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[54] **RECHARGEABLE CRYOSURGICAL INSTRUMENT**
9 Claims, 8 Drawing Figs.

[52] **U.S. Cl.** **128/303.1,** 62/293
[51] **Int. Cl.** **A61b 17/36,** F25d 3/00
[50] **Field of Search** .... 128/400, 400 (X), 254, 303, 399, 401; 62/6, 55, 292, 293; 165/24, 27; 62/514; 220/40; 128/303.1

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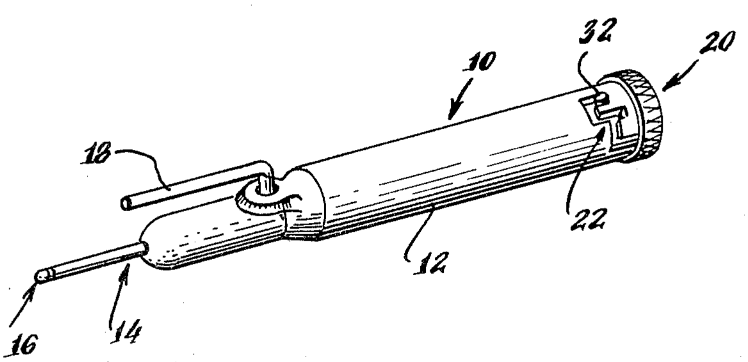
ABSTRACT: This disclosure relates to a rechargeable cryosurgical instrument having operating mechanism located at one end and a refrigerant cartridge-receiving chamber opening to the atmosphere at its other end. A removable end cap closes the open end of the instrument and is selectively positionable to locate a housed refrigerant cartridge in a dispensing or conserving position. In the dispensing position of the end cap, the pressurized refrigerant is dispensed from the cartridge through a delivery tube to a boiler valve located adjacent a cooling tip to reduce the temperature of the tip. The spent refrigerant is exhausted from the housing through an opening in the removable end cap. A selectively operable finger-actuable lever located at the exterior of the housing operates the boiler valve to either cool or warm the cooling tip.



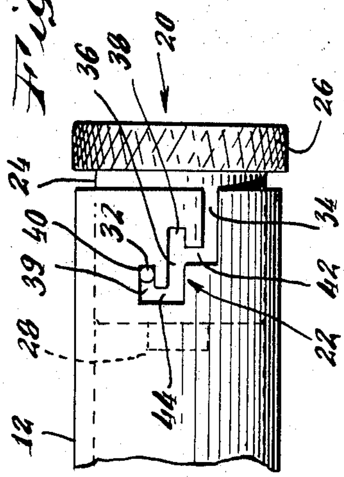


Fig. 4.

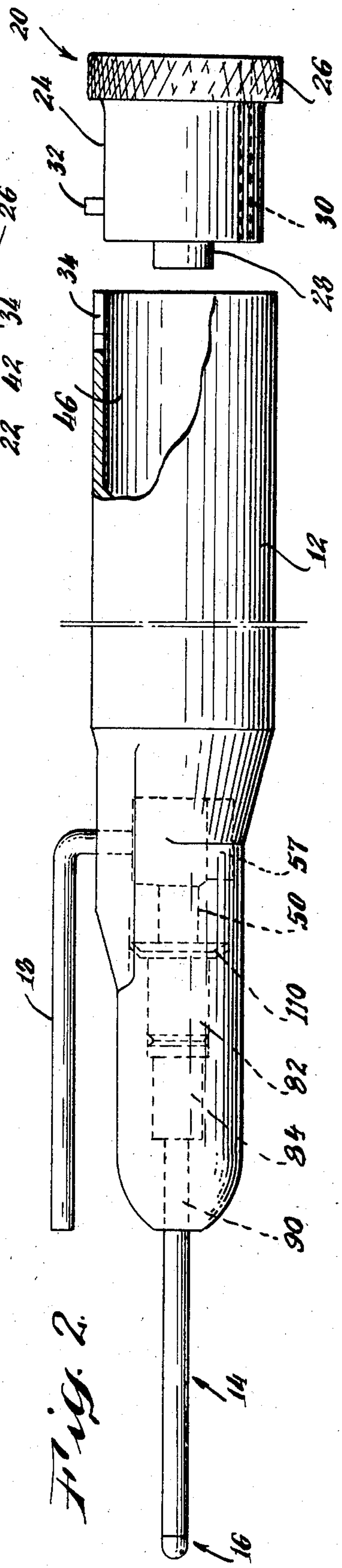


Fig. 2.

