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Basiulis et al.

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[54] **CRYOGENIC HEAT TRANSFER DEVICE**

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[51] **Int. Cl.**.......**A61b 17/36**, F25d 3/00, A01k 11/00

[58] **Field of Search**.......................128/303.1, 401 X, 128/400; 119/1; 62/293

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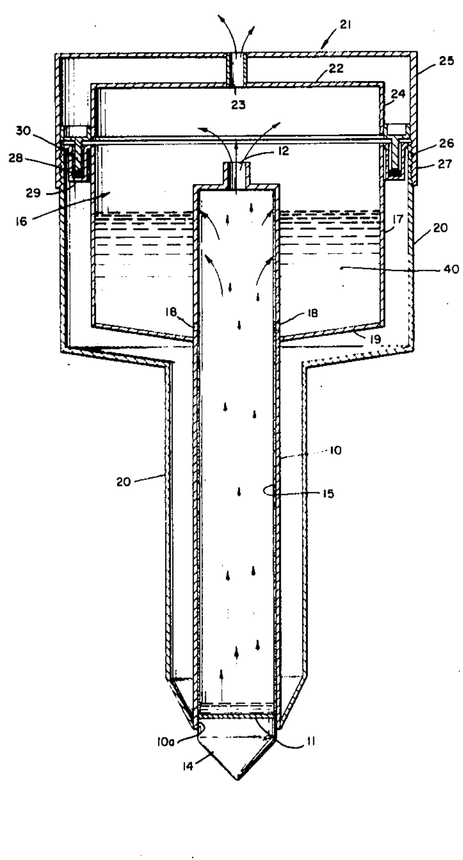
[57] **ABSTRACT**

Heat transfer devices especially suitable for cryosurgery are disclosed each including an elongated tubular housing of low thermal conductivity having an open end and a closed end. A conical probe member of high thermal conductivity is mounted at and extends from the closed end of the housing. A capillary wick lining the inner lateral surface of the housing is adapted to convey a volatile working fluid such as liquid nitrogen at a temperature of −196°C from the vicinity of the open end of the housing to the vicinity of the closed end. A working fluid reservoir is disposed about the open end of the housing in fluid communication with the capillary wick. An annular evacuated chamber is provided about the outer surface of the reservoir and a substantial portion of the outer lateral surface of the housing to afford thermal insulation.

