

[54] COOLING APPARATUS

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[58] Field of Search.....62/45, 514, 222

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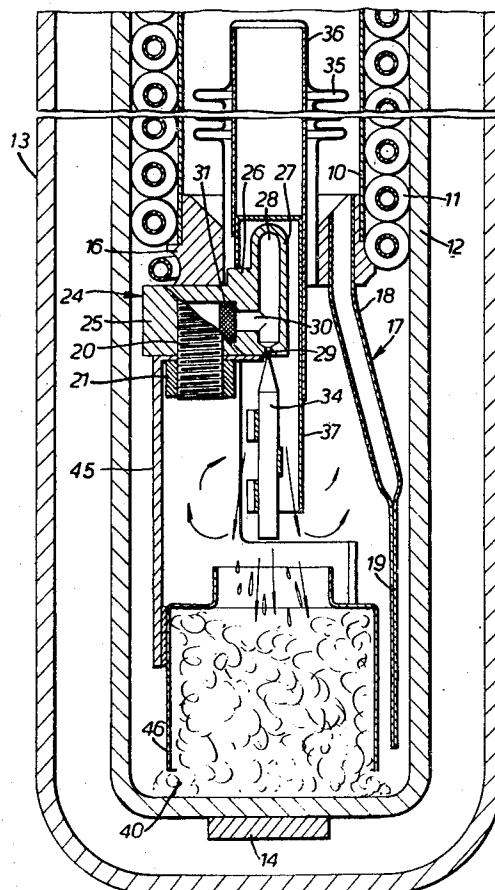
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[57] ABSTRACT

Cooling apparatus of the Joule Thomson type includes a load situated below and spaced from the nozzle, a body of absorbent material in heat exchange relationship with the load, and a valve controlling the effective area of the nozzle to vary the flow of refrigerant automatically under the control of a sensor situated in heat exchange relationship with the absorbent material. To achieve the required heat exchange relationship between them the sensor may be in contact with the absorbent material, or separated from it by a metal wall, or even slightly spaced from it, provided that sufficient heat flow can occur from the sensor to the absorbent material to cause the response to depend on the extent to which the absorbent material is saturated with liquid refrigerant.

