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(54) **A cryosurgical probe**

(57) A cryosurgical probe having a tip portion E designed to control iceball formation and thus the freezing efficiency of the probe. The probe operates by the Joule-Thompson effect of gas cooling when expanded through a restriction J. In known probes, after cooling in this way, the gas is immediately vented to exhaust so reducing the dwell time of the gas in the tip. The probe disclosed is designed such that the cooled gas after passing through the restriction travels along a terminating passage 61 in heat exchange relationship with the wall of the tip before being vented to exhaust. The length of the terminating passage formed in the tip increases the dwell time there thus enabling better control of iceball formation. Moreover the length of the terminating passage is made adjustable, so that the iceball shape formed at the tip, between the restriction and the extremity of the tip, can be varied.

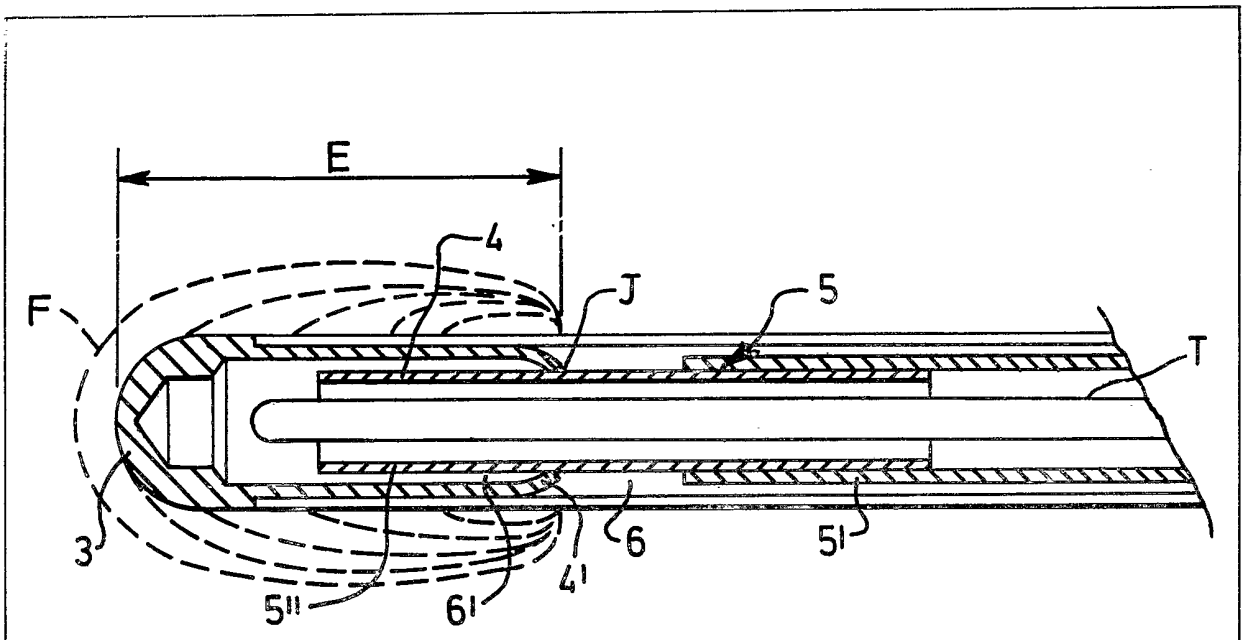


FIG.2.