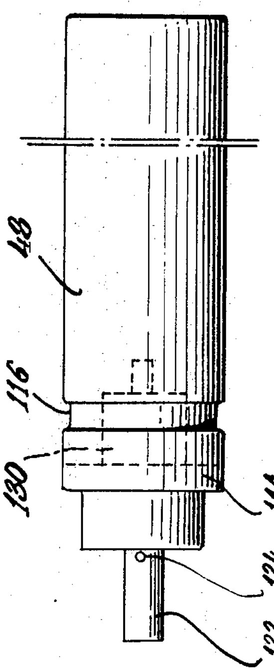


Fig. 3.

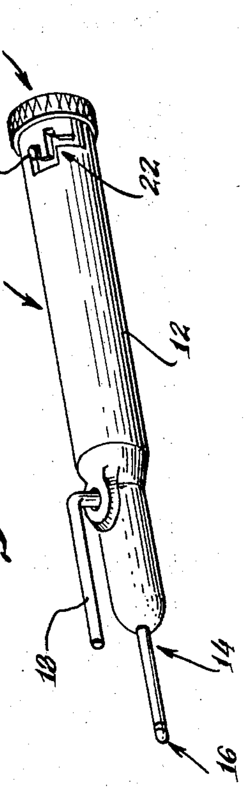


Fig. 1.

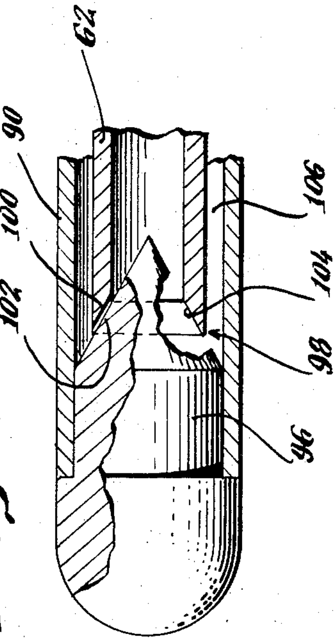


Fig. 8.

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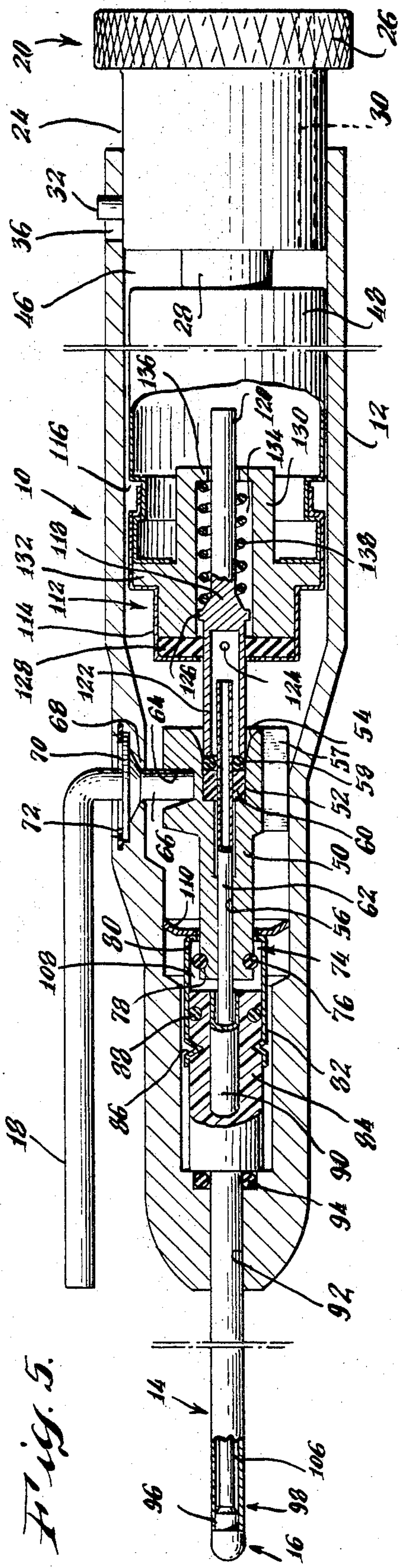

Fig. 5.

