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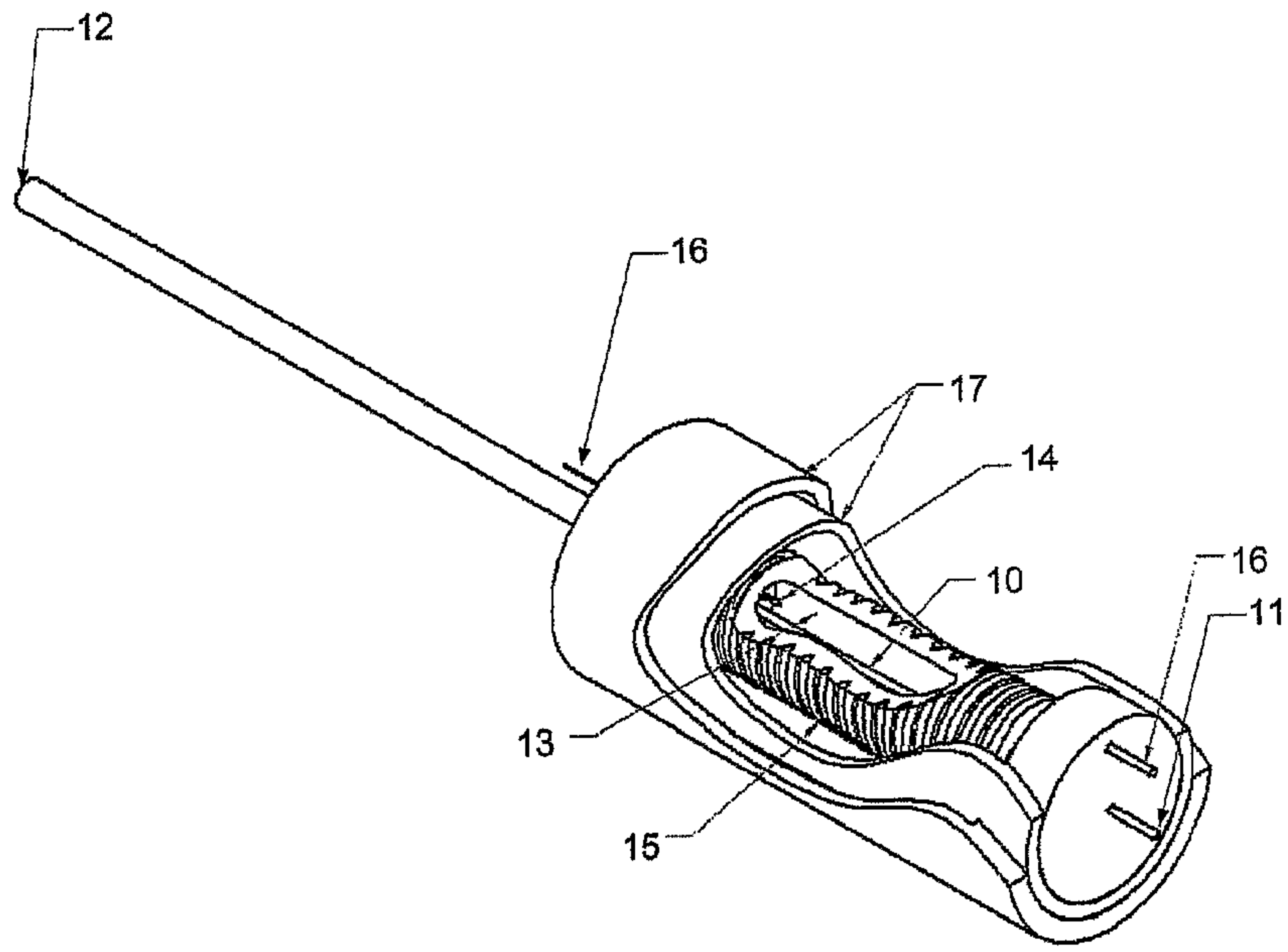
(54) **Titre : GENERATEUR D'AEROSOL CAPILLAIRE INDIRECTEMENT CHAUFFE**
(54) **Title: INDIRECTLY HEATED CAPILLARY AEROSOL GENERATOR**



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An indirectly heated capillary aerosol generator comprises a capillary tube 10 adapted to form an aerosol when liquid material in the capillary tube is heated to volatilize at least some of the liquid material therein and a thermally conductive material 13 in thermal contact with the capillary tube. The indirectly heated capillary aerosol generator provides substantially even and uniform heating across the heated length of the capillary tube.