GB 2 094 636 A

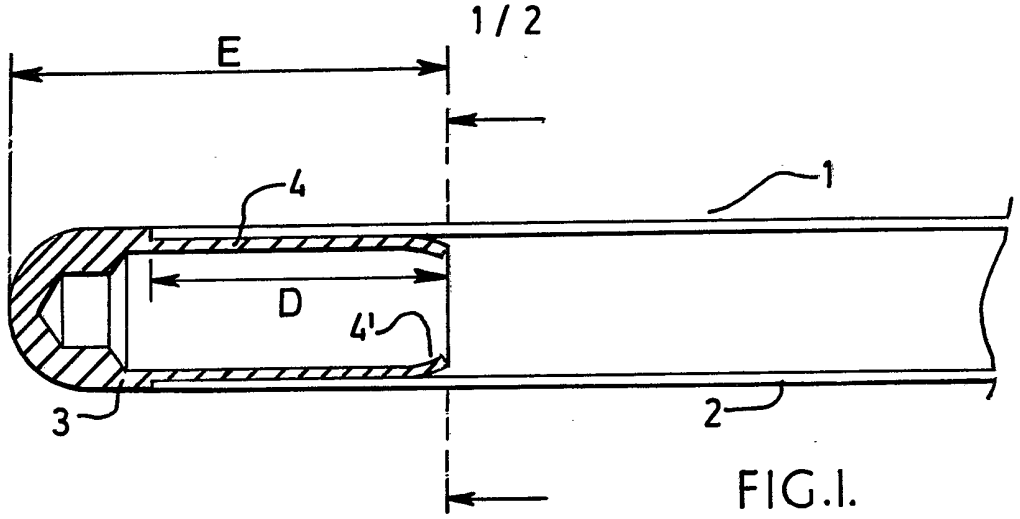


FIG.1.

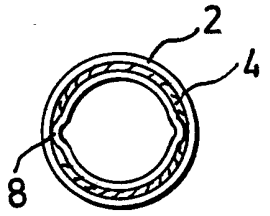


FIG.1A.

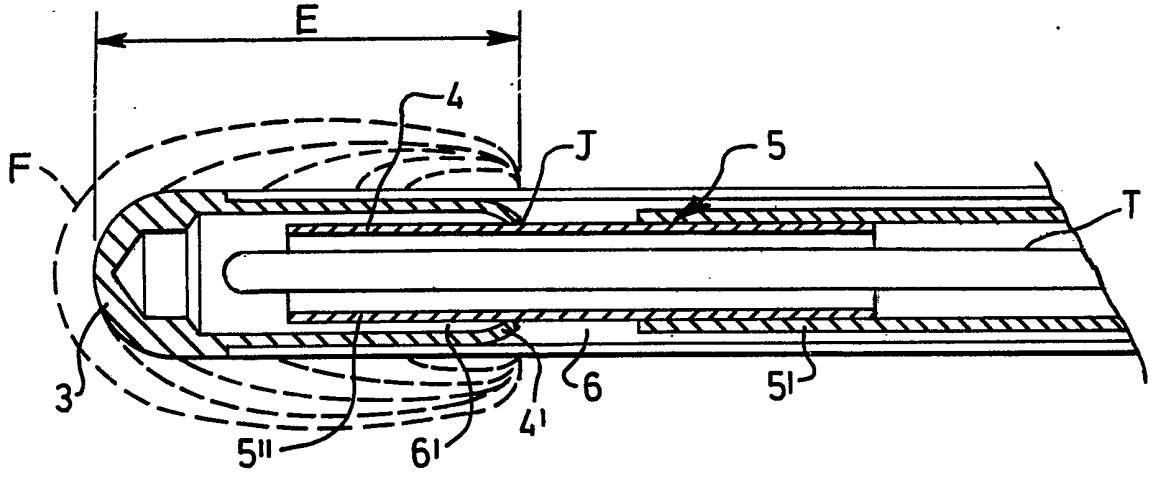


FIG.2.

