

[54] FAST-ACTING ELECTRICAL FUSE

[75] Inventor: **Francis Jules Brichant**, Belfort, France

[73] Assignee: **Lucien Ferraz et Cie**, Lyon, France

[22] Filed: **June 12, 1970**

[21] Appl. No.: **45,648**

[52] U.S. Cl.337/166, 337/161, 337/185

[51] Int. Cl.H01h 85/04

[58] Field of Search.....337/104, 161, 164, 166, 229, 337/251, 253, 295, 185, 4

[56] References Cited

UNITED STATES PATENTS

3,453,579 7/1969 Cinquin.....337/161
2,159,649 5/1939 Alford.....337/4

FOREIGN PATENTS OR APPLICATIONS

254,515 5/1963 Australia.....337/185

Primary Examiner—Bernard A. Gilheany

Assistant Examiner—F. E. Bell

Attorney—Arthur O. Klein

[57] ABSTRACT

A fast-acting electrical fuse in which the fusible element is in direct contact with a cooling liquid, there being means for directing cooling liquid under pressure upon the fusible element. In one preferred manner of use of the fuse of the invention, the liquid cooling system for the fuse is connected in series with the fuse, whereby failure of the cooling system for the circuit element causes a failure of the cooling system for the fuse and thus the opening of the circuit by the melting of the fusible element.

1 Claim, 5 Drawing Figures

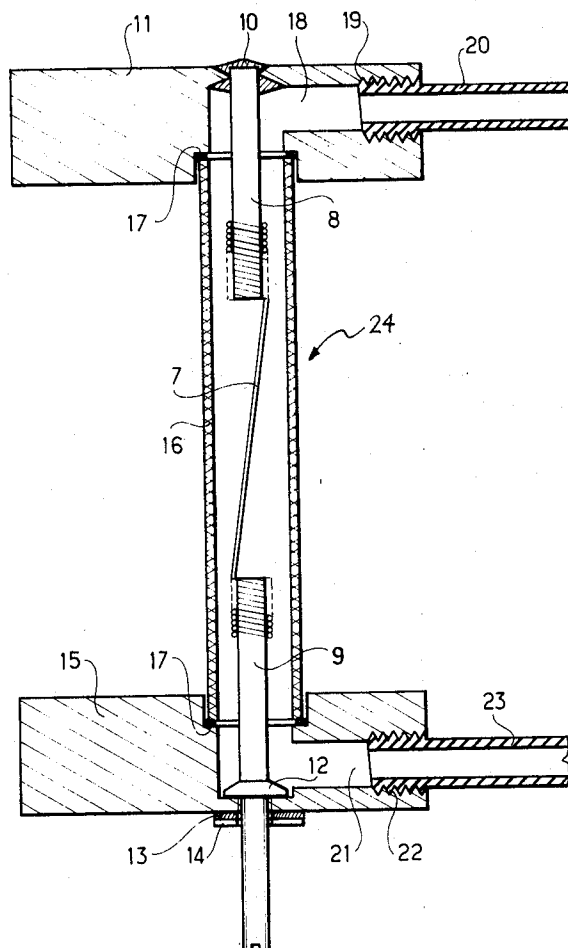


FIG.1

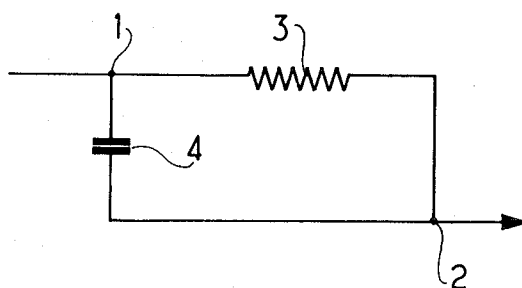
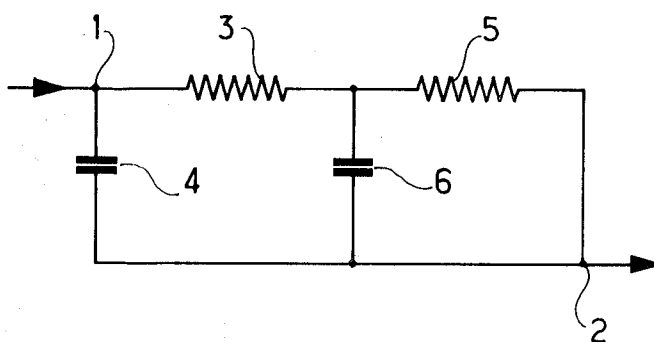


