SURGICAL INSTRUMENT FOR CATARACT REMOVAL

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Filed Apr. 12, 1965, Ser. No. 447,124
Int. Cl. A61b 17/36
U.S. Cl. 128—303.1

ABSTRACT OF THE DISCLOSURE

A cryosurgical system including a pencil-like hand instrument which can be easily and quickly manipulated by the surgeon in much the same way as a pencil. An automatic control system regulates the flow of liquid refrigerant into the handpiece wherein it is expanded adjacent the tip to effect the cooling thereof. The probes on the handpiece can be easily removed and replaced, and a heater coil is provided thereon for defrosting the tip. In one embodiment a small valve is provided in the handpiece for regulating the flow of liquid to the tip.

This invention relates to surgical equipment, and particularly to instruments and associated controls for cryosurgery.

The use of very cold temperatures has come into acceptance for many types of operations, both on human beings and animals. One such operation is the cataract operation wherein the cataract lens is removed from the eye, and others include peripheral and sector iridectomies, dislocated lens extraction, cryocoagulation of tumor cryobiopsy and retinal detachment. Perhaps the first successful use of cryosurgery was by Dr. Irving S. Cooper of St. Barnabas Hospital in New York City wherein a very cold temperature was used in treating Parkinson's disease. In all of these operations, the very cold temperature is applied to the area being treated, and there is no escape of the cryogenic liquid or is there any contact of the liquid or gas with the area being treated.

The instruments presently available are of the thermoelectric and the gas liquid type wherein a small probe is cooled to a very low temperature. Each of these instruments suffers from a series of disadvantages in that the probe is relatively large in diameter, for example, up to 1/4 inches in diameter, and therefore quite difficult for the surgeon to manipulate for ophthalmic surgery wherein maneuverability is mandatory. Moreover, these instruments and the controls therefor are bulky and expensive, and take a substantial amount of preparation prior to use of the instrument. Still the instruments are primarily suited for only a single type of operation and cannot be easily adjusted to perform other operations, and they do not provide the surgeon with the temperature and pressure control required.

Accordingly, an important object of the invention is to provide an improved compact cryogenic surgical instrument of the aforesaid type which is manipulated easily by the surgeon and has a control system for changing the pressure and temperature involved in the system as well as providing visual indication of these factors.

Another important object of this invention is to provide a surgical instrument for performing cryosurgery wherein the instrument can be prepared and ready for use in a very short time, and further to provide such an instrument which is capable of being easily modified for different types of operations by removing and replacing probes of different size and configurations.

Another object of this invention is to provide a surgical instrument of the aforesaid type with an improved control system which regulates the cold temperature of the tip through use of a foot switch which is conveniently accessible to the surgeon permitting freedom of his hands, and further provides for removal of all of the used fluids from the system after the operation is completed and for use when power fails or the primary supply of liquid gas is exhausted or unavailable.

Another object of this invention is to provide a compact surgical instrument having a pencil-like handpiece which is completely sealed wherein a liquid gas is expanded adjacent the tip of the probe thereof so that maximum cooling occurs at the probe, and particularly to provide such a handpiece having a heater on the probe for quickly returning the probe to room temperature after the operation is completed or at any point during the operation as required by the surgeon.

Another object of this invention is to arrive at a surgical instrument which can be sterilized by placing in an autoclave without detrimental effect to the materials thereon, and also to provide a surgical instrument which has a control valve in the handpiece itself so that the surgeon can quickly and easily regulate the flow of fluid to the tip and thus regulate the temperature thereof.

Other objects and advantages of the invention will be apparent from the following description, the accompanying drawings and the appended claims.