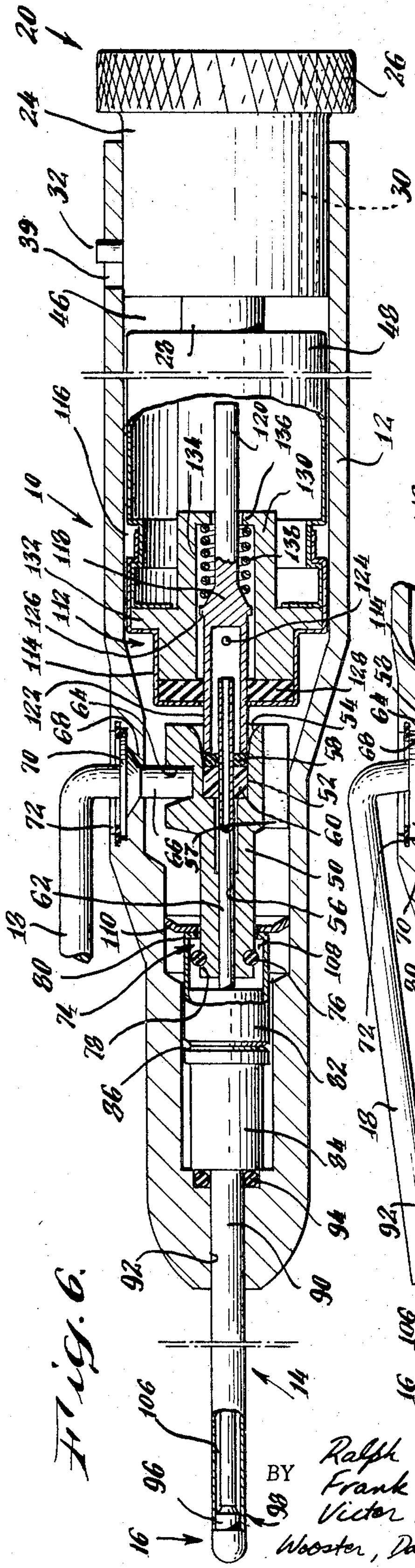

Fig. 6.

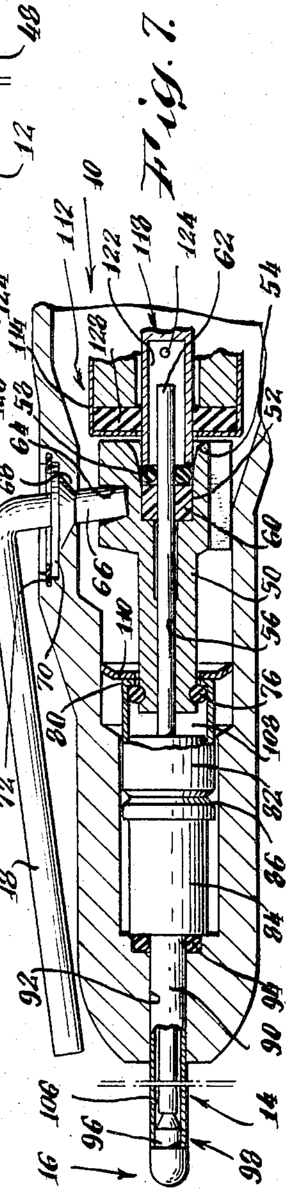

Fig. 7.

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RECHARGEABLE CRYOSURGICAL INSTRUMENT

BACKGROUND OF THE INVENTION

This invention relates to a rechargeable cryosurgical instrument and, more particularly, to such a device designed for delicate surgery, which is normally cold when in use and may be rapidly warmed as desired, and in which means are provided to conserve the refrigerant when the instrument is not in use.

