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[54] **METHOD AND APPARATUS FOR PRODUCING VARIABLE TEMPERATURE WITH THE AID OF A CRYOLIQUID**

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[51] **Int. Cl.²** **F25B 19/00**

[58] **Field of Search** 62/293, 514, 56, 216, 222, 62/527, 528

[56] **References Cited**

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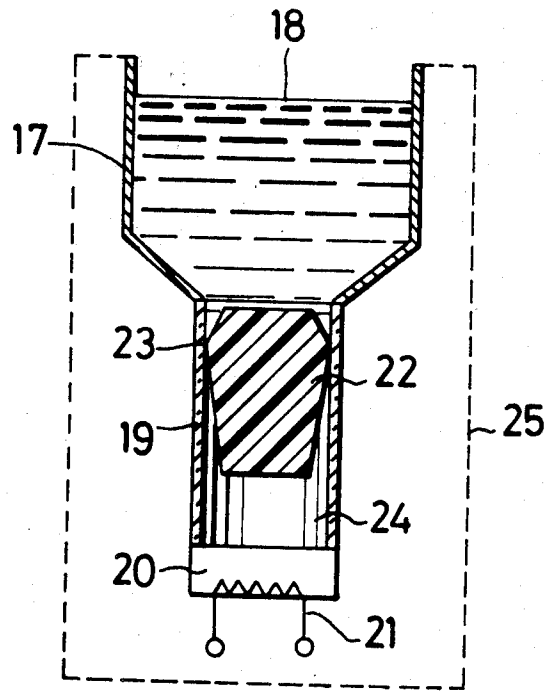
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Attorney, Agent, or Firm—Beaman & Beaman

[57] **ABSTRACT**

A method of producing variable temperatures with the aid of a cryoliquid, wherein the cryoliquid is throttled in a heat-insulated section at a point having poor heat conductivity, and at a distance from this point there is produced a variable temperature adjustable to values greater or equal to the boiling temperature of the cryoliquid, and apparatus for carrying out the method comprising a supply vessel for low-temperature gas, an evaporating device in which the low-temperature gas is arranged to be evaporated and at which the refrigerating output is arranged to be collected, and a regulating device for adjusting a predetermined temperature at the evaporating device, wherein the supply vessel is connected to a heat-insulated section, a heat-insulating flow resistor is arranged in the heat-insulated section, the heat-insulated section is sealed off by a gas-tight closure by which an evaporation chamber is defined, and a heating device with variable heating output is arranged at a distance from the flow resistor.

