

[54] CRYOGENIC SURGICAL INSTRUMENT

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[51] Int. Cl. **F25b 19/00**

[58] Field of Search **128/303.1; 62/293, 514**

[56] **References Cited**

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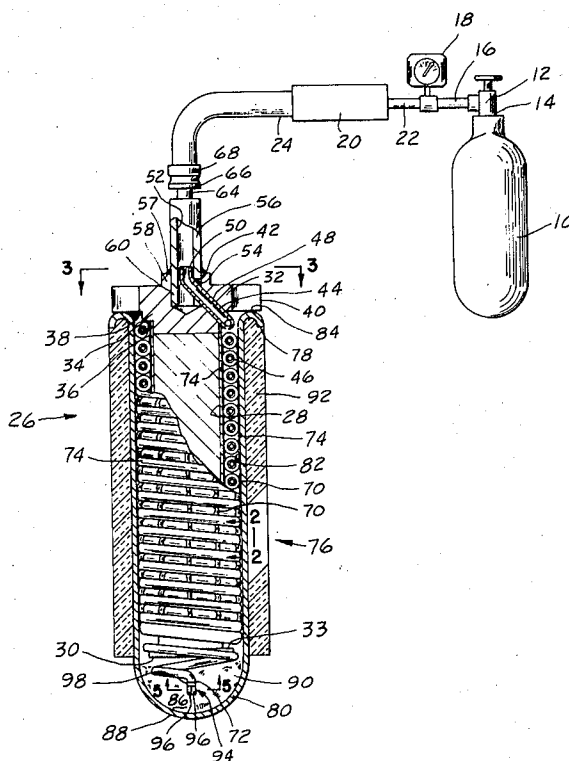
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[57] **ABSTRACT**

An apparatus for directly converting a gas into a liquid to lower the temperature of a cryogenic surgical instrument. A tube with a linear entrance and exit section is helically wound around a core. A thermal conductive member surrounds the tube between the entrance and exit sections. A gas under pressure is connected to the entrance section of the tube. A sleeve with a closed end frictionally engages and surrounds the thermal conductive member to form a closed chamber adjacent the exit section of the tube. The pressurized gas is throttled upon leaving the exit section causing the temperature in the chamber to be lowered to between -80° to -250°C causing the gas to liquefy. A path through the thermal conductive member from the chamber to the atmosphere will permit thermal energy in the throttled gas to be dissipated to the pressurized gas in the tube. The liquefied gas in the chamber will correspondingly cool the closed end of the sleeve allowing the external surface thereof to be used as a cryogenic surgical probe.

