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Schmidt et al.

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[54] **CURRENT FEEDING ARRANGEMENT FOR ELECTRICAL APPARATUS HAVING LOW TEMPERATURE COOLED CONDUCTORS**

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[22] Filed: **Dec. 4, 1973**

[21] Appl. No.: **421,693**

Related U.S. Application Data

[63] Continuation of Ser. No. 314,565, Dec. 13, 1972, abandoned.

[30] **Foreign Application Priority Data**

Dec. 20, 1971 Germany 2163270

[52] **U.S. Cl.** .... **174/21 R,** 174/15 R, 174/15 C, 174/DIG. 6

[51] **Int. Cl.** **H01v 11/00**

[58] **Field of Search**.. 174/15 R, 15 C, 16 R, 15 BH, 174/19, 21 R, DIG.6; 165/105; 62/55.5

[56] **References Cited**

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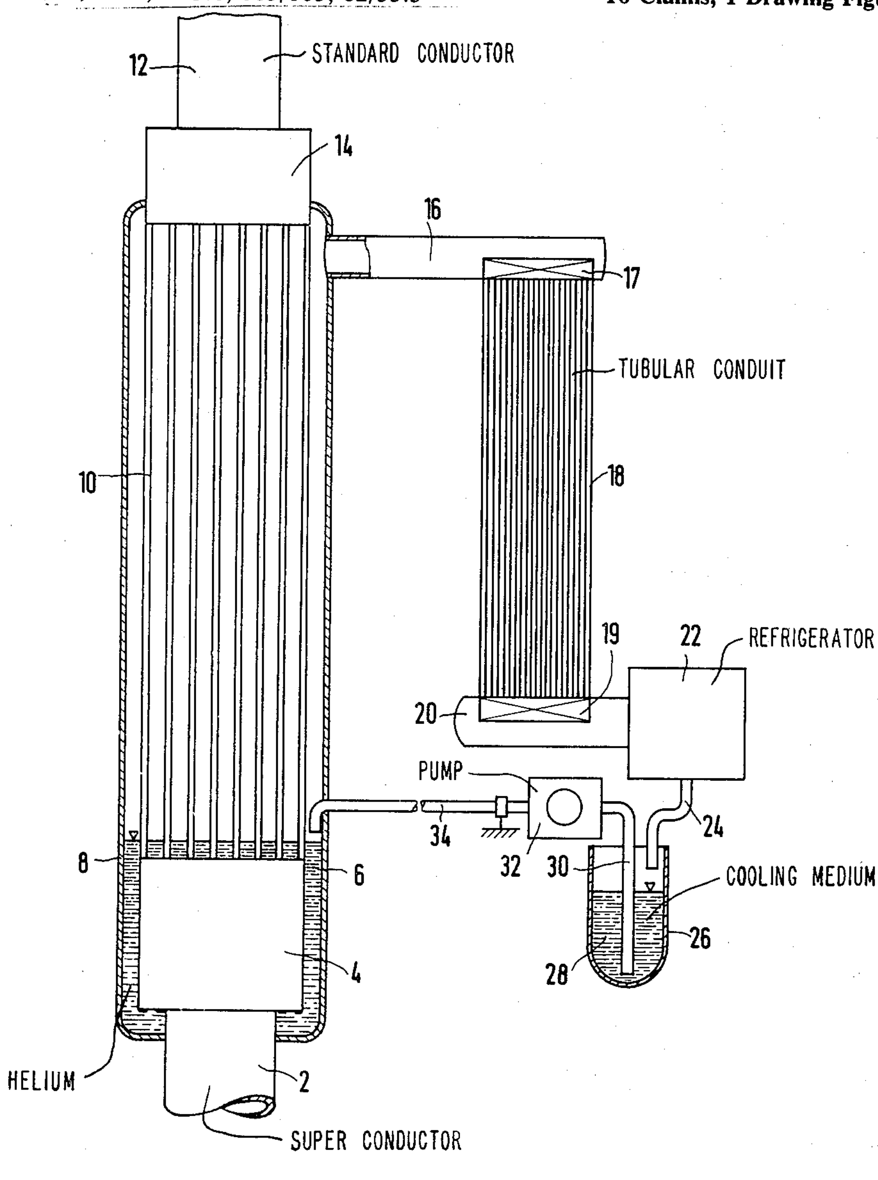
[57] **ABSTRACT**