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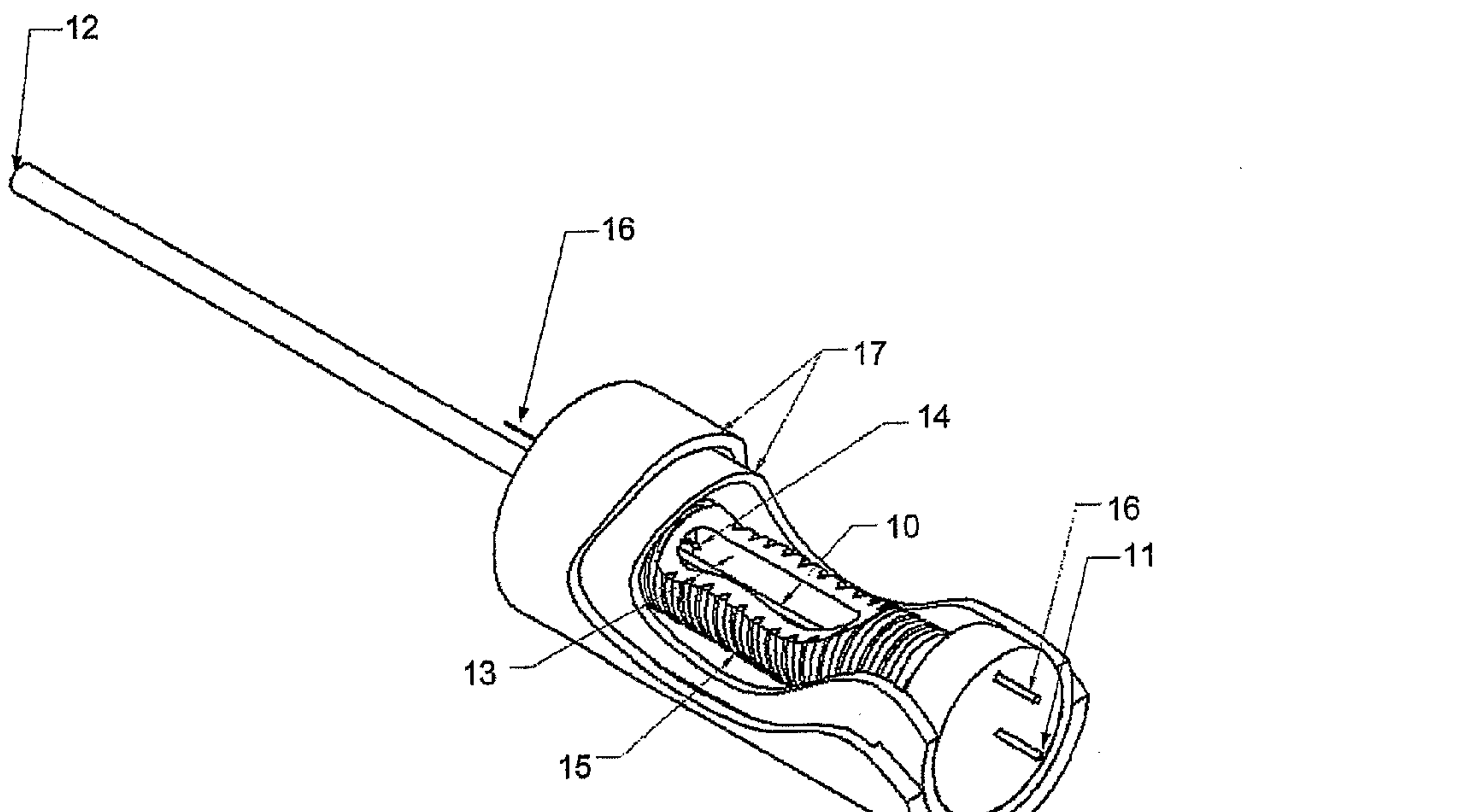
(54) Title: INDIRECTLY HEATED CAPILLARY AEROSOL GENERATOR



(57) Abstract: An indirectly heated capillary aerosol generator comprises a capillary tube 10 adapted to form an aerosol when liquid material in the capillary tube is heated to volatilize at least some of the liquid material therein and a thermally conductive material 13 in thermal contact with the capillary tube. The indirectly heated capillary aerosol generator provides substantially even and uniform heating across the heated length of the capillary tube.

WO 2007/141668 A3

INDIRECTLY HEATED CAPILLARY AEROSOL GENERATOR

SUMMARY

Provided is an indirectly heated capillary aerosol generator comprising a capillary tube adapted to form an aerosol when liquid material in the capillary tube is heated to volatilize at least some of the liquid material therein and a thermally conductive material in thermal contact with the capillary tube.