In the drawings:

FIG. 1 is a perspective view showing a surgeon using the surgical instrument constructed in accordance with the invention;

FIG. 2 is an elevation view of the control panel on the control console;

FIG. 3 is a perspective view of the surgical instrument as held in the hand;

FIG. 4 is an enlarged sectional view taken axially through the handpiece and along the line 4—4 of FIG. 5;

FIG. 5 is an end view looking from left to right in FIG. 4;

FIG. 6 is a sectional view taken along the line 6—6 of FIG. 5;

FIG. 7 is another sectional view taken along the line 7—7 of FIG. 4 with the outer cover removed;

FIG. 8 is a sectional view taken along the line 8—8 of FIG. 4 with the outer cover removed;

FIG. 9 is a plan view of the probe end of the instrument showing the manner in which the electrical connectors are secured to the handpiece;

FIG. 10 is a sectional view taken centrally through a probe and showing the manner in which the components thereof are secured together;

FIG. 11 is an enlarged sectional view showing the tip end of the probe;

FIG. 12 is a view of the right-hand end of the handpiece;

FIGS. 13 and 14 are elevation views partially in section showing other tips which can be used in the invention;

FIG. 15 is a schematic illustration of the electrical controls for the system;

FIG. 16 is a sectional view taken axially through another embodiment of the invention;

FIG. 17 is a sectional view of the handpiece taken along the line 17—17 of FIG. 16;

FIG. 18 is an enlarged sectional view showing the manner in which the probe is attached to the handpiece;

FIG. 19 is a sectional view taken along the line 19—19 of FIG. 18;

FIG. 20 is an enlarged sectional view of another embodiment of the tip end of the probe;

FIG. 21 is a schematic illustration of the fluid control circuitry for the invention;

FIGS. 22 and 23 are sectional and side views, respectively, of still further tip constructions.
FIG. 24 is a sectional view of another embodiment of the handpiece; and FIG. 25 is a schematic illustration of another embodiment of the control system. Referring to the drawings wherein preferred embodiments of the invention are shown, FIG. 1 illustrates a surgeon 10 who is about to remove the lens on the eye of a patient 11 laying prone on the operating table 12. While the invention is described in connection with its use in the case of a surgeon, it should be understood that the invention is not so limited and may be used to perform other operations in ophthalmology and in other fields of medicine, e.g., neurosurgery, dermatology, ear, nose and throat surgery.

The surgeon holds the pencil-like handpiece 14 in his hand 15, and due to its light weight and small size, it is easily maneuvered as required to place the probe 16 thereof in contact with the lens of an eye. The handpiece 14 is connected to the control console 18 which regulates the flow of electrical current and fluid under pressure to this handpiece. The foot switch assembly 20 is operated by the foot 21 of the surgeon 10 and is normally used to control the temperatures within the probe 16, as will be explained hereinafter. The liquid gas is supplied to the control console 18 from a suitable container 22, for example, the commercially used tanks to supply liquid gases. Both the console 18 and the container 22 are mounted on the table 24 which may be wheeled from place to place as required.

Referring now to FIGS. 3-12, the pencil-like handpiece 14 can be held easily in the hand of the surgeon as shown in FIG. 3 in substantially the same manner as a pen or pencil. When the probe 16 becomes very cold, the moist lens adheres extremely well and it is the simple task of the surgeon to remove the lens from the supporting tissue. As shown in FIG. 4, the handpiece 14 consists of an elongated metal body 25 having inlet and outlet passages 26 and 27 extending axially therethrough. The elongated needle-like tube 30 is press fitted in the opening 31 which communicates with the left-hand end of the inlet passage 26 so that the liquid gas flows from the passage 26 and through this small tube which extends through the probe 16 to a position near the tip 32 thereof, as shown in FIG. 10. The outlet passage 27 has a small sloping passageway 33 which connects to the threaded bore 34 in the left-hand end of the handpiece 14. The cylindrical sides of the handpiece 14 are covered by a suitable plastic material 35 which preferably is an insulator so that the surgeon’s hands remain at room temperature at all times. A preferred material is a heat shrinkable thermoplastic which is engendered each of these sleeves and are held in place by a suitable adhesive. As a result of this arrangement, the metal sleeves 56 are electrically insulated from the handpiece 14. FIGS. 7 and 8 show the respective arrangement of the passageways 26, 27, 43 and 44 within the handpiece 14 wherein they are arranged so that a minimum diameter is required.

Referring now to FIGS. 9 and 10, the removable probe 16 is threadedly secured in the bore 34 formed in the left-hand end of the handpiece 14. The probe 16 consists of a body member 60 which has the threaded extension 61 on one end thereof and is received within the threaded bore 34 of the handpiece 14. A radially outward extending flange 62 is provided on the intermediate portion of the body member 60 with a groove 64 formed between this flange 62 and the threaded extension 61. A resilient O-ring seal 65 is provided in this groove so that when the body member 60 is screwed into the bore 34, the O-ring 65 is clamped between the flange 62 and the shoulder 66 provided in the handpiece 14. This limits the extent to which the body member 60 is screwed into the bore 34 thereby providing a chamber at the right-hand end thereof which communicates with the passage 33.