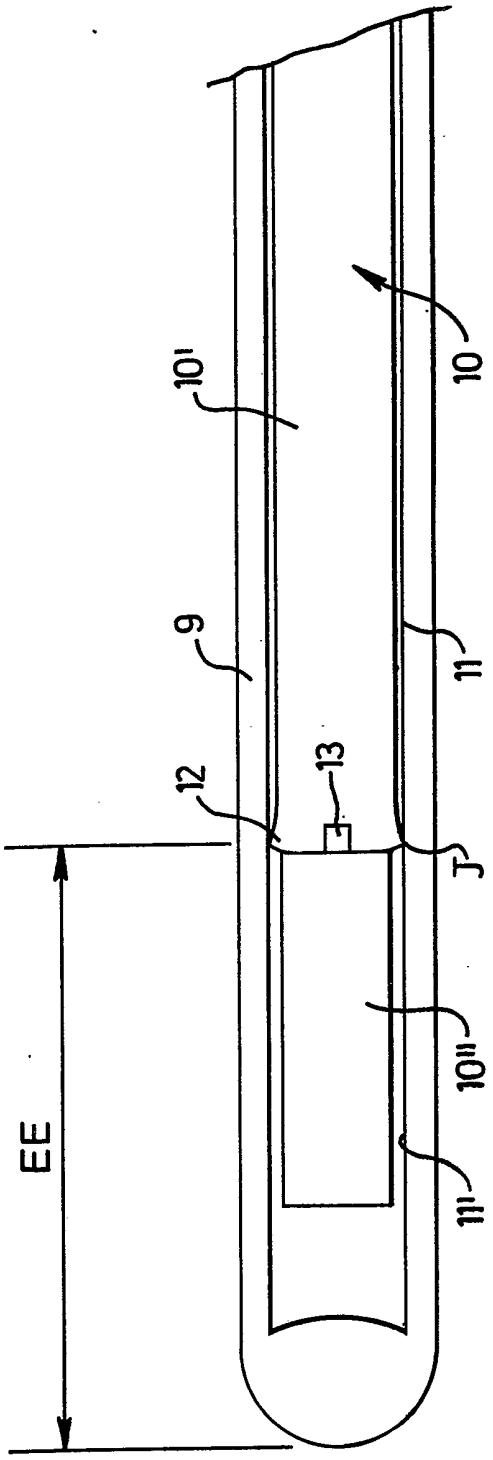


FIG. 3.

SPECIFICATION

A cryosurgical probe

The present invention relates to a cryosurgical probe.

A cryosurgical probe is known having a probe tip which is cooled by the Joule-Thompson effect of gas under pressure passing through a restriction. The pressurised gas is fed by means of a conduit along the probe, one end of the conduit being provided with a small opening forming the restriction positioned to open into a cavity in the probe tip. Thus cooling of the gas when expanding past the restriction causes ice to form on the probe tip which can then be used to freeze tissue, for example, during a cryosurgical operation.

The exhaust gas escapes from the cavity of the probe tip in a passage formed between the conduit and the internal surface of the probe wall.

Such a probe has been found to be of much value in cryosurgical techniques over the years. However it suffers from the disadvantage that since the cold exhaust gas is in heat exchange with the probe stem, the stem itself is liable to freeze up well away from the probe tip.

In addition, in this known conventional probe, it is difficult to control iceball formation on the tip. If the iceball is not properly formed on the probe tip then the overall freezing efficiency of the probe tip is diminished.

Moreover the opening forming the restriction through which the gas escapes into the probe tip cavity is prone to blockage by foreign bodies and when this occurs the probe has to be dismantled to clear the restriction.

Another cryosurgical probe is known wherein the pressurised gas is fed to a cavity in the probe tip through an annular passage surrounding a conduit extending centrally within the probe. The end of the conduit opening into the cavity is provided with a peripheral flange which provides a small clearance with the inner wall of the probe body. Thus cooling of the gas is effected as it passes through the annular restriction to cause cooling of the probe tip as required thereafter to pass to the conduit acting as the exhaust.

This arrangement which operates in a reverse glas flow mode compared with the previously described device, obviates to some extent the problem of freezing of the probe stem because the warm incoming gas screens the cold exhaust gas flowing up the central exhaust conduit. However the device is difficult to set-up in practice, and moreover control of the iceball formation on the probe tip with respect to shape and cooling efficiency, is not all that could be desired because of the short dwell time of the cooling gas in the cavity inasmuch as the gas is vented up the exhaust passage before its full cooling effects can be applied.

