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THERMOELECTRIC MEDICAL INSTRUMENT

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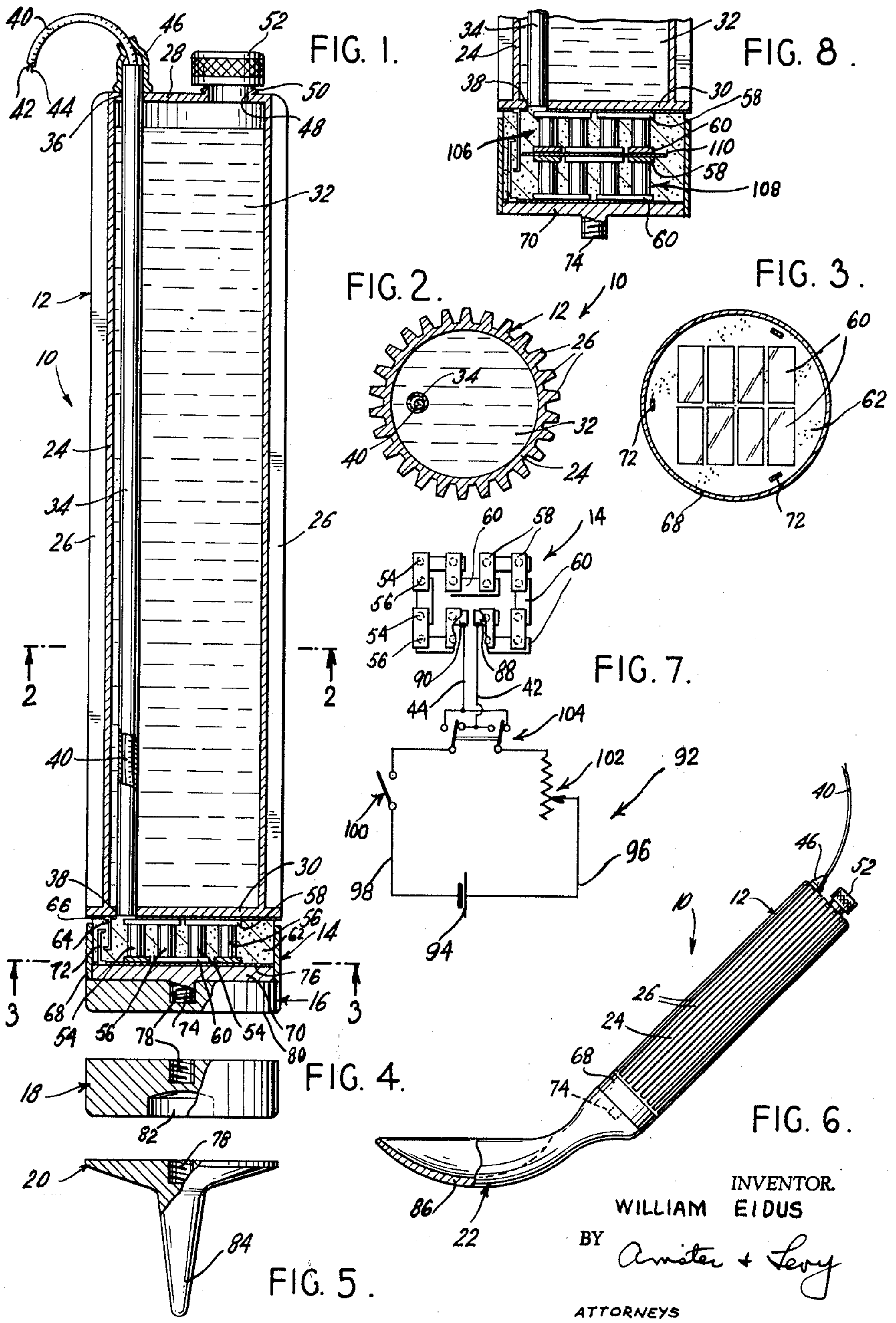

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THERMOELECTRIC MEDICAL INSTRUMENT

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The present invention relates to a novel and improved thermo-electric device for the application of localized or spot cooling effects in external and internal medical treatment. Specifically, the invention relates to a portable medical instrument having interchangeable headpieces which are cooled by small thermocouple units and which may be applied directly to external or internal body areas as heat transfer surfaces for spot cooling or heating.