The phenomenon of moist tissue adhering to cold metal is well known but until recently was seldom surgically utilized. Recently, cryoextraction has become a formidable opthalmological procedure based on this phenomenon. One use now made of this procedure is the intracapsular extraction of cataracts. Cataract surgery, which is one of the most delicate operations that a surgeon is called upon to perform, involves the removal of an opacified lens. Usually the lens, which comprises a very thin membrane containing a fluid, is extracted whole through an incision made at the intersection of the cornea and the outer edge of the iris. Most commonly in the past this has been accomplished by the exertion of traction thereon by means of a suitable device, for example, specially designed forceps. Although the cataract operation has been greatly improved in recent years by the use of better traction instruments, they have a tendency to cause the membrane to rupture. With the advent of the procedure of cryoadhesion and the invention of various surgical instruments based upon this principle, it is possible to provide the surgeon with a safe, reliable, and easily manipulatable instrument with which to accomplish the intracapsular extraction. This is done by contacting the lens with a cryosurgical instrument having a tip which may be cooled by a refrigerant that boils at approximately −30° C. The temperature of the tip on the warm lens is apt to be −10° to −20° C, depending on the duration of application. This freezes the membrane and forms an intralenticular ice mass contiguous to the probe which assists in distributing the extraction force over a large area of the membrane to prevent its rupture.

The principle of cryoextraction is also utilized in removing nonmagnetic intraocular foreign bodies, such as wood splinters. In such a surgical operation it is possible to introduce the probe of a cryosurgical instrument into the pupil and place it beside the foreign matter. As the tip of the probe is made cold, it freezes the adjacent vitreous and an expanding ice ball engulfs the foreign matter. By withdrawing the probe towards the surface but thawing and refreezing it at frequent intervals, it is possible to extract the ice-encased foreign matter from the vitreous without removing the central portion of the vitreous body in the process. Inevitably, the final removal of the foreign matter involves the loss of some of the surrounding vitreous, but this can be minimized by controlling the exit wound with sutures and by partially thawing the probe in the final stages of extraction.

Various cryosurgical instruments have been developed to utilize the technique of cryosurgery. These fall into three general categories, namely: (1) continuously operating units; (2) disposable instruments which may be used but a single time; and (3) solid probes which are cooled merely by being immersed in a cold liquid such as alcohol and dry ice. The first category is represented by various high-priced systems such as those operating on the Peltier effect, which must be connected to a source of electrical power, or those having a remote supply tank of a suitable refrigerant which must be piped to the instrument. The latter may also require a suction pump to exhaust the refrigerant to vary the degree of cooling of the tip. These instruments are designed to allow the surgeon to quickly warm the tip so that he may disengage it from the tissue inadvertently adhered thereto. Conventional instruments in the second and third categories, while being considerably less expensive than those of the first category, have the distinct disadvantage of lacking integral warming means and require the application of an externally applied warming medium to the area of the cryoadhesion if the

surgeon should accidentally touch adjacent healthy tissue with the tip of the cold probe. This is usually accomplished by irrigating the area with a warm saline solution and generally requires the intervention of another sterile person in the operating room. Alternatively, some prior art instruments are defrosted by means of an electrically heated wire. This creates a potentially dangerous situation in explosive environments and also requires a separate control. Furthermore, the instruments falling in these categories are generally crude and are often of dubious sterility.

SUMMARY OF THE INVENTION

Accordingly, it is the primary object of this invention to provide a cryosurgical instrument in the form of a rechargeable unit having a chamber therein to receive a cartridge of pressurized refrigerant.

Another object is to provide a cryosurgical instrument of the type described in the above paragraph, wherein the instrument includes valving to render the tip of the probe normally cold and means are provided to selectively warm the tip.

Still another object of this invention is to provide a rechargeable cryosurgical instrument which is lightweight, compact and inexpensive and which includes means to position the cartridge within the instrument body to prevent discharge of the refrigerant therefrom when the instrument is not in use.

To accomplish these objects, in one form a rechargeable cryosurgical instrument is provided having a body defining a refrigerant cartridge-receiving chamber opening to the atmosphere at one end and a cooling tip at the other end. The body houses a boiler valve adjacent the cooling tip and valve-operating means between the chamber and the cooling tip. Control means for the valve-operating means extends from the interior of the body to the exterior thereof and is selectively operable to move the boiler valve for cooling or warming the cooling tip. Means are provided for delivering the refrigerant from a refrigerant cartridge in the body chamber to the cooling tip and means are provided to exhaust the spent refrigerant from the cooling tip to the chamber. A removable end cap located in the open end of the body defines a vent therein and includes means for being selectively located in a refrigerant-conserving or in a refrigerant-dispensing position.