Also provided is a method for generating aerosol using an indirectly heated capillary aerosol generator comprising supplying energy to a thermally conductive material of the indirectly heated capillary aerosol generator and supplying liquid material to an inlet of the capillary tube. The thermally conductive material is in thermal contact with a capillary tube of the indirectly heated capillary aerosol generator and the capillary tube is adapted to form an aerosol when liquid material in the capillary tube is heated to volatilize at least some of the liquid material therein. Sufficient energy is supplied to the thermally conductive material such that the thermally conductive material supplies sufficient heat to the liquid material in the capillary tube to volatilize liquid material in the capillary tube and volatilized liquid material is driven out of an outlet of the capillary tube and mixes with ambient air to form aerosol.

Further provided is a method for forming an indirectly heated capillary aerosol generator comprising forming longitudinally extending semicircular grooves along a center axis of two corresponding half cylinders of a thermally conductive material, such that if the two half cylinders were placed together they form a cylindrical shell, and encasing the capillary tube with the two half cylinders, such that the thermally conductive material is in thermal contact with the capillary tube. The grooves are sized to fit closely around the capillary tube and the capillary tube is adapted to form an aerosol when liquid material in the capillary tube is heated to volatilize at least some of the liquid material therein.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 illustrates an embodiment of an indirectly heated capillary aerosol generator.

Figure 2 illustrates another embodiment of an indirectly heated capillary aerosol generator.

Figure 3 illustrates an embodiment of an indirectly heated capillary aerosol generator package.

DETAILED DESCRIPTION

Capillary aerosol technology and capillary aerosol generators have been described in US-A-5 743 251.

Inhaleable flavored aerosols, for example, tobacco flavored aerosol, which may be used to implement or simulate a smoking experience or other applications, may be generated from a capillary aerosol generator, the length of which can depend on heat requirements dictated by, among other factors, the composition of the aerosol generated. A potential problem associated with directly heated capillary aerosol generators is broad temperature variations inside the capillary tube that may lead to overheating and substandard aerosol formation, resulting in clogging of the capillary tube and/or total failure of a capillary aerosol generator.

A preferred embodiment provides a capillary aerosol generator which includes a capillary tube having an inlet and an outlet. A thermally conductive material is positioned adjacent to the capillary tube, such that the thermally conductive material maximizes heat transfer substantially evenly and uniformly from the thermally conductive material to the capillary tube. The thermally conductive material is preferably wrapped with heating wire and has electrical leads attached to it. The electrical leads are connected to a power source. The power source is selected in view of the characteristics of the components of the capillary aerosol generator.

In operation, electrical leads transfer power from the power source to the heating wire that is wrapped around the thermally conductive material, thereby heating the thermally conductive material. When heated, the thermally conductive material transfers heat to the capillary tube and thus substantially evenly and uniformly heats the capillary tube to a temperature sufficient to volatilize liquid material that is introduced to the heated capillary tube. The liquid material introduced to the heated capillary tube is volatilized and is driven out of the outlet of the capillary tube. The volatilized material mixes with ambient air outside of the capillary tube and forms a condensation aerosol.

The heating wire preferably has an outside diameter of 0.287mm (0.0113 inches), a resistance of 22 ohms/m (6.6 ohms per foot), and a specific heat of $460 J \cdot kg^{-1} \cdot K^{-1}$ (0.110 BTU/lb°F). The composition of the heating wire is preferably 71.7% iron, 23% chromium, and 5.3% aluminum. Such a heating wire is available from Kanthal Furnace Products, Bethel, Conn.

The capillary tube preferably has an inside diameter in the range of about 0.05mm to 0.53mm, more preferably in the range of about 0.1mm to 0.2mm. A particularly preferred inside diameter of the capillary tube is approximately 0.1mm. The capillary tube may be comprised of a metallic or non-metallic tube. For example, the capillary tube may be comprised of stainless steel or glass. Alternatively, the capillary tube may be comprised of, for example, fused silica or aluminum silicate ceramic, or other substantially non-reactive materials capable of withstanding repeated heating cycles and generated pressures and having suitable heat conduction properties may also be used. As the thermally conductive material is in thermal contact with the capillary tube, capillary tubes with low or high electrical resistance may be used. If desired or necessary, an inside wall of the capillary tube may be provided with a coating for reducing the tendency of material to stick to the wall of the capillary tube, which may result in clogging.

Liquid material is preferably introduced into the capillary tube through an inlet of the capillary tube connected to a source of liquid material. The volatilized material is driven out of the capillary tube through the outlet of the capillary tube, *i.e.*, back pressure of liquid from the source of liquid material causes the volatilized liquid to be ejected from the outlet. The back pressure of the liquid is preferably between about $1.4.10^5$Pa and about 2.10^5Pa (about 20 and 30 pounds per square inch).

