United States Patent [19]

Prast

[11] **3,910,063**

[45] **Oct. 7, 1975**

[54] **COOLING SYSTEM**

[75] Inventor: **Gijsbert Prast**, Eindhoven, Netherlands

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

[22] Filed: **Mar. 27, 1974**

[21] Appl. No.: **455,398**

[30] **Foreign Application Priority Data**

Apr. 9, 1973 Netherlands 7304885

[52] **U.S. Cl.** **62/514**; 62/200; 62/525

[51] **Int. Cl.²** **F25B 19/00**

[58] **Field of Search** 62/514, 467, 498, 115, 62/200, 525

[56] **References Cited**

UNITED STATES PATENTS

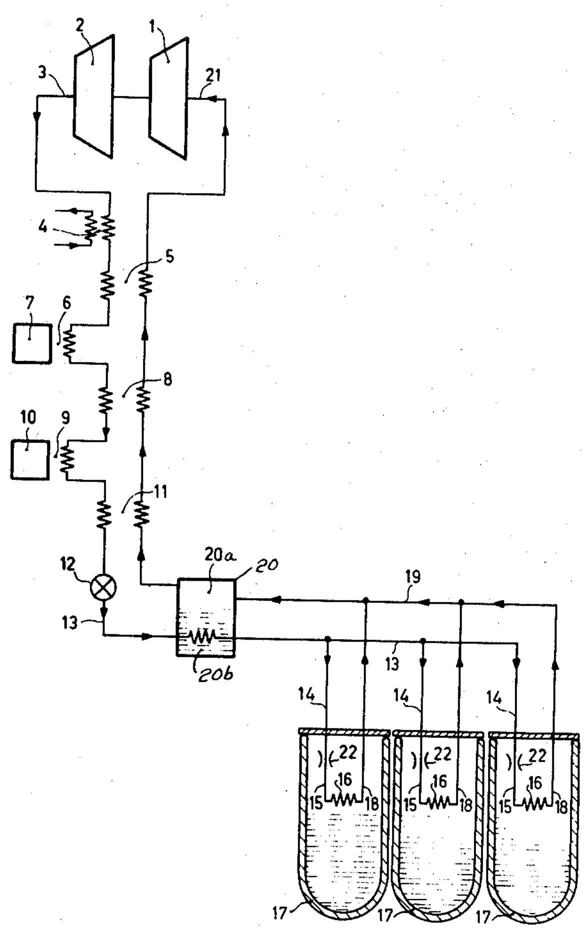
3,350,896	11/1967	Harnish	62/200
3,442,093	5/1969	Rietdijk	62/500
3,447,339	6/1969	Rietdijk	62/500
3,464,230	9/1969	Rietdijk	62/500
3,496,735	2/1970	Haisma	62/500