The devices of the invention are specifically adapted to utilize the Peltier effect for producing extreme cooling at the application head thereof. They are thus particularly advantageous for external use as dermatological instruments in the freezing treatment of warts, acne, and skin blemishes. Among other external uses, there may be mentioned, for example, the surface application of cold to blood vessels and capillaries for the retardation of bleeding.

The devices of the invention will also find use in internal surgery for various cerebral, cardiac, abdominal or intestinal operative or remedial procedures. For example, it is required to subject the heart to low temperatures in order to retard the heart-beat during heart surgery. According to present surgical practices, the chest cavity is filled with crushed ice for this purpose. During surgery, the ice melts and must be drained out before the chest incision is closed. Furthermore, it is difficult, if not impossible, to control the temperature at which the heart is maintained, where crushed ice is employed. The device of the present invention is particularly adaptable to supply controlled cooling temperatures to the heart during surgery with no slush or water which must be removed from the chest cavity.

In addition to the foregoing advantages, it is an object of the invention to provide a small compact thermo-electric cooling unit for hand-held operation, which cooling unit is adapted to produce cooling at a headpiece at one end thereof for direct localized cooling of selected body areas.

Another object of the invention is the provision of a device of the character described in which the headpieces are removable and replaceable so that individual headpieces may be used when required for varying types of direct application.

A further object of the invention is the provision of a device of the character described in which the body of the portable unit, serving as a handle, is hollow and is filled with water or other suitable liquid, the liquid serving as an extremely efficient heat sink for the thermoelectric units, thus providing cooling at very low temperatures.

Additional objects and advantages of the invention will become apparent during the course of the following specification when taken in connection with the accompanying drawings, in which:

FIG. 1 is an elevational view, with portions broken away and shown in section, of a thermo-electric medical instrument made in accordance with the present invention;

FIG. 2 is a transverse section taken along line 2—2 of FIG. 1;

FIG. 3 is a transverse section taken along line 3—3 of FIG. 1;

FIGS. 4 and 5 are respective side elevational views of replaceable headpieces for the instrument, with portions thereof broken away to reveal internal construction;

FIG. 6 is an elevational view, on a smaller scale, of the thermo-electric instrument with a modified form of headpiece attached thereto, the headpiece being partially broken away;

FIG. 7 is a schematic view of the thermocouple assembly of the device and the electrical energizing circuit therefor; and

FIG. 8 is a partial sectional view showing a modified form of thermocouple arrangement for the device.

Referring in detail to the drawings, it will be seen that the thermo-electric device **10** comprises in general a hollow body portion **12**, serving both as a handle and as a liquid reservoir, a thermocouple assembly **14** secured to one end of the body portion **12**, and a head member **16**, **18**, **20** or **22** removably attached to the thermocouple assembly.

The body **12**, made of a heat-conductive material such as aluminum, is elongated and preferably of tubular cylindrical shape, its peripheral body wall **24** being provided with spaced radial ribs or vanes **26** for the dissipation of internal heat. The hollow body **12** is closed off at one end by a top wall **28** and at its other end by a bottom wall **30**. The walls **28** and **30**, together with the body wall **24** completely enclose the hollow interior of the body **12**, providing a liquid-tight reservoir for a supply of water or other suitable liquid **32**.

A hollow pipe **34** extends longitudinally through the interior of the body **12**, with its ends extending through apertures **36** and **38** in the respective top and bottom walls **28** and **30**. The pipe **34** is sealed around these apertures **36** and **38** to maintain the water-tight condition of the hollow body **12**. The pipe **34** serves as a conduit for the passage of an electrical cable **40**, consisting of insulated leads **42** and **44**, from the top to the bottom of the body **12**.

The upper end of the pipe **34** projects above the top wall **28** and the cable **40** is held against movement therein by a rubber nipple **46** which is mounted on the projecting end of pipe **34** and embraces the adjacent portion of the cable **40**.