FIG. 2



INVENTOR:
Francis J. Brichant

By: *Arthur O. Klein*
Attorney

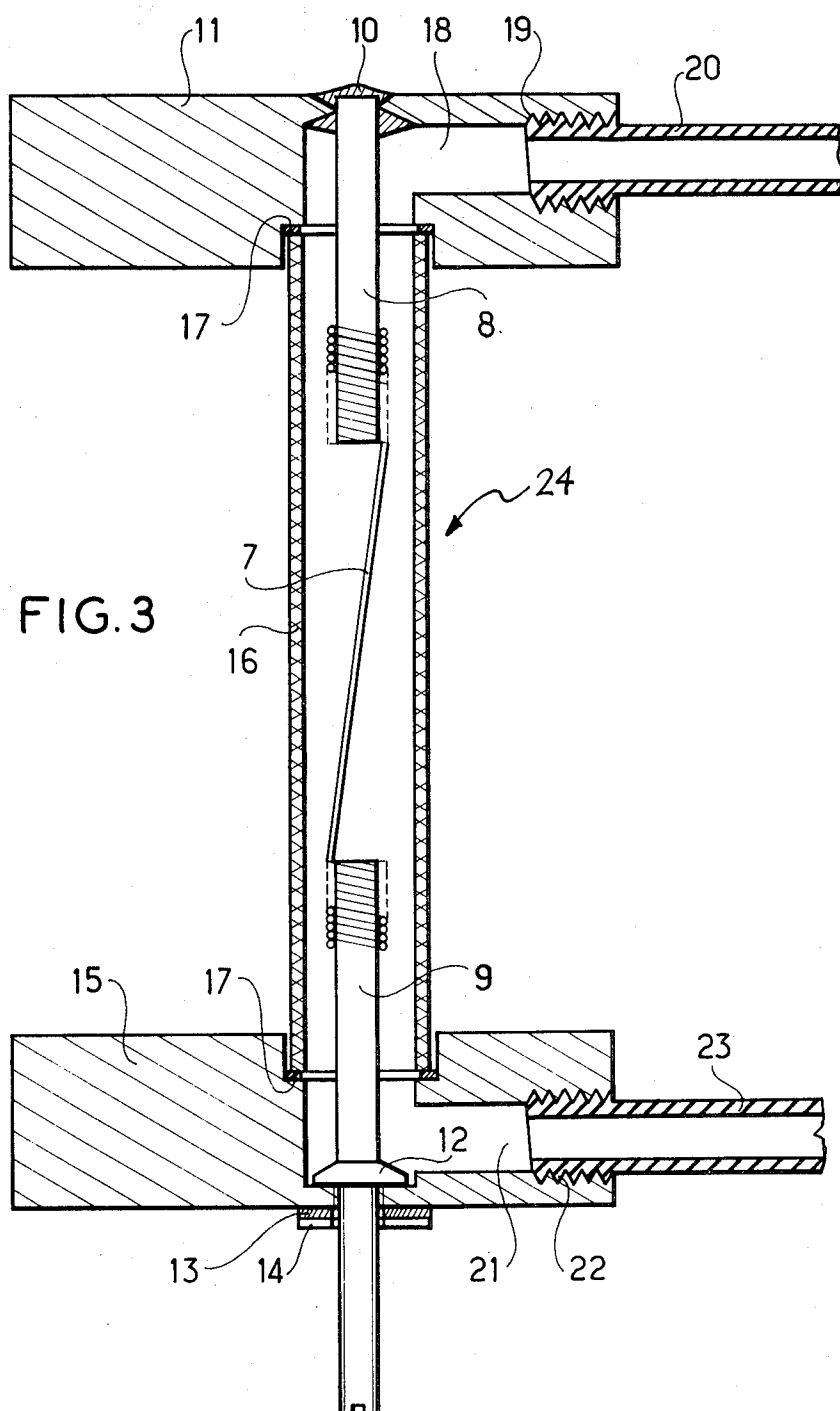


FIG. 3

INVENTOR:
Francis J. Brichant

by: *Arthur O. Klein*
Attorney

FIG. 4

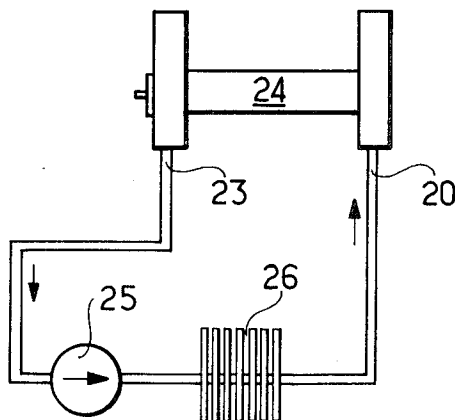
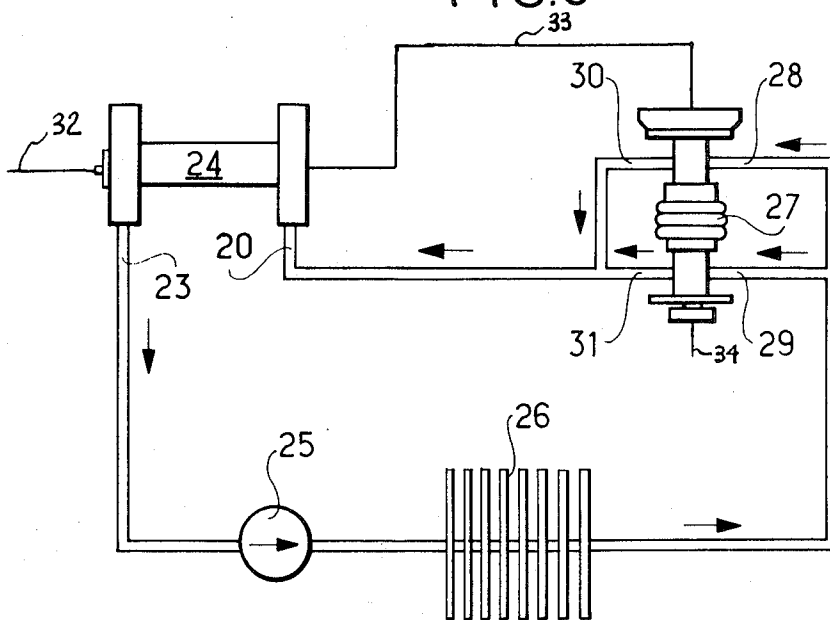


FIG. 5



INVENTOR:
Francis J. Brichant

by: *Arthur O. Klein*
Attorney

FAST-ACTING ELECTRICAL FUSE

Semi-conductor devices permit the passage of very large quantities of electrical current. However, by reason of their very small thermal capacity, they are able to endure only small excesses of current flow for a very short time. Thus, a power thyristor which can readily pass a mean amperage of 400 amperes under forced ventilation, can sustain an overcurrent condition of 7,000 amperes-peak for 10 milliseconds. The same thyristor, cooled with water, can sustain the continuous passage of 600 mean-amperes, that is to say, 1,350 effective amperes or 1,900 peak amperes, so long as the amount of current being passed does not vary substantially. In order to protect such semi-conductor devices, it is necessary to employ therewith fuses which are capable of sustaining such elevated currents while being adapted to melt rapidly in the case of the passage of an excess of current.

The most rapid fuses which one can practically procure have fusible elements which melt in 10 milliseconds for an excess current of 5 to 10 times the normal current; this, however, is insufficient to ensure the protection of the semi-conductor elements. Thus, there are fuses which limit the use of semi-conductor elements to values which are less than their possible maximums; it is also required that there be taken burdensome precautions to limit the excess currents, for example, by chokes or by transformers having high inductive values. This last solution requires, nevertheless, during normal functioning and also in the case of the opening of the circuit, some inconveniences which are not negligible, particularly the handling of very large current surges.

The present invention has for its object the provision of the novel, fast-acting electrical fuse. Such fuse, in which the fusible element is in direct contact with a cooling liquid, is characterized by the fact that it comprises a means of forced circulation of the cooling liquid directly upon the fusible element.

The results flowing from thus cooling the fusible element will be seen from the following theoretical discussion.

In the drawings forming part of the specification:

FIG. 1 is a schematic representation of a system employing a liquid cooled fast-acting electrical fuse;

FIG. 2 is another schematic representation of a system employing a liquid cooled fast-acting electrical fuse;

FIG. 3 is a view in axial section through a fast-acting electrical fuse in accordance with the invention, certain of the parts being shown in elevation;

FIG. 4 shows a fuse such as that of FIG. 3 connected in a liquid cooling circuit for the fuse; and

FIG. 5 shows a liquid cooled fuse such as that of FIG. 3 electrically connected in series with a thyristor, the cooling circuits for the fuse and the thyristor likewise being connected in series.