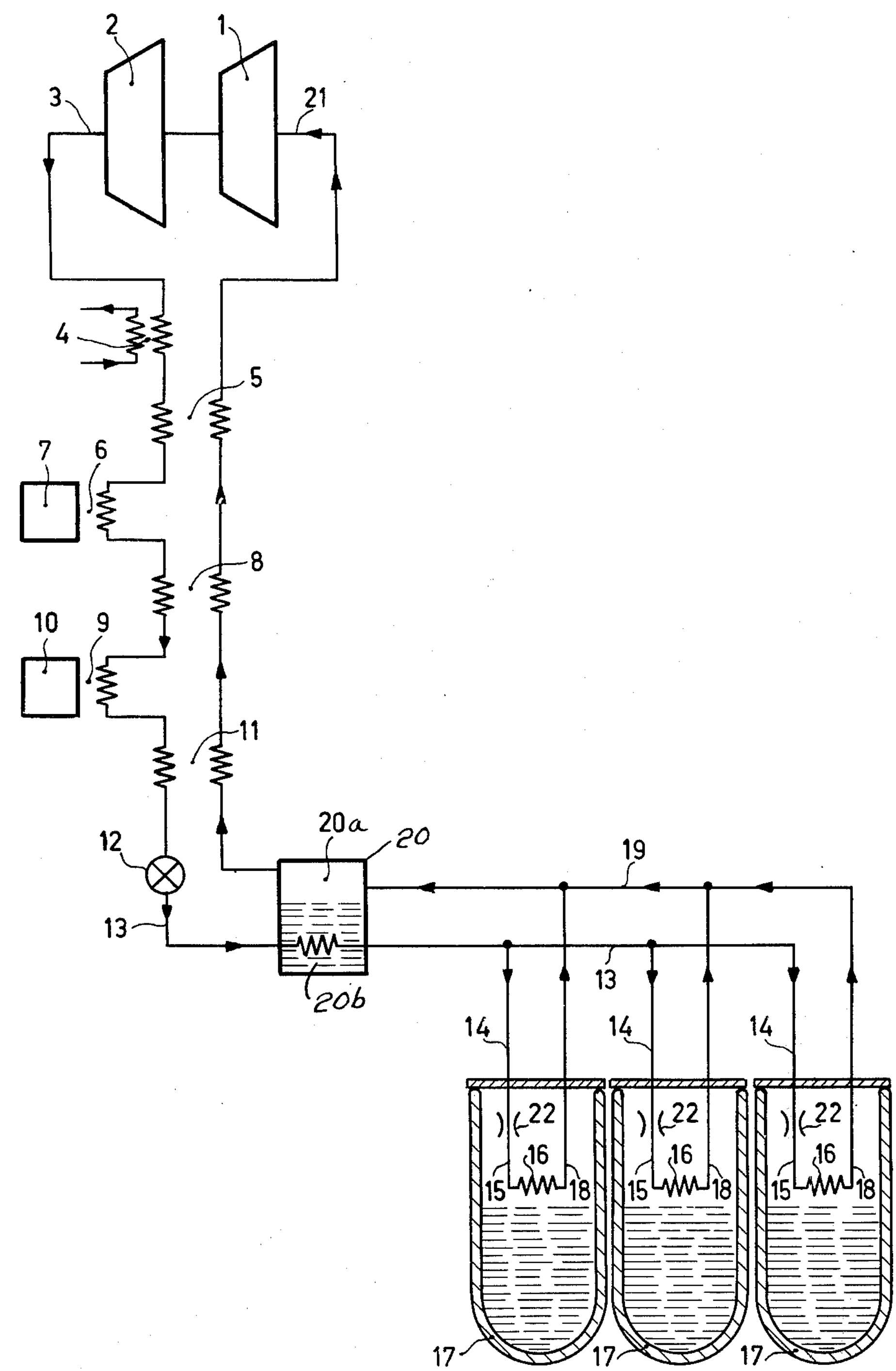
Primary Examiner—William F. O'Dea
Assistant Examiner—Ronald C. Capossela
Attorney, Agent, or Firm—Frank R. Trifari

[57] **ABSTRACT**

A cooling system including a plurality of heat exchange elements for a plurality of objects to be cooled, and a cooling fluid conveyed to said elements via a main supply pipe which includes a single pressure reducing device for said fluid to said heat exchange elements.

5 Claims, 1 Drawing Figure




1
2
3
21
4
5
6
7
8
9
10
11
12
13
20a
20
19
13
20b
14
14
14
22
22
22
16
16
16
15
18
15
18
15
18
17
17
17

COOLING SYSTEM

The invention relates to a cooling system for cooling at least one object, which system is provided with a compression device for compressing a cooling fluid to a higher pressure, the compressor outlet being connected to a main supply pipe via at least one heat exchanger in which the compressed fluid is cooled to a temperature below the inversion temperature associated with the higher pressure. The system has a plurality of heat exchange elements for heat exchange with the objects to be cooled, each element having a fluid inlet and a fluid outlet, which inlets are connected each via an auxiliary supply pipe to the main supply pipe and have fluid supplied to them via a pressure reducing device in which compressed fluid which has been cooled in the heat exchanger is reduced in pressure.

In a known cooling system the heat exchange elements take the form of cooling coils arranged in storage containers for liquefied gas. By recondensing liquid evaporated as a result of inward heat leakage or by directly cooling the liquid, the cooling coils ensure that the pressure in the storage containers does not exceed a given value.

In the pressure reducing device the fluid, which has been precooled to a temperature below the associated inversion temperature, is throttled from a higher pressure to a much lower pressure. In this process the temperature of the fluid drops, owing to isenthalpic expansion (Joule-Kelvin effect) and/or the fluid exhibits a phase transition from the gaseous to the liquid state, at least part of the fluid being liquefied. This liquefaction obviously requires that the temperature and the pressure should assume values below the critical temperature and the critical pressure respectively.

In the known cooling system each auxiliary supply pipe includes an expansion valve as a pressure reducing device.