7 Claims, 4 Drawing Figures



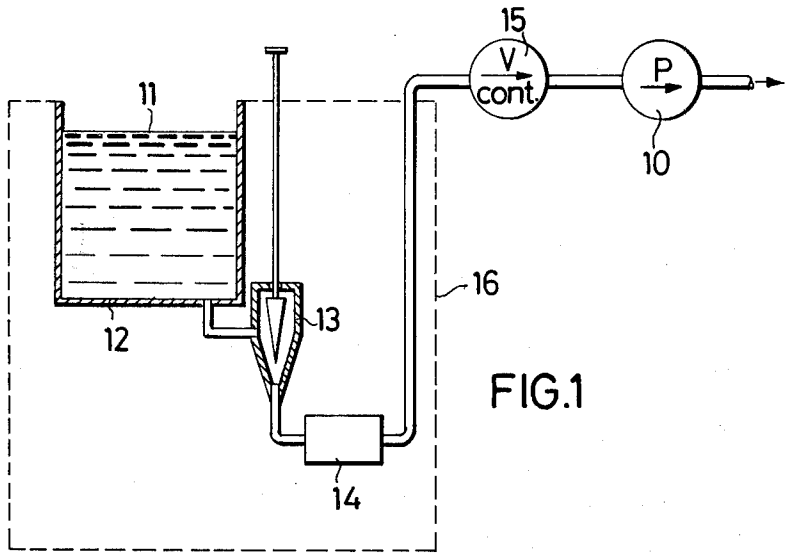


FIG.1

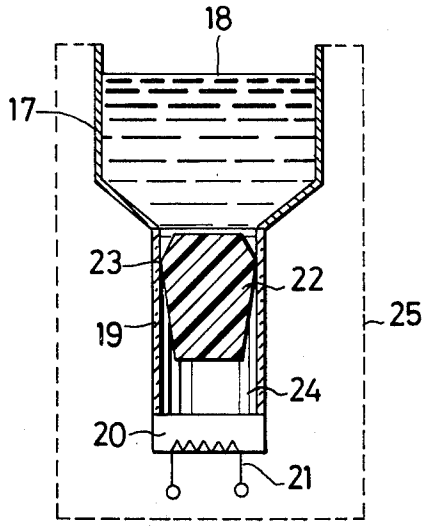


FIG.2

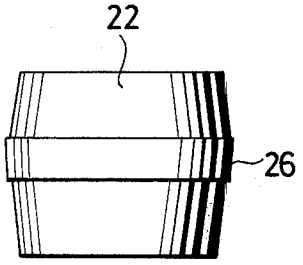


FIG.3

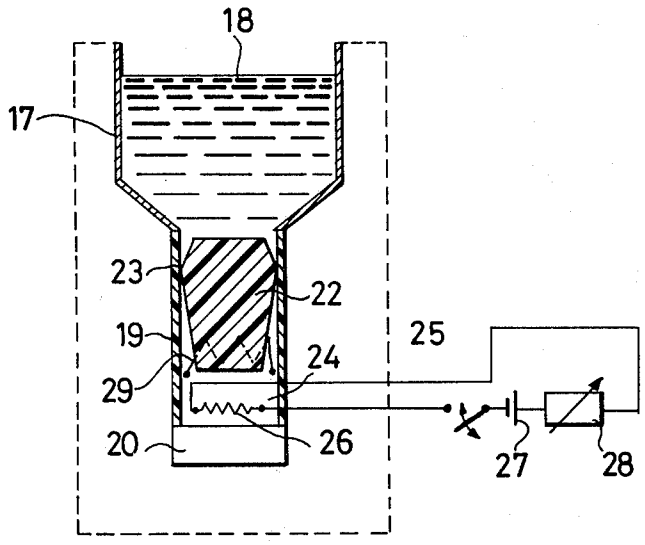


FIG.4

METHOD AND APPARATUS FOR PRODUCING VARIABLE TEMPERATURE WITH THE AID OF A CRYOLIQUID

BACKGROUND OF THE INVENTION

The invention relates to a method and apparatus for producing variable temperatures with the aid of a cryoliquid.

So-called cryostats are known with the aid of which a temperature lower than the ambient temperature can be maintained automatically, generally with great accuracy, over periods of time of any desired length. The lowest adjustable value of the temperature depends on the boiling point of the cryoliquid employed. If liquid nitrogen is employed, the boiling point is 77°K, while in the case of liquid helium it is 4.2°K.

In a known cryostat, the cryoliquid is supplied by way of a throttle valve, for example in the form of a needle valve, to an evaporator, by means of a pump and a control valve connected at the inlet side of the pump. A two-phase mixture, gas and liquid, is produced in the evaporator and a cooling effect is achieved by evaporation. The setting of the desired temperature is effected by appropriate adjustment of the throttle valve and the control valve or only by adjusting one of the two valves by means of a suitable regulating device. A cryostat of this kind is distinguished by comparatively high expenditure.

SUMMARY OF THE INVENTION

The problem underlying the invention, therefore, is to effect a method of producing variable temperatures with the aid of a cryoliquid which can be carried into effect by comparatively simple means and is able to dispense with the use of mechanical moving parts.

In the method of the present invention, this problem is solved in that the cryoliquid is throttled in a heat-insulated section at a point having poor heat conduction, and at a distance from this point there is produced by supply of heat a temperature adjustable to values greater or equal to the boiling temperature of the cryoliquid.

In the method according to the invention, in consequence of the supply of heat, a quasi-static vapour bubble is produced in the zone of the heat-insulated section behind the throttling point, which insulates this zone thermally from the cryoliquid, and this vapour bubble is used for cooling purposes. The quasi-static vapour bubble, which is under positive pressure, produces a phase boundary between the cryoliquid and the vapour bubble at the throttling point.