BRIEF DESCRIPTION OF THE DRAWINGS

Other objects and further details of that which is believed to be novel and the invention herein will be clear from the following description and claims taken with the accompanying drawings, wherein:

FIG. 1 is a perspective view of the rechargeable cryosurgical instrument constructed in accordance with this invention;

FIG. 2 is a side elevational view of the rechargeable cryosurgical instrument with its end cap removed and partially broken away to show the end cap-positioning slot;

FIG. 3 is a side elevational view of a typical valved refrigerant cartridge;

FIG. 4 is a partial top plan view of the end of the rechargeable cryosurgical instrument showing the end cap relative to the positioning slot;

FIG. 5 is a longitudinal sectional view of the rechargeable cryosurgical instrument shown with the end cap in the refrigerant-conserving position;

FIG. 6 is a longitudinal sectional view similar to that of FIG. 5 showing the rechargeable cryosurgical instrument with the end cap in the refrigerant-discharging position for normal cooling;

FIG. 7 is a partial longitudinal sectional view similar to that of FIG. 6 showing the instrument in its thawing condition; and

FIG. 8 is an enlarged partial longitudinal sectional view showing the cooling tip in detail.

DESCRIPTION OF THE PREFERRED EMBODIMENT

With reference to the drawings, there is illustrated in FIG. 1 a rechargeable cryosurgical instrument generally referred to by the numeral **10**. It is in the form of a pencillike instrument having a body **12** with a probe **14** at one end, terminating in a tip **16**, an operating lever **18** overlying the forward portion of the body, and a removable end cap **20** selectively movable into several positions in positioning slot **22** at its other end. The instrument is lightweight, the body **12** being made, for example, of a suitable metal or plastic material. As this instrument is rechargeable and therefore reusable, as will become apparent hereinafter, the material of which the body is made must be chosen so as to be dimensionally stable and otherwise unaffected by the use of a sterilizing gas such as ethylene oxide. Similarly, the material may be autoclavable.

Turning now to the details of the instrument, the removable end cap **20**, also made of metal or plastic, comprises a cylindrical body **24** with an enlarged cylindrical knurled head **26** at one end, a smaller diameter central axial boss **28** at the other end, and an axial vent **30** passing through the body **24** and head **26**. A radially extending positioning pin **32** located near the forward end of the body **24** cooperates with the positioning slot **22** defined in the thin wall of the instrument body. The positioning slot is of generally steplike configuration, including an axial entrance leg **34**, a first positioning leg **36** terminating at its right end (as viewed in FIG. 4) in a first positioning seat **38**, and a second positioning leg **39** having a positioning seat **40**. Step portion **42** connects the entrance leg **34** with the first positioning leg and step portion **44** connects the first positioning leg with the second positioning leg **39**.

The instrument body **12** is in the form of a generally cylindrical thin-walled shell defining a large chamber **46** to receive a refrigerant cartridge **48**. The internal mechanism of the rechargeable cryosurgical instrument will now be described with reference to FIGS. 5, 6 and 7. Located at the left end of the chamber **46** there is a reciprocable shuttle **50** including an axial bore **52** having a chamfered entrance **54** at one end and an axial concentric passage **56** extending to its other end. Several finlike support ribs **57** (one shown) are located at the lower end of the shuttle to assist in positioning it in the body **12** in the absence of the cartridge **48**. A sealing O-ring **58** and a positioning ring **60** are disposed within the bore **52** and a small diameter delivery tube **62** is located within the passage **56**, being secured in place within the bore of the positioning ring **60** with the left end of the delivery tube extending out of the body of the instrument. The shuttle **50** further includes a seat **64** defined therein to receive the end **66** of the operating lever **18** which passes through an opening **68** in the body formed through the wall thereof. The opening is sealed by a resilient sealing ring **70** encircling the lever which is held in place by means of a snap-type retaining ring **72**.