The top wall **28** of body member **12** has a fluid inlet opening **48**, bordered by a threaded neck **50**. The inlet opening is closed off by an internally-threaded closure cap **52** removably mounted on the neck **50**.

The lower end of the pipe **34** terminates flush with the under surface of bottom wall **30** to permit the thermocouple assembly **14** to be mounted flat against the bottom wall **30** in heat-exchange relationship therewith. The thermocouple assembly **14** comprises a suitable number (herein shown as eight) of individual thermocouple units connected in series, as best shown in FIGS. 1, 3 and 7.

Specifically, the thermocouple assembly **22** is composed of a series of semiconductor elements **54** of the p-type, alternating with semiconductor elements **56** of the n-type. Both elements **54** and **56** are preferably made of barium telluride; the p-type differing from the n-type in physical properties of the semiconductor employed. Barium telluride thermocouples of this type are well known and are commercially available.

Each individual pair of semiconductor elements **54** and **56** are connected at their upper ends by thin plates **58** of electrically-conductive metal such as copper, while adjacent pairs of elements **54** and **56** are connected at their lower ends by similar copper plates **60**. The plates **58** and **60** are thus arranged to connect the elements **54** and **56** in series, as best shown in FIG. 7. When electrical current is passed through the thermocouple series in one direction, the lower plates **60** will serve as cold junctions and the upper plates **58** as hot junctions. If the direction of the electrical current is then reversed, the lower plates **60** will become the hot junctions and the upper plates **58** the cold junctions.

The thermocouple units are embedded in a filler 62 of polyurethane foam which acts as heat insulating means to prevent the heat generated at the hot junctions from overtaking the cold prevailing at the cold junctions. The outer surfaces of the junction plates 58 and 60 are, however, exposed at the respective top and bottom edges of the foam filer 62, as shown in FIGS. 1 and 3, in order to be intimately associated with the metal pieces to which the thermocouple assembly is attached.

The thermocouple assembly 14 is mounted flat against the under surface of bottom wall 30 by a plurality of anchor elements in the form of channel members 64. These channel members 64 are secured to the bottom wall 30 and are embedded within the plastic foam filler 62. The top copper plates 58 of the thermocouple assembly are electrically insulated from the bottom wall 30 by a thin layer 66 of paint, epoxy resin, or other suitable material having insulating properties.

An end plate 70 is secured flat against the outer surface of the thermocouple assembly 14 by similar channel shaped anchor elements 72 which are secured to end plate 70 and embedded in the foam filler 62. The end plate 70 is made of a heat conductive metal and is insulated from the thermocouple plates 60 by an insulating layer 76.

The end plate 70 has a rigidly-secured or integral threaded stud 74 depending from the center thereof and permitting the removable mounting of the individual headpieces 16, 18, 20 and 22. For this purpose, each of said headpieces is formed with an internally-threaded socket 78 sized to receive the stud 74.

The headpieces may be made in a variety of sizes and shapes for direct application to selected skin and body areas. For purposes of illustration, the headpiece 16 is shown as having a flat outer application surface 80 of circular shape, conforming in size to the diameter of the body portion 12. The surface 80 provides a relatively large area of cooling for the treatment of surface blood vessels, reduction of bruise swelling, etc. The headpiece 18, on the other hand, is formed with a central cavity 82 sized to receive warts or small tumors. The headpiece 20 is provided with a pointed extension 84 for concentrated application of cold, while the headpiece 22 terminates in a spoon-shaped or cup-shaped extension 86, sized to receive a human heart during surgery.

The thermocouple assembly 14 is bordered by an annular metal ring 68 which is secured to the end plate 70. This ring 68 surrounds the plastic foam filler 62 and protects it from contamination during treating. The ring 68 is, however, slightly spaced from the bottom wall 30 to prevent the exchange of heat between the hot and cold junctions of the thermocouple assembly.

