United States Patent [19]

Severijns et al.

[11] 3,896,630

[45] July 29, 1975

[54] METHOD FOR STARTING A ^3He-^4He DILUTION REFRIGERATOR

[75] Inventors: **Adrianus Petrus Severijns; Frans Adrianus Staas,** both of Eindhoven, Netherlands

[73] Assignee: **U.S. Philips Corporation,** New York, N.Y.

[22] Filed: **Mar. 14, 1973**

[21] Appl. No.: **340,953**

[30] **Foreign Application Priority Data**

Mar. 17, 1972 Netherlands 7203556

[52] **U.S. Cl.** **62/56;** 62/45; 62/467; 62/514

[51] **Int. Cl.** **F25d**

[58] **Field of Search** 62/467, 514, 56

[56] **References Cited**

UNITED STATES PATENTS

3,195,322	7/1965	London	62/467
3,376,712	4/1968	London	62/467
3,447,333	6/1969	Goodstein	62/514
3,472,038	10/1969	Staas	62/467
3,581,512	6/1971	Staas	62/514
3,589,138	6/1971	Severijns	62/514
3,713,305	1/1973	Staas	62/514

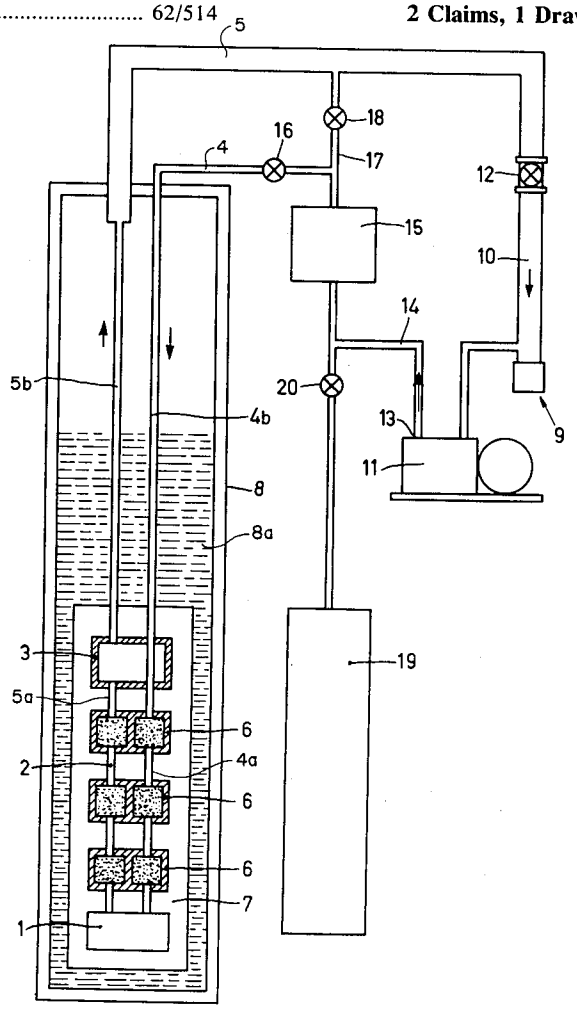
Primary Examiner—William J. Wye

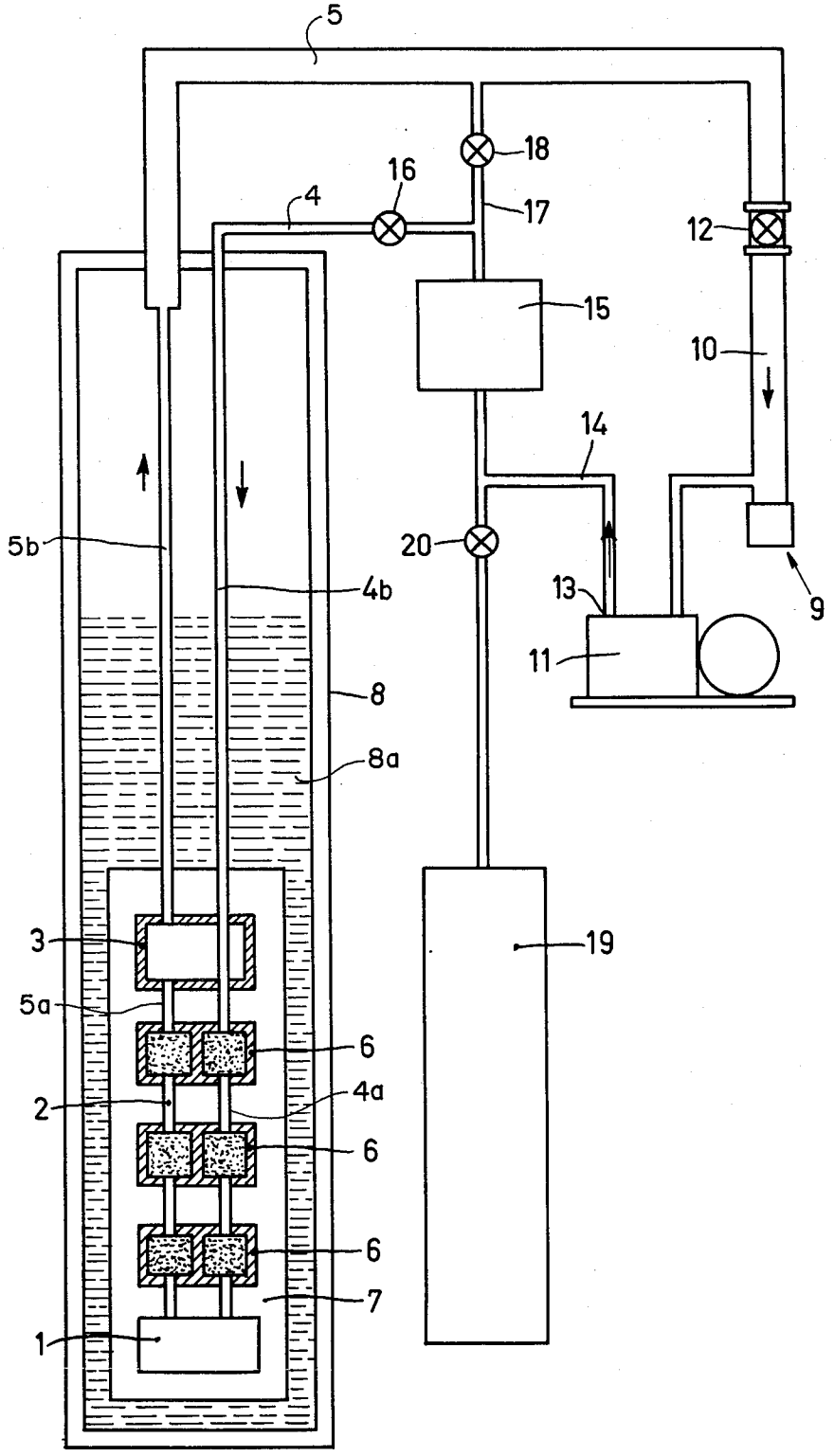
Attorney, Agent, or Firm—Frank R. Trifari

[57] **ABSTRACT**

A method of starting a device for transporting heat from a lower to a higher temperature level, the said device comprising a mixing chamber which is provided with an inlet duct and a connection duct which exchanges heat therewith, the other end of the said connection duct communicating with an evaporation reservoir, the inlet duct communicating with the outlet side of the pumping device, the drawing side of which is connected, via an outlet duct, to the evaporation reservoir, the quantity of ^3He and ^4He mixture required during operation being condensed in the device, during starting, via the outlet duct, after which part of the gas is withdrawn from the device, via the outlet duct, by means of the pumping device and is stored in an auxiliary reservoir. Subsequently, this