9 Claims, 3 Drawing Figures



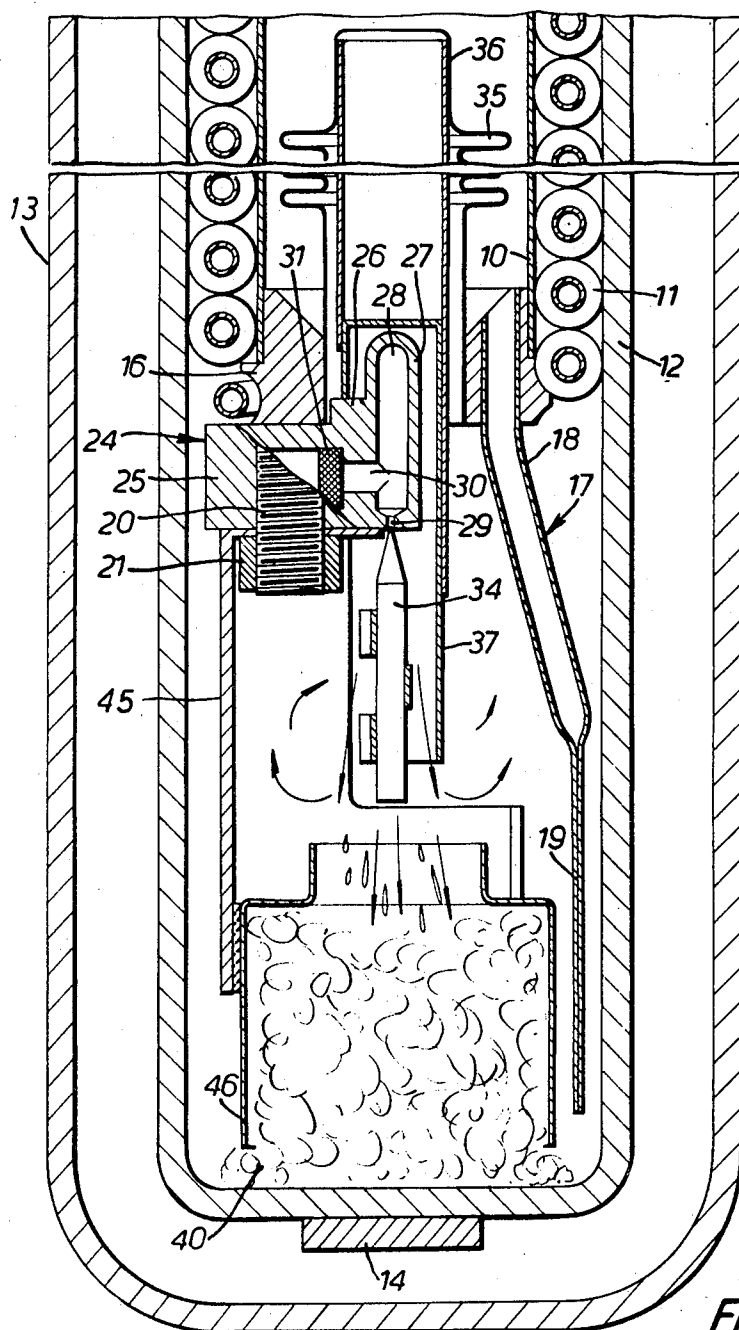


FIG. 1.

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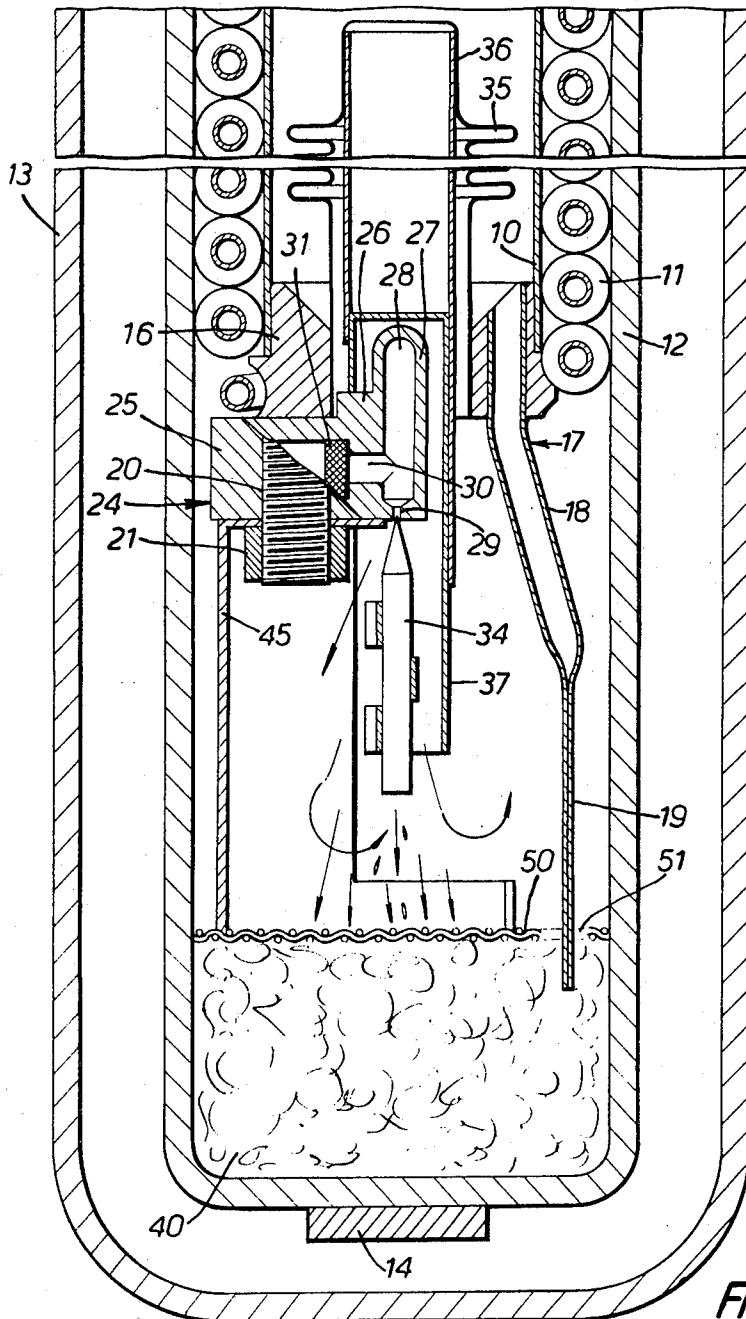


