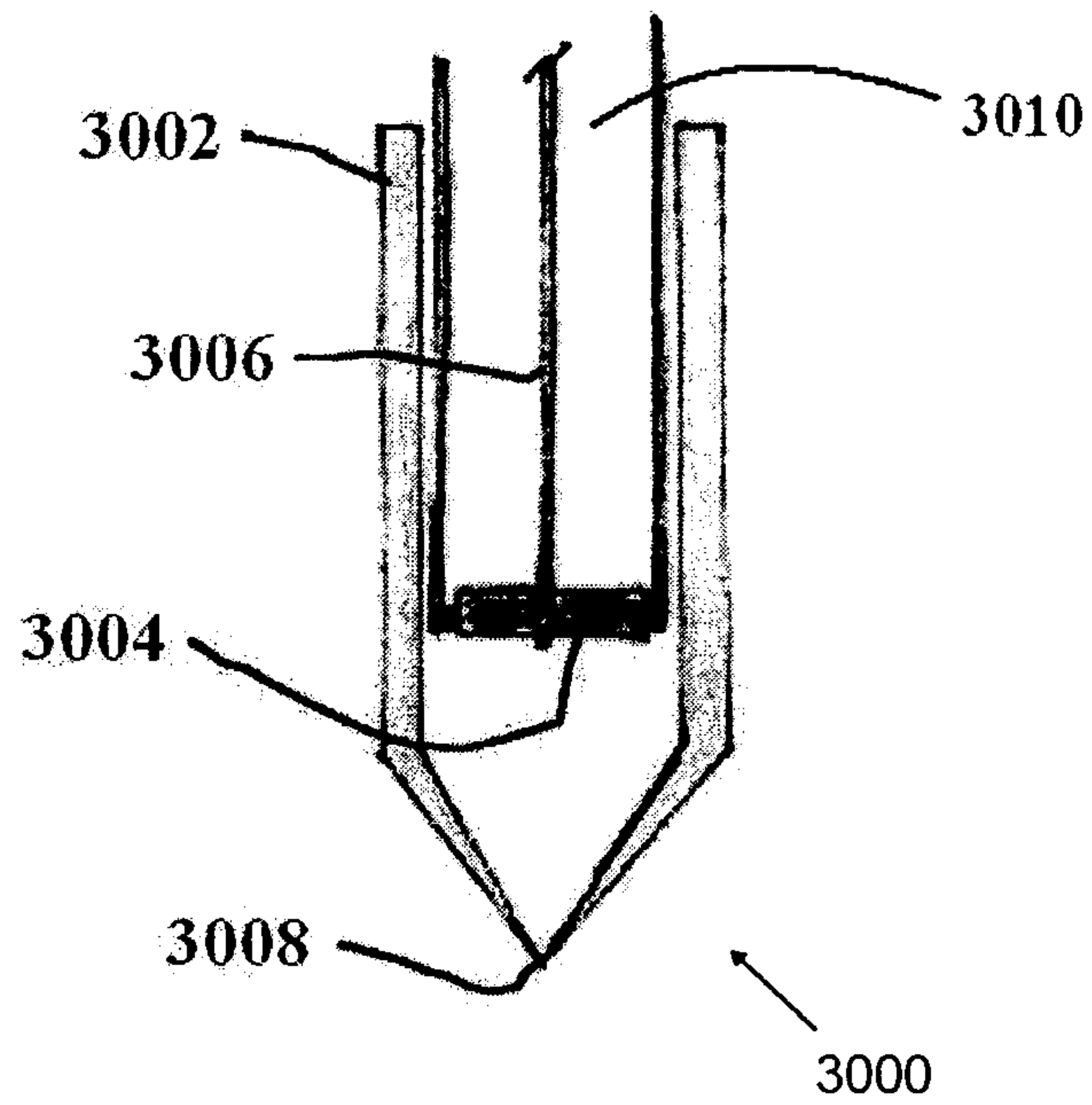


FIG. 33

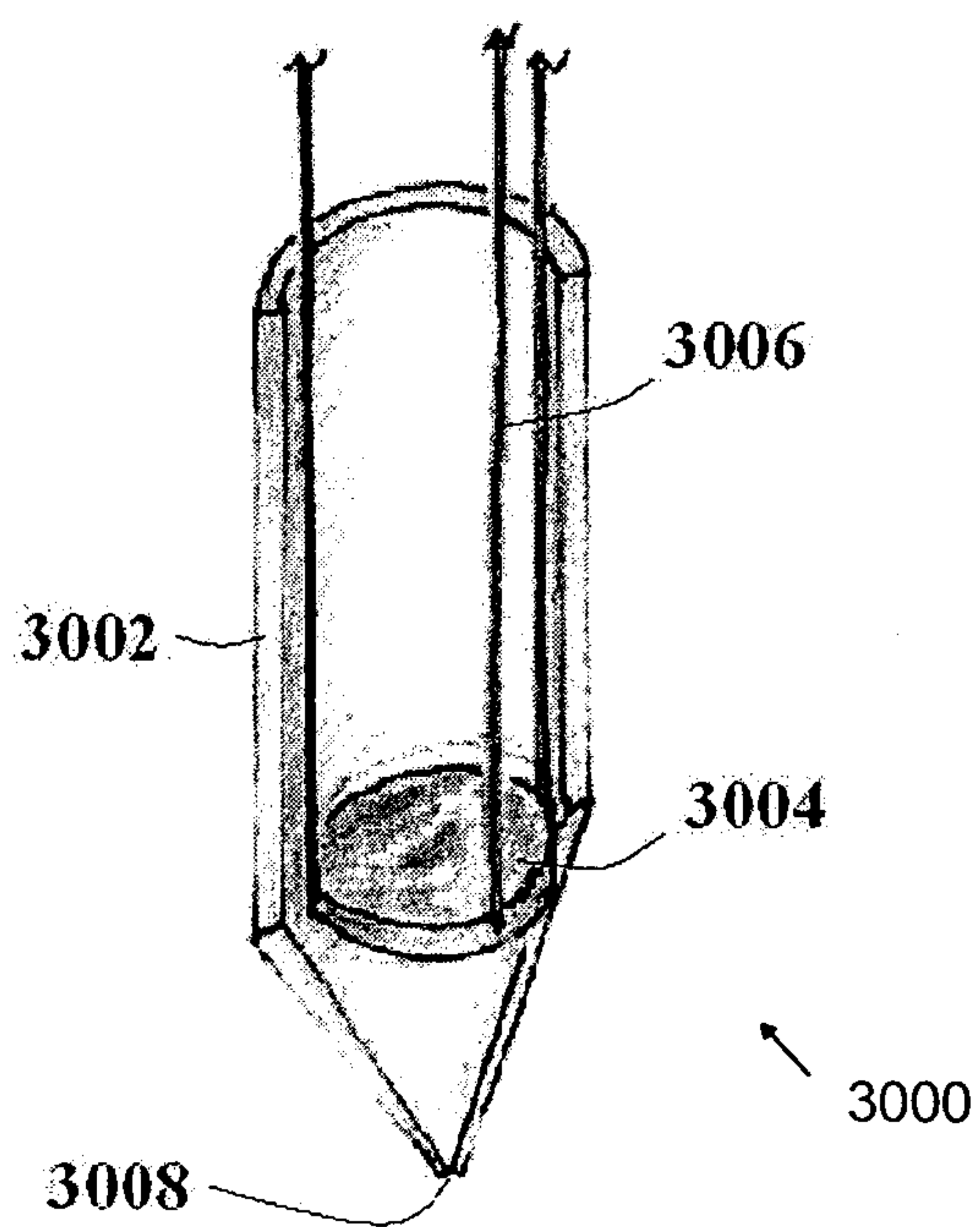