An exhaust valve **74** located at the left end of the shuttle **50** includes a sealing O-ring **76** seated in a circumferential groove **78** in the shuttle which cooperates with a radially inwardly turned lip **80** formed at the end of a thin-walled metallic cylindrical shell **82**. The shell **82** is secured in a suitable manner to a collar **84** such as by being crimped thereon as at **86**. An O-ring **88** seated between the shell and the collar effectively prevents gas leakage between these two members. The collar **84** is securely mounted upon an exhaust tube **90** at one end thereof and supports the exhaust tube so that it coaxially surrounds the delivery tube **62** forming the probe **14** extending outwardly from the body **12** through an axial opening **92** therein which opening is sealed by means of O-ring **94**.

As clearly illustrated in FIG. 8, the cooling tip **16** is in the form of a metal plug **96** which seals the open end of the exhaust tube **90** to prevent gas flow therefrom. It is made of a suitable metallic material selected to provide a path of high thermal conductivity therethrough. The exterior portion of the tip is shown as being rounded; however, it may comprise any configuration designed to perform a particular surgical function. A boiling chamber **98** formed at the interior of the probe **14** adjacent the cooling tip **16** includes a boiler valve which when closed will allow the gas to expand through a metering orifice **100**. The form of the boiler valve illustrated in FIG. 8 is but one example of the several constructions comprehended by this invention. It includes a conical valve seat **102** integral with the cooling tip **16** which cooperates with the machined open end **104** of the delivery tube **62** in which the metering orifice **100** is cut. An annular passage **106** in the probe **14** between the delivery tube **62** and the exhaust tube **90** extends from the boiling chamber **98** to a chamber **108** defined between the collar **84** and the exhaust valve **74**.

The entire assembly of: the shuttle **50** carrying the positioning ring **60**, the delivery tube **62** and the O-ring **76**, and the collar **84** carrying the exhaust tube **90** and the shell **82** is held in the body **12** against the sealing O-ring **94** by means of a springlike washer-type retaining ring **110**. This assembly is the reusable portion of instrument **10** which receives the refrigerant cartridge **48**.

The cartridge **48**, made of metal for good strength and lightweight, contains approximately 10—12 cc. of a suitable pressurized refrigerant which may be a liquid, such as Freon 12®(a mark of Dupont for dichlorodifluoromethane), or a gas, such as CO_2. In the illustrated Freon version, an aerosol-type valve **112** is disposed at one end of the cartridge **48** and is secured by means of a metal cap **114** which may be turned into a circumferential recess **116** in the cylindrical wall of the cartridge. The aerosol-type valve **112** clearly illustrated in FIGS. 5 and 6 includes a valve stem **118** whose right end is in the form of a solid rod portion **120** and whose left end is in the form of a tubular portion **122** open at one end defining a radial port **124** therethrough. A flange **126** girdles the rod adjacent the midpoint thereof. Resilient sealing ring **128** is positioned adjacent the planar end wall of the cap **114** tightly encircling the left end of the valve stem **118** which passes through an opening in the cap end wall. A valve body **180** includes a radially outwardly extending circumferential flange **132** captured between the cap **114** and the mouth of the tank. A central axial bore **134**, in the valve body **130**, terminates in a lip **136** which receives the rod portion **120** of the valve stem **118** and its associated compression spring **138** which biases the valve stem **118** in a leftward direction. Thus, the port **124** is positioned normally at the exterior of the cartridge **48** to prevent discharge of the refrigerant.

The rechargeable cryosurgical instrument **10** is presented to the surgeon in the operating room in a sterile condition. The refrigerant cartridge **48**, preferably containing a sterile pressurized refrigerant, is also delivered to the surgeon in the operating room in a sterile condition and be packaged in a sterile pouch. In order to utilize the instrument, the refrigerant cartridge **48** is inserted into the body chamber **46** and the tubular portion **122** of the valve stem **118** is directed into the chamfered entrance **54** and the axial bore **52** of the reciprocable shuttle **50** and is seated against the O-ring **58**. Then the end cap **20** is inserted into the open end of the body, the positioning pin **32** entering the entrance leg **34** of the positioning slot **22** so that the end cap boss **28** abuts the end of the refrigerant cartridge **48** and drives it leftwardly into the body **12**. Initially, the tubular portion **122** of the valve stem **118** is urged into contact with the sealing O-ring **58**, then the shuttle **50** is moved leftwardly, urging the delivery tube **62** against the conical valve seat **102**. Further insertion of the end cap **20** carries the tank of the refrigerant cartridge **48** over the valve stem **118** compressing the compression spring **138**. When insertion of the end cap **20** is stopped as the positioning pin **32** abuts the step portion **42**, it should be rotated in a clockwise direction until the positioning pin abuts the first positioning leg **36**. Releasing the end cap allows the compression spring **138** to snap it rearwardly to lodge the positioning pin in the first positioning seat **38**. It should be noted with reference to FIG. 5 that in this first position the port **124** of the aerosol-type valve underlies the resilient sealing ring 128 so that the pressurized refrigerant is unable to escape the cartridge. In this first or "ready" position of the rechargeable cryosurgical instrument 10, the refrigerant may be conserved and the instrument is ready for use.