13 Claims, 3 Drawing Figures



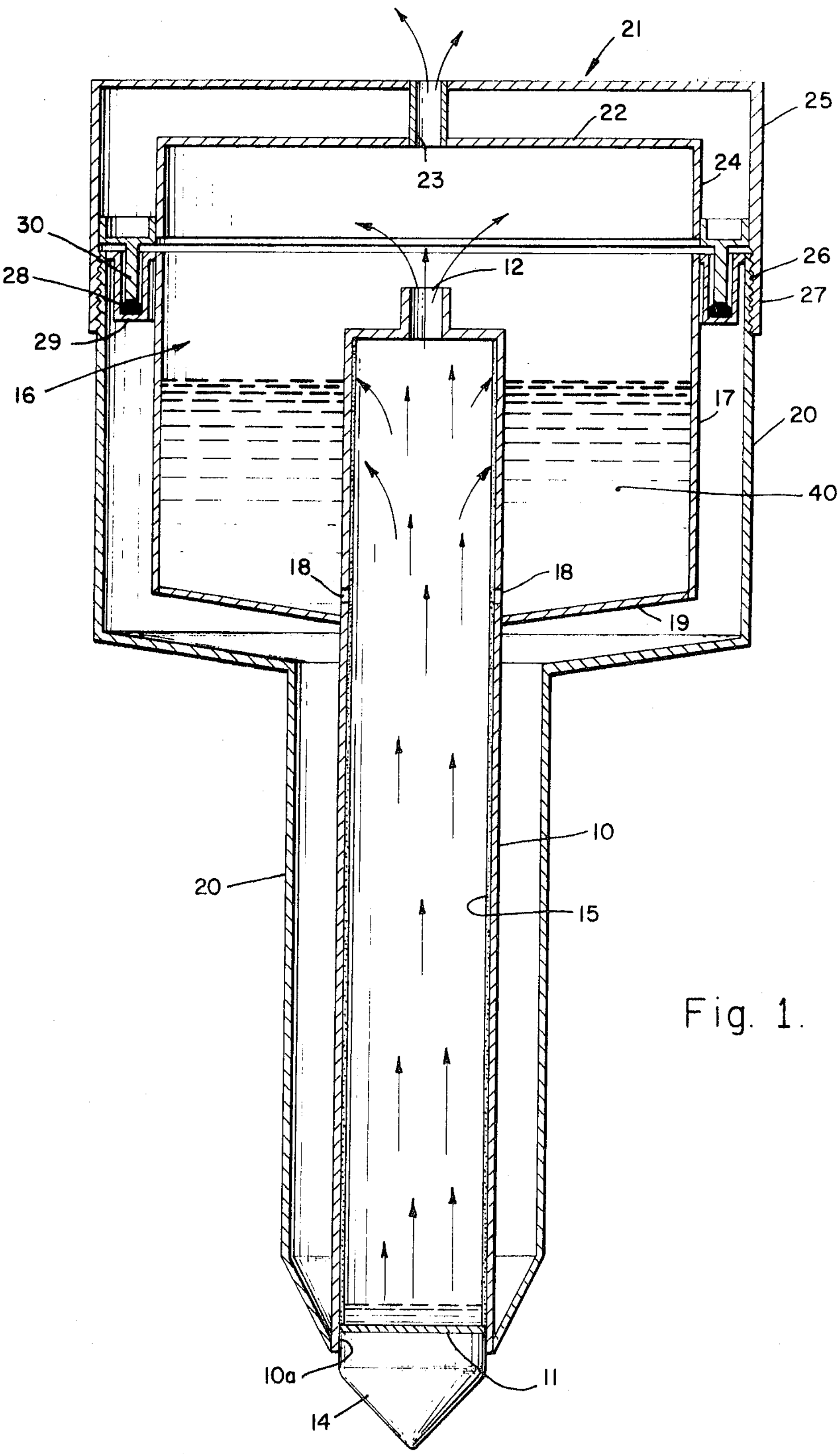
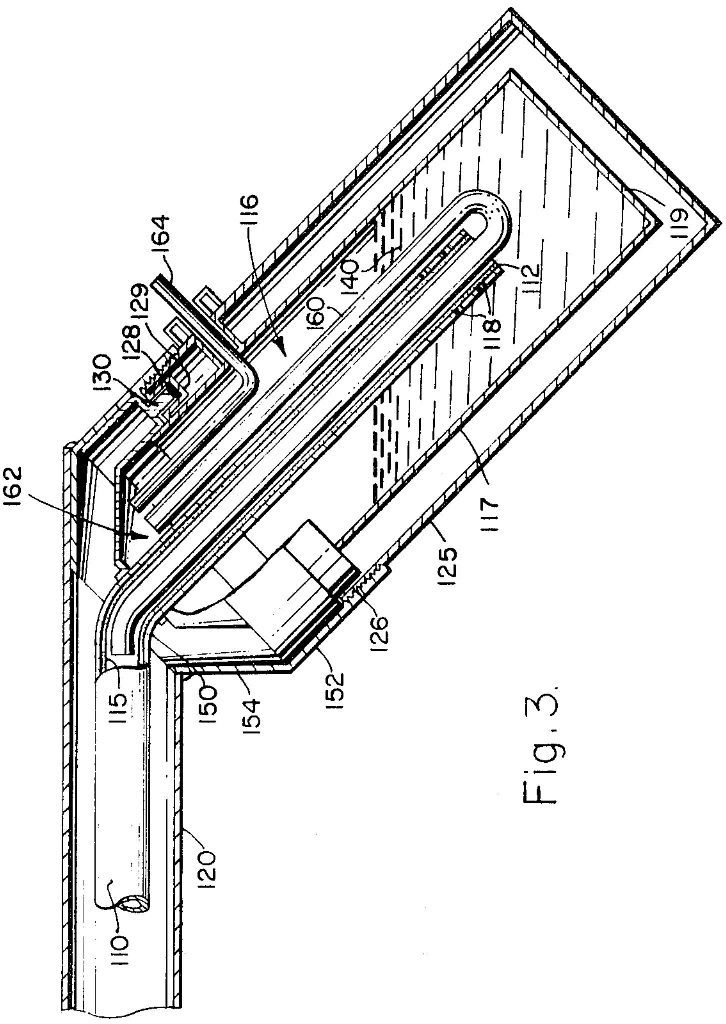