The electrical cable 40 extends entirely through the pipe 34, and its leads 42 and 44 are connected to respective terminal strips 88 and 90 at the ends of the thermocouple series, as best shown in FIG. 7. When direct current is fed to the thermocouple assembly through the leads 42 and 44 in one direction, the upper thermocouple plates 58 will be heated, such heat being dissipated by the heat sink provided by the liquid-filled body member 12. At the same time, the lower thermocouple plates 60 will be cooled, the cooling effect being distributed over the headpiece attached to the stud 74, and through the headpiece application surface to the body area being treated.

FIG. 7 shows schematically a power source unit 92 which may be employed for supplying electric current to the leads 42 and 44. The unit 92 may be adapted to be connected to a source of live D.C. current, or may be a self-contained unit including nickel-cadmium or other dry cells as the power source. In either event, the terminals of the power source 94 are connected by leads 96 and 98 through a switch 100, a variable resistor 102 and a polarity-reversing switch 104 to the leads 42 and 44 connected to the thermocouple assembly 14. The switch 100 is of the usual single-pole, single throw type and may be manually operated to open and close the circuit, or may be associated with a timer (not shown) to automatically open the circuit after a designated heating or cooling period. The polarity-reversing switch 104 may be employed to change the polarity of the current at the terminals 88 and 90 so that either heating or cooling will be produced at the headpiece. The variable resistor 102 may be employed to regulate the power supplied and therefore the degree of heating or cooling produced.

In one commercial embodiment of the device, eight thermocouple units, each consisting of a pair of barium telluride rods of 4 mm. diameter and ⅛ inch length were assembled in series and operated at 1.25 volts at 20 amperes. Under these operating conditions, and with the thermocouple assembly wired to produce a cooling effect at the headpiece, a steady state temperature of between −20° C. and −25° C. was produced at the headpiece. This temperature may, of course, be varied by adjustment of the variable resistor 102.

It is to be understood that the instrument is particularly intended to be used to produce cooling at the headpiece, although by use of the polarity-reversing switch 104 it can be instantly converted to an instrument for providing controlled heat to body areas. When the device is used for cooling applications, for example, the relatively large amount of water or other liquid contained in the body member 12 renders the latter an extremely efficient heat sink. The heat generated at the upper plates 58 passes through the bottom wall 30, is absorbed by the contained liquid 32, and is dissipated to the atmosphere through the vanes 26. Because of the high efficiency of the heat sink, extreme cooling is produced at the lower plates 60, which is transferred through the end plate 70 and distributed over the connected headpiece.

FIG. 8 illustrates a modified thermocouple arrangement in which two thermocouple assemblies are mounted in tandem to produce an even greater degree of cooling at the headpiece. In this embodiment, one thermocouple assembly 106 is mounted in flush abutment with the bottom wall 30 of body member 12, while a second thermocouple assembly 108 is mounted in flush abutment with the end plate 70. The opposite surfaces of the thermocouple assemblies 106 and 108 rest flush against each other, being electrically insulated from each other by a layer of "Mylar" film 110 or other suitable insulating material.

The thermocouple assemblies 106 and 108 are connected in parallel to the electrical cable leads 42 and 44 in such a manner that the upper plates 58 of the thermocouple assemblies are the hot sides while the lower plates 60 of the assemblies are the cold sides. Consequently, the hot side of the lower thermocouple unit 108 is in flush, heat-exchange relationship with the cold side of the upper thermocouple unit 106. The heat generated at the top plates 58 of the lower thermocouple assembly 108 is immediately absorbed by the cold bottom plates of the upper thermocouple assembly 106, so that the top plates of the lower thermocouple assembly 108 are kept cool and intense cold is produced at the end plate 70 and the attached headpiece. In other words, the upper thermocouple assembly 106 serves as a refrigerated heat sink for the lower thermocouple assembly 108.

In utilizing the headpiece 22, shown in FIG. 6, the entire instrument may be inserted into the chest cavity of a patient during heart surgery. The spoon-shaped headpiece extension 86 is sized and shaped to receive enough of the heart area to retard the heart-beat when cooling is applied. The degree of cooling is uniform over the headpiece and may be selectively regulated by adjustment of the variable resistor 102 to control the condition of the heart during the course of surgery, an advantage which cannot be obtained with the use of crushed ice in conventional surgery techniques.