FIG. 2.

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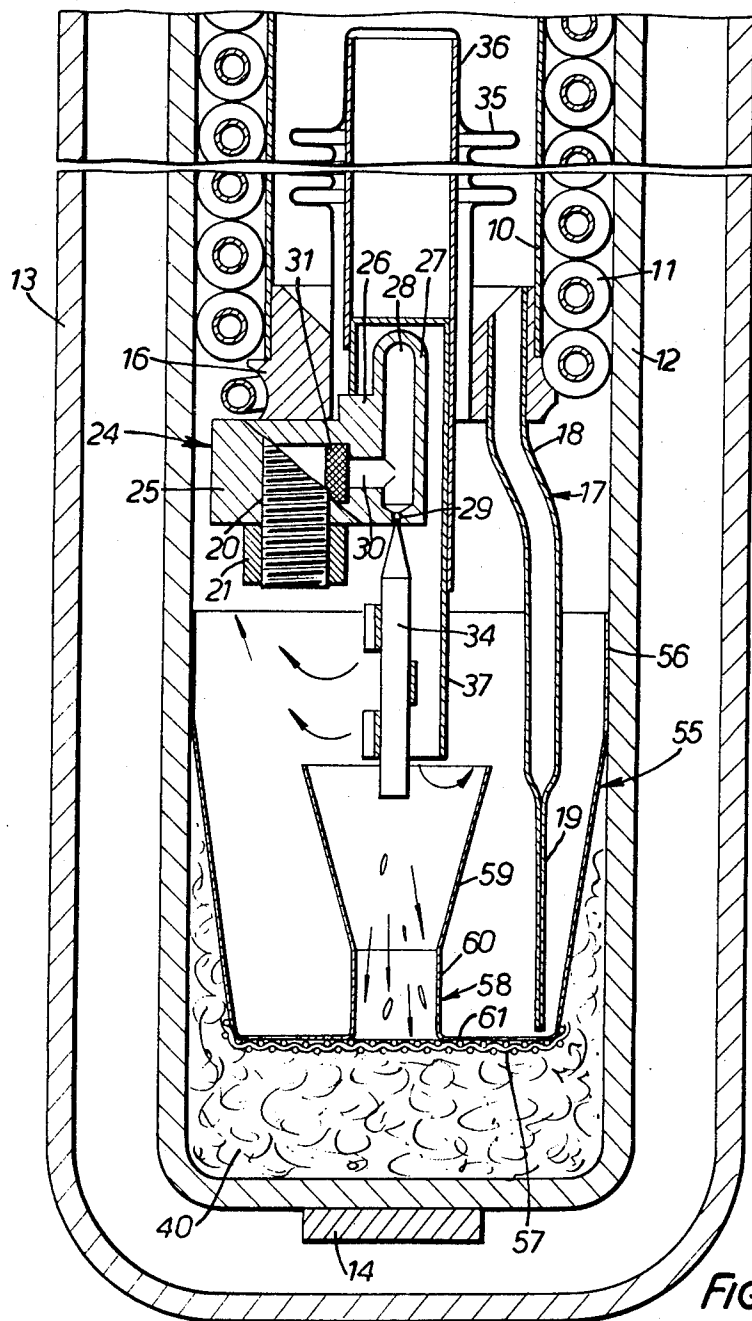


FIG. 3.