FIG. 34

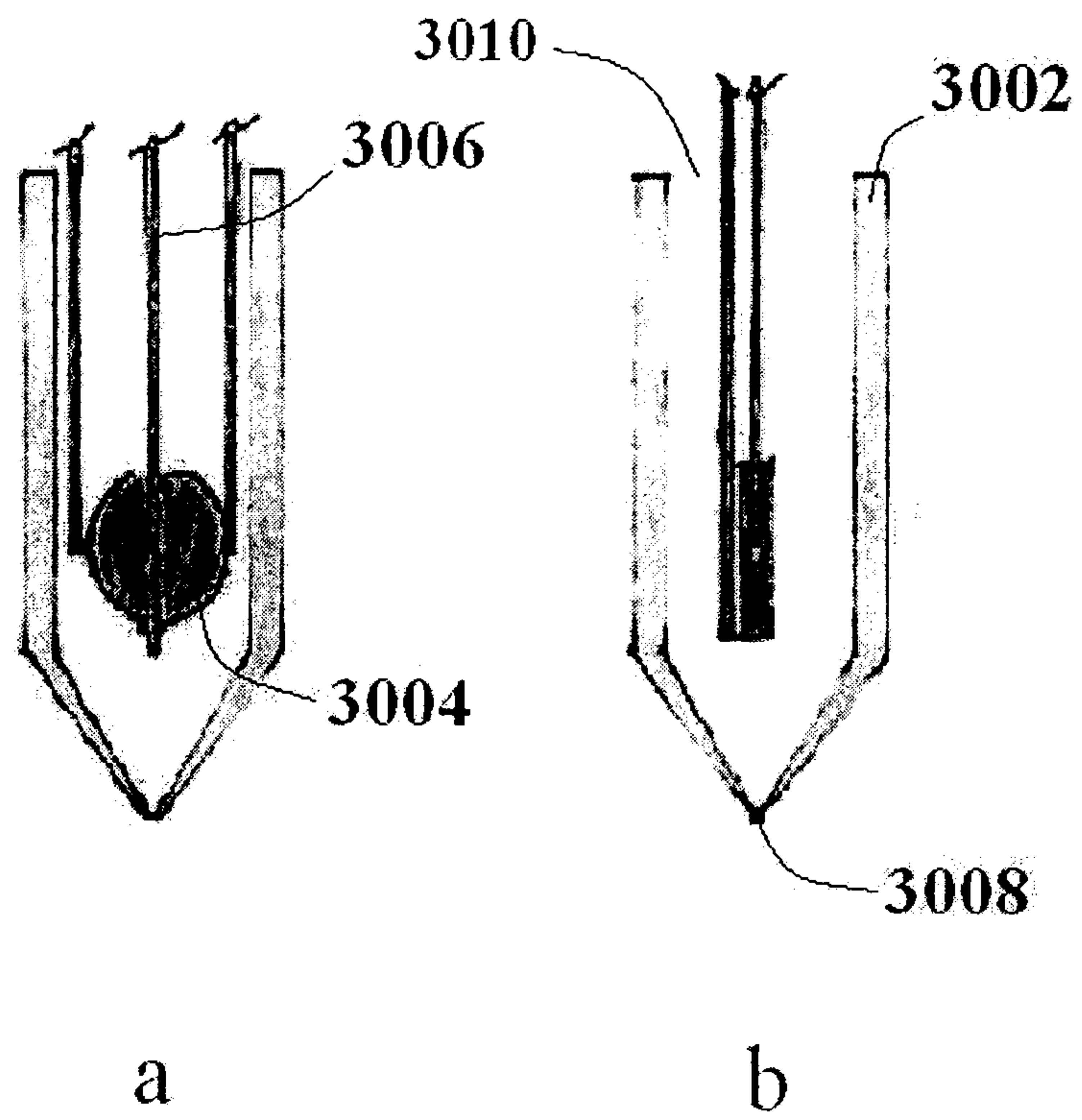


