United States Patent

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[54] **METHOD AND DEVICE FOR CIRCULATING A CRYOGENIC LIQUID WITHIN A BODY IMMERSED IN THE CRYOGENIC LIQUID**
10 Claims, 3 Drawing Figs.

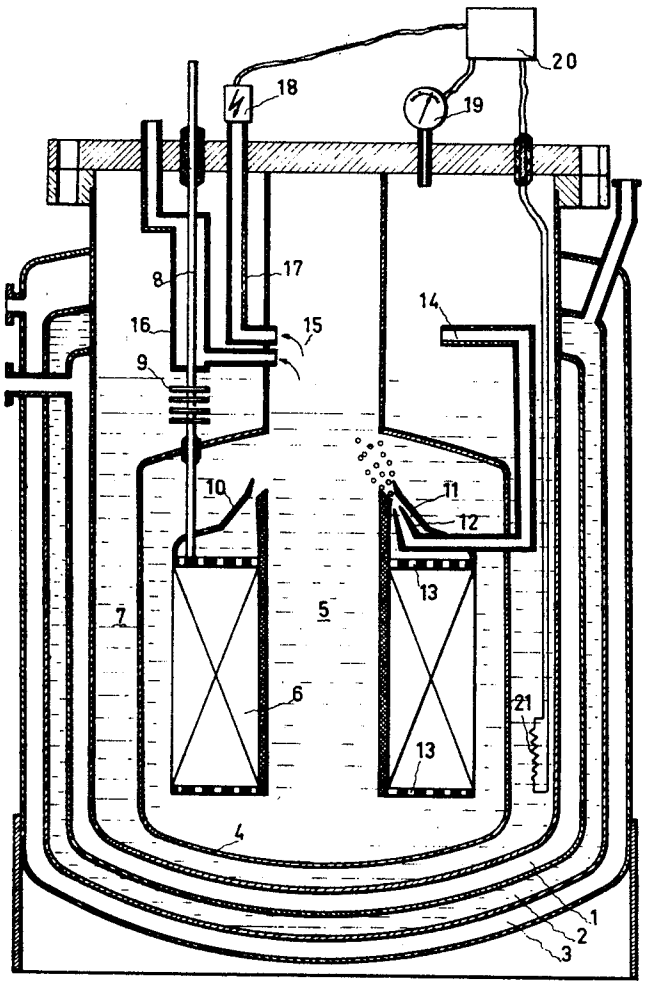
[52] **U.S. Cl.** **174/15,** 62/514
[51] **Int. Cl.** **G21c 15/02**
[50] **Field of Search** ..... 174/15, 15 (C), 16, (SC); 335/216; 62/514

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ABSTRACT: Gasified cryogenic liquid is collected at the top of the cryostat and injected by a nozzle for equivalent into the liquid, the gas carrying liquid along thus setting up liquid circulation.