Further during cooling differential thermal contraction will occur in the various structural parts forming the probe, and this can cause difficulties mainly due to the variations in the size of the restriction and consequent gas flow.

It is an object of the invention to provide a cryosurgical probe wherein it is possible to control very accurately the shape and thickness of the iceball formation on the probe tip.

It is a further object of the invention to provide a cryosurgical probe wherein the stem does not freeze up during use and iceball formation is maintained only at the tip portion where it is required.

It is a further object of the invention to provide a cryosurgical probe wherein the restriction providing the Joule-Thompson effect of cooling, is not prone to blockage and the arrangement of the structural parts of the cryosurgical probe compensates for thermal contraction during cooling thereby maintaining the size of the restriction constant.

According to the invention there is provided a cryosurgical probe comprising a probe body, a hollow tip portion of the probe body of high thermal conductivity, a delivery passage for pressurised gas to said hollow tip portion, an exhaust passage for discharging gas from the tip portion and being surrounded by said delivery passage, and a restriction in said delivery passage forming a terminating portion of said delivery passage within said hollow tip portion and downstream of said restriction, thereby to cause cooling of the gas by Joule-Thompson effect in passing through the restriction into said terminating part of said delivery passage.

The advantage of a cryosurgical probe of this design over conventional probes is the control which it gives in respect of uniform freezing of the operating tip portion of the probe. Improved iceball formation is possible in a uniform manner around the tip portion due to the fact that the dwell time of the cooled gas in the probe tip area is increased since the cooled gas is made to travel along that part of the delivery passage downstream of the restriction before being vented to exhaust.

Other features and advantages of the present invention will become apparant from the following description of a preferred embodiment.

The present invention will now be described by way of example with reference to the accompanying drawings wherein:

Figure 1 is a longitudinal sectional view through a cryosurgical probe according to an embodiment of the invention but omitting the exhaust tube for discharging cooling gas;

Figure 1A is a cross-sectional view along A-A of Figure 1;

Figure 2 is a longitudinal sectional view through the probe of Figure 1 but with the exhaust tube mounted in position; and

Figure 3 is a longitudinal view through a cryosurgical probe according to another embodiment of the invention.

The cryosurgical probe shown in Figures 1 and 2 comprises a hollow tubular main probe body 1 formed of a stainless steel portion 2 and a rounded

The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.

probe tip 3 made of silver brazed to the portion 2. The materials used are chosen for their high thermal conductivity. Hence instead of silver for the probe tip 3, stainless steel could be used.

The tip 3 has an integrally formed tubular extension 4 within the stainless steel portion 2 in abutment with its internal surface to form a double walled section of the probe of silver and stainless steel, extending a distance D along the probe stem.

The exposed silver of the tip 3 and the double walled section D form a hollow operating tip portion E of the probe on which ice is caused to form as will be described.

A tubular conduit 5 of stainless steel extends within the probe body 1 to form an annular passage 6 for delivery of pressurised gas to the hollow operating tip portion E of the probe.

The conduit 5 is formed of a main conduit part 5' and an extension conduit part 5" of smaller cross-section brazed or glued to the conduit part 5'.

The conduit part 5" extends within the tubular extension 4 into the hollow operating tip portion E, its smaller cross-section being necessary to accommodate the double walled section D of the probe.

An end portion 4' of the extension 4 is swaged down onto the surface of the conduit part 5" to form a restriction annulus J in the annular passage 6 and a narrow annular terminating passage portion 6' of the delivery passage 6 downstream of the restriction J.

A thermocouple T is positioned down the conduit 5 and into the hollow operating tip portion E as shown, to monitor probe tip temperature.