By varying the supply of heat in the zone of the quasi-static vapour bubble, any desired temperature can be adjusted with great accuracy in the bubble and outside the heat-insulated section. The application of the method according to the invention is independent of whether the cryostat consists of metal, glass, plastics or the like and includes the possibility of using all cryoliquids, such as helium, hydrogen, neon, argon, nitrogen, oxygen, etc.

The essential advantage of the method according to the invention consists in that for almost the same efficiency as in the case of the known cryostat only extremely small expenditure is required. Costly parts subject to wear, such as regulating valves, pumps and the like, are eliminated.

An embodiment of the method according to the invention provides that the heat-insulated section be sealed off under good heat-conducting conditions and be variably heatable in this zone. This measure, on the one hand, makes possible the problem-free supply of heat to the evaporation chamber between the throttling point and the heat-conduction seal or closures, and, on the other hand, the desired temperature can thereby be adjusted on the outside in the region of the seal.

An apparatus for carrying the method according to the invention into effect comprises an arrangement with a supply vessel for low-temperature gas, an evaporating device in which the low-temperature gas is evaporated and at which the refrigerating output is collected, and a regulating device for adjusting a predetermined temperature at the evaporating device and is characterised in that the supply vessel is connected to a heat-insulated section, a heat-insulating flow resistor is arranged in the heat-insulated section, the heat-insulated section is sealed off by a gas-tight closure by which an evaporation chamber is defined, and a heating device with a variable heating power is arranged at a distance from the flow resistor.

In consequence of the supply of heat by the heating device, a quasi-static vapour bubble is built up under positive pressure in the evaporation chamber, as a result of which a phase boundary is set up between the liquid and the vapour bubble at the flow resistor. The flow resistor is of decisive importance, since the gas and liquid phases are separated thereat. The apparatus according to the invention enables any desired temperature above the boiling point of the cryoliquid employed to be adjusted in the zone of the quasi-static vapour bubble and in the immediately adjacent zone.

According to a development of the invention, it may be advantageous to design the flow resistor to be variable in flow cross-section. In another development of the invention it is provided that the closure consist of material having good heat conductivity, preferably copper. In this connection, it has proved to be advantageous to arrange the heating device in the closure. The heating device may be designed in any suitable conventional manner. Preferably, it is in the form of an electric heating device. An electric heating device offers the advantage of exact control of the desired supply of heat in dependence upon the desired temperature at the heat-conducting closure and inside the evaporation chamber. The heat-conducting closure is advantageously provided with clamping or other retaining means to enable a sample to be flanged on.

As already stated above, the evaporation chamber must be heat-insulated with respect to the supply vessel and the cryoliquid, which is effected with the aid of a suitably designed flow resistor. On the other hand, this may be designed in any appropriate manner. According to a further advantageous development of the invention, it is provided that the heat-insulated section be a heat-insulated tube and that the flow resistor be formed by an insert body inserted into the tube and consisting of material having poor heat conduction and which is provided with one or more fine passages. Heat-insulating sintered material, for example, may be employed as such material. It is particularly advantageous, however, if the insert body consists of heat-insulating plastics, preferably polystyrene, polyurethane, etc.

According to another development of the invention, the insert body has as its periphery an encircling sealing

surface which can be brought into sealing engagement with the inner face of the heat-insulating section. The above-mentioned boundary between the gas and liquid phases is formed in the sealing zone between the insert body and the inner face of the section.

Since the above-indicated material preferably employed for the insert body has unsatisfactory sealing properties, a development of the invention provides in this connection that, in particular when plastics is employed for the insert body, a sealing collar preferably consisting of polytetrafluoroethylene and copolymer of tetrafluoroethylene and hexafluoropropylene, polytrifluorochloroethylene or the like is placed around the insert body.

As likewise already mentioned hereinbefore, the throttling of the cryoliquid may be variable in order to ensure, for example, that the cryoliquid can be introduced directly into the evaporation chamber so that rapid cooling is produced.

To this end, it is advantageous to arrange the insert body movably and shape it conically for the purpose of varying the width of the gap between the insert body and the inner face of the heat-insulated section.