Fig. 1.


116
164
129
128
130
160
140
112
118
119
162
117
125
126
152
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150
115
120
110

Fig. 3.

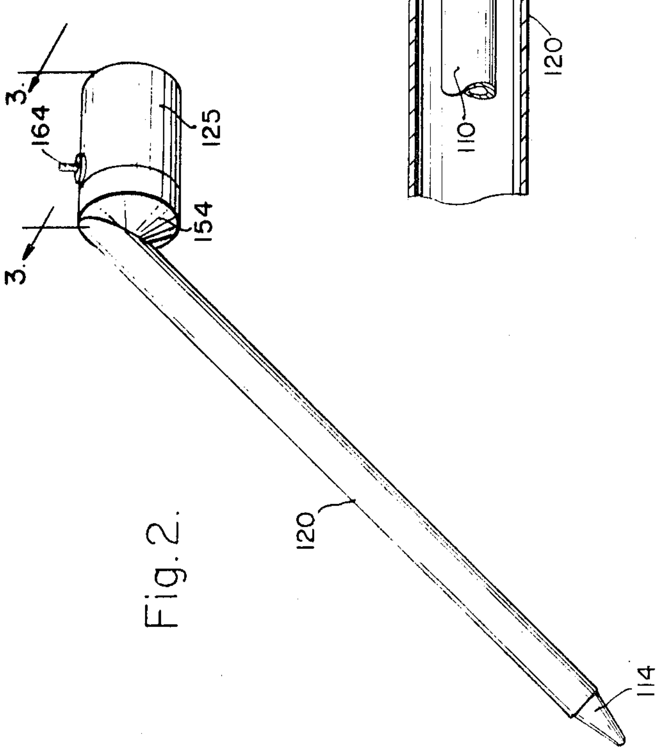
3.
164
125
154
3.
120
114

Fig. 2.

CRYOGENIC HEAT TRANSFER DEVICE

FIELD OF THE INVENTION

This invention relates generally to heat transfer devices, and more particularly relates to a wholly self-contained, handheld cryogenic surgery tool which is readily portable, easily and quickly activated and convenient to use.

DESCRIPTION OF THE PRIOR ART

Certain surgical operations, such as a hemorroidectomy, may be performed quickly and painlessly by freezing the cells of the affected tissue. As subfreezing temperatures are reached and ice formation occurs in the cell, cellular organization is irreversibly altered. As the frozen tissue thaws, water is removed from the interior of the cell, resulting in cellular dehydration and destruction. Cryosurgical techniques are also being used in the treatment of chronic cervicitis, endometrial carcinoma, Parkinsonism, cataracts, and other diseases.

The usual procedure in cryosurgery is to lower the temperature of the diseased tissue to at least about −20°C. There are a variety of techniques for achieving such low tissue temperatures. One method is to dip an applicator such as a cotton swab or copper disk into liquid nitrogen (which is at −196°C) and then apply it to the diseased tissue. However, the use of such an applicator usually requires repeated applications, and great care must be taken to insure that only the diseased tissue is destroyed and not the surrounding healthy tissue.