Electrical current passed directly through a conductive capillary tube may provide uneven heating across the length of the capillary tube, with temperature variations inside the capillary tube on the order of about 50°C to 100°C possible. In contrast, an indirectly heated capillary aerosol generator provides substantially even and uniform heating across the heated length of the capillary tube. Because the thermally conductive material of the indirectly heated capillary aerosol generator has a mass that is preferably at least about ten times (*e.g.*, about twenty times, about thirty times, about forty times, about fifty times, about sixty times, etc.) the mass of the capillary tube and the heating wire is preferably equally distributed across the length of the capillary tube, the temperature inside the capillary tube preferably varies by less than about 5°C. Further, by providing electrical energy to the heating wire in a controlled manner, the temperature inside the capillary tube can be accurately maintained.

Since the indirectly heated capillary aerosol generator provides substantially even and uniform heat distribution along the length of the capillary tube, liquid material or volatilized liquid material can be heated to a desired temperate range without overheating the liquid. Overheating may cause substandard aerosol formation and/or result in clogging of the capillary tube and/or total failure of a capillary aerosol generator.

In an indirectly heated capillary aerosol generator, the temperature of the thermally conductive material is heated to and maintained at an operating temperature (*i.e.*, a temperature at which liquid material in the capillary tube is volatilized), which may be in the range of about 250°C to 400°C. In an indirectly heated capillary aerosol generator, the flow of liquid material in the capillary tube has limited to minimal impact on the amount of energy the capillary aerosol generator requires to maintain the operating temperature.

The indirectly heated capillary aerosol generator may be fabricated by encasing a capillary tube in a thermally conductive material. The thermally conductive material may take the form of two aluminum half cylinders, in which longitudinally extending semicircular grooves sized to receive the capillary tube are formed. The semicircular grooves run along a center axis of the half cylinders, such that if the half cylinders were placed together they form a cylindrical shell. The grooves are preferably sized to fit closely around the capillary tube. Preferably, the thermally conductive material has a threaded exterior similar to a thread on a typical screw to facilitate attachment of end caps to each end of the mated half cylinders. The aluminum half cylinders are optionally anodized. While anodization makes the electrically conductive parts non-conductive, it does not negatively impact the thermal conductance of the aluminum parts.

Preferably, a high temperature bushing is applied to each end of the capillary aerosol generator to allow for the easy addition of heating wire and electrical leads. Heating wire is preferably wrapped along the entire length of the thermally conductive material. The length of the capillary aerosol generator may be in the range of a few millimeters to hundreds of millimeters (*e.g.*, about 25mm to 35mm), depending on the heat requirement dictated by the liquid material makeup and flow rates. However, with the thermally conductive material the capillary passage can be 50mm or longer and still be provided substantially even and uniform heating.

A thermocouple is preferably incorporated into the capillary aerosol generator. Placement of the thermocouple is preferable to ensure accurate temperature monitoring. By utilizing the thermocouple as a feedback device, a closed loop temperature control system can be used to control the temperature of the capillary tube. To complete the capillary aerosol generator package, electrical and liquid material connectors are added.

With reference to Figure 1, the capillary tube 10 of an indirectly heated capillary aerosol generator has an inlet 12 and outlet 11, as described above. The capillary tube 10 is surrounded by thermally conductive material 13. The temperature of the thermally conductive material 13 may be monitored by use of a thermocouple 14. The thermally conductive material 13 is preferably wrapped with heating wire 15. Electrical leads 16 are preferably attached to the heating wire. The thermally conductive material may be surrounded by insulating sheaths 17.

With reference to Figure 2, the capillary tube 10 of an indirectly heated capillary aerosol generator is preferably surrounded by a top half cylinder 20 and bottom half cylinder 21, each of which is comprised of thermally conductive material. The temperature of the thermally conductive material may be monitored by use of a thermocouple 14. The thermally conductive material is preferably wrapped with heating wire 15. Electrical leads 16 are preferably attached to the heating wire. The indirectly heated capillary aerosol generator preferably further includes a front bushing 22, corresponding to the outlet end of the capillary tube, and a rear bushing 23, corresponding to the inlet end of the capillary tube.

With reference to Figure 3, an indirectly heated capillary aerosol generator package preferably includes an indirectly heated capillary aerosol generator 30, as described above with reference to Figures 1 and 2, a face plate 31, an electrical connector 32, a main body bracket 33, and a liquid material connector 34.

While various embodiments have been described, it is to be understood that variations and modifications may be resorted to as will be apparent to those skilled in the art.

CLAIMS:

1. An indirectly heated capillary aerosol generator comprising:

a capillary tube adapted to form an aerosol when liquid material in the capillary tube is heated to volatilize at least some of the liquid material therein; and

a thermally conductive material in thermal contact with the capillary tube,

wherein the thermally conductive material has a mass that is at least ten times the mass of the capillary tube.