The thermal schematic of a fuse or of a fusible element which is disposed in direct contact with a cooling liquid in enforced circulation may be represented only in an approximated manner, such manner being sufficient, however, in order to understand the importance of the invention. A fusible element has both a thermal resistance 3 and a thermal capacity 4, the resistance 3 and the capacity 4 being shown in FIG. 1 connected in

parallel between terminals 1 and 2. In such circuit the temperature of the fusible element (represented by elements 3 and 4) is taken as t_f , the temperature of the cooling medium (cooling liquid) is taken as t_r . The thermal resistance 3 is taken as having a value r which is the thermal resistance between the fusible element and the cooling liquid, and a thermic capacity 4 as having a value c , which is the thermal capacity of the fusible element. The various parts are so related that for a power P dissipated by the fusible element, a difference $t_f - t_r$, in the time t , follows the law:

$$t_f - t_r = r P e^{-(t/rc)}$$

The rapidity of the fuse is thus a function of the thermal time constant rc : the smaller such time constant becomes, the more rapid is the action of the fusible element. If one decreases the thermal resistance r , the relationship between the excess current and the normal current is very small, and the fusible element melts, in the case of an over-current, in a time which is the shorter as the thermal resistance r becomes smaller.

However, the forced circulation of a cooling liquid upon the fusible element reduces considerably such thermal resistance r . In effect, when the temperature of the fusible element is a little below a certain value, the value being about 130°C in the case when the cooling liquid is water, it produces a nucleated ebullition in the liquid which produces a very large thermal exchange between the fusible element and the liquid, and, since the fusible element exceeds such temperature, it forms a layer of vapor on the fusible element and, as a result, the thermal exchange between such fusible element and the liquid becomes very poor, and the fusible element melts.

It should be remarked that such effect is produced by the circulation of a liquid upon the fusible element in that when one simply immerses the fusible element in a liquid one does not obtain all of the result which he seeks. The thermic scheme then simply becomes that shown in FIG. 2 where there is now disposed between the terminal 1 of the fusible element and the terminal 2 of the cooling medium (here the ambient air), not only a circuit: thermal resistance 3 between the fusible element and the liquid and the capacity 4 of the fusible element, but also a circuit: thermal resistance 5 between the liquid and the external air, introducing a further capacity 6 in the mass of liquid.

In practice, the thermal exchange between the cooling liquid and the exterior of the enclosure which confines it is poor, particularly if the wall of such enclosure is made of electrically insulating material. It follows that the calories furnished by the fusible element to the liquid will be very limited. If the cooling liquid is to remain in liquid phase, one improves very little the phenomenon of nucleated ebullition because one will be limited by the cooling of the liquid itself.

On the other hand, since the fusible element will not have attained the ambient temperature, it will be capable, because of the thermal capacity of the cold liquid, to support without melting the intensities of very large electric currents. Thus the fuse, instead of being a rapidly melting fuse, is a slow fuse, which is very interesting in certain applications such as those of starting electric motors or the protection of electrical spot welding apparatus. Such devices, however, are very

dangerous for the protection of semi-conductor devices, where one risks having a short circuit at the moment of the closing of the electrical circuit which is to be protected.

In an electrical fuse according to the invention, the cooling liquid may circulate in an open circuit the liquid being furnished by a source of liquid under pressure and being expelled after passage over the fusible element, or in closed circuit with a circulation pump and a heat exchanger in order to cool the liquid after its passage over the fusible element. The speed of circulation of the cooling liquid, water, for example, is advantageously above 1 meter/sec. along the length of the fusible element, for example, 4 or 5 meter/sec., but it may attain the values of 20 - 24 meter/sec.

Such forced circulation of the cooling liquid on the fusible element, eliminates the bubbles of vapor which are formed on the surface of the fusible element since the surface temperature of the element is now less than a certain value, 130°C in the case wherein the element is cooled by water, so that one may thus obviously improve the phenomenon of nucleated ebullition. On the other hand, the fuse finds itself under practically permanent ambient conditions since it is placed in the electrical circuit which it is to protect and it immediately plays its role of protection. Because of such constant properties of the fuse, its calibration may be carried out in a very precise manner. Finally, in a fuse which is cooled by the forced circulation of cooling liquid over the fusible element, the pipes which lead the cooling liquid to and from the fusible element provide for the volume expansion of the water which is vaporized very rapidly. In a sealed fuse, it is necessary, to the contrary, to provide special means to avoid the risk of explosion.