An opening 68 extends axially through the body member 60 and has an inner diameter which is substantially larger than the outer diameter of the small tube 30. The tubular member 70 is secured to the left-hand end portion 71 of the body member 60 by press fitting the same into the enlarged diameter portion 72 of the opening 68. This tubular member 70 extends to the left beyond the left-hand end of the tube 30 and then has a curved portion 74 which turns through an angle of approximately 80°. The end of the member 70 has a tip 73 which is serrated on the outer surface of its equivalent. The outside surface of this tip 73 is covered by a thin film 75 of polytetrafluoroethylene, which is sold under the trademark Teflon by the E. I. du Pont de Nemours & Company to prevent adhesion of tissue thereto. The thin tube 30 extends from the handpiece 14 axially through the body and tubular members 60 and 70 to a point which is a short distance from the tip 31.

An insulated heating coil or resistance wire 77 is wrapped around the curved portion 74 of the tubular member 70, as shown in FIG. 10, with one end 78 being soldered adjacent the tip 32 (FIG. 11) whereas the other end has an elongated lead wire 79 connected thereto and extending from beneath the right-hand end of the heat shrinkable polytetrafluoroethylene cover 81. The connector 83 is adapted to be inserted into one of the receptacles 56 so that the groove 84 in the end thereof passes beyond the end of the metal receptacles 56 to snugly receive and hold the connector 83 in place. The number of turns of the wire 77 around the curved portion 74 of the member 70 are dictated by the heat required to return the tip 32 to room temperature, and this in turn depends upon how fast the temperature elevation is required, as well as the size of the tubular member 70 and the material from which it is constructed.

A thermistor 85 is secured internally of the tubular member 70 in a bore formed in the tip 32 which is then covered by solder 86 or its equivalent. As is well known, any change in the electrical resistance of the thermistor 85 causes a proportional change in the electrical current produced in the insulated lead wire 90, and thus the thermistor is used as a temperature sensing element. This insulated lead wire 90 extends through a tightly insulated and epoxy sealed opening 91 in the tubular member 70 and then between the cover 81 and the heating wire 77 and 61 on either side of the right-hand end of the member 70. The other end lead wire 92a is grounded in the tip 32.

The end of the wire 90 has a male connector 93 which is inserted into receptacle 56. The end of the wire 70 has a male connector 93 thereon similar to that used on the heating coil 77, and this connector is adapted to be re-
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leasably inserted in the other end of the receptacle 56, in the manner explained above. The inlet and exhaust tubes 40 and 41 and the electrical wires 50 and 51 which lead from the handpiece 14 are enclosed by a cover tube 100 of heat shrinkable material which is slipped on to these wires and tubes and heated to cause the cover to contract. This provides for a neat appearance, and more importantly, it restricts the movement of these various wires and tubes so that they in no way interfere with the use of the instrument by the surgeon. The cover 100 terminates a short distance from the control console 18 and, as shown in FIG. 2, the 40 and 41 releasably connect to the supply and exhaust openings 101 and 102, respectively. The connectors on the tubes 40 and 41 and on the consoles are preferably of the type that prevent flow through the tubes 40 and 41 and the openings 101 and 102 except when they are engaged to prevent discharge of the liquid gas in case of inadvertent disengagement during use. The heater and thermometer wires 50 and 51 are connected to conventional female jacks 104 and 105 on the console 18.

The console is arranged so that it provides the surgeon with an accurate visual indication of the pressures and temperatures present in the system during use. The console 18 encloses the various components of the control system as illustrated schematically in FIGS. 15 and 21 which are explained in connection with the operation of the system. To start the system in operation, it is merely necessary to connect a conventional container 22 of liquid gas, such as Freon, to the inlet opening 112 in the control console 18 by use of the conventional tubing 113 and a releasable coupling 114. The "liquid" gas must drain from the bottom of the container 22 to enable the gas to remain in its liquid state and to enable the pressure within the container 22 to provide sufficient pressure for the entire system. To start the system, the console is connected by way of a conventional connection to a wall socket, not shown.