Apparatus presently employed for performing cryosurgery consists of a control console with a liquid nitrogen supply and a cryoprobe. The console houses a Dewar container, having a capacity of 5 liters, and associated control and monitoring circuits. A heating system for thawing the cryoprobe is also included in the console. An input hose conveys liquid nitrogen from the Dewar container to the cryoprobe, while an output hose returns the liquid nitrogen to the console where it is exhausted into the atmosphere. In operation, liquid nitrogen (at −196° C) is placed in the Dewar container, and the container is sealed. Pressure within the container is increased, forcing the nitrogen through the input hose to the cryoprobe. The cryoprobe tip is cooled to about −180°C by the flow of the liquid nitrogen past the cryoprobe. The liquid nitrogen is then returned to the supply console via the output hose to be exhausted to the atmosphere as a vapor.

Although the aforedescribed apparatus has been used successfully in performing cryosurgery, about one minute of operation time is required before stabilization at the desired low temperature is achieved, largely because of the inefficiency of cooling by liquid flow. Moreover, since the cryoprobe is connected to the console unit by bulky hoses, two hands are required to hold the cryoprobe apparatus during the surgery. Thus, the apparatus is rather cumbersome to use, and the surgeon must be assisted in all but the simplest of operations. In addition, the entire apparatus (including the control and supply console) is relatively bulky and weights about 100 pounds, and a relatively large supply of liquid nitrogen is required for the apparatus to operate properly. Thus, a constraint is imposed on use of the apparatus by the availability of manpower to move both the apparatus itself and an adequate supply of liquid nitrogen to the site where the operation is to be performed.

SUMMARY OF THE INVENTION

Accordingly, it is an object of the present invention to provide a simple, reliable and convenient heat transfer device especially suitable for operation at cryogenic temperatures.

It is a further object of the present invention to provide a heat transfer device for performing cryosurgery which reaches the desired operating temperature very quickly and maintains that temperature readily.

It is a still further object of the invention to provide a small, handheld cryosurgery tool which is completely self-contained and readily portable.

In accordance with the foregoing objects, a heat transfer device according to the invention includes an elongated housing of low thermal conductivity having an open end and a closed end. A probe member of high thermal conductivity is mounted at and extends outwardly from the closed end of the housing. A capillary wick is longitudinally disposed within the housing for conveying a volatile working fluid from the vicinity of the open end of the housing to the vicinity of the closed end. A working fluid reservoir is provided about the open end of the housing in fluid communication with the capillary wick. Thermal insulation is provided about the outer surface of the reservoir and a substantial portion of the outer lateral surface of the housing.

The foregoing and other objects and features of the present invention will become readily apparent from the following detailed description of preferred embodiments of the invention when considered in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings:

FIG. **1** is a longitudinal sectional view illustrating a heat transfer device according to one embodiment of the present invention;

FIG. **2** is a perspective view illustrating a heat transfer device according to another embodiment of the invention; and

FIG. **3** is a longitudinal sectional view of a portion of the device of FIG. **2** as taken along line **3—3** of FIG. **2.**

Referring more specifically to FIG. **1**, a heat transfer device according to the invention may be seen to include a thin-walled elongated tubular housing **10** having a closed end **11** and an open opposite end **12** which may be of reduced diameter as shown. The housing is preferably of a material of low thermal conductivity such as stainless steel, for example. The vicinity of the closed end **11** of the housing **10** functions as an evaporation region where a working fluid contained within the housing is vaporized by applied heat. A tapered probe **14,** shown as having a generally conical configuration, is mounted within extension **10a** of the housing **10** with its base contacting the housing end wall **11** alternatively, separate end wall member **11** may be eliminated with the base of probe **14** constituting an end wall for the housing **10.** The probe **14,** which should be of a material of high thermal conductivity, absorbs heat from a source, such as living tissue for example, and transfers heat by conduction to the housing wall **11.** The probe may be held in place by frictional force with the inner lateral surface of housing extension **10a** or, alternatively, by threads provided on extension **10a** and probe **14.** It is pointed out that while a particular probe shape has been illustrated, the shape of probe **14** is not critical and may vary depending upon the particular application of the heat transfer device.