This is economically unattractive. In systems in which a large number of cryostats filled with liquefied gas or other objects are to be cooled an equal, large number of expansion valves are required, which frequently take the form of expensive needle valves.

Secondly the said provision of expansion valves provides technical difficulty. Each of the auxiliary supply pipes passes a fraction of the main flow through the main supply pipe. This means that the expansion valves in the auxiliary supply pipes have passages of comparatively small internal cross-sectional areas. Owing to these small-area passages impurities readily deposit in the expansion valves, with the result that the fluid flows through the auxiliary supply pipes will become widely different and that some valves may even become clogged. Thus the cooling of several Dewar flasks filled with liquid gas is impaired or even stopped so that the pressure in these flasks will rapidly rise.

It is an object of the present invention to provide a cooling system of the type referred to in which the said disadvantages are avoided.

SUMMARY OF THE INVENTION

A cooling system according to the invention is characterized in that the pressure reducing device is included in the main supply pipe while the auxiliary supply pipes include fixed or fixedly set restrictions having passages of at least substantially equal internal cross-sectional areas.

Thus, only one pressure reducing device is provided in the main supply pipe instead of a plurality of such devices, one in each of the auxiliary supply pipes, which greatly reduces the cost of the system. The entire fluid flow passes through the pressure reducing device common to all the auxiliary supply pipes. Hence the pressure reducing device has a larger area passage so that clogging is very unlikely.

The fixed or fixedly set restrictions included in the auxiliary supply pipes ensure a distribution of the fluid flow between the auxiliary supply pipes which is as equal as possible. Thus substantially equal cooling powers are available for the objects to be cooled.

The restrictions may have comparatively large-area passages associated with pressure drops which, taken absolutely, are small, for example **0.1** atmosphere, but in relation to the pressure drops in the remainder of each auxiliary pipe are large, for the distribution of the fluid flow between the auxiliary pipes is determined by the overall pressure drop in the supply pipes. Because the pressure drop in the part of the auxiliary pipe downstream of the heat exchange element is greatly dependent upon the thermal load imposed on this element, (for example a greater gas fraction in the discharged auxiliary fluid in the case of increased evaporation), the distribution of the fluid flow between the heat exchange elements also would be dependent of the thermal load, which is unacceptable. Hence the restrictions in the auxiliary supply pipes are located at the fluid inlet sides of the heat exchange elements. Owing to the comparatively large-area passages of the restrictions clogging is very unlikely.

In principle the refrigeration capacity of the cooling system need only be such as to compensate for the leakage of heat into the liquefied gas storage containers. With a view to small weight, small size and low cost of the cooling system the latter is frequently optimized so that in normal operation hardly any unnecessary cooling power is available. This implies, however, that the accuracy with which the cooling power and hence the fluid flow is distributed between the heat exchange elements has to satisfy stringent requirements, in particular when part of the fluid supplied to these elements is gaseous and the remainder is liquid, for refrigeration mainly utilizes the latent heat (the heat of evaporation) of liquid fluid and substantially no sensible heat, so that in the refrigerating process proper, the gaseous fluid is not significant. Under conditions in which, owing to unaccurate distribution, a comparatively small amount of liquid fluid is supplied to an evaporation coil while the storage container concerned just requires comparatively much cooling, difficulties may arise.

According to the invention it can be ensured that without having to increase the amount of cooling fluid circulating in the system, the distribution of the fluid flow between the auxiliary supply pipes is less critical. Thus the relative equality of the restrictions has to satisfy less exacting requirements.

For this purpose the cooling system according to the invention is characterized in that the outlets of the heat exchange elements open into a container for separating gaseous fluid from liquid fluid, the gas space of the container being connected to the suction inlet of the compression device while the liquid space is in thermal contact with a part of the main supply pipe, which part lies downstream of the pressure reducing device, for condensation of gaseous fluid flowing through the said pipe.

Condensation of the gas fraction in the flow of fluid from the pressure reducing device results in that substantially only liquid fluid is supplied to the heat exchange elements so that the effective cooling power available per heat exchange element increases. Thus the influence of inaccuracies in the distribution of the cooling fluid flow between the auxiliary supply pipes is reduced, permitting the restrictions to be of simple construction and hence of low cost.