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COOLING APPARATUS

This invention relates to cooling apparatus of the Joule Thomson type including a heat exchanger affording two paths through one of which refrigerant gas from a supply under pressure, and at a temperature below its inversion temperature, is supplied to an expansion nozzle located adjacent the cold end of the heat exchanger, whence the low pressure gas returns through the other path, to effect cooling by expansion and produce liquid refrigerant in a container.

It will be appreciated that the term nozzle is used herein to cover any conventional or preferred static device permitting expansion of gas, whether it be a plain orifice, a specially shaped nozzle, or a number of orifices whether alone or associated with a porous plug or membrane, for example as described in the commonly owned British Pat. specification No. 863,961.

Such coolers may be used to produce liquefied gas which is used to remove heat by evaporation from a load to be cooled, for example an infra-red detector, or a laser.

Where the ambient temperature of the environment or the load varies widely, the amount of heat to be extracted in order to keep the load within a given temperature range will also vary.

The commonly owned British Pat. specification No. 1,164,726 describes apparatus of this type including automatic modulating means responsive to the temperature in the region of a part of the heat exchanger to reduce the amount of gas flowing through the nozzle as the said temperature falls. The commonly owned British Pat. specification Nos. 29785/67 and 21042/68 describe such apparatus in which the modulating means include a sensor located in the container at least partly below the level of the nozzle, and so as to come into heat exchange relationship with the liquid, and arranged to reduce the amount of gas flowing through the nozzle when the liquid level in the container exceeds a given level.

The preferred forms of apparatus described in the prior specifications referred to have a number of advantages when employed in an upright position under steady conditions, but although some degree of regulation is obtained the advantages are less marked, and some modification may be required, when they are employed in a tilted or inverted position or under conditions of acceleration or reversed gravity. An object of the present invention is to provide modifications enabling similar advantages to be obtained under the latter conditions.

For convenience, however, the apparatus will be described in an upright position with the hot end uppermost so that phrases such as "below the nozzle" are used herein to mean on the side of the nozzle remote from the hot end.

According to the present invention apparatus as set forth above includes a load situated below and spaced from the nozzle, a body of absorbent material in heat exchange relationship with the load, and a valve controlling the effective area of the nozzle to vary the flow of refrigerant automatically under the control of a sensor situated in heat exchange relationship with the absorbent material.

To achieve the required heat exchange relationship between them the sensor may be in contact with the ab-

sorbent material, or separated from it by a metal wall, or even slightly spaced from it, provided that sufficient heat flow can occur from the sensor to the absorbent material to cause the response to depend on the extent to which the absorbent material is saturated with liquid refrigerant.

The sensor may include a vapor bulb containing a liquid in equilibrium with its vapor the pressure of which controls the operation of the valve.

In one form of the invention the sensor includes portions near the periphery of the container at points distributed around the axis, so as to be immersed before the nozzle if the device is tilted about any horizontal axis. Conveniently the sensor has a portion of annular form surrounding the axis.

Preferably means is provided for directing the refrigerant from the nozzle so as to impinge on the absorbent material. Thus the nozzle may be provided with a duct extending from it towards the load, so as to confine the refrigerant and direct it towards the load and cause it to impinge on the absorbent material. The duct may extend into contact with the absorbent material so that the refrigerant is constrained to pass through the latter on its way to exhaust via the low pressure path of the heat exchanger.

The invention may be put into practice in various ways, but three specific embodiments will be described by way of example with reference to the accompanying drawings in which

FIGS. 1 to 3 are sectional elevations respectively of the lower parts of three different forms of cooling apparatus working on the Joule Thomson principle.

In the embodiments shown the cooling apparatus, like most of those of the specifications referred to above, is of elongated form, and will be described in the position in which it would normally be used with its axis vertical and its cold end at the bottom.