A capillary wick **15** lines the inner lateral surface of the housing **10.** The wick **15** may be made of any material through which fluid can travel by capillary forces, examples of suitable wick materials being felt cloth, stainless steel screen, and sintered metal fibers. It is pointed out that the capillary wick **15** need not line the entire inner lateral surface of housing **10,** and other wick arrangements such as a plurality of longitudinally extending wick strips circumferentially spaced along the inner surface of housing **10** may be employed in the alternative.

A working fluid reservoir **16** is provided for the housing **10** in the vicinity of its open end **12.** The reservoir **16** is defined by a tubular member **17** coaxially mounted about housing **10** at its open end region and an annular member **19** extending inwardly from the lower edge of member **17** to the outer surface of housing **10.** The annular member **19** is welded or otherwise attached to the member **17** and to the housing **10** so as to form a fluid tight seal therewith. The reservoir members **17** and **19** are preferably of a material of low thermal conductivity such as stainless steel, for example. In order to provide fluid communication between the reservoir **16** and the capillary wick **15,** a plurality of circumferentially spaced apertures **18** may be provided in housing **10** just above where it is sealed to annular reservoir member **19.**

In order to provide thermal insulation for the device, a tubular metal shell **20** is coaxially disposed about the housing **10** and the reservoir members **19** and **17** in a manner providing an annular space between the shell **20** and the members **10, 17** and **19,** the end regions of the shell **20** being in hermetically bonded relationship with the respective end regions of the housing **10** and the reservoir member **17.** The annular space between the shell **20** and the housing **10** and reservoir members **17** and **19** is evacuated to provide the desired thermal insulation. A coating of fiberglass or plastic may be applied over the outer surface of the shell **20** to provide additional thermal insulation, if desired.

The open upper end of reservoir **16,** which affords a fluid inlet to the reservoir **16,** may be covered by a cap **21** during operation of the device. The cap **21** consists of a flat circular member **22** having a central exhaust port **23** axially aligned with the opening in end **12** of housing **10** and a lip **24** projecting downwardly from the circumferential edge of member **22.** Thermal insulation for the cap **21** may be afforded by an evacuated chamber defined by members **22, 24,** and a metal shell **25** disposed about and spaced from the members **22** and **24** and in a hermetically bonded relationship therewith.

The cap **21** may be attached to the reservoir **16** by mating threads **26** on the inner surface of an annular extension **27** of the shell **25** and on the outer surface of the shell **20** adjacent its upper end. A fluid tight seal may be provided between the cap **21** and the reservoir **16** by means of an O ring **28** disposed in an annular groove-defining member **29** mounted between the shell **20** and the reservoir member **17** at the upper ends thereof, and an annular flange **30** projecting from the cap **21** into the groove of member **29** and adapted to compress O ring **28.**

In operation of the heat transfer device of FIG. 1, a suitable low temperature working fluid **40** at a temperature below its boiling temperature is poured into the reservoir **16.** Examples of particular working fluids which may be employed are liquid nitrogen at −196° C, oxygen at −183° C, or freon at −81° C.