This invention is concerned with a current feeding arrangement for a superconductor having a cooled standard conductor connected to it. The invention is comprised of subdividing the gas stream of the cooling medium into individual streams which each flow through a flow channel having small wall spacing. The current feeding arrangement has the advantage that at the walls of the individual flow channels a substantially lower density of charge carriers is obtained, and thus a corresponding increase in the dielectric strength of the gaseous cooling medium.

10 Claims, 1 Drawing Figure



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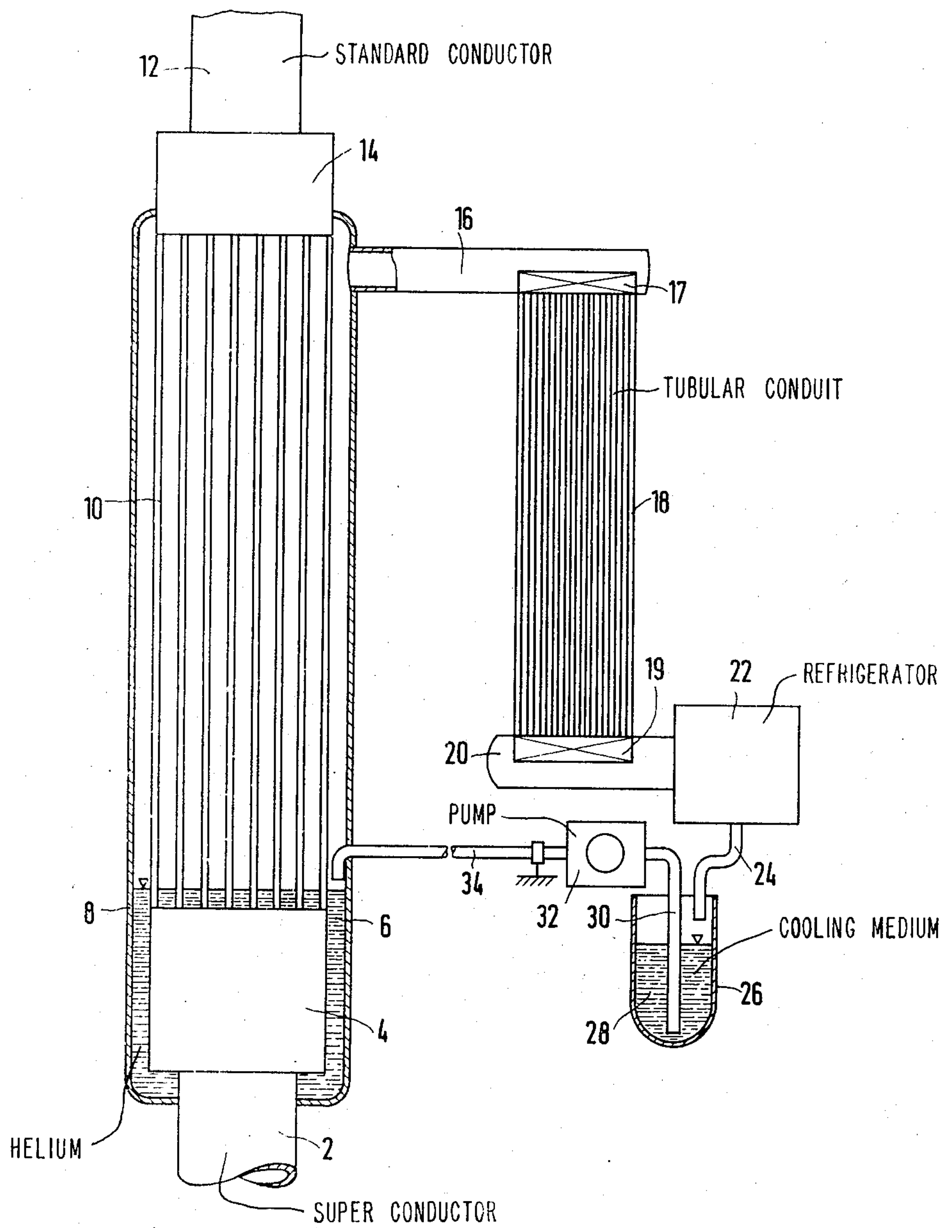