FIG. 35

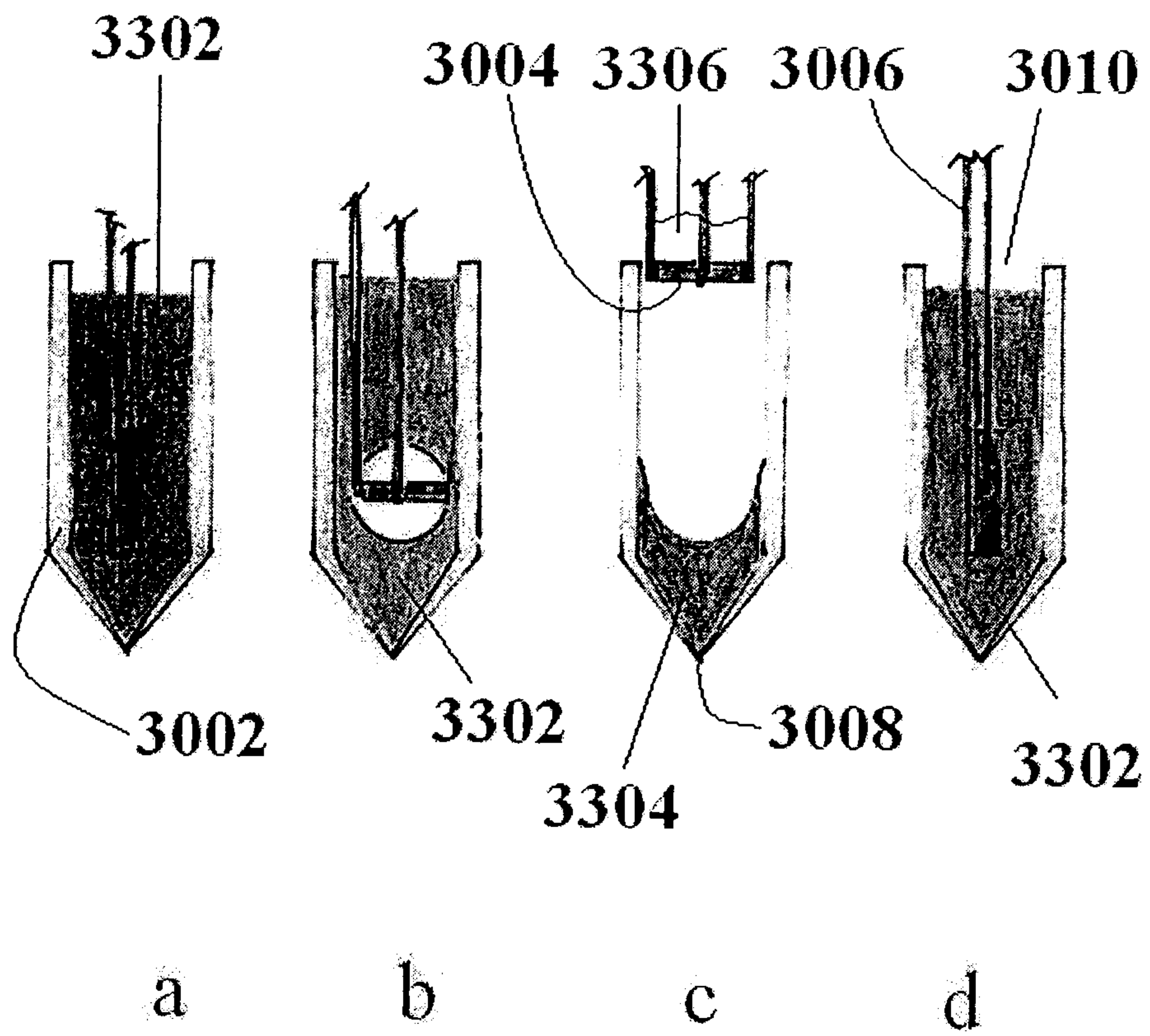


FIG. 36