In use gas under pressure is fed down the delivery passage 6 and is cooled at the restriction annulus J by the Joule-Thompson effect of the gas expanding into the terminating passage portion 6' of the delivery passage 6 downstream of the restriction. The narrow passage 6' ducts the cold gas down to the furthest extremity of the probe tip and acts to effect a longer dwell time for the cooled gas in the operating tip portion E before the gas is vented up the conduit 5. This considerably increases the freezing efficiency of the probe leading to improved iceball formation on the operating tip portion E. The positioning of the end of the conduit 5" within the operating tip portion E provides for control of shape of the iceball, for example if the length of the conduit part 5" downstream of the restriction J is short then spherical iceballs may be formed, whereas if the length is increased then the shape of the formed iceball becomes sausage-shaped.

Layers of ice are formed sequentially on the operating probe tip portion 3 as shown in dotted lines F. It will be seen that formation only occurs commencing at a point on the probe body adjacent the restriction annulus J and extends around the operating probe portion E.

In addition to controlled iceball formation and freezing efficiency the fact that the cold exhaust gas escaping up the conduit 5 is screened by the incoming warmer gas down the delivery passage 6, means that freezing of the probe stem upstream of the restriction annulus J is obviated.

The swaged end portion 4' of the tubular extension 4 is provided with diametrically opposed dimples or grooves 8 as will be seen in Figure 1A. This enables the device to be calibrated in terms of providing the necessary control of flow of gas through the probe. Although gas passes to the narrow passage 6' all the way around the restriction annulus J nevertheless it is necessary to provide such dimples or grooves 8 to enable the required gas flow to be attained, the size of the dimples or grooves 5 corresponding to the flow required.

An alternative embodiment of the cryosurgical probe according to the present invention is shown in Figure 3. This comprises a hollow probe body 9 made of stainless steel with a stainless steel conduit 10 extending within the hollow body 9 to open into the probe tip as shown.

The conduit 10 forms an annular passage 11 with the internal surface of the probe body 9 for delivery of pressurised gas to the probe tip, the conduit 10 itself acting as an exhaust duct for gas leading from the probe tip.

The conduit 10 is formed of a conduit part 10' brazed to a forward extension conduit part 10" of smaller cross-section. Brazing occurs at a belled-out end portion 12 of the conduit part 10', the belled-out portion 12 forming a restriction annulus J in the outer delivery passage 11, opening into a narrow annular terminating passage portion 11' of the delivery passage 11 downstream of the restriction J.

The belled-out portion 12 is provided with diametrically opposed cut-outs 13 for the purposes of calibrating the device as hereinbefore described.

In use gas under pressure is passed down the delivery passage 11 and is cooled by the Joule-Thompson effect in passing through the restriction J to enter the narrow passage 11' downstream thereof. The time taken for the gas to travel down the narrow passage 11', therefore determines an increased dwell time for the flowing cold gas before the gas is vented up the conduit 10, thus providing maximum heat exchange benefits in the operating tip portion EE.

This embodiment similarly provides the advantages of the embodiment of Figures 1 and 2, but its configuration is ideal for smaller cryosurgical probes where the space available to operate the device is at a premium.

Embodiments of the invention as described above employ materials which are thermally matched in the sense that they have close or equal thermal coefficients of expansion. Moreover their design is such as to fully compensate for axial contraction during thermal cooling since the Joule-Thompson restriction annulus J is configured to allow for sliding of the exhaust conduits 5 and 10 during axial contraction.

This is in contrast to prior art probes where thermal contraction affects the performance of the device due to the uncontrollable variations in the Joule-Thompson restriction annulus.

In summary the present invention provides a cryosurgical probe which obviates the problems of conventional probes in the following respects.

1. With conventional probes the cold exhaust gas causes freezing up of the probe stem. The cryosurgical probe of the present invention has the cold

exhaust gas effectively screened by the warm incoming gas flowing at the outside of the probe which is in heat exchange relationship with the probe body thereby to prevent freezing of the stem.