2. An indirectly heated capillary aerosol generator according to claim 1 wherein the thermally conductive material has a threaded exterior.

3. An indirectly heated capillary aerosol generator according to claim 1 or 2 wherein the thermally conductive material is wrapped with heating wire, which has electrical leads attached to it.

4. An indirectly heated capillary aerosol generator according to any one of claims 1, 2 and 3 wherein the thermally conductive material is electrically non-conductive.

5. A method for generating aerosol using an indirectly heated capillary aerosol generator comprising:

supplying energy to a thermally conductive material of the indirectly heated capillary aerosol generator, wherein the thermally conductive material is in thermal contact with a capillary tube of the indirectly heated capillary aerosol generator has a mass that is at least ten times the mass of the capillary tube, wherein the capillary tube is adapted to form an aerosol when liquid material in the capillary tube is heated to volatilize at least some of the liquid material therein; and

supplying liquid material to an inlet of the capillary tube;

wherein sufficient energy is supplied to the thermally conductive material such that the thermally conductive material supplies sufficient heat to the liquid material in the capillary tube to volatilize liquid material in the capillary tube;

wherein volatilized liquid material is driven out of an outlet of the capillary tube and mixes with air to form aerosol.

6. A method according to claim 5 wherein supplying energy to the thermally conductive material comprises supplying energy to heating wire that is wrapped around the thermally conductive material.

7. A method according to claim 5 or 6 further comprising monitoring the temperature of the thermally conductive material with a thermocouple.

8. A method according to any one of claims 5, 6 and 7 comprising supplying electrical energy to the thermally conductive material.

9. A method according to any one of claims 5, 6, 7 and 8 wherein after supplying energy to the thermally conductive material, temperature in the capillary tube varies by less than about 5 °C.

10. A method according to any one of claim 5 to 9 further comprising maintaining temperature of the thermally conductive material after supplying sufficient energy to the thermally conductive material such that the thermally conductive material supplies sufficient heat to the liquid material in the capillary tube to volatilize liquid material in the capillary tube.

11. A method according to any one of claims 5 to 10 wherein a temperature in the capillary tube in the range of about 250 °C to 400 °C provides sufficient heat to volatilize liquid material in the capillary tube.

12. A method for forming an indirectly heated capillary aerosol generator comprising:

forming longitudinally extending semicircular grooves along a center axis of two corresponding half cylinders of a thermally conductive material,

such that if the two half cylinders were placed together they form a cylindrical shell, wherein the grooves are sized to fit closely around a capillary tube and wherein the thermally conductive material has a mass that is at least ten times the mass of the capillary tube; and

encasing the capillary tube with the two half cylinders, such that the thermally conductive material is in thermal contact with the capillary tube;

wherein the capillary tube is adapted to form an aerosol when liquid material in the capillary tube is heated to volatilize at least some of the liquid material therein.