The foot pedal assembly 20 which consists of three foot operated switches 115, 116 and 117 is connected through the umbilical 118 to the multiple pin connector 120 on the console 18. The foot switches are in parallel with the main valve, bleed, and heater switches 121, 122, and 123, respectively, as shown in FIG. 2 so that the operation effected by these switches can be operated either by the foot or by hand, although in practice they are normally operated by the foot switches.

After the handpiece 14 is connected to the console 18, as described above, the main electrical switch 125 is closed to supply current from the source 126 (FIG. 15) through the lines 127 and 128 to the transformer 130 which provides a low voltage D.C. current for the system. This action energizes the signal light 131 on the control console 18 indicating the system is ready for operation.

Referring now to FIGS. 2 and 21, the next step in preparing for operation is to open manually the main supply valve 133 so that the liquid gas in the container 22 flows through the conduit 134 and into the intermediate conduit 136. The solenoid valve 138 is normally closed and thus flow through the conduit 136 is terminated at this point. This intermediate conduit has a pressure gauge 137 therein which indicates the pressure in the main supply cylinder and is disposed immediately above the main valve 133 on the console 18. In addition, a sight glass 140 is provided so that the surgeon can observe whether the liquid is present in the conduit 136, and the filter 142 is provided in this conduit to remove any impurities from the liquid gas. The exhaust valve 144 is also manually opened so that the exhaust passage 145, which connects to the outlet tube 41 from the handpiece 14, is connected to the atmosphere. The instrument is now in condition to commence operation at the will of the surgeon. When the foot operated main switch 115 in the line 150 (FIG. 15) is depressed, or the manual switch 121 in line 151 is closed, current flows through the lines 153, 154, 155 to the solenoid 156 of the valve 138. This shifts the valve 138 against the bias of the spring 157 to the position shown in FIG. 21 to connect the adjacent conduits 136 and 160. This liquid gas then flows through the conduit 163 which leads to the adjustable pressure regulating valve 165 and the output conduit 166. This output conduit 166 is connected through the releasable connector 167 to the inlet tube 40 in the handpiece 14 and thus the liquid gas under a predetermined pressure flows into the flow passage 26 and then through the small tube 50 inside the probe 16 from which it is sprayed into the space formed in the end of the probe 16.

As the liquid gas is sprayed into this space, there is a substantial decrease in the pressure thereof causing the liquid to immediately evaporate thereby cooling the adjacent portion of the probe 16. Since the insulating cover 100 is provided around the probe except for the tip 32, the tip 32 becomes very cold and this temperature is very near the boiling point of the liquid gas under use. For example, if Freon is used, whose boiling point is approximately —40° C the tip will be in the area of about —30° C.

At all times, the temperature indicating gage 175 on the control console 18 indicates the precise temperature of the tip 32 as sensed by the thermostor 85. The surgeon need only glance at the control console to ascertain the precise temperature of the tip 32. The gage 175 itself has a number of scales 176 which can be manually selected by the switch 177 and this provides for accurate reading of the temperature. When much warmer temperatures are used or when the heater is used, it is necessary to shift range of the instrument to accurately read the temperature on the scale.

The cryometer or temperature measuring device 175 is exchangeable in the console 18 depending on the temperature range desired. By releasing lock nuts 300 and disconnecting the connector cable 302 the unit is removed. The female external recorder jacks 303 permit a recorder, e.g., a Yellow Springs Instrument Company, Yellow Spring, Ohio, Model 80 to be connected so the surgeon may have a permanent graph record. The plug 304 is completed to a direct line from the temperature selector switch 306 which allows the surgeon to alternate temperature recording between the surgical probe and other externalized thermostors which may be provided. The thermostor 85 in this instrument is connected to the cryometer and to a recording sensitive console also acts as a temperature regulator for the probe. This may be accomplished by attaching the recording device and to a micrometering valve which regulates the amount of liquid refrigerated expanding at the tip of the instrument. The tip of this instrument may also be heated by reversing the flow of current through the thermostor which creates resistance and warms the adjacent area.