auxiliary reservoir is connected to the outlet duct, so that the gas condenses in the device again, this procedure being repeated a few times, after which the inlet duct is connected to the outlet and the outlet is connected to the inlet of the pumping device, and the heat transport commences.

2 Claims, 1 Drawing Figure




5
18
16
4
17
12
15
10
14
20
13
9
11
5b
4b
8
8a
3
5a
6
2
4a
6
6
7
1
19

METHOD FOR STARTING A 3HE-4HE DILUTION

BACKGROUND OF THE INVENTION

The invention relates to a method of starting a device for transporting heat from a lower to a higher temperature level, both levels being situated below the λ-temperature of helium. Such a said device comprises a mixing chamber provided with an inlet duct and a connection duct which exchanges heat therewith, and the other end of the connection duct communicates with an evaporation reservoir. The mixing chamber, the part of the inlet duct which communicates therewith, the evaporation reservoir and the connection duct are arranged in a vacuum space which in turn is situated in a cryostat in which liquid helium is present during operation. The inlet duct communicates with the outlet side of a pumping device, the suction side of which communicates, via an outlet duct, with the evaporation reservoir. The cryostat is filled with liquid helium upon starting, and a mixture of ^{3}He and ^{4}He is introduced in the device in which it condenses, after which the pumping device is started.

The described method can be performed, for example, for starting a device as described in U.S. Pat. No. 3,195,322. During operation, this known device contains a mixture of ^{3}He and ^{4}He, the mixing chamber having a temperature of approximately 0.06°K, the evaporation reservoir having a temperature of approximately 0.7°K.