In each of FIGS. 1 to 3, the apparatus includes a tubular heat exchanger comprising an inner tubular body 10 around which is helically wound a finned inlet tube 11 forming the inlet path of the heat exchanger. An external coaxial tube 12, which may be the inner wall of a Dewar flask 13, is located round the finned coil 11 and the space between the inner body 10 and the external tube 12 provides the second or exhaust path of the heat exchanger for exhaust gas flowing past the fins to cool the incoming high pressure refrigerant within the helical coiled tube 11 forming the inlet path. The lower end of the external tube is closed to provide a reservoir in which the liquid working fluid can accumulate. The upper end of the helical finned tube 11 communicates with a central bore (not shown) in the upper end of the body to which working fluid under pressure is supplied at a temperature below its inversion temperature.

At its lower end the inner tubular body 10 has welded to it a reinforcing ring 16 having a sensor 17 projecting parallel to the axis from one point of it as described below, and having, projecting parallel to the axis from a diametrically opposite point, a threaded stud 20 for mounting a seating member 24.

The seating member 24 comprises a stout disc 25 one face of which has projecting eccentrically from it a part-circular boss 26 from which in turn a smaller circular boss 27 projects still further. The disc has in it a hole which receives the threaded stud 20, and is held in

place by a nut 21. The small circular boss 27 projects coaxially up into the cold end of the heat exchanger, whilst the part-circular boss 26, which may comprise approximately a semi-circle, is also coaxial with the heat exchanger and fits snugly into the reinforcing ring 16. The small circular boss 27 of the seating member 24 has a coaxial bore 28 extending through it from its upper end to a valve orifice 29 opening through its lower end, and a transverse bore 30 which opens into the axial bore 28 and contains a filter 31, and of which the outer end is closed by a screw plug (not shown). A further transverse bore (not shown) opens into this transverse bore 30 and the lower end of the helical heat exchanger tube is sealed into this last transverse bore. The upper end of the axial bore 28 is closed.

The effective area of the expansion nozzle 29 is arranged to be controlled by means of a needle valve 34 which is itself controlled by a bellows 35.

The bellows 35 has its lower open end secured to the reinforcing ring 16 whilst its movable closed upper end is secured to the upper end of a depending tube 36, which will be referred to herein as a hollow piston rod. This extends down beyond the seating member 24 and half the circumference of its lower portion is cut away whilst the remaining half receives and is secured to and reinforced by a tubular valve carrier 37. The valve carrier is also cut away for half its circumference except at its end portion. Thus the seating member 24 projects into the open half of the hollow piston rod 36 and the valve carrier 37 from the side, and the small cylindrical boss 27 of the seating member 24 projects up into and fits in the upper end of the valve carrier to guide it. The lower end of the valve carrier carries the needle valve 34 which has a lower cylindrical portion and an upper tapered portion projecting into the expansion orifice 29 of the seating member 24.

As referred to above the reinforcing ring 26 in the lower end of the tubular body 10 of the heat exchanger carries a sensor 17. This is in the form of a metal tube 18 sealed in a hole extending through the reinforcing ring 16 parallel to the axis and having its lower end portion squashed flat to form an extended heat conducting tail 19. The sensor tube 17, and the space outside the bellows 35 inside the tubular body 12 of the heat exchanger, are filled with liquid and vapor in equilibrium of a suitable material, which may or may not be the same as the refrigerant.

Thus in operation, as described in the prior specifications referred to above, as the liquid refrigerant collects in the outer vessel 12 and the level of the pool of liquid gradually rises, progressively immersing the extended tail 19 of the sensor 17, the temperature of the sensor tube progressively falls, the pressure applied to the outside of the bellows 35 falls correspondingly, and the bellows expands, raising the hollow piston rod 36 and causing the needle valve 34 to progressively close the expansion orifice 24 so as to reduce the flow of refrigerant.