10 Claims, 6 Drawing Figures



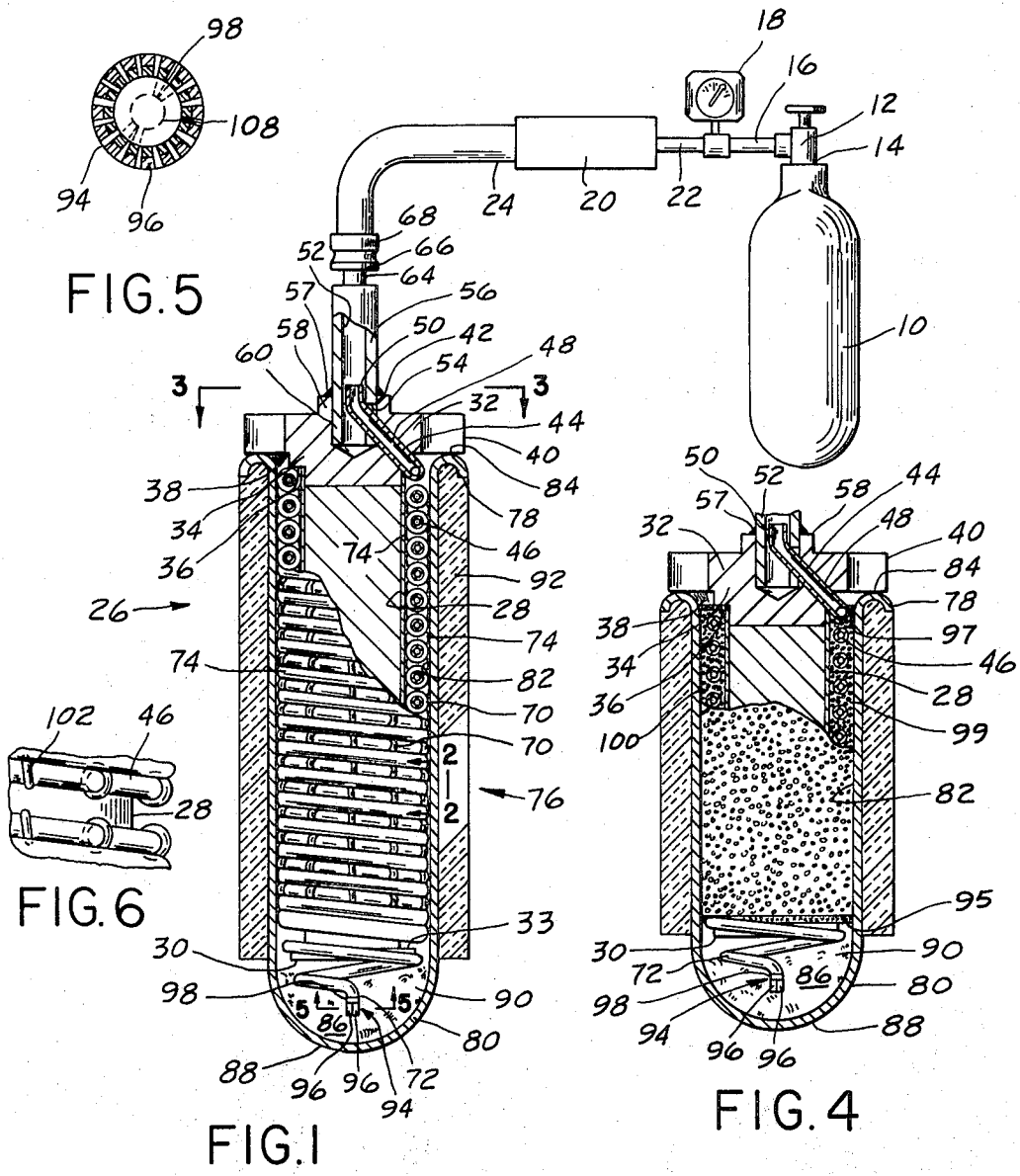


FIG. 5

FIG. 4

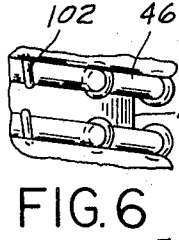


FIG. 6

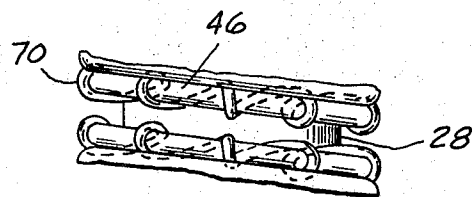


FIG. 2

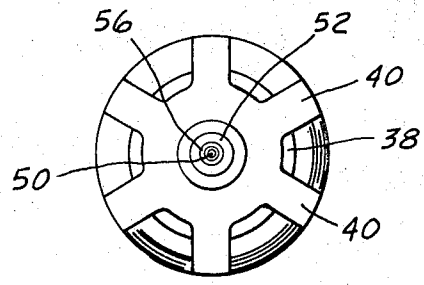


FIG. 3

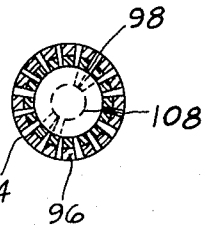


FIG. 5

CRYOGENIC SURGICAL INSTRUMENT

BACKGROUND OF THE INVENTION

Cryogenic surgical instruments have been developed for use in treating diseases wherein other methods would be detrimental to the patient. These cryosurgical instruments usually have a tip or probe which is cooled by a low boiling liquid. However, the storage required for low boiling presents a problem to the mobility of the surgical instrument.

Later a cryogenic device was developed wherein cooling of the probe was achieved utilizing the Joule-Thomson effect wherein high pressure gases cool upon expansion. With this device the probe could be cooled to about -80°C . At -80°C upon touching tissue with the probe, the moisture in the tissue is turned into ice which adheres to the probe. In order to prevent the probe from sticking to tissue, a heating means for instantaneously raising the probe temperature evolved from necessity. Thus, the operator could remove the probe without injury to the healthy tissue. In experimentation where the probe had inadvertently touched healthy tissue, cell destruction has been prevented by immediately warming the end of the probe. However, the surface cells still would be destroyed but in the body's internal repair process of the damaged cells little or no scar tissue could be observed. This was attributed in part to the dead cells which were disposed of through the function of the body.