The working liquid **40** in the reservoir **16** flows into the housing **10** through apertures **18,** wetting the capillary wick **15.** The liquid **40** moves into the wick **15** and is conveyed by capillary action along the wick **15** toward the end of the housing **10** adjacent the probe **14** as long as wick **15** is not saturated. However, once the wick **15** becomes saturated, additional liquid is precluded from entering the housing **10** via apertures **18.**

Upon reaching the evaporator wall **11,** the liquid **40** becomes vaporized because the temperature of evaporator wall **11** is initially much higher than the boiling temperature of the liquid **40.** It is well known that in the process of vaporization a liquid will absorb heat from its surroundings and thereby lower the temperature of the surroundings. Thus, as the liquid **40** reaching evaporator wall **11** continues to be vaporized, the temperature of evaporator wall **11** (and hence probe **14**) is lowered to the boiling temperature of the liquid **40.**

When the probe **14** is placed in contact with a heat source, such as living tissue for example, heat is transferred from the heat source to the probe **14** and conveyed by conduction to the evaporator **11,** causing a slight rise in the temperature of evaporator **11.** This in turn causes more liquid **40** to be vaporized which again lowers the temperature of evaporator **11** and probe **14.** Thus, the probe **14** is maintained essentially at the boiling temperature of the working fluid **40.**

Since the vaporizing fluid causes a pressure increase in the region of the housing **10** adjacent the evaporator **11,** the vapor travels along the housing to the vicinity of the open end **12.** There some of the vapor condenses into liquid as it contacts the colder temperature of the capillary wick **15.** The remaining vapor passes through the opening at end **12** and is exhausted to the atmosphere through port **23.**

A heat transfer device according to another embodiment of the present invention is illustrated in FIGS. 2 and 3. Components in the embodiment of FIGS. 2 and 3 which are similar to respective components in the embodiment of FIG. 1 are designated by the same reference numerals as their corresponding components in FIG. 1 except for the addition of a prefix numeral "1."

The embodiment of FIGS. 2 and 3 differs from the embodiment of FIG. 1 in that housing **110** is bent by about 45° in the region **150** where housing **110** enters reservoir **116.** Also, apertures **118** providing fluid communication between the reservoir **116** and the housing **110** are located closer to the open end **112** of the housing **110.** The reservoir **116,** including tubular member **117** and end member **119,** as well as thermally insulating outer shell member **125,** is detachable from the remainder of the device in order to facilitate filling the reservoir **116** with working fluid. Mating threads **126** are provided on the outer surface of shell **125** near its end region and on the inner surface of enlarged tubular extension **152** of a funnel-like transition member **154** hermetically bonded to the shell **120** surrounding the portion of housing **110** outside of reservoir **116.** An essentially U-shaped vent tube **160,** mounted within the reservoir **116** by means not shown, has one end extending into the housing **110** to the vicinity of bend **150** and the other end extending to a region **162** externally of the housing **110** in the vicinity of the transition member **154.** The vent tube **160** conveys vaporized working fluid through the contained liquid **140** in the reservoir **116** to the region **162** from where it is vented to the atmosphere externally of the reservoir via an essentially L-shaped exhaust tube **164.**

It should be apparent from the foregoing that the present invention provides a self-contained, simple, and readily portable heat transfer device which is especially suitable for performing cryosurgery. Moreover, the device reaches the desired low operating temperature very quickly and maintains that temperature readily. In fact, heat transfer devices according to FIG. **1** and FIGS. **2–3** have been constructed which weigh slightly over two pounds and reach an operating temperature of −196° C within 30 seconds after their respective reservoirs **16** and **116** have been filled with liquid nitrogen at a temperature of −196° C.

Although the present invention has been shown and described with reference to particular embodiments, nevertheless, various changes and modifications obvious to one skilled in the art to which the invention pertains are deemed to lie within the purview of the invention.

What is claimed is:

1. A heat transfer device comprising:

an elongated housing of low thermal conductivity having an open end and a closed end;

a probe member of high thermal conductivity mounted at said closed end of said housing and extending therefrom;

capillary wick means longitudinally disposed within said housing for conveying a volatile working fluid from the vicinity of said open end to the vicinity of said closed end of said housing;

means defining a working fluid reservoir disposed about said open end of said housing in fluid communication with said capillary wick means; and

thermally insulating means disposed about the outer surface of said reservoir means and a substantial portion of the outer lateral surface of said housing.