The Dewar flask 13 has a flat end or bottom with an infra-red detector 14 secured to the inner wall 12 in the vacuum space and constituting the load of the cooler.

The load 14 is covered with a disc or wad of absorbent material 40 such as felt or cotton wool to absorb the liquid, which is caused to impinge upon it.

In the arrangement shown in FIG. 1 the nozzle 29 is surrounded by a hollow cylindrical duct 45, with half the circumference of its upper portion cut away, extending down and connecting with an enlarged skirt 46 surrounding the wad of absorbent material 40. The valve carrier 37 and the duct 45 together direct the fluid from the nozzle 29 to pass through the absorbent material 40 before escaping under the side walls of the skirt 46. The duct 45 is of heat insulating material and secured to the seating member 24 by the nut 21. The sensor 17 extends down to one side of the skirt 46 alongside the absorbent wad 40.

The arrangement shown in FIG. 2 is similar to that of FIG. 1 except that the skirt 46 is omitted and the whole of the bottom portion of the Dewar flask 12 is filled with the absorbent material 40 which is covered by a flat disc 50 of wire gauze, which is held down by the lower end of the duct 45.

The sensor projects down through a hole 51 in the gauze disc into contact with the absorbent material.

The arrangement of FIG. 3 is again similar, with the absorbent material 40 filling the whole of the bottom portion of the Dewar flask and covered by a cup member 55, the upper portion 56 of which is a snug fit in the Dewar flask. The bottom 57 of the cup member is formed of wire gauze, and in the middle it supports a funnel 58, comprising an upper frusto-conical portion 59 tapering down to a cylindrical portion 60 which ends in an annular disc-shaped base 61 resting on and secured to the gauze bottom 57 of the cup.

Thus the refrigerant from the nozzle is directed down through the funnel through the middle of the gauze bottom into the absorbent material and passes through the latter before escaping up through the portion of the gauze surrounding the annular base 61.

The sensor extends down to a point close to the latter part of the gauze disc.

Accordingly in operation whatever the attitude and effective gravity of the cooler the mist of refrigerant liquid and gas projected from the nozzle, by a pressure of perhaps 6,000 pounds per square inch, is directed into the absorbent material.

As the absorbent material becomes saturated with liquid refrigerant, being in contact with the inner wall of the Dewar vessel, it provides effective cooling for the load on the other side of that wall. The duct ensures that droplets of refrigerant cannot by-pass or bounce back from the absorbent but are absorbed into it by capillary action.

The effect of the absorbent material in cooling the sensor is very much less when the absorbent material is dry than when it is saturated with liquid refrigerant and accordingly the operation of the valve depends sensitivity on the extent to which the absorbent is saturated with liquid refrigerant and is to a large extent independent of the attitude of the cooler. Moreover, the use of an annular sensor surrounding the load renders the arrangement still less dependent upon attitude since even if the lower part of the absorbent is more saturated or more rapidly saturated than the upper part, a portion of the sensor will always be in the lower part and a portion in the upper part when the cooler is tilted to a considerable angle.

The preferred constructions described in the specifications referred to above have a number of advantages.

Apart from the substantial economy of gas effected by cutting down the flow when the general temperature level falls below a given value, the provision of a sensor extending below the expansion nozzle makes it possible to provide more precise control in accordance with the liquid level rather than primarily in accordance with temperature. The closing of the valve responds to a temperature which depends upon a balance between the heat flowing in from the hot end and the heat flowing out to the cold end. This balance is sharply modified by contact of the sensor with liquid refrigerant. Moreover, the closing of the valve can be effected before the level of liquid refrigerant rises to the nozzle, and if the pool of liquid is shielded from direct impingement by the jet of liquid, disturbance of the liquid pool can be prevented. This is of great importance, in particular in the case of an infra-red detector which is sensitive to both pressure and temperature, since a disturbance of the pool results in high frequency fluctuation in both these parameters, and can introduce serious noise into the output. In addition since the nozzle is not submerged it can be at a substantially higher temperature than the liquid and this can be an important advantage in avoiding the blockage of the nozzle by freezing of impurities.