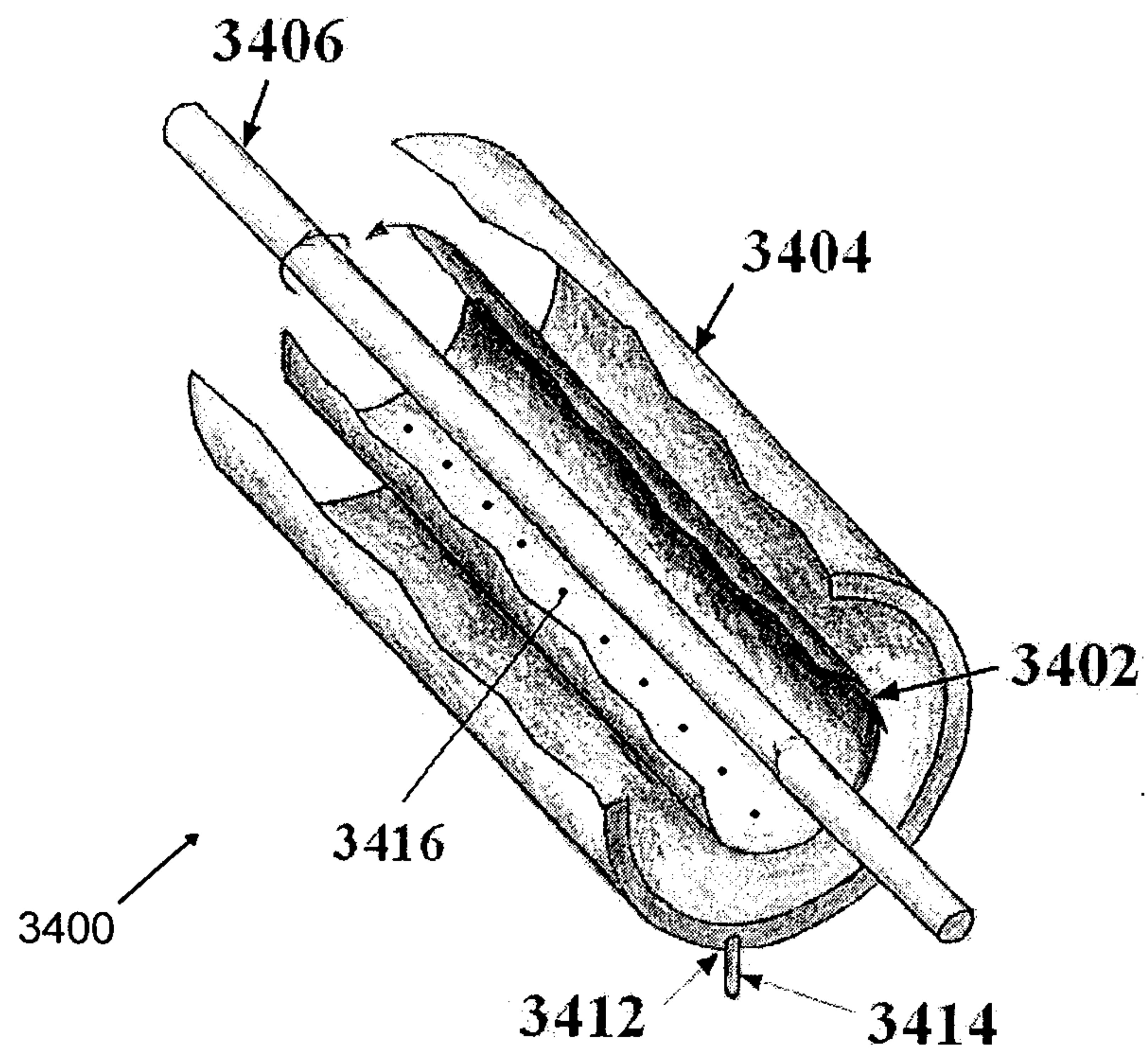


FIG. 37

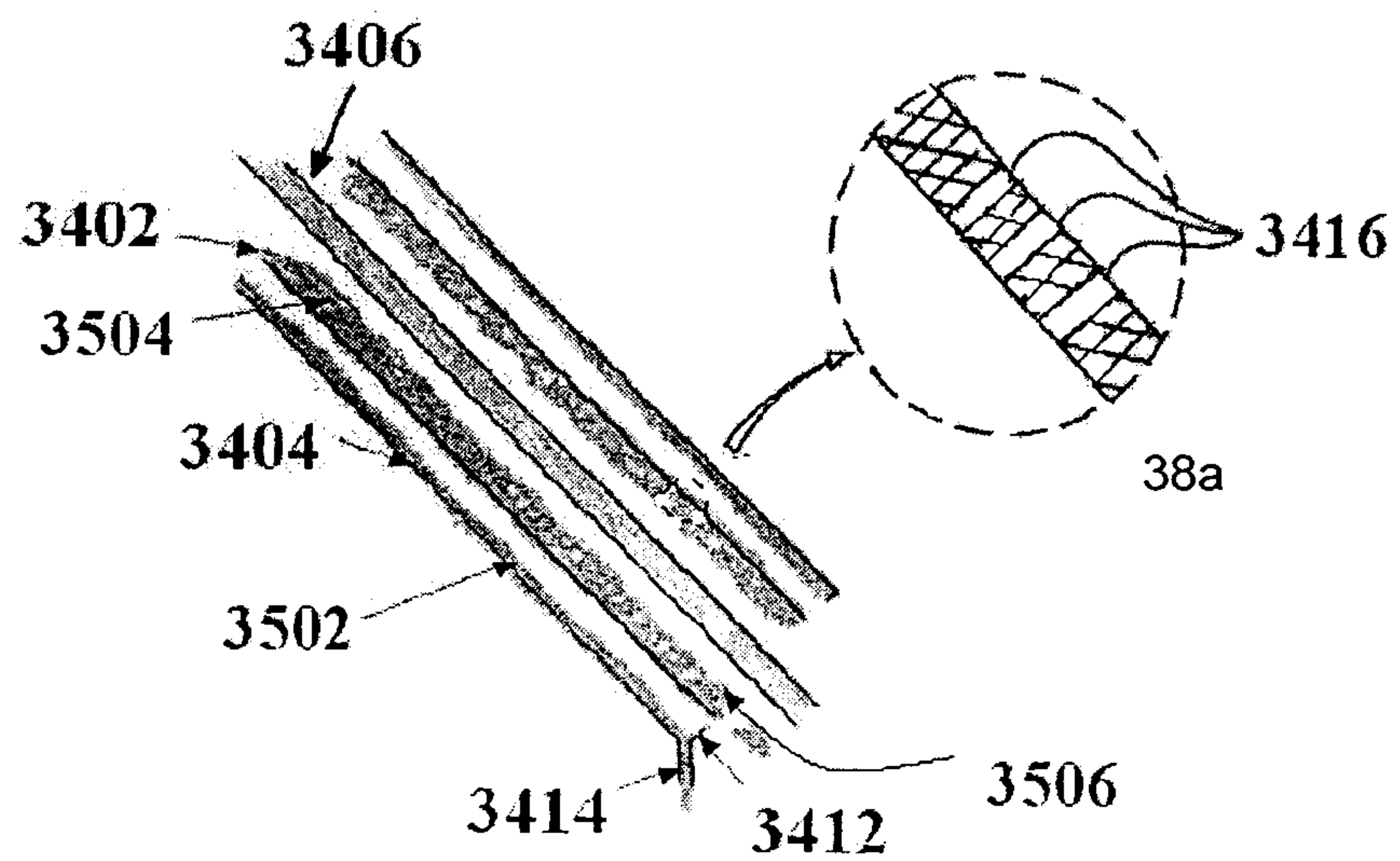