Further, a fuse which is cooled by the forced circulation of cooling liquid upon the fusible element, constitutes an excellent detector of the lack of liquid cooling liquid in an installation which is cooled in series by the same circulation of liquid, for example, of thyristors or diodes, and permits, as a result, the protection of such installations against a breakdown of the cooling circuit.

In FIG. 3 there is shown a fuse which is generally designated 24 and which has a fusible element 7 constituted here by a metallic wire, for example, of copper or silver, but which may also be made of a metallic sheet. The wire 7 is soldered or welded to metallic supports 8 and 9, which are fixed, support 8 being soldered or welded at 10 to a metallic block 11, support 9 carrying a washer 12 and a shoulder thereon, the element 9 being secured to the block 15 through the medium of a washer 13 and a nut 14 screwed to the outer shank portion of the support 9. The metallic blocks 11 and 15 are made of metal which is a good conductor of electricity such as copper, and they carry terminals, not shown, which permit the fusible element 7 to be connected in an electrical circuit which is to be protected.

The fusible element 7 is contained in a tube 16 which is made of an electrically insulating material such as nylon or is laminated of glass fibers held together by a cured synthetic resin. The tube 16 is secured and sealed at its respective ends to counterbores in the metallic blocks 11 and 15 by being glued thereto and/or being screwed therinto as shown, there being sealing rings 17 interposed between the counterbore and the metal-

lic blocks in the ends of the tube 16. The metallic block 11 has a cavity 18 therein which connects the interior of the tube 16 to an orifice 19 in which there is screwed a tube 20 made of insulating material; the metallic block 15 also has a cavity 21 therein, such cavity connecting the interior of the tube 16 to an orifice 22 in which there is screwed a tube 23 made of insulating material. The tubes 20 and 23 may also be glued and/or screwed to the walls of the orifices 19 and 22; they may also be metallic and prolonged by pipes made of electrically insulating material.

One of the tubes, 20, for example, is connected to a source, not shown, of cooling liquid which is, by preference, water but which may also be of another liquid such as benzene or freon, for example. The tube 23 serves to lead away the cooling liquid which has flowed along the length of the fusible element 7. The liquid flowing out of the tube 23 may be simply caught by a sump through which it flows to the sewer; the source of cooling liquid may be fresh water which is continually supplied to the interior of the fuse housing, such water being demineralized or softened.

One may also, as shown in FIG. 4, cause a circulation of cooling liquid in a closed circuit. The fuse, shown in this example, is also designated generally by the reference character 24. A discharge tube 23 is connected to the entry port of a circulation pressure pump 25, the discharge orifice of the pump being connected to the tube 20 by the intermediary of a cooling means 26, which in this instance is shown as a finned tube.

It is particularly interesting to combine the installation for cooling the fuse with that of the apparatus which is protected by the fuse. An example of such apparatus to be protected is for the thyristor. The thyristor, which is generally designated 27, has a housing which is fed with cooling liquid through two pipes 28 and 29, the liquid being fed to such pipes from a cooling means 26. Liquid discharged from the housing of the thyristor 27 flows through pipes 30 and 31 which are connected to the entry pipe 20 of the fuse 24. With such arrangement, a breakdown of the cooling circuit for the thyristor 27 also causes a breakdown of the cooling circuit for the fuse 24, which accordingly causes a melting of the fusible element 7 and thus protects the thyristor 27 by cutting off the current thereto.

Although the invention is illustrated and described with reference to one preferred embodiment thereof, it is to be expressly understood that it is in no way limited to the disclosure of such a preferred embodiment, but is capable of numerous modifications within the scope of the appended claims.

What is claimed is:

1. A fast-acting electrical fuse comprising an electrically insulating housing having a pair of terminal members sealed thereto at spaced locations, a fusible electrically conducting element in the housing connecting said terminals, and means to pass a stream of cooling liquid under pressure through the housing along the fusible element in contact therewith to cool the fusible element, the housing of the fuse forming a part of a closed cooling circuit comprising conduit means connecting the two ends of the housing, a liquid force pump, and a liquid cooling means, said last two means being interposed in series in said conduit means, and an electrical circuit element to be protected by the fuse

5

connected in series with the fusible element of the fuse, the electrical circuit element having a cooling jacket which is interposed in said conduit means, cooling liquid flowing sequentially first through one of the housing of the fuse and the jacket of the electrical ele-

6

ment and then through the other of such members, whereby a failure of the liquid cooling circuit causes the fusible element of the fuse to melt to interrupt the flow of current through the electrical circuit element.

* * * * *

10

15

20

25

30

35

40

45

50

55

60

65