While in the evaporation reservoir mainly the more volatile ^{3}He escapes and is drawn off by the pumping device, a mixture which consists mainly of ^{3}He is applied to the mixing chamber via the connection duct after having been cooled in the various heat exchangers. Below 0.9°K, a phase separation takes place in liquid ^{3}He-^{4}He mixtures, i.e. into a ^{3}He-rich phase and a ^{3}He-poor phase. The phase separation takes place in the mixing chamber. The transition from the applied ^{3}He-rich phase to the ^{3}He-poor phase causes dilution and the mixing heat required for this purpose produces a cooling effect. After that, the ^{3}He in the superfluid ^{4}He present in the outlet duct will expand further, thus producing a large quantity of cold which, however, is required substantially completely for the cooling of the ^{3}He flow in the inlet duct.

The circulation of ^{3}He while the ^{4}He is mainly stationary in the mixing chamber, the connection duct and the evaporation reservoir, thus produces a cooling effect at a very low temperature.

It was found that the starting of such ^{3}He-^{4}He mixing refrigerators gives rise to problems. The starting is often impossible or the refrigerating process starts only very slowly so that the full refrigeration effect is achieved only after a starting period of several hours. It also occurs that one day the machine functions while the next day it does not. So as to eliminate this drawback, an excess of ^{3}He is known to be used for starting. The drawback of this method is that the excess ^{3}He must be stored after the starting; this requires much time and the excess ^{3}He is inactive for the remainder.

SUMMARY OF THE INVENTION

In order to eliminate the above-described drawback, the invention has for its object to provide a method by which reliable starting with the fixed quantity of ^{3}He-^{4}He mixture in the closed system is ensured. To this end, this method is characterized in that the quantity of ^{3}He-^{4}He mixture required during operation is condensed in the device via the outlet duct, while the inlet duct is closed, after which, using the pumping device, part of the gas is withdrawn from the device via the outlet duct and is stored in an auxiliary reservoir which is subsequently connected to the outlet duct so that the gas condenses again in the device; this procedure being repeated a few times, after which the inlet duct is connected to the outlet and the outlet duct is connected to the inlet of the pumping device, and the heat transport commences.

Due to the successive pumping and condensing along the outlet duct (repeated approximately four times), the gas drawn by the pump has a very rich concentration of ^{3}He (96 % ^{3}He or more), so that the refrigeration process starts immediately. If this were not done, the gas mixture applied to the inlet duct would not contain enough ^{3}He and the device would not start or only very slowly.

The invention furthermore relates to a device which is suitable for performing the afore described method, comprising a mixing chamber which is provided with an inlet duct and a connection duct which exchanges heat therewith, the other end of the said connection duct opens into an evaporation reservoir. The mixing chamber, the part of the inlet duct which communicates therewith, the evaporation reservoir and the connection duct are arranged in a vacuum space which is situated in a cryostat in which liquid helium is present when the device is in operation, the inlet duct communicating with the outlet of a pumping device, the drawing side of which is connected, via an outlet duct, to the evaporation reservoir.

According to the invention this device is characterized in that it comprises a reservoir which can be connected, via at least one valve, to the outlet duct and which can contain a mixture of ^{3}He and ^{4}He which is sufficient to fill the device in the operating condition, a connection duct being provided between the inlet duct and the outlet duct in which a valve is provided, the inlet duct also comprising a valve, an auxiliary reservoir being incorporated in the outlet duct between the said valve and the outlet of the pumping device, it being possible that the outlet duct also comprises a valve. The invention will be described in detail with reference to the drawing.

BRIEF DESCRIPTION OF THE DRAWING

The drawing is a diagrammatic representation of a ^{3}He-^{4}He mixing refrigerator.

DESCRIPTION OF THE PREFERRED EMBODIMENT

A thermally insulated cryostat has walls **8** which define therein a first chamber **8***a* for liquid helium which chamber surrounds a vacuum space **7**. A mixing chamber is denoted in the drawing by the reference numeral **1**. Via a connection duct **2**, the mixing chamber **1** is connected to an evaporation reservoir **3**. An inlet duct **4** has first part **4***a* within space **7** and second part **4***b* within chamber **8***a*. The first part **4***a* communicates with the mixing chamber inlet. An outlet duct **5** has first part **5***a* or **2** within the space **7** and a second part **5***b* within the chamber **8***a*. The second part **5***b* communicates with the evaporation reservoir **3**. The inlet duct **4***a* exchanges heat with the connection duct **2** at the

area 6. The mixing chamber 1, the evaporation reservoir 3 and the connection duct 2 are arranged in a vacuum space 7 which in its turn is arranged in a diagrammatically shown, thermally insulated cryostat 8.