FIG. 38

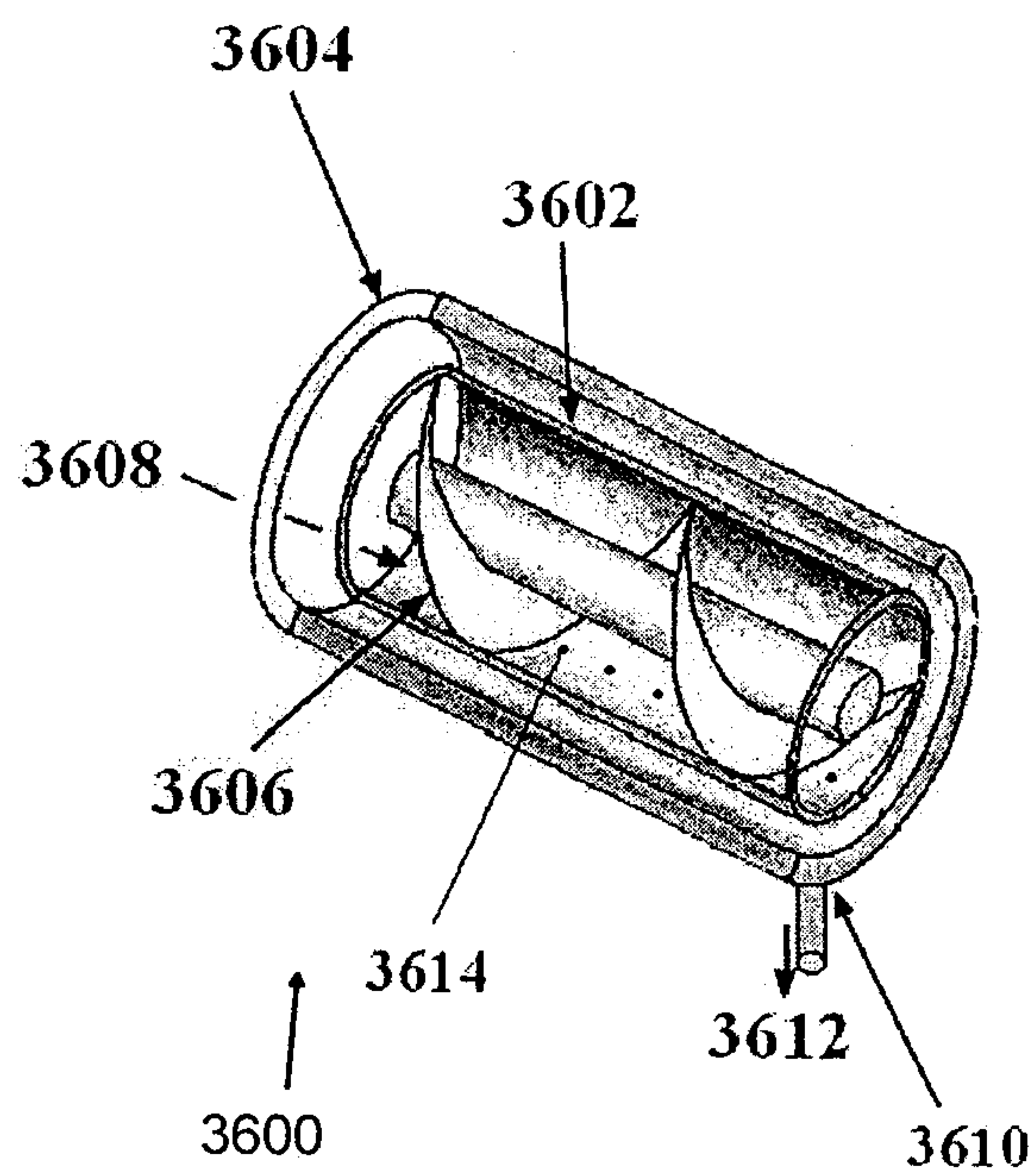


FIG. 39