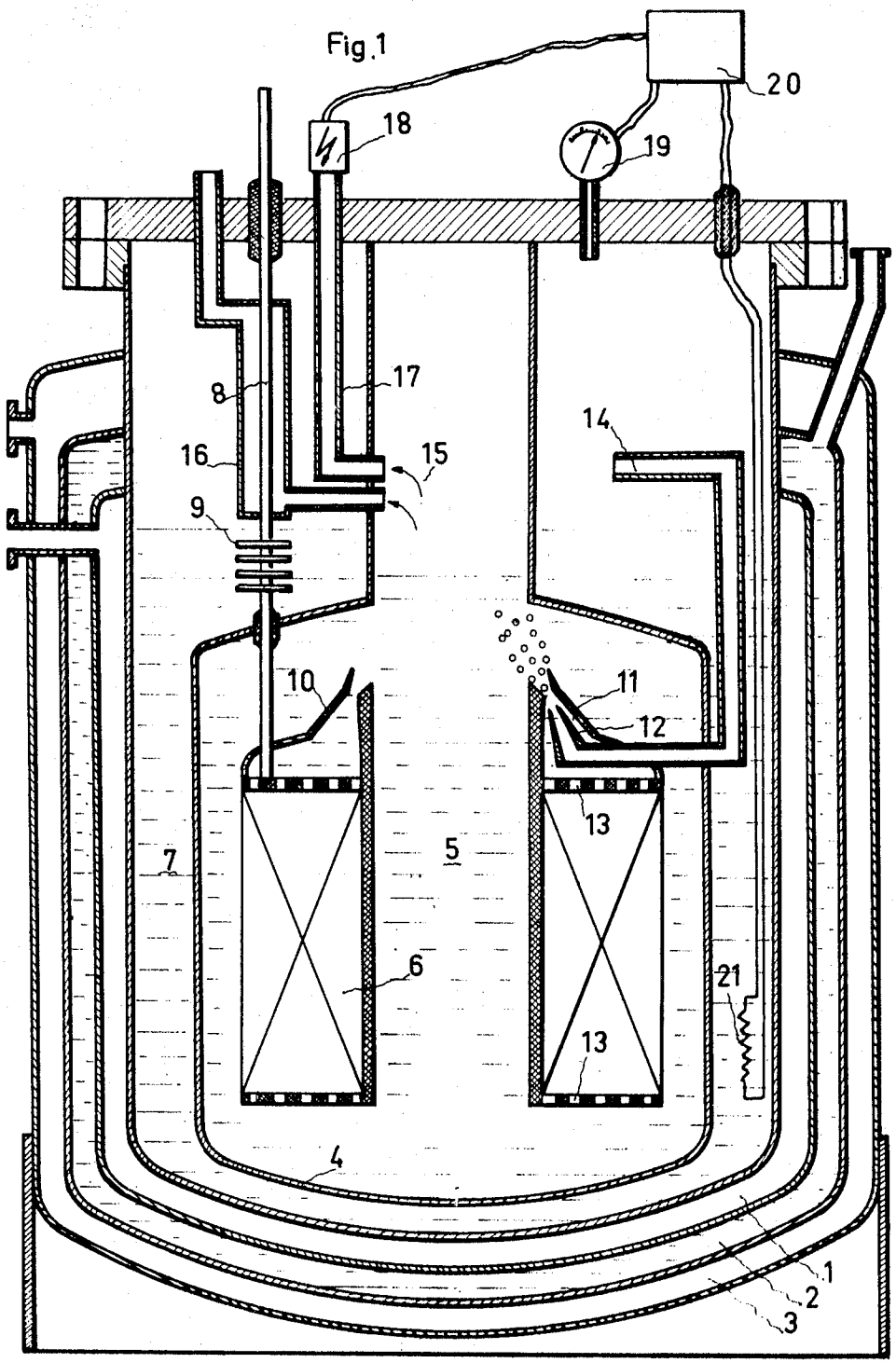


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SHEET 1 OF 3

Fig.1



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Fig:2

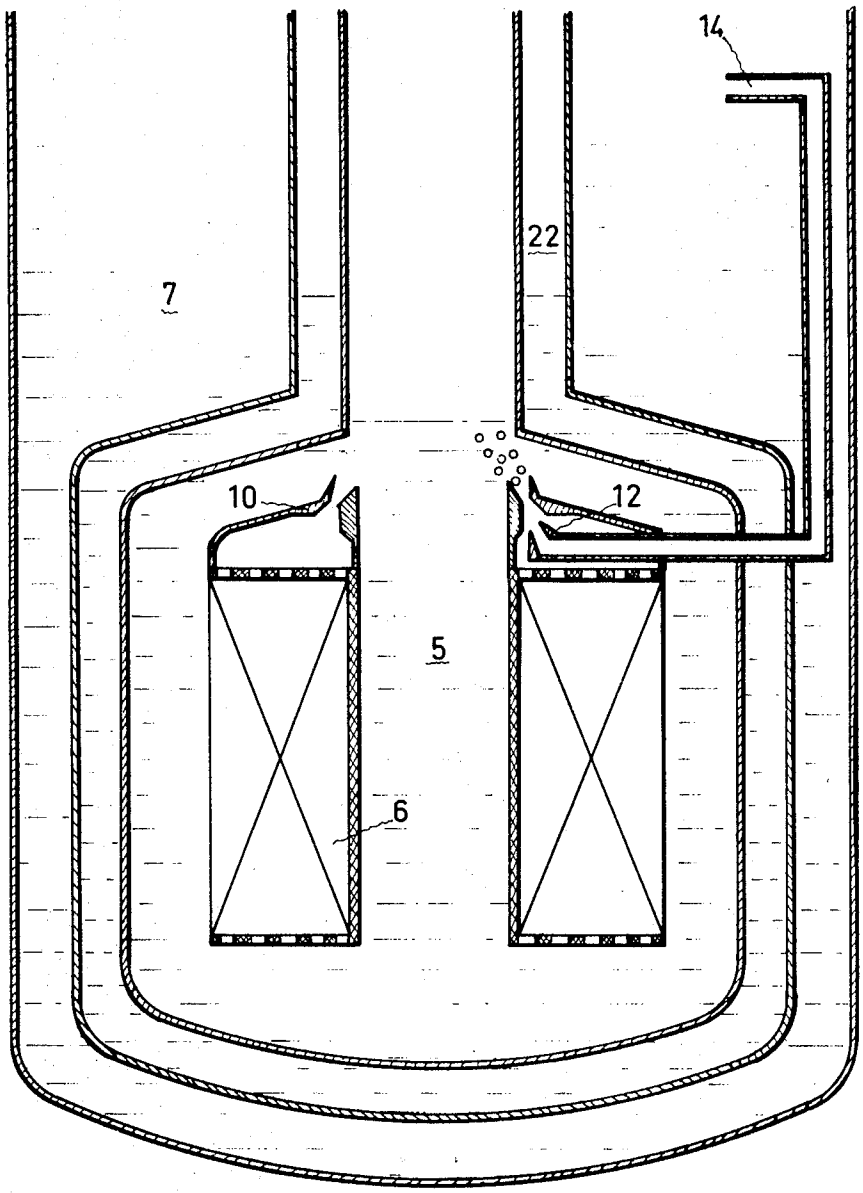
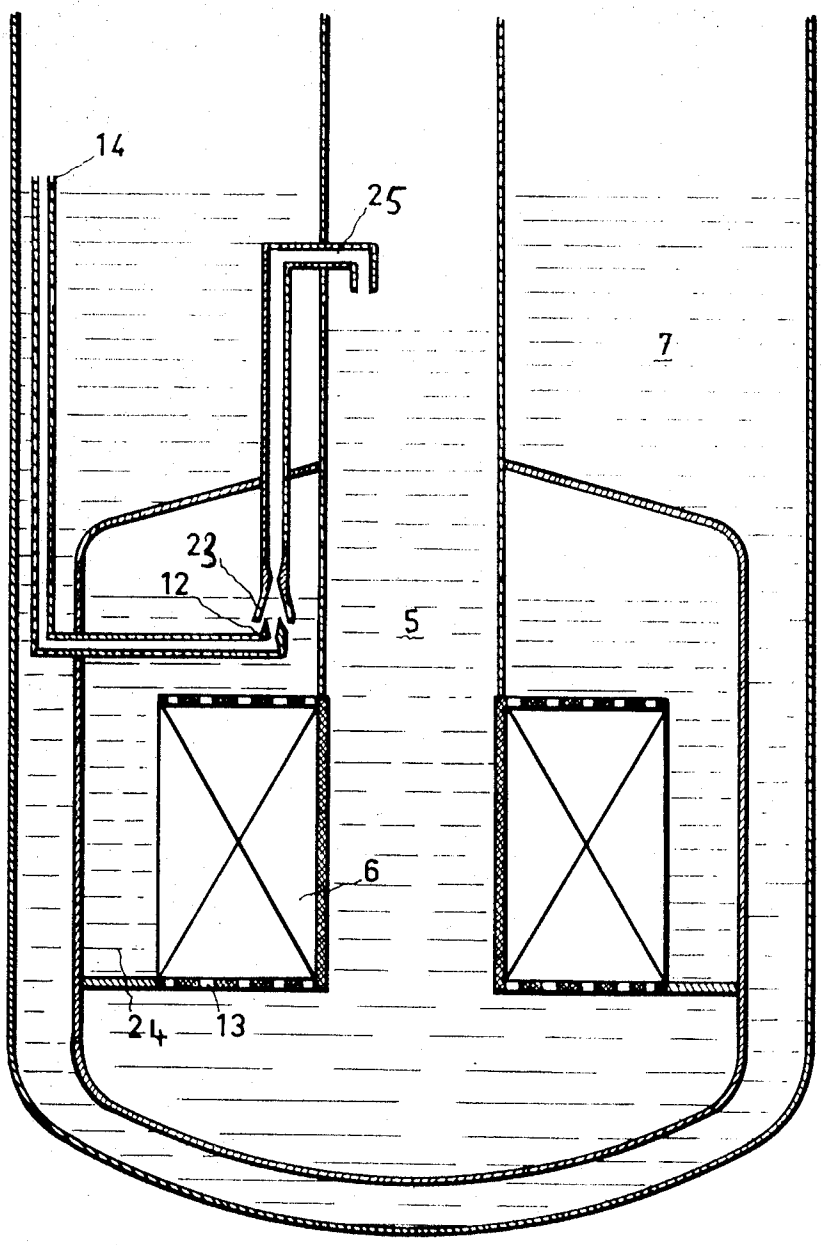


Fig:3



METHOD AND DEVICE FOR CIRCULATING A CRYOGENIC LIQUID WITHIN A BODY IMMERSED IN THE CRYOGENIC LIQUID

The present invention relates to a method and device for cooling bodies in a cryogenic fluid, and more particularly to superconductive magnet coils immersed in cryogenic liquid.