In another development of the invention it is provided that the heating device be arranged within the evaporation chamber or in or at one of the walls of the parts defining the evaporation chamber, preferably in the lower zone of the flow resistor.

It is true that an apparatus of this kind permits only the measurement of samples within the evaporation chamber. To make up for this, production is far simpler and makes possible a considerable reduction in the cost of manufacture. For example, it is not necessary — as it is in the case of the above-described embodiments — to make a difficult glass-to-metal seal to produce the closure of the evaporation chamber which has good heat-conducting properties in the above-mentioned embodiments.

According to a development of the last-mentioned embodiment, the heating device, which preferably has one or more electric heating coils, is arranged in a desired location within the evaporation chamber or at the end of an insert body which forms the flow resistor in the heat-insulated section.

In a further development of the invention, the gas-tight closure of the heat-insulated section likewise consists of heat-insulating material, preferably the material of the insert body, for example polystyrene, polyurethane, etc.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will now be further described, by way of example, with reference to the accompanying drawings, in which:

FIG. **1** shows diagrammatically the construction of a known cryostat;

FIG. **2** shows diagrammatically one embodiment of the cryostat according to the invention;

FIG. **3** shows in elevation part of an insert body for a cryostat according to FIG. **2**;

FIG. **4** shows diagrammatically another embodiment of the cryostat according to the invention.

DESCRIPTION OF PREFERRED EMBODIMENTS

In the known cryostat shown in FIG. **1** a pump **10** draws cryoliquid **11** out of a supply vessel **12** and by way of a needle valve **13** through an evaporator **14.** A control valve **15** is connected at the inlet side of the pump **10.** The necessary vacuum chamber is indicated by a dashed line **16.** The evaporator is a two-phase evaporator and the desired temperature is adjusted by adjusting the needle valve and the control valve with the aid of a suitable regulating device. The adjustment of the needle valve determines the throughput of liquid, while the control valve **15** determines the throughput of gas.

In the cryostat according to the present invention shown in FIG. **2,** a supply vessel **17** is once again filled with a cryoliquid **18.** The supply vessel **17** is followed by a tube-like section **19** the wall of which is formed of material having poor heat-conducting properties, such as glass, refined steel or plastics with poor heat conductivity. The free end of the section **19** is provided with a gas-tight seal by means of a copper plate **20.** Arranged in the copper plate is a heating coil **21** which can be connected to a voltage source (not shown). The voltage source is controllable so as to render possible a desired emission of heat by the heating coil **21.** An insert body **22** in the form of a double cone is inserted in the upper zone of the section **19.** The edge **23** of the body is designed to fit the inner periphery of the wall of the section **19,** so that a sealing action is produced at this point. The insert body **22** consists of material having poor heat conductivity, preferably polystyrene, polyurethane or the like. The insert body **22,** the cooper plate **20** and the section **19** define an evaporation chamber **24.** A vacuum chamber is indicated by a dashed line **25.**

By means of the heating coil **21,** a temperature higher than the boiling temperature of the cryoliquid **18** is produced in the evaporation chamber **24,** the cryoliquid leaking into the evaporation chamber in small amount over the edge **23.** As a consequence, there is built up in the evaporation chamber **24** a quasi-static vapour bubble under positive pressure, which supports the cryoliquid **18** in the supply vessel **17.** The boundary between the gas and liquid phases is created in the region of the edge **23.** In dependence upon the energy supplied to the heating coil **21,** any desired temperature between the boiling point of the cryoliquid **18** and temperatures far above the ambient temperature can be achieved. The maximum value attainable for the temperature is determined by the properties of the materials employed for the cryostat. A sample may either be flanged on to the copper plate **20** or be introduced into the evaporation chamber **24.** In the latter case, an access opening is required. Furthermore, a window may be provided in the section **19** to make optical checking and observation and optical measurements possible.

By shifting the insert body **22** upwardly, the sealing gap at the edge **23** can be enlarged in order to pass cryoliquid directly into the evaporation chamber **24** so that this chamber and the copper plate **20** are rapidly cooled.