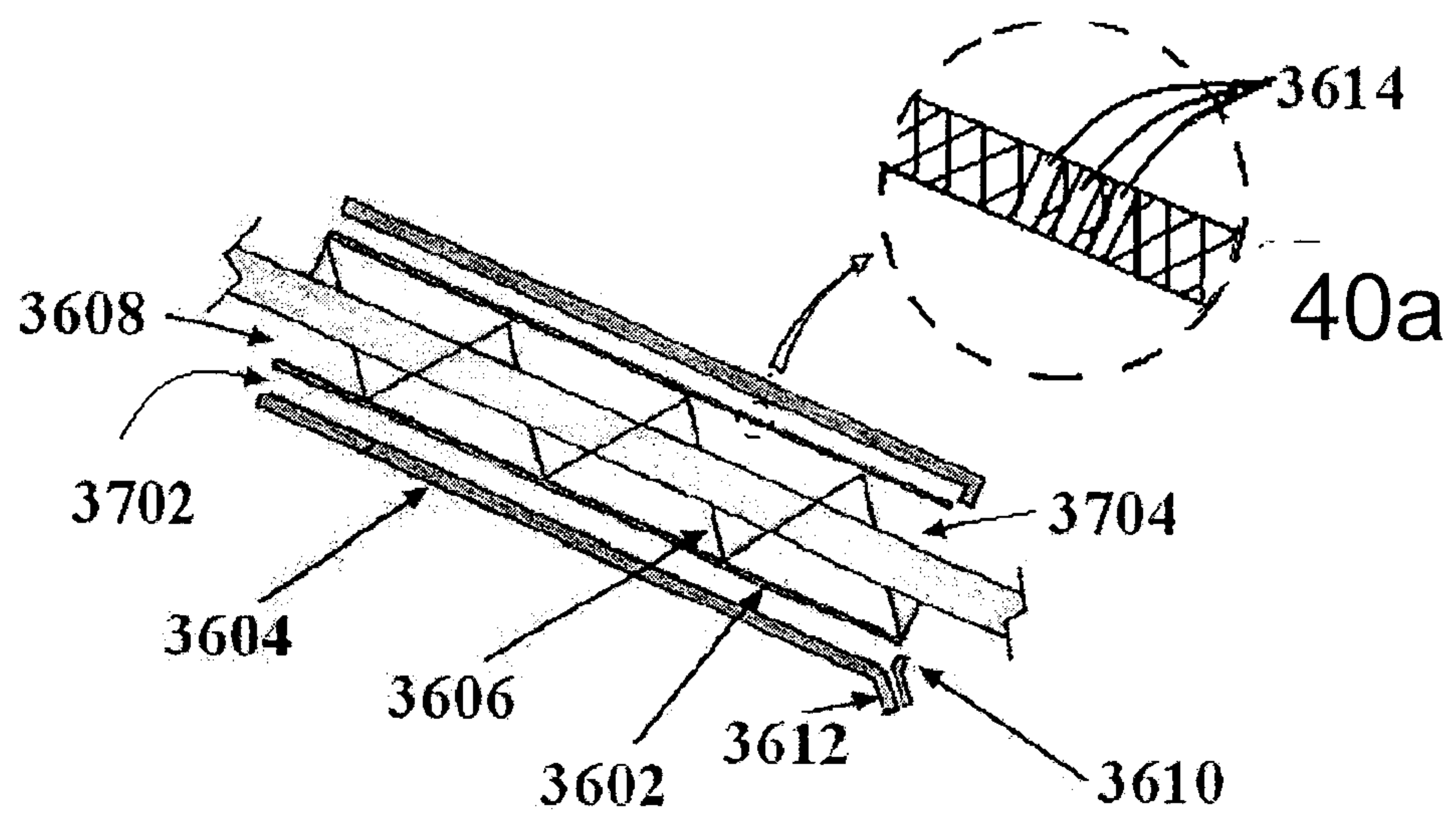


FIG. 40

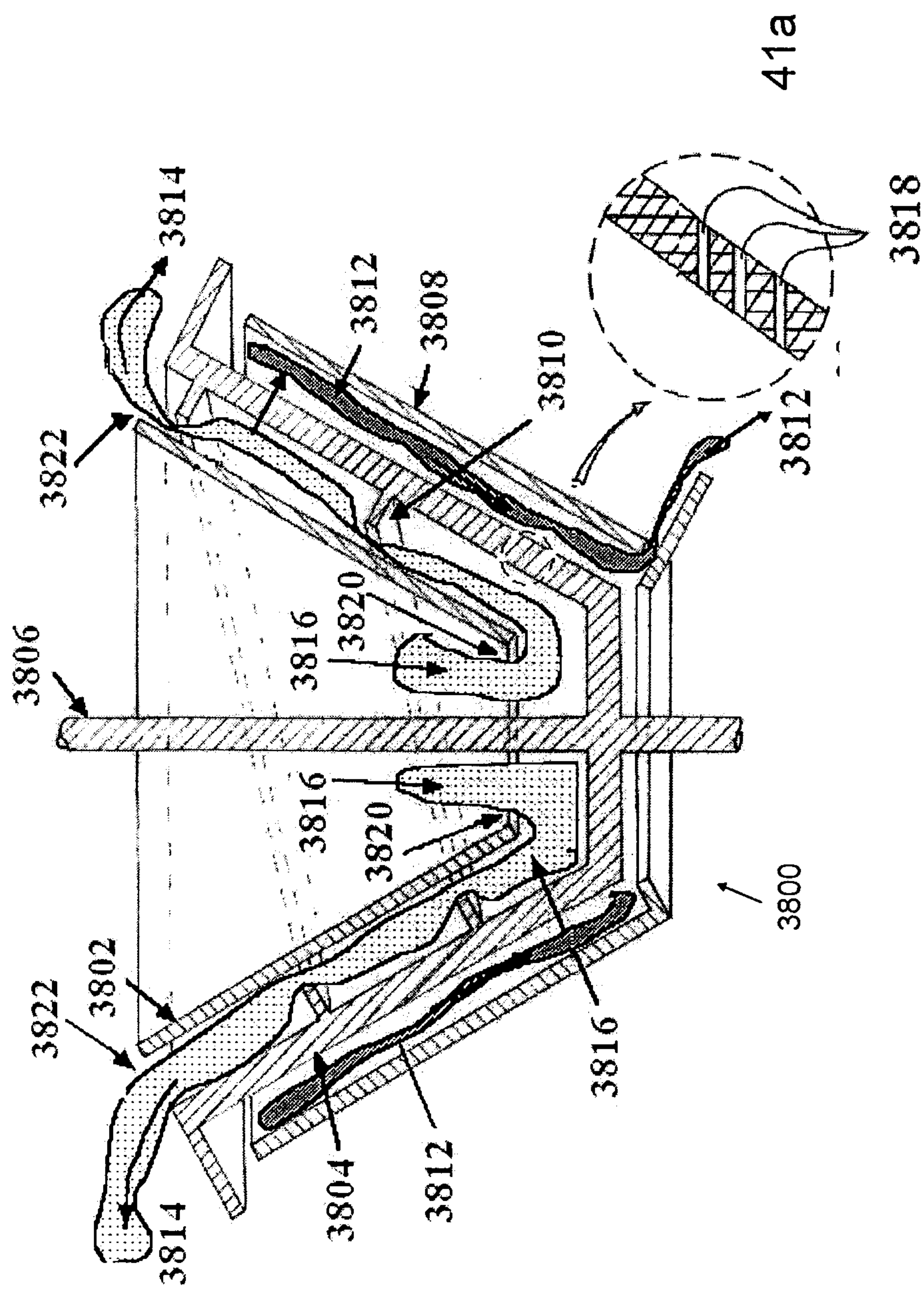