In the cataract operation, assuming that the surgeon has made the usual incision in the cornea and the iris is dilated, the surgeon touches the tip 32 to a portion of the lens and holds it there for a short time. The tip 32 immediately adheres to the moist lens and the adjacent portion of the lens freezes so that it cannot rupture when force is applied thereto. After a few seconds, the surgeon merely withdraws the handpiece 14 in such a manner to facilitate the lens from the eye.

If at any time during the operation, or after the operation is complete, it is desired to return the tip 32 to the room temperature, the surgeon merely releases foot switch 115 and depresses the foot switch 117 in line 180, or actuates the manual switch 123. This causes the conduit 136 on the console 18 to be completed between the lines 153 and 183 thereby allowing current to flow through these lines and lines 154 and 183, the adjustable rheostat 185, and line 186 to heater 77 around the probe 16 to immediately heat the tip to at least the room temperature. The rheostat 185 regulates the amount of power
supplied to the heating coil 77 and thus governs the amount of heating produced by the coil 77.

An ammeter 190 and a voltmeter 191 are provided in the circuit with the coil 77 to give the operator an indication of power being supplied to the coil. If the lens or other tissue has adhered to the tip 32, the heating operation immediately effect release thereof. This polytetrafluoroethylene coating may inhibit adherence of tissue to this tip and then no heater is necessary. This may be a definite advantage in retinal detachment and brain surgery as it deters the formation of ice crystals thereon. Moreover, this coating permits the tip to be cleaned by merely wiping it across a dry towel. Each time it is desired to return the tip to its cold condition, it is merely necessary to actuate the foot switch 115, or the console switch 121, causing the valve 138 to be opened to allow the flow of the liquid gas to the tip 32.

An important part of the invention is the use of the small tube 30 which is sufficiently small in diameter that no evaporation occurs prior to the time that the liquid gas leaves the end of this tube. The tube provides a restriction in the flow line from the container 22 to the probe 16 so that the pressure is sufficient therein to maintain the gas in its liquefied form until it leaves the tip of tube 30. The more efficiently this gas is evaporated the more efficient is the freezing of the probe tip. This immediately allows the operator to determine tit the tip 32 while maintaining the handpiece 14 and the other portions of the system relatively warm since no evaporation occurs. As indicated above, after the gas has been expanded it passes through the probe 16 between the tube 30 and the inner surface of the probe, through the passages 33 and 27 and into the control console 18 wherein the gas is exhausted to atmosphere or to a closed operating room vacuum system through the conduit 145 and valve 144.

After use of the instrument is completed, it may be desirable to remove all the liquid gas from the console 18 in the container 22 so that the system can be stored. This can be done by depressing the exhaust foot pedal 116 in line 200, or the manual switch in line 201, causing a circuit to be completed between the lines 153 and 202 to energize the solenoid 204 of the valve 162. The solenoid 204 shifts the valve 162 to the right position as viewed in FIG. 22, causing the conduit 160 to be connected to the atmosphere through the muffler 207, the passage 145, and the valve 144. When this occurs, the entire system is subjected to atmospheric pressure and thus the liquid gas immediately boils so that the handpiece 14 and the conduits in the control console 18 are cleared of the liquid gas. This evaporation occurs within a very short time and the muffler 207 dampens any sounds produced by the rapid expansion of the liquids.

An emergency container 210 of liquid gas is provided within the control console 18, and this can be used when the main supply is unavailable, exhausted, or inoperative for any reason. It is merely necessary to close manually the main valve 133 on the control console 18 and to open the emergency valve 211 also on the control console. The liquid gas then flows directly to the conduit 136 through the conduit 212 and the system otherwise operates in the manner set forth above.

An emergency bypass line 215 is provided between the conduits 156 and 163 to bypass the valves 138 and 162. This bypass conduit is opened by the manual operated valve 216 on the control console 18 and when this valve is open the liquid gas flows directly from the emergency container 210 to the supply container 22 and to the conduit 163 which leads to the handpiece 14. Thus, when the electrical power fails or is not available, the system can be activated by use of this bypass.