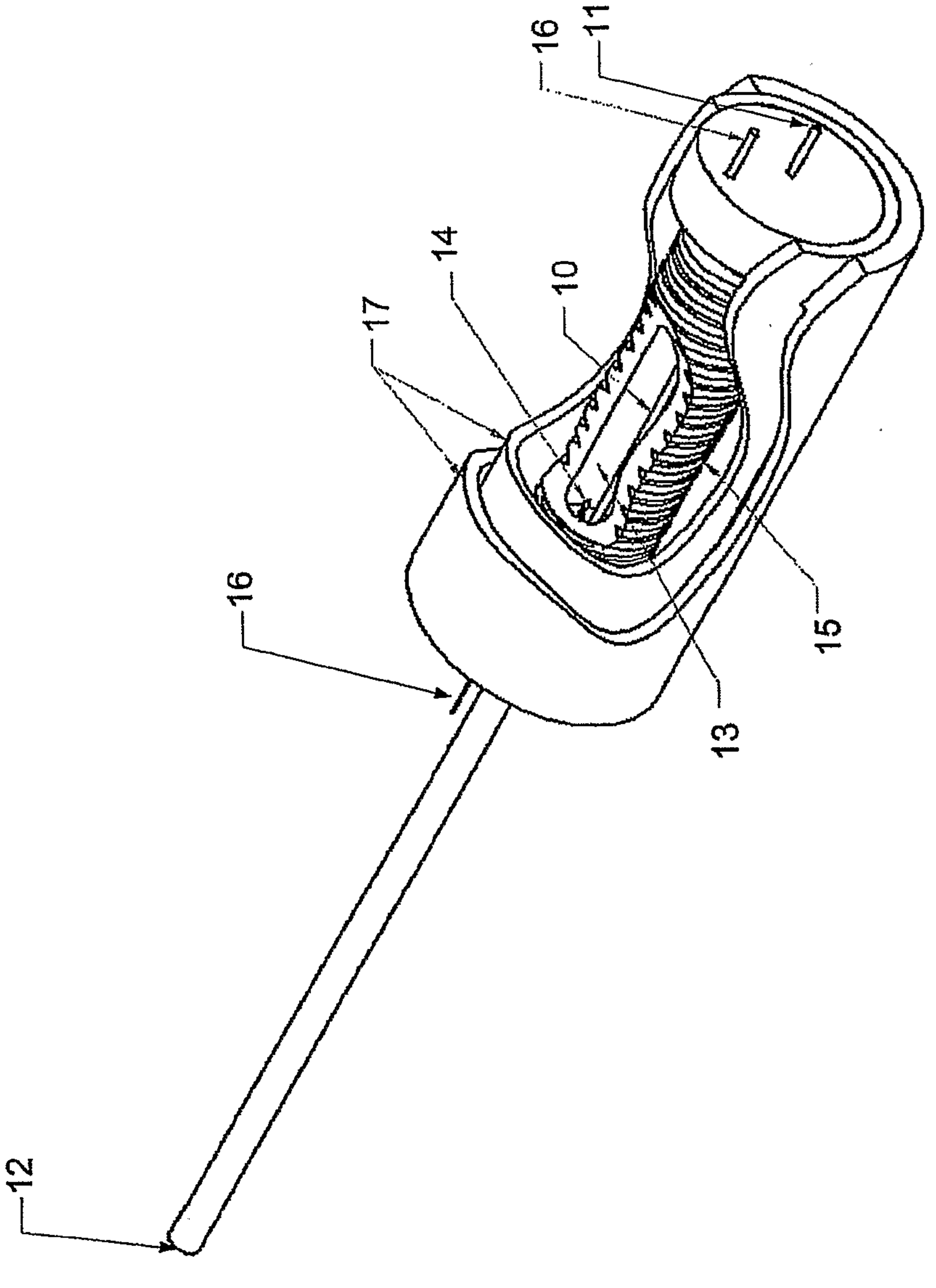


Figure 1

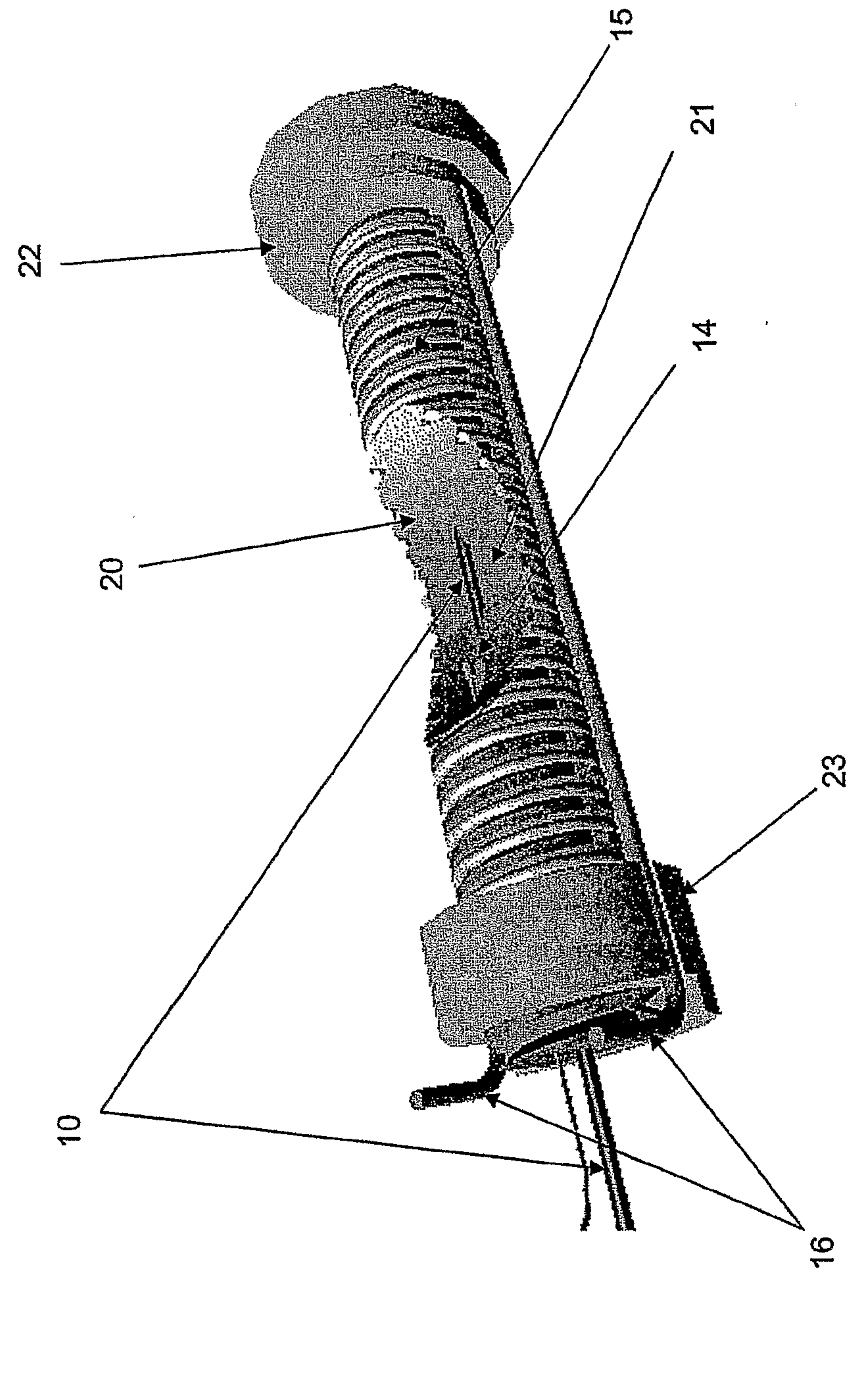