SUMMARY OF THE INVENTION

It was observed that if the temperature of the probe could be maintained below -80°C adherence of the tissue cells to the probe could be averted. However, to achieve a mobile cryogenic surgical unit without the problems associated with liquefied gases, it was considered a necessity that the easily stored gas be converted into a liquid upon demand. To directly convert a gas into a liquid between -80° to -250°C we have devised an appropriate cryogenic apparatus. In our apparatus a pressurized gas is connected to a tube which is coiled around a cylindrical core. A thermal conductive material in turn surrounds the tube and a sleeve with a closed end frictionally secured to the conductive material. The closed end of the sleeve and the end of the cylindrical core form a chamber into which the end of the tube extends. Gas under pressure is throttled into the chamber causing the temperature therein to be lowered. A path through the thermal conductive material will permit the throttled gas to escape to the atmosphere. As the throttled gas goes through the thermal conductive material, thermal energy is absorbed and transferred to the pressurized gas in the tube to initially cool this gas before it is throttled in the chamber. In this manner if nitrogen is used as the pressurized gas, the initial throttling systematically reduces the temperature of the pressurized nitrogen to the point where liquefaction occurs upon throttling. Once the liquefaction has begun, the thermal transfer by the conductive material maintains the overall efficiency at an effective level.

It is therefore the object of this invention to provide a cryogenic surgical apparatus with means to directly convert a gas to a liquid between -80° to -250°C .

It is another object of this invention to provide a means of initially cooling a gas under pressure by trans-

ferring thermal energy produced by throttling to maintain a portion of the gas in the chamber as a liquid.

It is another object of this invention to provide a cryogenic surgical instrument with the means of liquefying different gases corresponding to the required temperature needed to provide medical treatment.

These and other objects will be apparent from reading this specification and viewing the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a diagrammatic view of a medical cryogenic system with an enlarged sectional view showing a proposed surgical instrument constructed in accordance with our invention.

FIG. 2 is a sectional view substantially along lines 2—2 of FIG. 1 showing the fluid supply tube surrounded by a thermal conductive member.

FIG. 3 is a sectional view along lines 3—3 of FIG. 1 showing a top view of the surgical instrument.

FIG. 4 is a sectional view of another surgical probe for use in the medical cryogenic system of FIG. 1.

FIG. 5 is an enlarged sectional view of a bimetal strip regulator for controlling cryogenic fluid flow through the surgical instrument taken along lines 5—5 of FIG. 1.

FIG. 6 is a sectional view of a secondary embodiment of a finned cryogenic supply conduit for the surgical instrument of FIG. 1.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

The medical cryogenic system in FIG. 1 has a supply vessel 10 containing a suitable pressurized gas. The type of gas is chosen for its liquefaction temperature, which should be between -80° to -250°C , for an example nitrogen gas, whose liquefaction temperature is -196°C . A control valve 12 is located in the outlet 14 of the supply vessel 10 to regulate flow of the pressurized gas therefrom. A supply line 16 is connected to gage 18 which will register the level of pressurized gas flowing from the supply vessel 10 when the regulator is opened. The gage 18 in turn is connected to container 20 by conduit 22. The container 20 is filled with a chemical dryer, such as lithium oxide or a molecular sieve where excessive moisture is removed from the pressurized gas. The container 20 is connected to a surgical instrument means 26 by a delivery line 24.

The surgical instrument means 26 consists of a cylindrical core 28 which has a front end 30 and a rear end 32. The front end 30 has a shoulder 33 which extends from the cylindrical core 28. The rear end 32 has a stepped shoulder 34 which extends from the cylindrical core 28 with a first ledge 36 and a second ledge 38. A series of radial fingers 40 extend from the second ledge 38. A central bore 42 in the rear end 32 is connected by a passageway 44 which terminates between the first and second ledges 36 and 38, respectively. A tube 46 has a linear entrance section 48 which extends through passageway 44 into the central bore 42. The entrance section 48 is sealed in the passageway 44 and the end 50 thereof centrally located in bore 42. A jacket member 52 having a central passageway 56 with a slot 54 is placed around the end 50 of tube 48 and between a rearward projection 58 surrounding the central bore 42. A slight taper can be present in the external surface of the jacket member 52 adjacent the end 60 of the jacket member 52 so that a tight interference fit will be

achieved between the end 50 of the tube and the central passage when the end 60 contacts the bottom 62 of the central bore 42. An additional seal 57 located between jacket 52 and the rearward projection 58 provides a unitary structure capable of withstanding fluid pressures delivered by the storage vessel 10 to the tube 46. The other end 64 of the jacket member 52 retains a male connector 66 which engages a female connector 68 on the flexible delivery line 24.