The constant pressure control valve 165 is adjusted by means of control 220 on the control console 18 to regulate the pressure and thus the rate of flow to the handpiece 14 so that the system can provide for maximum or minimum heat removal from the tip 32. The pressure gage 221 in conduit 166 provides an indication of this rate of flow. A needle and directional control valve 226 may be placed in the inlet line 40 adjacent to the quick disconnect 101 to regulate probe tip temperature. A flow control valve on the exhaust 41 may also control probe tip temperature by regulating expansion pressure at the end of the tube 30. The lights 233, 234, and 235 on the control console 18 are energized when the foot switches 115, 116, and 117, or the manual switches 121, 122, 123 respectively, are closed thereby giving visual indication to the surgeon of the status of the system.

Another embodiment of the handpiece 14a is shown in FIGS. 16–19 wherein the inlet and outlet tubes 40 and 41 are connected to the inlet and outlet passages 26 and 27 in substantially the manner as described above. However, the handpiece has a cylindrical bore 230 formed therein perpendicular to the axis thereof which intercepts the inlet passage 26, as shown in FIG. 16. A micro constant pressure valve 232 is provided within this bore with the spring 233 interposed between the bottom 234 of the bore and the valve 232 to urge the valve 232 outwardly from the bore 230. An actuator lever 235 is pivotally secured on the bracket 236 on handpiece 14a and the adjustment screw 238 extends through one section 239 of this arm to limit the pivotal movement of the heavier at this time. When this actuator lever 235 contacts the top surface 242 of the valve 232 and limits its movement outwardly of the valve body. By depressing the lever section 241, the valve 232 is similarly depressed into the bore 230 against the bias of the spring 33.

The valve 232 has three adjacent circumferential grooves 244, 245 and 246 formed therein, and the outer two 244 and 246 of these grooves receive O-ring seals 247 and 248 which form a seal between the inside surface 250 of the bore and the valve 232. The lowermost of these O-rings 247 is aligned with the relatively small diameter passage 251 when the valve 232 is in its raised or closed position so that fluid flow between the passages 251 and 252 is blocked. When the valve 232 is depressed by the lever 235, the central groove 245 aligns with the passages 251 and 252 and permits the flow of liquid gas to the passage 252 and also the passage 255. The probe 255 is similar to the probe 16 described above but includes a frustoconical mating member 256 which is threadedly received within the bore 257 in the left-hand end of the handpiece 14a. An O-ring 258 is interposed between the handpiece and the mounting member 256 to the probe 255 and when the two are aligned as shown in FIG. 18. The tubular portion 260 extends from this mounting member 256 and has a curved outer portion 262, and the probe 255 also has the heater coil 77, a thermistor 85, cover 81a thereon, and a coated tip 32a, substantially as described above.

An important feature of this embodiment is that the small tube 265 is secured within the probe 255 rather than to the handpiece 14a and thus this small tube 265 is removed with the probe 255. The three braces 266, as shown in FIG. 19, support the small tube 265 within the probe 255 at two or more locations along its length. When the probe 255 is secured in position on the handpiece 14a, the right-hand end of this tube extends snugly into the passage 252 so that the liquid gas flows readily from the passage into the tube 265.

Since the tube 265 is never removed from the probe 255, the tube 265 can extend through the entire probe 255 and terminate immediately adjacent the tip 32a, as shown in FIG. 16, rather than being straight along its entire length. This permits quicker cooling of the tip 32a and less heat transfer to the remainder of the probe 255. Moreover, it permits the use of very long thin tips without deflection in the use of many different configurations including those having compound curves as might be used for detached retina or other operations.
Both embodiments of the invention can use tip 32 or 32a of different sizes or shapes depending upon the requirement of the particular operation, for example, a very small round tip 32 is illustrated in FIG. 13, and a larger disk shaped concave tip 33 is shown in FIG. 14. Another embodiment of the invention includes an annular tip 32e illustrated in FIGS. 23 and 24 including the annular passage 32f for receiving the refrigerant from the small tube to thereby cool the outer surface 32g of this embodiment (e.g., in retinal detachment surgery).

The leads 267 and 268 of the heater 77 and thermistor 85 extend through suitable passages 270 in the mounting member 256 so that they are held in place and into separate female receptacles 271 in the side of the instrument, as shown in FIG. 17. The electrical wires 273 extend through the passage 272 and are secured to the receptacles 271 substantially the same as the receptacles 56.