Figure 2

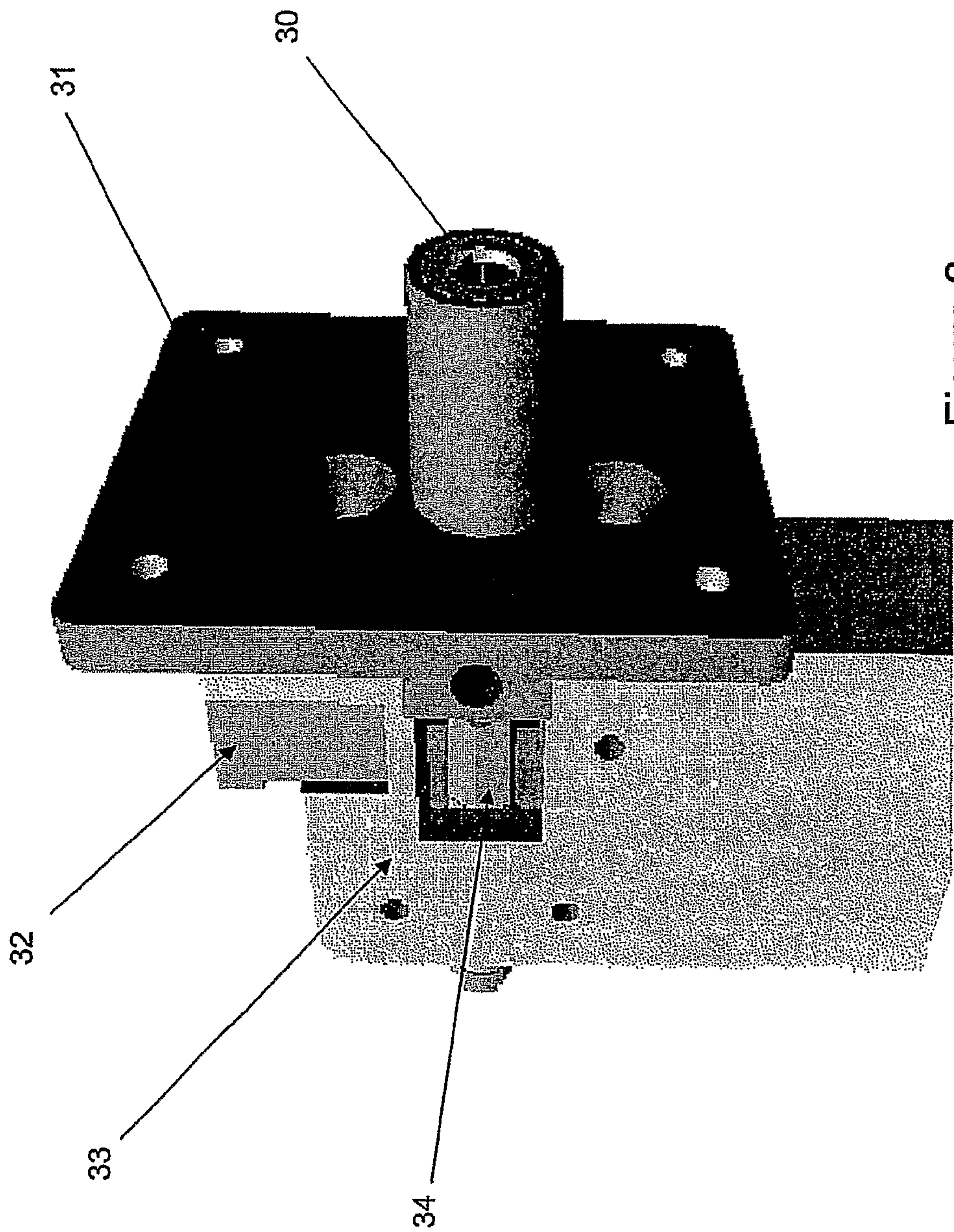
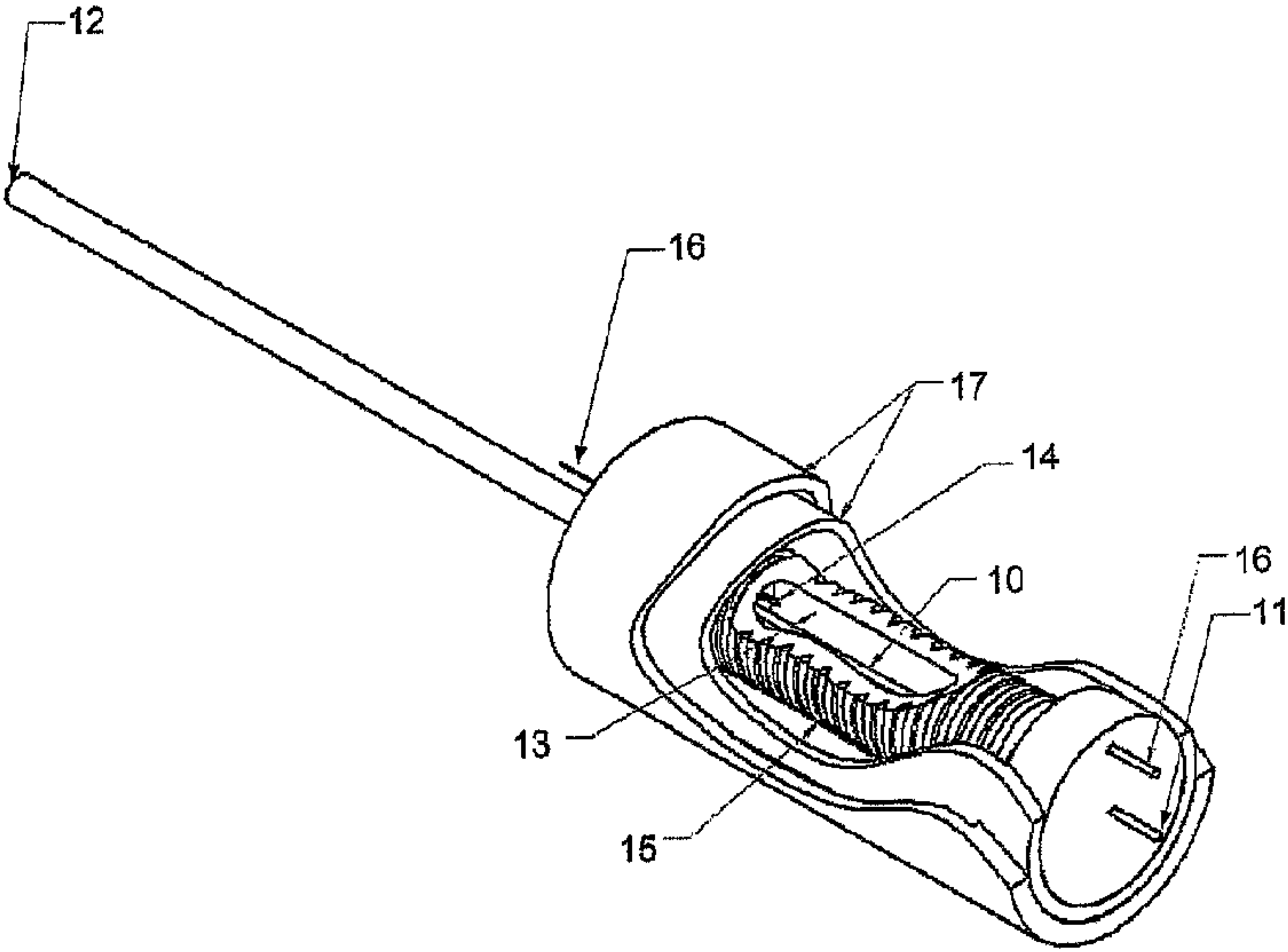


Figure 3



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