CURRENT FEEDING ARRANGEMENT FOR ELECTRICAL APPARATUS HAVING LOW TEMPERATURE COOLED CONDUCTORS

This is a continuation, of application Ser. No. 314,565 filed Dec. 13, 1972, now abandoned.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention is concerned with a current feeding arrangement for electricl apparatus having conductors cooled to a low temperature, more particularly it is concerned with a current feeding arrangement for superconductors, the end of the superconductors being connected to a standard conductor, cooled by a gaseous cooling meium.

2. Description of the Prior Art

In electrical apparatus having superconductors, for example, in cables, coils or machines, electric current must frequently be fed from a point at a higher temperature, particularly room temperature, to the superconductor, which is cooled to a temperature below its transition temperature. Because the superconductor loses its superconductivity at a temperature far below room temperature, an electrically normal conductive metal, like aluminum or copper, is used to bridge the temperature difference, and is connected with the superconductor at a point maintained at a temperature below the transition temperature of the superconductors. The standard conductor is therefore gradually cooled, in stages, up to the connection point.

The end of the superconductor, held below its transition temperature, can, for example, be arranged in a bath of a cryogenic medium, such as, a helium bath. The standard conductor is then comprised of laminations or grids at the connection point. Such a design is shown in "Review of Scientific Instruments,"vol. 38, No. 12 (Dec. 1967), p. 1776 to 1779. Due to the thermal losses at the junction, the liquid helium evaporates and the helium gas rises through the conductor laminations, wires or the conductor grid and removes the joulean heat and the heat flowing in from the outside. In the process, the helium gas is warmed up to approximately room temperature. At the upper junction of the standard conductor with the current supply, the helium gas is collected and returned to a refrigeration machine for liquification. Because the heat content of the gaseous cooling medium is well utilized in such current feeds, they require only a relatively small cooling effort.

If, however, high transmission rates are to be obtained, at which superconducting cables become economical, one is compelled to use correspondingly high voltages of 220 kV and higher. This type of current feed utilizes contact at one end with the highly cooled conductor, while the other end to which the conventional current supply is connected, is at a higher temperature, preferably room temperature. The cooling medium therefore flows along the indvidual conductors of the current feed and is in close contact with the high voltage conductor. The refrigeration machine for cooling medium, however, is generally at ground potential. To conduct the gas of the cooling medium away from the high-voltage potential by an insulating tube is not directly possible because helium at about 300°K has a very low breakdown voltage.

It is an object of the invention therefore to design an exhaust, gas-cooled, current feeding arrangement in such a way that it can be operated economically at high voltage and with a transfer of the cooling gas to the refrigeration equipment.

In the known arrangement an electric field is formed, in the exhaust gas line, between the upper junction of the standard conductor with the current supply and the refrigeration equipment. This field forms free charge carriers, the number of which is essentially determined by the potential gradient and the length of the gas line. A high voltage-resistant current feed therefore requires a correspondingly long gas line. In a long gas line, however, a large number of charge carriers are generated because of the well-known avalanche effect. This in turn causes a corresponding reduction in the dielectric strength of the gas. It is therefore not possible to bridge a large potential difference by a corresponding lengthening of the gas line alone.