When a body such as for example an electric coil is immersed in a cryogenic liquid such as helium, hydrogen, nitrogen, it is sometimes necessary or at least extremely desirable to be able to set up a circulation of cryogenic liquid within this immersed body.

Thus in a superconductive magnet, quality, safety, reliability and operational durability depend first and foremost on the perfection of its thermal stabilization, which determines also in part its cost and its effectiveness in performances. As is known, thermal stability is a function of the coefficient of thermal exchange between the stabilized conductor and the cryogenic liquid e.g. helium. As is also well known, the coefficient of exchange increases rapidly with the speed of circulation of the liquid helium in contact with the conductor.

At present, superconductive coils are chilled in a stationary bath of liquid helium, and the circulation of cryogenic fluid begins only after a transition, that is, when the boiling provoked by the transition initiates—with an appreciable lag—circulation and movement by thermosiphon action. It would obviously be preferable that at least during increase of the field of a magnet, the helium should permanently circulate in the colling channels. Difficulty is encountered because presently there does not exist a pump for liquid helium, due to the extremely low vaporization point of this fluid and of the readiness with which cavitation may occur. Tests have indeed been made of a low delivery pump with relatively high pressure, but techniques usually adapted for the construction of superconductive magnets would require, to the contrary, a very high delivery of helium under only a low pressure.

It is an object of the present invention to provide a method and a device causing circulation of a cryogenic fluid form within a body immersed in this liquid, while at the same time avoiding the risks of cavitation.

SUBJECT MATTER OF THE INVENTION

A housing with converging walls is installed in the cryogenic liquid bath, in which an injection of the cryogenic fluid is introduced in the form of a gas under superpressure in such a way as to draw cryogenic liquid contained in the said immersed body into circulation.

The cryogenic fluid injected in gaseous form into the housing may be taken off an external liquifying apparatus. According to a feature of the inventive concept, the cryogenic injection source is created within the cryostat itself. The cryostat is divided into two concentric tanks, of which the inner tank contains the body to be cooled. Cryogenic gas at the surface of the bath of the exterior tanks, which is at a higher pressure due to thermal leaks cause by the wall of the cryostat and, in an electrical device, electrical connections, is collected and used for injection.

In accordance with another feature a radiator is added over the electrical connections in their passage through the cryogenic liquid of the exterior tank of the cryostat. Regulation is possible by bypassing a portion of the cryogenic gas (the amount of which may be adjusted as it leaves the inner tank) around the connections.

Pressure within the inner tank may be increased and if necessary regulated by introducing an adjustable heating device into the cryogenic liquid held by the tank.

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

FIG. 1 is a schematic sectional overall view of a cryostat equipped with a cryogenic liquid circulating device and using the method, in accordance with the present invention.

FIG. 2 and 3 represent partial views of the inside of this cryostat, illustrating different embodiments.

FIG. 1 shows a cryostat whose wall includes, in known manner a space 1 subjected to a vacuum, a space 2 filled with liquid nitrogen, and a space 3 subjected to vacuum. The inside of the cryostat is divided by wall 4 into two tanks; an inner tank 5 in which is placed a body 6, for example, a superconductive coil immersed in liquid helium and an outer tank 7, also filled with liquid helium. Superconductive coil 6 is connected with the outside by electrical connections 8, which have radiating fins 9 immersed in the liquid of tank 7.

Superconductive coil 6 is covered in its upper portion by a casing or shroud 10 whose profile tapers in such a way as to form a channel or even a nozzle 11, within which a series of injectors 12 (of which only one is represented) send gaseous helium under pressure in such a way as to entrap and draw along the liquid contained in casing 10 and thus create a circulation of liquid helium in conventional channels 13 arranged within superconductive coil 6. The gaseous helium feeding injectors 12 is taken off by ducts 14 above the level of the liquid in external tank 7.