If the insert body consists of polystyrene or polyurethane, it is advantageous to take special precautions for producing a sealing action between the insert body **22** and the inner face of the section **19.** Therefore, for example, a sealing collar **26** consisting, for instance, of polytetrafluoroethylene and copolymer of tetrafluoroethylene and hexafluoropropylene may be provided. The sealing collar **26** is advantageously so designed that

the outer sealing face is slightly conical in order to produce an effective seal.

The cryostat shown in FIG. **4** is essentially constructed like that of FIG. **2.** Like parts are moreover provided with like reference numerals. There is a difference, however, in the heating arrangement. A heating coil **30** is arranged in the evaporation chamber **24** and by means thereof there is produced in this chamber a temperature higher than the boiling temperature of the cryoliquid **18,** a small amount of which leaks into the evaporation chamber over the edge **23.** As a consequence, there is built up in the evaporation chamber **24** a quasi-static vapour bubble under positive pressure, which supports the cryoliquid **18** in the supply vessel **17.** The boundary between the gas and liquid phases is created in the region of the edge **23.** In dependence upon the energy supplied to the heating coil **30** from the current source **27,** any desired temperature between the boiling point of the cryoliquid **18** and temperatures far above the ambient temperature can be adjusted. The maximum value attainable for the temperature is determined by the properties of the materials employed for the cryostat. The samples are introduced into the evaporation chamber **24.** An access opening (not shown) is required for this purpose. Furthermore, a window may be provided in the section **19** to make optical checking and observations and optical measurements possible.

A regulating device **28,** which is not described in detail, is connected in the current path of the heating coil **30** for the purpose of adjusting the current supply to the heating coil **30** to any desired values.

By shifting the insert body **22** upwardly, the sealing gap at the edge **23** can be enlarged in order to pass cryoliquid directly into the evaporation chamber **24** so that it is rapidly cooled.

Instead of arranging the heating coil within the evaporation chamber **24,** it may also be provided at the lower end of the insert body **22,** as indicated by the reference numeral **29.** The heating coil **29** can be supplied with current in the same way as the heating coil **30.**

What is claimed is:

1. Apparatus for utilizing a cryoliquid to produce variable temperatures within an evaporation chamber comprising, in combination, a supply reservoir of cryoliquid having a bottom outlet, a thermally insulated expansion chamber in communication with said bottom outlet through a conduit passage and having a lower portion, a flow resistor longitudinally movably mounted within said conduit passage controlling the flow of cryoliquid into said chamber in dependence upon the position of said flow resistor within said passage, and heating means within said chamber heating said chamber to produce a predetermined vapor pressure within said chamber for positioning said flow resistor to permit a predetermined flow of cryoliquid into said chamber to maintain a predetermined temperature within said chamber.

2. Apparatus for utilizing a cryoliquid as in claim **1** wherein said flow resistor includes sealing means cooperating with said conduit passage, said sealing means having a variable cross section in the direction of flow resistor movement.

3. Apparatus for utilizing a cryoliquid as in claim **1** wherein said heating means comprises an electric resistance element within said chamber lower portion.

4. Apparatus for utilizing a cryoliquid as in claim **1** wherein said chamber lower portion includes a copper plate and said heating means includes an electric heating element within said plate.

5. Apparatus for utilizing a cryoliquid as in claim **1** wherein said flow resistor is of a conical configuration in the direction of flow resistor movement to vary the flow past said flow resistor in dependence upon the position of said flow resistor within said conduit passage.

6. Apparatus for utilizing a cryoliquid as in claim **1** wherein said expansion chamber includes an upper cylindrical wall, said upper wall constituting said conduit passage receiving said flow resistor.

7. Apparatus for utilizing a cryoliquid to produce variable temperatures within an evaporation chamber comprising, in combination, a supply reservoir of cryoliquid having a bottom outlet, a thermally insulated expansion chamber in communication with said bottom outlet through a conduit passage having a lower portion, a flow resistor mounted within said conduit passage controlling the flow of cryoliquid in said chamber, and heating means within said chamber heating said chamber to produce a predetermined vapor pressure within said chamber to maintain a predetermined temperature within said chamber.

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