SUMMARY OF THE INVENTION

This invention is based on the discovery that the dielectric strength of the cooling gas can be increased substantially if the number of the charge carriers in the gas are reduced by an appropriate design of the gas circulation between the standard conductor and the refrigeration equipment. According to the invention, this problem is solved by dividing the gas stream of the evaporated cooling medium into individual streams, each of which passes through a flow channel bounded by at least two walls of electrical insulating material, whose displacment is not more than 30 mm, with the preferred range of less than 3 mm and up to 10 mm.

In a tube the density of charge carriers formed decreases steeply in a radial direction outward from the center toward the wall, with a maximum amount occurring at the center. The effect on the gas of using electrical insulation material in the wall is to destroy the charge carriers. This "wall effect"is used in this invention to increase the dielectric strength of the gaseous medium. According to the invention, the gas stream therefore is subdivided into many individual flow channels, which can preferably be made like capillaries, the diameter of which theoretically should not substantially exceed the mean free path of the charge carriers, which for gaseous helium, is about 10^{-5} cm. This wall effect, however, is also reached with a larger wall spacing, not substantially exceeding 30mm, especially if means are provided to generate turbulent flow in the flow channels and thereby cause a large number of the charge carriers in the gas to strike the wall as the gas flows through the channel and thereby give off their charge. The partial gas stream entering the flow channel can be given a rotary flow motion. Without such means, a substantial reduction in the number of charge carriers is obtained if the gas flows through tubular channels having a diameter substantially equal to 0.3 mm. Such indivudual channels for the partial streams can be produced by using a woven grid in the tubular conduit for the gas, or by using a fiber-like insert in the form of a wick in the conduits. The gas then flows along the individual fibers and the wall effect is obtained. Alternatively the capillary flow channels can also be formed from pores in an electrical insulating, gas-permeable material. Another alternative is to fill the flow channels with a powdered, electrical insulating material, the grain size of which is chosen to obtain the required, capillary-like flow channels. A still further alternative is to design the flow channels from molecular sieves.

BRIEF DESCRIPTION OF THE DRAWING

To explain the invention in further detail, reference is made to the drawing, which illustrates schematically an emobodiment of a current feed arrangement construced according to the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

In the FIGURE, the end of the superconductor **2** is connnected to a standard conductor by member **4** and a cooling medium bath **6**, containing helium in container **8** which also encloses a laminated end **10** of a standard conductor **12**, the terminal of which is **14**. In accordance with the invention, the gas flow is distributed over individual gas lines **18** between two pipe lines **16** and **20**. Connected to pipe line **20** is a refrigeration machine which is connected by pipe line **24** to container **26**, from which the liquid cooling medium **28** can be fed to the bath **6** by a feed pipe **30**, a pump **32** and feed line **34**.

The junction **4** between the laminations **10** of the standard high-voltage conductor **12** and the superconductor **2** is located in the boiling helium of bath **6**. Because of the joulean heat of the current-carrying laminations **10** and the heat inflow from the standard conductor **12** through the laminations, part of the helium evaporates. The gas cools laminations **10** by rising upward between them into the upper part of the container **8** and acts as a gas cushion. From there it is fed through the pipe line **16** to the tubular conduits **18**, formed of electrical insulating material which are preferably subdivided for the gas flow into individual capillaries formed from a powdered filling, particularly glass powder or glass wool. On the way through these capillaries, many of the charge carriers generated by the electric field are anihilated by the wall effect thereby increasing the dielectric strength of the cooling gas to such and extent that voltage breakdown in the gaseous cooling medium is prevented. The cooling medium can therefore be fed by pipeline **20** to refrigerator **22**, where it is reliquified and fed through pipeline **24** to the supply tank **26**.

Another particularly advantageous embodiment of the current feeding arrangement of the present invention consists in providing filters **17** and **19** at the upper and the lower terminals of the fillings for the pipes **18**. These filters can be made from glass frit, the openings of which are preferably smaller than the grain size of the insulating powder in the pipes **18**.