FIG. 41

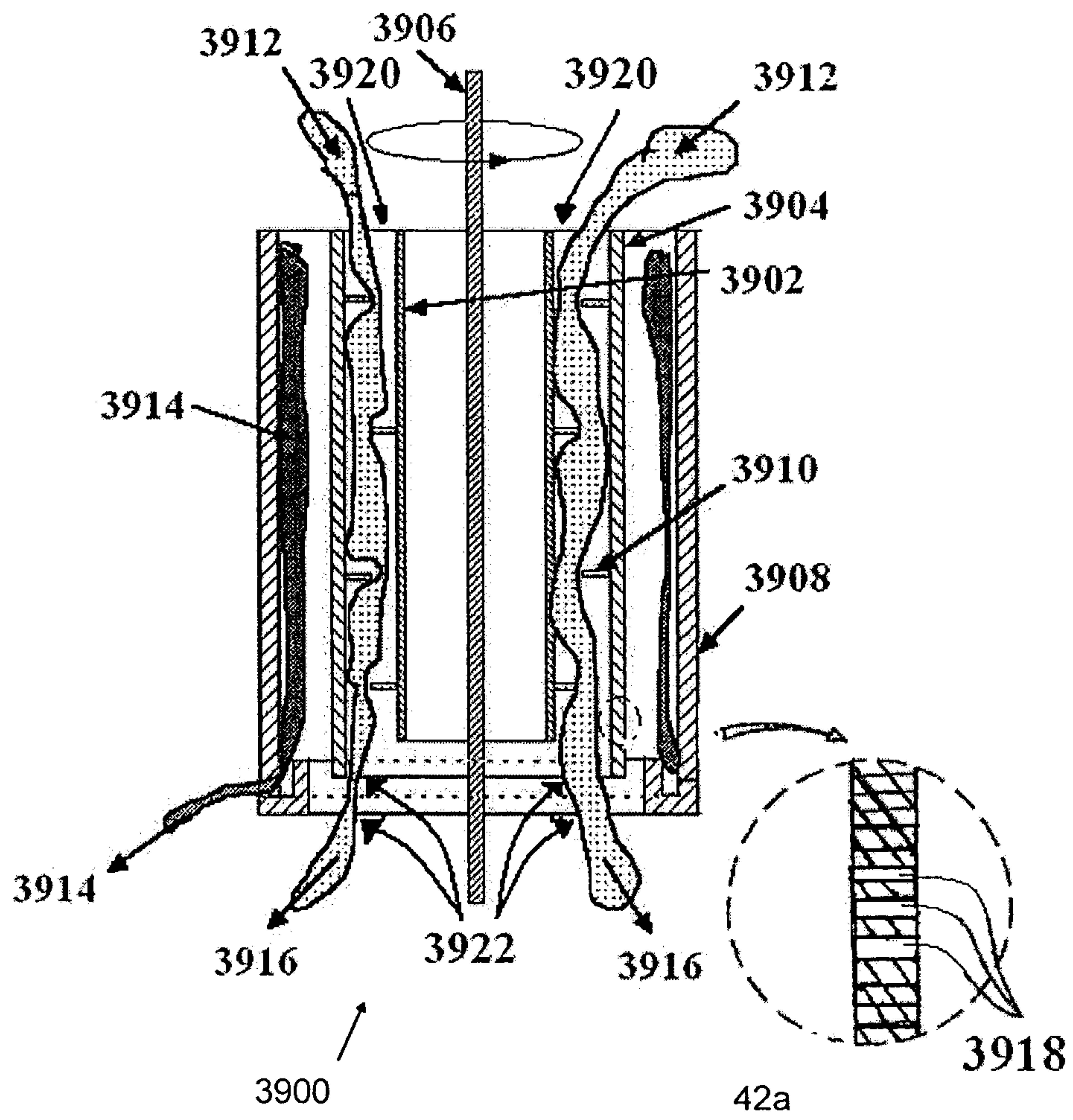