In the case of the prior construction these advantages are normally obtained if it can be assumed that the cooler is upright and steady. Constructions in accordance with the present invention can result in one or more of these advantages even when the cooler is tilted or inverted or under conditions of acceleration or reverse gravity. Thus in the first place if the cooler is to be operative when inverted the refrigerant fluid must be caused to impinge on the load or on a part in heat exchange relationship with it, in order that cooling of the load may be effective and the liquid refrigerant may not migrate or fall directly into the exhaust path of the heat exchanger. The interposition of a wad of absorbent material in heat exchange relationship with the load enables this result to be obtained whilst damping out and minimizing the disturbance and noise that would be liable to result from direct impingement.

In addition if the sensor is in direct contact with the wad of absorbent material it will respond sensitively according to whether or not the wad is saturated with liquid refrigerant. Whilst it may be possible to ensure saturation of an absorbent wad with liquid refrigerant merely by impingement more reliable operation may, in some cases, be obtained by providing a guiding duct to ensure that the liquid is brought into intimate contact or constrained to flow through the absorbent material and cannot simply bounce off it back into the heat exchanger.

The absorbent material may be in intimate contact with the load such as an infra-red detector, through nothing more than a single wall such as the inner wall of a Dewar flask. Alternatively a cooling sink in the form of a metal disc may be interposed in order to smooth out temperature fluctuations. In many applications the mass of such a cooling sink may have to be strictly limited since the cooler is called upon to cool it in addition

tion to cooling the load, and this may adversely affect the rate at which the load is cooled to the required temperature range.

I claim:

1. Cooling apparatus of the Joule Thomson type which includes a heat exchanger affording first and second paths through the first of which refrigerant gas from a supply under pressure, and at a temperature below its inversion temperature, is supplied to an expansion nozzle located adjacent the cold end of the heat exchanger, whence the low pressure gas returns through the second path, to effect cooling by expansion and produce liquid refrigerant in a container, including a load situated below and spaced from the nozzle, a body of absorbent material in heat exchange relationship with the load, a valve controlling the effective area of the nozzle, means for directing the refrigerant liquid from the nozzle so as to impinge on the absorbent material, a sensor situated in the path of liquid from the absorbent material to the second path of the heat exchanger while being shielded from direct impingement by liquid projected from the nozzle toward the load, said sensor responding to the balance between heat flowing to it from the hot end of the apparatus and heat extracted from it to the liquid refrigerant, and means under the control of the sensor for operating the valve to vary the flow of refrigerant automatically in accordance with the amount of liquid in the container.

2. Apparatus as claimed in claim 1 in which the sensor is in contact with the absorbent material.

3. Apparatus as claimed in claim 1 in which the sensor is separated from the absorbent material by a metallic wall.

4. Apparatus as claimed in claim 1 in which the sensor is spaced from the absorbent by a gap so small that sufficient heat flow can occur from the sensor to the absorbent material to cause the response to depend on the extent to which the absorbent material is saturated with liquid refrigerant.

5. Apparatus as claimed in claim 1 in which the sensor includes a vapor bulb containing a liquid in equilibrium with vapor the pressure of which controls the operation of the valve.

6. Apparatus as claimed in claim 1 in which the sensor includes portions near the periphery of the container at points distributed around the axis, so as to be immersed before the nozzle if the device is tilted about any horizontal axis.

7. Apparatus as claimed in claim 6 in which the sensor has a portion of annular form surrounding the axis.

8. Apparatus as claimed in claim 1 in which the nozzle is provided with a duct extending at least part of the distance between it and the load, so as to confine the refrigerant and direct it towards the load and cause it to impinge on the absorbent material.

9. Apparatus as claimed in claim 8 in which the duct extends into contact with the absorbent material so that the refrigerant is constrained to pass through the latter on its way to exhaust via the low pressure path of the heat exchanger.

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