When he wishes to use the cryosurgical instrument, the surgeon may initiate the normal cooling of the tip 16 by pushing the end cap 20 further into the body, moving the cartridge against the bias of the compression spring 138, to move the positioning pin 32 in the first positioning leg until it abuts the step portion 44 and then rotating the end cap in a clockwise direction until the positioning pin 32 abuts the second positioning leg. Releasing the end cap allows the compression spring 138 to snap it rearwardly to lodge the positioning pin 32 in the second positioning seat. In this position, as shown in FIG. 6, the refrigerant cartridge has been moved leftwardly over the valve stem so that the port 124 communicates the interior of the cartridge with the exterior thereof in the manner of actuating a usual aerosol-type valve. In this condition the pressurized refrigerant may escape the tank through the port 124, passing between the solid rod portion 120 of the valve stem 118 and the bore 134 of the valve body 130 past the compression spring and the flange 126. Since the instrument body is open to the atmosphere through the gas port 30 in the end cap 20, the pressurized refrigerant seeks an escape path thereto and flows from the cartridge 48 through the port 124 and the tubular portion 122 of the valve stem 118, down the delivery tube 62 to the boiling chamber 98 where it passes through the metering orifice 100 in the open end of the delivery tube. The sharp drop in pressure occurring across the metering orifice 100 permits the refrigerant to expand rapidly, absorbing heat from the area of the cooling tip 16 to cool it rapidly to a temperature low enough to cause cryoadhesion of the tip to warm moist tissue. The expanded and warmed spent gas is conducted through the annular passage 106 to the chamber 108 where it flows out the open exhaust valve 74 through the annular passage defined between the refrigerant cartridge 48 and the inside wall of the body 12, and out the gas port 30 to the atmosphere. This is the only path available to the escaping gas since the axial opening 92 in the body is sealed by the O-ring 94, and the opening 68 in the body through which the lever end 66 enters is sealed by the resilient sealing ring 70.

If, as the operation progresses, the surgeon inadvertently contacts adjacent healthy tissue, such as the cornea or the iris, these tissues will also freeze and adhere to the cooling tip 16. In such case the surgeon must immediately disengage the tip. This may be quickly and easily accomplished by depressing the lever 18 (note FIG. 7) which is located under his index finger. Warming of the tip takes place in the following manner. The lever end 66 is pivoted about the edge of the opening 68, thereby applying a force against the right side of the seat 64 to move the shuttle 50 against the compression spring 138 through O-ring 58 and the valve stem 118. Movement of the shuttle 50 toward the right withdraws the delivery tube 62 slightly from the conical valve seat 102, permitting a flood of warm refrigerant to flow into the annular passage 106 and into the chamber 108. The lip of the shell 80 and the O-ring 78 forming the exhaust valve 74 are disposed in such a relationship that when the lever 18 is pivoted and draws back the shuttle 50, the exhaust valve 74 will be closed after a small amount of warm refrigerant is permitted to escape from the chamber 108 to ensure that the chamber 108 and the annular passage 106 are full. When the exhaust valve 74 has been completely closed, the pressure built up within the chamber 108 and the annular passage 106 prevents the refrigerant from boiling with the resultant heat absorption. Thus the sensible heat of the refrigerant brought into the end of the probe is sufficient to warm the tip 16 to permit disengagement of the tip from the tissue.

As long as the lever 18 is maintained in the depressed position the tip 16 will be warm. It is merely necessary for the surgeon to release the lever to cause the shuttle 50 and the delivery tube 62 to move leftwardly under the bias of the compression spring 138 and return the instrument 10 to the normally cold operating condition as illustrated in FIG. 6.