An embodiment of the invention will now be described, by way of example, with reference to the accompanying diagrammatic drawing in the single FIGURE of which a cooling system for cooling storage containers for liquefied gas is shown schematically and not to scale.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to the FIGURE, the cooling system shown has a compression device comprising a low-pressure compressor **1** and a high-pressure compressor **2** having an outlet **3**. The outlet **3** is connected to a cooler **4** in which the heat of compression of the compressed fluid, in the present case helium under a pressure of for example **30** atm., is dissipated. From the coil the compressed helium flows through a heat exchanger **5** in which it exchanges heat with helium at a lower pressure and temperature. In a heat exchanger **6** the high-pressure helium is cooled by a refrigerator **7** to a temperature of for example **60**°K. Then the high-pressure helium agains exchanges heat with helium at a lower pressure and temperature in the heat exchanger **8** and subsequently is cooled to a temperature of for example 15°K by a refrigerator **10** in a heat exchanger **9**. The temperature is then further decreased in a heat exchanger **11** by heat exchange with helium at a lower pressure and temperature. Thus the high-pressure helium finally has a temperature below its critical temperature of 5.3°K.

The high-pressure helium then enters a throttle valve **12** which acts as a pressure reducing device and in which the helium expands to below its critical pressure of **2.26** atm. and part of it, about **50%**, liquefies. The throttle valve **12** is included in a main supply pipe **13** to which, in the present embodiment, three parallel auxiliary supply pipes **14** are connected which lead to inlets **15** of heat exchange elements **16** in the form of cooling coils which are arranged in the vapor space of closed storage containers **17** which contain liquid helium. The outlets **18** of the heat exchange elements **16** are connected to a common return flow pipe **19** which opens in a container **20** the vapor space **20*a*** of which communicates via the heat exchangers **11, 8** and **5** with the suction inlet **21** of the compressor **1.**

The auxiliary supply pipes **14** include substantially equal restrictions **22.**

In the container **20** the mixture of gaseous and liquid helium issuing from the throttle valve **12** is completely converted into the liquid phase by heat exchange with the liquid helium contained in the liquid space **20*b*** of the container **20.** For this purpose part of the main supply pipe **13** is formed as a heat exchanger arranged in

the container **20.** After passing through this heat exchanger in the container **20** the flow of liquid helium is equally divided between the three heat exchange elements by means of the restrictions **22,** which may be simple diaphragms. In the heat exchange elements part of the liquid helium, in the embodiment under consideration, **50%,** evaporates owing to condensation on these elements of helium evaporated in the containers **17** as a result of inward leakage of heat. Thus the pressure in the containers remains low.

The mixture of gas and liquid which issues from the heat exchange elements is separated into gas and liquid in the container **20.** The **50%** in the form of liquid helium just ensures condensation of the **50%** in the form of gaseous helium in the helium flow from the throttle valve **12.**

Precooling of the high-pressure helium may be effected in cold gas refrigerators. Alternatively expansion engines (piston expansion engines, expansion turbines) may be used in which a part tapped from the high-pressure helium flow expands while performing mechanical work, in order to produce cold which is used to precool the high-pressure helium main flow.

What is claimed is:

1. In a closed system operable with a cooling fluid flowing through a continuous passage for cooling a plurality of objects, and including first means for compressing said fluid to a first high pressure, second means for cooling said fluid to a reduced temperature below the inversion temperature associated with said high pressure, a tubular cooling element with inlet and outlet means, a main supply duct for conveying said reduced temperature fluid, an auxiliary supply duct communicating each of said inlet means with said main supply duct, a main return duct communicating each of said outlet means with said first means, the improvement in combination therewith comprising Joule-Kelvin throttle valve means in said main supply duct for reducing the pressure of said fluid at said reduced temperature before it flows to said cooling elements, and fluid flow restriction means in each of said inlet means, said restriction means all having substantially equal internal cross-sectional areas.

2. Apparatus according to claim **1** further comprising downstream of said valve means a container having liquid and vapor spaces therein respectively for containing liquefied gas and vapor thereof, said main-supply duct being in heat exchange relationship with said liquefied gas in said liquid space for condensing gaseous fluid in said main supply duct, and said main return duct feeding into said vapor space which then feeds into said first means.

3. Apparatus according to claim **2** wherein said objects each comprise a Dewar flask for containing a quantity of liquefied gas therein, and situated within each flask is one of said cooling elements and restriction means.

4. Apparatus according to claim **2** wherein said second means comprises a plurality of heat exchangers for successively cooling said cooling fluid, each heat exchanger including a source of cold.

5. Apparatus according to claim **2** wherein said restriction means comprise diaphragms.

* * * * *