Material to fabricate the capillaries in the tube condiuts **18** can be insulating powder of quartz, ceramic material or plastic. Well suited is glass powder having a grain diameter of approximately 50 to 150 μ**m.**

By using a diameter in tubes **18** smaller than 10 mm, and more particularly, smaller than 3 mm, with additional special devices, one can obtain a good wall effect within the gas stream. For larger tube diameters or a larger distance between the walls of flat tubular condiuts, the wall effect can advantageously be increased by either introducing a turbulent flow gas stream into the individual tubes **18** or providing additional means inside the tubes **18**. Such means can be a helix, which during the flow of the gas in the tube, permits as large a part as possible of the gas coming into contact with the wall.

In the example of the embodiment a current feeding arrangement is described cooled by liquid or gaseous helium, but it should be realized that other boiling gases are also suitable. For a superconductor, hydrogen can also be considered, and for conductors cooled down to low temperatures, nitrogen or neon can also be used.

In the foregoing, the invention has been described in reference to specific exemplary embodiments. It will be evident, however, that variations and modifications, as well as the substitution of equivalent constructions and arrangement for those shown for illustration, may be made without departing from the broader scope and spirit of the invention as set forth in the appended claims. The specification and drawing are accordingly to be regarded in an illustrative rather than in a restrictive sense.

What is claimed is:

1. A current feeding arrangement for electrical apparatus having conductors, cooled to a low temperature, connected to a standard conductor by a connecting means, in which the connecting means is contained in a container and is cooled by a gasified liquid coolant, the improvement comprising connecting the end of the container located at the end of the connecting means disposed away from the conductor cooled to a low temperature, to a plurality of flow channels each having at least two walls covered by an electrical insulating material, and separated by a displacement of not more than 30 mm.

2. A current feeding arrangement for electrical apparatus as in claim **1** in which the displacement of said walls is not substantially greater than 3 mm.

3. A current feeding arrangement for electrical apparatus as in claim **1** further comprising means for generating a rotary flow of the gas through the flow channels to increase the frequency of contact between charge carriers and the insulating material.

4. A current feeding arrangement for electrical apparatus as in claim **1** in which the displacement of said walls in not substantially greater than 0.3 mm.

5. A current feeding arrangement for electrical apparatus as in claim **4** in which the flow channels are formed from a woven grid.

6. A current feeding arrangement for electrical apparatus as in claim **4** in which the flow channels are formed from the fibers of a wick of electrical insulating material.

7. A current feeding arrangement for electrical apparatus as in claim **4** in which the flow channels are formed from the pores of an electrical insulating, gas permeable material.

8. A current feeding arrangement for electrical apparatus as in claim **4** in which the flow channels are formed from grains of an electrical insulating powder.

9. A current feeding arrangement for electrical apparatus as in claim **4** in which the flow channels are formed from a molecular sieve.

10. A current feeding arrangement for electrical apparatus as in claim **1** in which said conductor cooled to a low temperature comprises a superconductor, and in which said coolant comprises helium.

* * * * *

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,849,589 Dated November 19, 1974

Inventor(s) Fritz Schmidt, Günther Matthäus, Peter Massek

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

In column 1, line 11, change "electricl" to --electrical--

In column 1, line 16, change "meium" to--medium--

In column 2, line 32, change "displacment" to --displacement--

In column 2, line 58, change "indivudual" to --individual--

In column 3, line 7, change "emobodiment" to --embodiment--

In column 3, line 8, change "construced" to --constructed--

In column 3, line 40, change "and" to --an--

In column 3, lines 53 and 61, change "condiuts" to --conduits--

In column 4, line 43, change "in" to --is--

Signed and sealed this 11th day of March 1975.

(SEAL)
Attest:

RUTH C. MASON
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents
and Trademarks

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