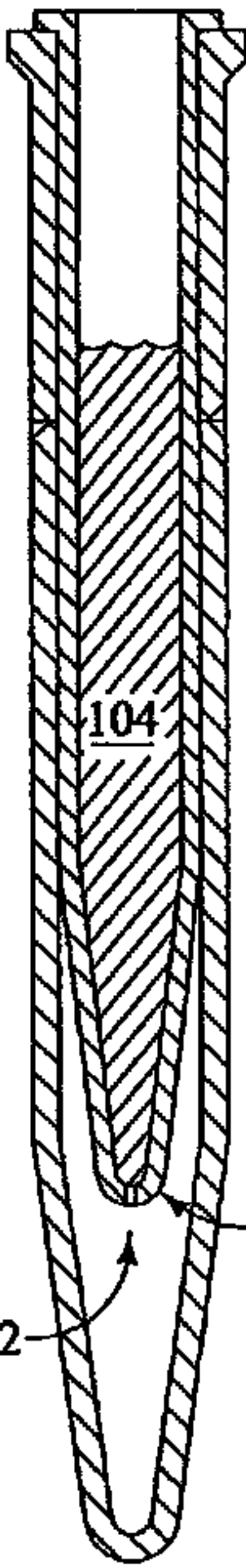


FIG. 42

90



90

104

100

102

106