If the surgeon desires to utilize some other surgical instrument, the cryosurgical instrument of this invention may be temporarily deactivated to conserve the refrigerant charge. This may be accomplished by moving the end cap 20 to the first position, as clearly illustrated in FIG. 5. When the refrigerant has been exhausted, the end cap 20 can be removed to dispose of the spent cartridge and a second cartridge may be inserted if necessary.

It should also be understood that there often exist conditions which require that the probe be introduced to the tissue in a warm condition prior to cooling. If, for example, the lens has been displaced from its normal position and has slipped back into the vitreous, it must first be located with the tip of the probe and then the lever must be released to quickly freeze the lens to the tip so that it may be withdrawn from the vitreous. Therefore, it is within the comprehension of this invention to reverse the operation of this rechargeable cryosurgical instrument by having the cooling tip normally warm and rendering it cold by manual actuation of the control lever.

Having described this invention of a rechargeable cryosurgical instrument, it should be readily appreciated by those skilled in this art that there is provided herein an instrument which is simple in design, low in cost and ingenious in operation. As set forth in the objects, there is provided a rechargeable instrument that may be selectively heated or cooled at the option of the surgeon and which is compact and easy to handle and which may be rendered temporarily inactive to conserve the refrigerant charge.

It should be understood that the present disclosure has been made only by way of example and that numerous changes in details of construction and the combination and arrangement of parts may be resorted to without departing from the true spirit and scope of the invention as hereinafter claimed.

We claim:

1. A rechargeable cryosurgical instrument comprising a body defining a refrigerant cartridge-receiving chamber, opening to the atmosphere, at one end and a cooling tip at the other end; boiler valve means in said body adjacent said cooling tip; a reciprocable member in said body located between said chamber and said cooling tip, carrying a delivery tube at one end and having an opening in its opposite end to receive the dispensing tube of a refrigerant cartridge; control means connected to said reciprocable member and extending to the exterior of said body, being selectively operable to move said boiler valve means for cooling or warming said cooling tip; means for exhausting spent refrigerant from said cooling tip to said chamber; a removable end cap seated in the open end of said body; and positioning means on said end cap and said body cooperating to selectively locate said end cap in a first position for retaining a refrigerant cartridge in said chamber in a nondispensing condition and a second position forcing the dispensing tube of said cartridge against said reciprocable member to release refrigerant into said delivery tube.

2. The rechargeable cryosurgical instrument defined in claim 1 wherein said positioning means linearly guides said end cap between said first and second positions.

3. The rechargeable cryosurgical instrument defined in claim 1 wherein said positioning means includes a positioning slot defined in the wall of said body adjacent said open end, and a radial positioning pin located on said end cap.

4. The rechargeable cryosurgical instrument defined in claim 3 wherein said positioning slot has a first pin-receiving seat to position said end cap to urge a housed replaceable refrigerant cartridge into a refrigerant conserving position.

5. The rechargeable cryosurgical instrument defined in claim 3 wherein said positioning slot has a second pin receiving seat to position said end cap to urge a housed refrigerant cartridge into a refrigerant-dispensing position.

6. The rechargeable cryosurgical instrument defined in claim 1 wherein said end cap defines a vent therethrough.

7. The rechargeable cryosurgical instrument defined in claim 1 wherein said positioning means includes a positioning slot defined in the wall of said body adjacent said open end and a radial positioning pin located on said end cap, said positioning slot having a first pin-receiving seat to position said end cap relative to said body to urge a housed refrigerant cartridge into a refrigerant-conserving position and a second pin-receiving seat to position said end cap to urge a refrigerant cartridge into a refrigerant-dispensing position, and said end cap defines a vent therethrough.

8. The rechargeable cryosurgical instrument defined in claim 1 wherein support means are provided on said reciprocable member to maintain said reciprocable member in position to receive the dispensing tube of a refrigerant cartridge.

9. The rechargeable cryosurgical instrument defined in claim 1 wherein said control means comprises a pivotable lever; said reciprocable member includes a seat formed therein to receive one end of said lever; and said body defines an opening therein through which said lever passes, positioned to be in substantial alignment with said seat, the rim of said opening forming a fulcrum about which said lever pivots.