The gaseous helium coming from injectors 12 and evaporating in the inner tank 5 above the liquid level can also pass, following arrows 15, into a pipe 16 which is airtight with regard to tank 7, which surrounds a portion of connections 8, and in a parallel pipe 17 which permits direct escape of the gaseous helium. The passage of gaseous helium around connections 8 in pipe 16 has the effect of reducing thermal losses introduced by these connections. An electromagnetic or electropneumatic valve 18 permits adjustment of the portions of cryogenic gas passing respectively in pipe 16 and in pipe 17.

Pressure inside tank 7 must remain lower than critical pressure, but it must be sufficiently high for the speed of circulation of liquid helium in channels 13 to permit good cooling action. Pressure in tank 7 is measured by a manometer 19 which transmits its indications to a regulator 20. Regulator 20 commands, whenever pressure in tank 7 exceeds a given maximal value, the closing of valve 18, which increases the quantity of gaseous helium passing around connections 8, and consequently reduces the seeping in of heat by way of connections 8 and thus evaporation in tank 7. If pressure in tank 7 goes below a given minimal value, regulator 20 commands the feed of current to an electrical resistance 21. Instead of electrical resistance 21, any other adjustable heating device could be installed, such as a copper tube that could be adjusted to varying depths of penetration, a jet of hot gaseous helium, etc.

Boiling in body 6 must be avoided. In certain installations it may be necessary, as is represented in FIG. 2, to place between enclosures 5 and 7 a supplementary thermal isolation enclosure 22, so as to be able to more intensely cool the liquid helium within enclosure 5. This enclosure 22, filled with liquid helium, can if necessary be subjected to pumping at lower pressure.

In the embodiment of FIG. 3, casing 10 has been replaced by a casing 23 which is no longer fixed on coil 6 but above it, the coil being immersed within a separate compartment 24 connected with the rest of tank 5 by channels 13 in its lower portion and by ducts 25 mounted on casing 23 in its upper portion. The liquid helium drawn by injectors 12 into casing 23 rises in duct 25 and passes into the central portion of tank 5. The level of liquid helium in compartment 24 must not sink below that of injector 12 and of casing 23. A level sensing of conventional construction (not shown) is preferably provided which controls, whenever the level of liquid sinks below a minimum, the opening of a valve permitting the decompression of the volume of gas contained in upper portion of compartment 24.

I claim:

1. Device for circulating a cryogenic liquid within a body immersed in a bath of such a liquid, having a tank containing said liquid characterized by injection means injecting a gas of the same substance as said liquid into said bath of cryogenic liquid said injecting means injecting said gas in a direction and under sufficient pressure to draw along and entrap cryogenic liquid immersing said body.

2. Device in accordance with claim 1, characterized in that the bath of cryogenic liquid is divided into two concentric tanks, of which the inner tank contains the said body;

and means are provided for collecting the cryogenic gas for injection at the surface of the bath contained in the outer tank.

3. Device in accordance with claim 2, characterized by an adjustable heating device located within the outer tank to heat the cryogenic liquid held in the tank.

4. Device in accordance with claim 2, to cool electrical apparatus immersed in said liquid and having terminal connections which connect said apparatus with the exterior of the tank, characterized by a radiator placed on the electrical connections in their passage through the cryogenic bath of the outer tank.

5. Device in accordance with claim 2, to cool electrical apparatus immersed in said liquid and having terminal connections, characterized by means conducting an adjustable portion of the cryogenic gas emanating from the inner tank around the electrical connections which connect the apparatus with the exterior.

6. Device in accordance with claim 1, wherein said injection means comprises a housing having converging walls and forming a constricted opening between said walls, and means introducing gasified liquid between said walls whereby the velocity of said gas escaping through said constricted opening will draw liquid along.

7. Device in accordance with claim 1, wherein said injection means comprises a nozzle; and duct means are provided connected to the nozzle and to a source of gasified liquid.

8. Device in accordance with claim 1, wherein said tank is sealed; the liquid is at a level below the top of the tank leaving a region therein filled with gas of the liquid; means are provided controlling the pressure in said tank; and said injection means includes duct means intercommunicating said gas-filled region and a region in said tank adjacent said body.

9. Method of circulating cryogenic liquid in a tank around a body immersed in said liquid comprising injecting gasified liquid into the liquid of said tank adjacent said body in a direction, and under a pressure sufficient to entrap liquid and draw it along the injection path to cause circulation of the liquid about said body.

10. Method of circulating including the step of collecting the gas from gasified liquid at the surface thereof and reintroducing it into said liquid by injection.