2. A heat transfer device according to claim **1** and further including means for providing a vapor exhaust path from said reservoir.

3. A heat transfer device according to claim **2** wherein said means defining said reservoir includes a removable cap member having a vapor exhaust port therein.

4. A heat transfer device according to claim **1** wherein said means defining said reservoir includes first and second detachable members, and means for forming a hermetic seal between said first and second members when in attached relationship.

5. A heat transfer device according to claim **1** wherein said thermally insulating means includes a shell member disposed about and spaced from said housing and a portion of said reservoir means and hermetically bonded thereto, the space between said shell member and said housing and said reservoir portion being evacuated.

6. A heat transfer device for performing cryosurgery by freezing comprising:

an elongated tubular housing of low thermal conductivity having an open end and a closed end;

a tapered probe member of high thermal conductivity mounted at said closed end of said housing with

its portion of greatest cross-section adjacent to said closed end;

capillary wick means longitudinally disposed along the inner lateral surface of said housing for conveying a volatile working fluid from the vicinity of said open end to the vicinity of said closed end of said housing;

means coaxially disposed about said housing in the vicinity of said open end for defining a working fluid reservoir, said housing defining a plurality of circumferentially spaced apertures in its lateral surface near said open end to provide fluid communication between said reservoir and said capillary wick means;

means for providing a vapor exhaust path from said reservoir; and

thermally insulating means disposed about the outer surface of said reservoir means and a substantial portion of the outer lateral surface of said housing.

7. A heat transfer device according to claim **6** wherein said means defining said reservoir includes a removable cap member having a vapor exhaust port therein.

8. A heat transfer device according to claim **6** wherein said housing is bent in the region where it enters said working fluid reservoir.

9. A heat transfer device according to claim **6** and further including an essentially U-shaped vent tube having one end extending into said housing via said open end, and an essentially L-shaped exhaust tube in vapor communication with the other end of said vent tube and extending externally of said means defining said reservoir.

10. A heat transfer device comprising:

an elongated housing having an open end and a closed end;

a probe member of high thermal conductivity mounted at said closed end of said housing and extending therefrom;

capillary means longitudinally disposed within said housing for conveying a volatile working fluid liquid from the vicinity of said open end to the vicinity of said closed end of said housing;

means defining a working fluid reservoir disposed about said open end of said housing in fluid communication with said capillary means for containing volatile working fluid liquid; and

thermal insulating means disposed about some of the outer surface of said reservoir means and some of the outer lateral surface of said housing for thermally insulating those surfaces.

11. A heat transfer device for performing cryosurgery by freezing comprising:

an elongated tubular housing having an open end and a closed end;

a tapered probe member of high thermal conductivity mounted at said closed end of said housing with its portion of greatest cross-section adjacent to said closed end;

capillary means longitudinally disposed along said housing for conveying a volatile working fluid liquid from the vicinity of said open end to the vicinity of said closed end of said housing;

means disposed about said housing in the vicinity of said open end for defining a working fluid liquid reservoir, said housing having a plurality of circumferentially spaced apertures in its lateral surface near said open end to provide liquid working fluid communication between said reservoir and said capillary means;

means for providing a working fluid vapor exhaust path from the vicinity of said closed end of said housing; and

thermal insulating means disposed about a portion of the outer surface of said reservoir means and a portion of the outer lateral surface of said housing.

12. A heat transfer device comprising:

reservoir means for the containment of a cryogenic liquid working fluid;

capillary means connected to said reservoir means for receiving cryogenic liquid and transporting cryogenic liquid along said capillary means;

probe means connected to said capillary means to deliver heat to said cryogenic liquid working fluid to boil said fluid into a gas whereby said probe means is cooled; and

vapor conduit means for conducting cryogen gas away from said probe means.

13. The heat transfer device of claim **12** wherein said capillary means and said cryogen gas conduit means are housed in the same housing.

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