The operation of this embodiment is quite similar to that described above. The liquid gas is supplied to the inlet passage 26 in the manner described above but this flow can vary in accordance with the temperatures desired at the tips 32 and 32a. The refrigerant used under the tradename "Freon 22" has been found to be quite satisfactory for the cataract operation since it produces the temperature of approximately 30° C. and is commercially available in standard containers throughout the world. Moreover, this gas is inert and does not create detrimental effects when it is exhausted into the operating room. However, other liquid gases such as liquid oxygen, nitrogen, hydrogen, carbon dioxide and the other cryogenic liquids can be used in this invention without departing from the scope of the invention. It is important to realize that valves 101 and 102 are quick disconnect couplings and have directional flow control. This allows the handpiece to be easily disconnected while retaining all liquid in the master control console.

The use of a small tube prohibits expansion of the fluid in the tube, thereby restricting the fluid in the flow line and thereby maintains the liquid under pressure until it flows from the end of the small tubes. Thus maximum cooling is provided at the tip and there is little cooling throughout the remainder of the system thereby conserving the liquids. The inner diameter of the tubes 36 and 265 is dependent on the liquid being used, the rate of flow of the liquid, and the pressure of the liquid within the system. By increasing the rate of flow, the amount of heat removed from the tip is increased so that these tips remain cold even when they are applied to a relatively warm surface.

Another embodiment of the handpiece 350 is shown in FIG. 24 wherein the small diameter tube 351 can be moved longitudinally within the handpiece 350, or replaced by a larger or smaller tube as desired. Specifically, this instrument includes an elongated bore 353 extending centrally therethrough with internal threads at the inlet end 354 thereof. These threads receive the externally threaded insert member 355 which has the small diameter tube 351 rigidly soldered thereto in communication with the small passage 356 therethrough. The exhaust passage 358 extends parallel to the central bore 353 and communicates with the probe 255 to remove the gas therefrom. An O-ring seal 367 is provided on the insert member 355 to ensure that the liquid gas cannot leak between the insert and the adjacent portion of the handpiece. The elongated tube 351 has the left-hand portion limited in radial movement by the reduced diameter portion 361 of the handpiece 350.

The probe 355 may be identical to that shown in FIG. 10 and thus the components thereof are shown with identical reference characters and are not further described herein. The small tube 351 is moved longitudinally within the probe and handpiece 350 to space the outlet end 362 thereof closer to or farther from the tip 320 to increase or decrease the cooling of the tip which is determined in the distance that the heating action is spaced from the tip 32a. Moreover, the insert member 355 can be removed from the handpiece 350 and another insert utilized having a small tube 351 which is larger or smaller in diameter to enable an increased or decreased rate of liquid flow to the tip 32a thereby varying the temperature and the amount of heat removed from the tip. Inlet and outlet tubes connect the instrument to the control console in the manner described above. Another advantage of this embodiment is that there is no liquid gas present in the bore 353 and thus the outside of the handpiece need not be insulated to the same extent as those described above.

Referring now to FIG. 25, another embodiment of the control system for any of the handpieces 14, 14a or 350 is shown. This control system consists primarily of a console 370 having a compressor 371 therein for compressing the gas into a liquid and forcing the same through the conduit 372 which connects to the inlet tube 40 of the handpiece 14. The outlet tube 41 of this handpiece is connected to the inlet of compressor 371 through the conduit 374, and the solenoid operated valve 375 controls the flow through these conduits 372 and 374. In the position shown, the valve 375 permits flow to and from the handpiece 14, whereas when the valve is shifted to its alternate position the inlet conduit 374 of the compressor is connected through a bypass in the valve 375 directly to the outlet end 372 and there is no flow of liquid gas to the handpiece 14.

While this embodiment is shown somewhat schematically, it is to be understood that the other conventional controls such as relief valves and the like, will be used in the system. Moreover, the valve may effect a metering operation so that the supply of liquid gas to the handpiece is varied to regulate the temperature produced at the tip 32. The valve can be shifted in response to a foot pedal, manual switch, or automatic control device (not shown). This system is somewhat simplified and is entirely closed so that it needs no extension supply of liquid gas during normal operation and requires only a source of power to operate the compressor.