While preferred embodiments of the invention have been shown and described herein, it is obvious that numerous additions, changes and omissions may be made in such embodiments without departing from the spirit and scope of the invention.

What I claim is:

1. A medical instrument for use with a liquid comprising an elongated handle member having a hollow interior forming a reservoir for said liquid and having a bottom wall in heat-exchanging communication with the liquid within said reservoir, said reservoir and the liquid contained therein serving as a heat sink, a thermocouple assembly having hot junctions and cold junctions, means mounting said thermocouple assembly flush against said bottom wall with one of said junctions in heat-exchanging relationship therewith, a headpiece mounted adjacent the opposite junctions of said thermocouple assembly in heat-exchanging relationship therewith, and means for connecting said thermocouple assembly to a power source.

2. A medical instrument comprising an elongated handle member having a bottom wall, a thermocouple assembly having hot junctions and cold junctions, means mounting said thermocouple assembly flush against said bottom wall with one of said junctions in heat-exchanging relationship therewith, a heat-conductive end member mounted adjacent the opposite junctions of said thermocouple assembly and having mounting means, a removable headpiece connected to said mounting means in heat-exchanging relationship with said end member, and means for connecting said thermocouple assembly to a power source.

3. A medical instrument according to claim 2 in which said end member and headpiece have cooperating screw means for the removable connection of said headpiece and said end member.

4. A medical instrument according to claim 2 in which said end member is mounted adjacent the cold junctions of said thermocouple assembly.

5. A medical instrument for use with a contained liquid, said instrument comprising an elongated, heat-conductive handle member having a main body wall and top for said liquid and bottom walls forming a hollow liquid reservoir containing said liquid, a thermocouple assembly having hot junctions and cold junctions, means mounting said thermocouple assembly flush against said bottom wall of the handle member with its hot junctions in heat-exchanging relationship therewith and said liquid reservoir and the liquid contained therein, said reservoir and the liquid contained therein serving as a heat sink, a heat-conductive end member mounted flush against the cold junctions of said thermocouple assembly and having mounting means, a removable headpiece connected to said mounting means in heat-exchanging relationship with said end member, said headpiece being heat-conductive and being sized for direct application to a small area of the body, and circuit means for connecting said thermocouple assembly to a power source.

6. A medical instrument according to claim 5 in which said circuit means includes a variable resistor for controlling the temperature of said headpiece.

7. A medical instrument according to claim 5 in which said circuit means includes a polarity reversing switch for reversing the polarity of said power source and thereby cause the cold junctions to become hot junctions.

8. A medical instrument according to claim 5 in which the main body wall of said handle member is provided with a series of outwardly-projecting heat-dissipating fins.

9. A medical instrument for use with a liquid comprising an elongated handle member having a hollow interior forming a reservoir and having a bottom wall in heat-exchanging communication with liquid within said reservoir, a thermocouple assembly comprising rows of alternate p-type and n-type semiconductor elements electrically connected at their ends to form hot junctions and cold junctions, means mounting said thermocouple assembly flush against said bottom wall with said hot junctions in heat-exchanging relationship therewith, whereby the liquid reservoir receives the generated heat through said bottom wall and serves as a heat sink, a heat-conductive end plate mounted adjacent the cold junctions of said thermocouple assembly and having mounting means, a removable headpiece connected to said mounting means in heat-exchanging relationship with said end plate, and means for connecting said thermocouple assembly to a power source.

10. A medical instrument according to claim 9 in which said thermocouple assembly comprises a pair of thermocouples mounted flat against each other with the hot junction of the upper thermocouple in engagement with said bottom wall of the handle member, the cold junction of the lower thermocouple in engagement with said end plate, and the cold junction of the upper thermocouple resting flush against the hot junction of the lower thermocouple, the upper thermocouple serving as a heat sink for the lower thermocouple.

11. A medical instrument according to claim 9 in which said headpiece is spoon shaped and sized to receive and hold a portion of the heart during surgery.

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