The device furthermore comprises a pumping device 9 which is formed by a diffusion pump 10 and a rotation pump 11. The inlet of pumping device 9 communicates, via a valve 12, with the outlet duct 5, while the outlet 13 of the pumping device communicates, via a duct 14, incorporating an auxiliary reservoir 15, and via a valve 16, with the inlet duct 4. A connection duct 17 with valve 18 connects the duct 14 to the outlet duct 5. The device furthermore comprises a reservoir 19 which can communicate with duct 14 via a valve 20. It is to be noted that this reservoir 19 can also be directly connected to the outlet duct 5 via a valve.

The starting of this device is as follows. A quantity of liquid helium is introduced into chamber 8*a* of the cryostat 8. Subsequently, valves 12 and 16 are closed, and valves 18 and 20 are opened so that the ^{3}He-^{4}He mixture present in reservoir 19 condenses in the cold part 8*a* of the device. Subsequently, valves 20 and 18 are closed and valve 12 is opened, after which the pumping device draws gas via the outlet duct 5 which is stored in auxiliary reservoir 15. After that, valve 12 is closed again and valve 18 is opened with the result that the gas flows from the auxiliary reservoir 15 to the cold parts 8*a* of the device again, where it condenses. This is repeated about four times after which valve 18 is closed and valves 12 and 16 are opened. The refrigeration process is then started, the pump now drawing a richly concentrated gas mixture (at least 96% ^{3}He) via outlet duct 5, and feeding this mixture to the inlet duct 4. This rich gas mixture is subjected to a phase transition in the mixing chamber 1, i.e. to the ^{3}He-poor phase, thus producing cold. It is thus achieved that the starting is reliable and that cold is directly produced.

What is claimed is:

1. A method of starting a device for transporting heat from a lower level to a higher level, both levels being below the λ temperature of helium, this device including: a cryostat whose walls define therein a vacuum space, and surrounding said space a first chamber for liquid helium, and within said vacuum space a mixing chamber with inlet and outlet means, a first evaporation reservoir with inlet and outlet means, a connection duct between the mixing chamber outlet and the evaporation reservoir inlet, and an inlet duct having a first part within said vacuum space in heat exchange with said connection duct and discharging in said mixing chamber inlet, and within said first chamber an outlet duct connected to said evaporation reservoir outlet and a second part of said inlet duct leading to said first part, the device further comprising a second reservoir containing a ^{3}He-^{4}He mixture and pumping means having inlet and discharge means, an auxilliary reservoir intermediate the pump discharge and second part of the inlet duct, and the pump inlet communicating with said evaporation reservoir, the method comprising the steps of: introducing a quantity of liquid helium into said first chamber of said cryostat, communicating said second reservoir with said second part of the inlet duct within said first chamber, and thereby flowing ^{3}He-^{4}He mixture in said second part and condensing said mixture therein, pumping gas from said pump outlet duct to said auxilliary reservoir, communicating gas from said auxilliary reservoir to said second part of the inlet duct for condensation therein according to the condensation step above, repeating the condensation steps, starting the refrigeration process by communicating said pump inlet with said outlet duct and said pump discharge with said second part of said inlet duct, whereby the pump now draws richly concentrated gas mixture and feeds same to the inlet duct where it is subjected to a phase transition in the mixing chamber to ^{3}He-poor phase, and thus produces refrigeration.

2. In a cryostat apparatus for producing refrigeration including thermally-insulated walls defining therein a first chamber for liquid helium, and within said first chamber a vacuum space, and within said vacuum space a mixing chamber with inlet and outlet and spaced apart from said mixing chamber an evaporation reservoir also within said vacuum space with inlet and outlet, a connection duct interconnecting said mixing chamber outlet and evaporation reservoir inlet, and an inlet duct first part in heat exchange relationship with said connection duct and feeding said mixing chamber inlet, the apparatus further comprising within said first chamber a second part of said inlet duct feeding the first part thereof, and an outlet duct connected to the evaporation reservoir outlet, the apparatus further comprising an external reservoir for ^{3}He-^{4}He mixture, duct means communicating said external reservoir with said inlet duct, pump means having an inlet communicating with said outlet duct, and an outlet communicating with said inlet duct, and an auxilliary reservoir intermediate said pump outlet and said inlet duct and means for permitting flow selectively (i) only from the external reservoir to the outlet duct second part, and (ii) only from the pump to the auxilliary reservoir and thence to said outlet duct, and (iii) only from the pump to the input duct and to the pump from the outlet duct.

* * * * *