Where the tube 46 emerges from the passageway 44 individually attached fins such as discs or plates 102, see FIG. 6, or a continuous helically wound fin 70 shown in FIG. 2 is secured to the tube 46, until reaching a predetermined length. This finned tube 46 is now wound in a coil series around the cylindrical core 28. The fin 70 extends to the shoulder 33 and an exit section 72 extends past the end 30 of the cylindrical core 28. After the coil series tube 46 is located around the cylindrical core 28, a resilient barrier means 74 is alternately wound on the cylindrical core 28. Sleeve means 76 having an opened end 78 and a closed end 80 surrounds the resilient barrier means 74. The resilient barrier means being compressed between the cylindrical core 28 and the internal surface 82 to frictionally retain the surface 84 of the opened end 78 against the radial fingers 40. The radial fingers 40 provide a stop for establishing a fixed volume chamber 86 between the front end of the cylindrical core 28 and the closed end 80.

MODE OF OPERATION OF THE PREFERRED EMBODIMENT

When a surgeon determines cryogenic surgery is necessary to relieve an unwanted tissue condition, he turns the control valve 12 to an open position. The pressure of the fluid (nitrogen for example) flowing from the storage vessel 10 is registered on gage 18. The fluid passes through the chemical drier 20 where any moisture therein is removed. This fluid under pressure is transmitted through the supply line 24 into the entrance section 48 of the tube 46. The fluid flows around the coil series and emerges from the tube 46 through the orifice 98 of the exit section 72 into the fixed volume chamber 86. The fluid which passes through the orifice 98 which has a smaller cross sectional area than the entrance section 48, goes from a high pressure to a lower pressure. This change in pressure is directly proportional to the area of orifice 98 as compared to the area of the fixed volume chamber 82. When the pressurized gas passes from a high pressure area to a low pressure area throttling occurs with a corresponding drop in the temperature. The cooled gas can now travel around the tube 46 over by the fins 70 in a path to the rear 32 of cylindrical core 28. The fins being thermally conductive will absorb thermal energy from the cooled gas and dissipate this thermal energy to the gas flowing inside the tube 46. Thus, the gas in tube 46 is systematically and sequentially reduced in temperature to a point where the temperature in the fixed volume chamber 82 approaches -196°C if nitrogen is used. When -196°C is reached, a portion of the throttled gas is converted into a liquid. The liquid in turn will uniformly distribute its temperature to the closed end 80 of the sleeve means 76. The external surface 88 of the closed end 80 can now probe the damaged tissue and surgically destroy the diseased part.

To maintain the liquid in the fixed volume chamber 86 in any orientation, a liquid absorbing material 90 is placed in the fixed volume chamber 86. With the liquid in the chamber being inhibited from escaping by following the flow path around the tube 46, the surgical instrument 26 can be used in any position the surgeon may need. Since this instrument is designed to be hand held in order that the temperature from the body does not affect the thermal transfer between the throttled gas and the pressurized gas in the tube 46, a non-thermal conductive material 92 is placed around the opened end 78. Further, in order to protect the surgeon, the number of fins around the tube as compared to the helically wound tube 46 around the cylindrical core are selected such that the dissipation of thermal energy between the fixed volume chamber 86 and the gas which passes between the finger 40 and surface 84 will not cause discomfort to the hand of a surgeon if exposed to it over a period of time.

In the embodiment shown in FIG. 4 like parts are numbered the same as in FIG. 1. The tube 46 upon emerging from the passageway 44 is helically wound around the cylindrical core 28. A screen 94 is placed on shoulder 33 and granular particle means 98 poured into the space 100 between surface 82 and the cylindrical core 28. The conductive granular particles could be bronze coated with a brazing alloy having a melting point below that of bronze, said conductive granular particles being coated with a flux before placing in the instrument.

When the cavity 100 is filled with this bronze coated flux, the temperature is raised causing the flux to flow and securely bind the particles together in a desired configuration. As the gas flows from chamber 86, the flow paths available will be many since the individual particles will block any direct flow to the exit 78. The granular particles 98 will absorb the thermal energy developed by throttling and dissipate the same to the gas flowing in tube 46 as described with reference to FIG. 1.