It is possible to use the handpiece shown in FIGS. 16-19 without the control console 18 by merely attaching the inlet tube 40 to a source of liquid gas and using the valve 232 to control the cooling operation. In such an arrangement, no heating need be present and thus a very lightweight and portable instrument is created which can be carried in a small bag.
The invention has thus provided a surgical instrument which is pencil-like in size and is easily maneuvered by the surgeon for delicate operations. In this connection, FIG. 3 of the drawing shows the relative size of the handpiece 14 and the surgeon’s hand 15, whereas the other illustrations of the drawings are greatly enlarged to illustrate the details of the invention. The instruments have removable tips and are designed so that maximum cooling occurs at the tip so that the remainder of the instrument requires little insulation thus permitting its small size. The control console regulates the flow of liquid gas and electrical current to the instrument as controlled by manual switches on the console or in the foot assembly, thereby providing easy operation of the instrument, for visual display of the temperatures and pressures involved, and the status of the system at all times. The system is also adapted for use under emergency conditions, and the handpieces can be adapted for use with a less sophisticated control system.

While the forms of apparatus herein described constitute preferred embodiments of the invention, it is to be understood that the invention is not limited to these precise forms of apparatus, and that changes may be made therein without departing from the scope of the invention which is defined in the appended claims.

What is claimed is:

1. A surgical instrument for use in performing the cataract operation to remove the clouded lens of the eye comprising, a pencil-like handpiece having relatively small outer diameter to enable easy manual manipulation, parallel inlet and outlet passages extending longitudinally through said handpiece, means defining a bore in said handpiece adjacent the downstream end of said handpiece, said bore being perpendicular to the axis of said handpiece and communicating with said inlet passage, a valve in said bore adapted to regulate the flow of refrigerant through said inlet passage, handle means to operate said valve and to stabilize the handling and positioning of said handpiece, a relatively short hollow probe releasably secured in a fluid-tight manner to the downstream end of said handpiece in alignment with said inlet passage, said probe having a straight portion parallel to the axis of said handpiece, a curved outer end portion on said straight portion of said probe and defining an internal expansion chamber, a tip on the end of said curved portion of said probe and a heater coil wrapped around the outside surfaces of said straight and curved portions of said probe except in the area of said tip, first electrical connectors in said downstream end of said handpiece connected to electrical conductors in said handpiece, second electrical connectors secured to said heater coil and extending through said probe and releasable connection with electrical conductors in said downstream end of said handpiece for supplying electrical current to said heater coil to raise the temperature of said tip thereby defrosting said tip so as to permit easy separa-

2. A surgical instrument as defined in claim 1 wherein said probe, said handpiece, and said inlet and outlet conduits are constructed of materials capable of being autoclaved.

3. A surgical instrument as defined in claim 1 wherein said probe, said handpiece, and said inlet and outlet conduits are constructed of materials capable of being autoclaved.

4. A surgical instrument as defined in claim 1 wherein said small diameter tube is secured in said handpiece with said one end extending into said probe when said probe is mounted on said handpiece, said probe being removable from said tube and said handpiece.

5. A surgical instrument as defined in claim 4 wherein adjustable means are provided on said small tubal for removal from said handpiece to enable replacement thereof by another small tube having a different diameter.

6. An instrument as defined in claim 1 wherein said tip has a thin coating of polytetrafluoroethylene permanently secured thereon to prevent the adherence of tissue or ice thereto.

7. An instrument as defined in claim 1 wherein said tip has a concave working surface.

8. An instrument as defined in claim 1 wherein said tip includes a toroidal tubular passage in communication with said hollow probe for receiving the flow from said small tube.

9. A surgical instrument as defined in claim 1 wherein said probe includes three circumferential grooves, seal means in the outer two of said grooves, and seal means blocking said inlet passage when said valve is in its normal initial position and the middle of said grooves when said valve member is moved to an operative position providing for flow through said inlet passage.

10. A surgical instrument as defined in claim 1 wherein O-ring seals are provided in the outer two of said grooves, and one of said seals blocking said inlet passage when said valve member is in its normal initial position and the middle of said grooves being aligned with said inlet passage when said valve member is moved to an operative position providing for flow through said restricted passage.

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