2. In contrast to existing probes the cooled gas after passing through the restricting annulus is maintained in heat exchange relationship with the wall of the operating tip portion of the probe before being vented to exhaust. This provides much improved control of the freezing power of the probe since there is controlled exchange of heat at the operating tip portion of the probe as a function of controlled pressure reduction of the cooled gas passing through a narrow passage before being vented to exhaust.

3. The cryosurgical probe according to the present invention permits control of iceball shape due to the fact that the dwell time of the cooled gas in the operating tip portion of the probe can be varied by shortening or lengthening the narrow terminating passage in which the cooled gas flows after passing through the restriction annulus. Thus spherical or sausage-shaped iceball formation can be achieved.

4. Small orifices acting as a Joule-Thompson restriction in conventional probes are prone to blockage. The circumferential annulus formed by the arrangement of the present invention is much harder to block with foreign matter.

5. In the present device contraction effects will be most pronounced along one direction parallel to the main probe body. Thus in this configuration the Joule-Thompson restriction annulus will not be altered on cooling since the contracting exhaust conduit will merely slide longitudinally of the probe body and gas flow will be unaffected.

6. The configuration of the cryosurgical device according to the present invention lends itself to simplicity of assembly and maintenance.

Other features and advantage of the present invention will be appreciated to those skilled in the art and within the present inventive concept. Especially it will be realised that although the probe described and illustrated herein has a rounded tip, for nerve freezing the probe may have a pointed operating tip to penetrate tissue. Moreover when silver is used the tip may be hard chromed to give corrosion resistance, wear resistance and additional strength. Such treatment has minimal affect upon conductivity.

CLAIMS

1. A cryosurgical probe comprising a probe body, a hollow tip portion of the probe body of high thermal conductivity, a delivery passage for pressurised gas to said hollow tip portion, an exhaust passage for discharging gas from the tip portion and being surrounded by said delivery passage, and a restriction in said delivery passage forming a terminating portion of said delivery passage within said hollow tip portion and downstream of said restriction, thereby to cause cooling of the gas by the Joule-Thompson effect in passing through the restriction into said terminating part of said delivery passage.

2. A cryosurgical probe as claimed in Claim 1 wherein a conduit acting as said exhaust passage extends within the probe body to open out into said hollow tip portion, said delivery passage being formed around said conduit.

3. A cryosurgical probe as claimed in Claim 2 wherein the main probe body is sleeved to said hollow tip portion to form a double wall section of the probe, the inner wall of which, being of the material of said hollow tip portion, is around an end section of said conduit and has an extremity which is swaged over said end section to form said restriction, with said terminating portion of said delivery passage being between the outer wall of the said end section and said inner wall of the tip portion downstream of said restriction.

4. A cryosurgical probe as claimed in Claim 3 wherein the swaged extremity of said inner wall is provided with diametrically opposed dimples or grooves to permit the probe to be calibrated in terms of required gas flow rate through said restriction.

5. A cryosurgical probe as claimed in Claim 4 wherein said conduit is formed of a main conduit part and an extension conduit part of smaller cross-section brazed or glued thereto at a point upstream of said restriction.

6. A cryosurgical probe as claimed in Claim 2 wherein said conduit is adjustably positioned to permit variation of the length or said end section downstream of said restriction.

7. A cryosurgical probe as claimed in Claim 2 wherein said conduit is formed of a main conduit part and an extension conduit part of smaller cross-section brazed or glued thereto, the end of the main conduit part at the join between the main and extension conduit parts being belled-out to engage the inner wall of said probe body thereby to form said restriction in said delivery passage and said terminating passage between said extension conduit part and the inner wall of said probe body downstream of said restriction.

8. A cryosurgical probe as claimed in Claim 7 wherein the belled-out portion is provided with diametrically opposed cut-outs for calibrating the probe in terms of determining the flow rate of gas in the probe through said delivery passage.

9. A device as claimed in Claims 5 or 7 wherein a thermocouple extends within said conduit to within the tip portion of said probe.

10. A cryosurgical probe as claimed in Claim 2 wherein said probe body, said tip portion and said conduit are made of stainless steel.

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