The size of the fixed volume chamber 86 and the area of the exit section 72 construction will vary with the particular gas used in the supply chamber. However, as is apparent when nitrogen gas is used, the possibility of fire or damage from breathing a pollutant is greatly reduced. Moreover, in order to conserve the nitrogen supply, a regulator 94 which is responsive to the liquefaction temperature in chamber 86 is attached to the opening on the exit section 72. The regulator 94, see FIG. 5, has a series of bimetal strips 96 attached to a base 98. The bimetal strips 96 form an orifice 98 through which the pressurized gas flows into the fixed volume chamber 86. As the pressurized gas is throttled, the bimetal strips will contract to form an orifice as illustrated by numeral 100 when the liquefaction of the gas has occurred. The bimetal strips being sensitive to temperature change can contract and expand as needed to maintain the temperature on the external surface 88 within a preselected temperature range. Equally appropriate regulators such as described in U. S. Pat. Nos. 3,517,525, 3,590,597, 3,630,047 and incorporated herein by reference could be adapted to control the flow of the pressurized gas. However, we have found that the bimetal strip regulator 94 adequately controls the flow of pressurized gas to maintain the cryogenic surgical instrument 26 within the desired operating range.

We claim:

1. An apparatus for directly converting a gas into a liquid for use in cryosurgery, said apparatus comprising:

a cylindrical core having a front end and a rear end, said rear end having a series of radial stops extending therefrom;

a tube helically wound around said core having an entrance section which extends past said rear end and an exit section which extends past said front end;

screen means secured to the front and rear ends of the cylindrical core;

thermal conductive means surrounding said tube from said entrance section to said exit section, said thermal conductive means including granular particle means retained between said screen means, said particle means contacting each other and said tube, a source of gas under pressure connected to said entrance section of said tube; and

sleeve means having a closed end and an open end frictionally engaging and surrounding said thermal conductive means, said open end abutting said radial stops to form a fixed volume chamber between the exit section of the tube and the closed end, said gas under pressure being throttled by passing through said exit section into said fixed volume chamber, said throttled gas lowering the temperature in said fixed volume chamber to between -80° to -250°C by liquefying, said thermal conductive means providing a flow path from said fixed volume chamber around said tube and out said rear end, said flow path providing an escape route for pressurized gas during said throttling, said flow path from the fixed volume chamber being intercepted by the granular particle means causing numerous deflections permitting the granular particle means to absorb thermal energy from the pressurized gas flowing along the path and to transfer this thermal energy to the gas under pressure in the tube by conductions, said liquefied gas conducting a corresponding temperature to said closed end for permitting the external surface thereof to be used as a cryogenic surgical instrument.

2. The apparatus, as recited in claim 1, wherein said exit section of said tube includes: regulator means responsive to the temperature of the

liquefied gas in fixed volume chamber for restricting the flow of the pressurized gas.

3. The apparatus, as recited in claim 2, wherein said regulator means includes:

a base attached to said exit section; and a series of bimetal strips attached to said base, said bimetal strips reacting to the temperature in the fixed volume chamber to form an orifice through which the pressurized gas flows into the fixed volume chamber.

4. The apparatus, as recited in claim 3, wherein said thermal conductive means includes:

fin means attached to said tube to form a finned section thereon, said finned section cooperating with the granular particle means to said flow path.

5. The apparatus, as recited in claim 4, wherein the length of the finned section as compared to the length of the helical tube is adequate to dissipate sufficient thermal energy from said pressurized gas to eliminate discomfort to an operator in contact with the entrance section of said tube.

6. The apparatus, as recited in claim 5, wherein the external surface of said sleeve means is covered with a thermal non-conductive material to prevent outside thermal energy from affecting dissipation of the internal thermal energy of said gas by the conductive fins.

7. The apparatus, as recited in claim 1, wherein said source of pressurized gas passes through a dryer to remove any moisture therefrom which would adversely affect said throttling.

8. The apparatus, as recited in claim 2, wherein said source of gas passes through a regulator to stabilize the pressure and flow of said gas.

9. The apparatus, as recited in claim 8, wherein said apparatus further includes:

a liquid absorption material located in said fixed volume chamber to retain the liquefied gas in said fixed volume chamber and allow unrestricted movement of said closed end without loss of said liquefied gas through said path.

10. The apparatus, as recited in claim 9, wherein the size of the fixed volume chamber and the exit section of the tube are mated to provide effective throttling for the source of gas under pressure.

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