July 13, 1965 V. J. COX 3,194,925

ELECTRICAL FUSES IMMERSED IN A DIELECTRIC FLUID

Filed May 29, 1961

Fig. 1.

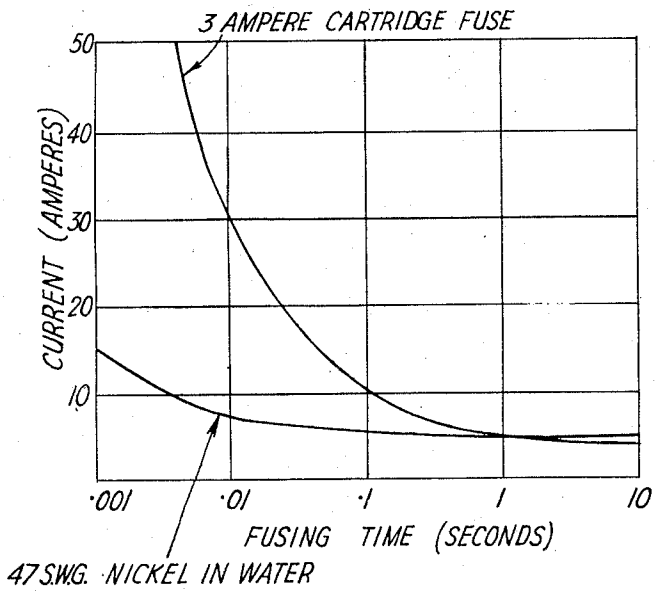
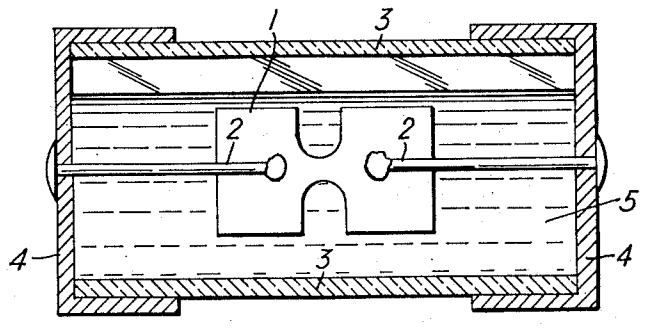


Fig. 2.



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United States Patent Office 3,194,925 Patented July 13, 1965

3,194,925

ELECTRICAL FUSES IMMERSED IN A DIELECTRIC FLUID

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Filed May 29, 1961, Ser. No. 113,456
Claims priority, application Great Britain, May 31, 1960, 19,138/60
4 Claims. (Cl. 200—131)

The commonly used systems of fuses for protection of electrical equipment are based on the use of fusible links of pure metals or alloys which, when subjected to a current overload, melt and thus interrupt the circuit.

The fuses may, in some applications, be surrounded with a solid or other insulator in order to improve the current interruption capability and for some special applications a small explosive charge may be included in order to enable a relatively small fuse to interrupt large currents.

While these fuse systems have been satisfactory for the general run of electrical and electronic systems, difficulties are encountered when it is necessary to ues fuses to protect systems employing semi-conductor devices, e.g. germanium or silicon transistors or rectifiers, as in many cases the thermal time constant of these devices is shorter than the thermal time constant of the common variety of fuses. This means that while the fuse will successfully protect the semi-conductor device against moderate overloads, the application of a sudden large overload will destroy the semi-conductor device before the fuse has time to melt and interrupt the circuit.

The thermal time constant of a fuse may be reduced by choosing a material of low specific heat, and latent heat of fusion, and using the minimum quantity of fuse material but, in general, this technique has already been fully exploited and little improvement can be expected in this direction because as soon as the cross section of the fuse wire is reduced appreciably, the operating temperature rises which results in a short fuse life.

According to the present invention a fuse comprises a fusible metallic element submerged in a liquid vaporisable at a temperature below the temperature of fusion of the fuse element and which permits the continuous operation of the element at a current higher than that element would carry in air.

In such a fuse the cooling of the element by the liquid is automatically controlled so that appreciable cooling takes place until the predetermined current is reached at which the fuse is required to interrupt the circuit, by which time there has been formed, between the surface of the element and the heat conducting liquid, a substantially heat insulating layer of vapour. This causes a rapid cumulation of heat in the element and its rapid fusion.

In the invention a very small amount of active element may be used without the defects mentioned above. To illustrate the effect a length of 47 gauge nickel wire mounted in free air will normally blow at a current of 0.6 amp. but when immersed in water this current is increased to 6.0 amps. This means that at the fusing point the energy available to melt the same volume of material is very much greater, which results in a substantial decrease in the time required to interrupt the circuit.

The rise of temperature in the element of the liquid cooled fuse is approximately as the square of the current but of course this rise in temperature is very much lower than in air cooled fuses. The rate of temperature rise continues until the boiling point of the liquid is reached and nucleate boiling commences. From this point onwards the increased dissipation is absorbed by the latent heat of evaporation of the liquid and very large heat

transfer rates are achieved for quite small increases in wire temperature. The wire should normally be very small in diameter in comparison with the diameter of the enclosure and while it is necessary for the liquid to boil in order to absorb the energy dissipated at the wire, the walls of the enclosure are sufficiently large to dissipate this same energy with a relatively small temperature rise. This means that the liquid as a whole is maintained far below boiling point and the vapour bubbles condense in the liquid and boiling of the whole volume does not take place. As the current is increased further, the liquid boils vigorously on the surface of the wire and larger and larger bubbles are produced. These large bubbles, to some extent, thermally insulate the wire from the liquid and the wire temperature rises until a critical temperature is reached, where the boiling is so vigorous that the wire becomes surrounded with a cloud of vapour with a corresponding violent reduction of the heat transfer co-efficient. At this point, the wire is then behaving as a gas cooled fuse but at a current very many times greater than its fusing current with the result that it melts with extreme rapidity.

An example of the improvement possible with this technique is shown in FIGURE 1 which compares the fusing time versus current relationship for a 47 S.W.G. nickel wire in water with that of a standard 3 amp. cartridge fuse.

There is a fairly wide choice of liquids that can be used for this purpose but, unfortunately, the fluids which are most thermally suitable are not always electrically satisfactory. For low voltage circuits, where extreme speed of circuit interruption is vital, distilled water with or without an anti-freeze additive is very satisfactory as its very high latent heat of evaporation gives very fast operation. Unfortunately, the interruption is not complete due to the conductivity of the liquid.

Methyl alcohol is again good thermally and is a fair electrical insulator but the fire risk with this material makes it unattractive for most applications. For higher voltages the fluorocarbon series of liquids, developed for heat transfer applications, are more suitable, particularly as the dielectric strength of the vapour is much higher than that of most materials which permits the satisfactory interruption of large currents and voltages.

Due to the very efficient cooling afforded by the liquid medium, for a given fusing current, the cross sectional area required for the fuse element is very much smaller than required for conventional fuses, which means that for fuses of ratings of 5 amps. or less, it is difficult to manufacture and handle wire of sufficiently small diameter. Although mechanically convenient, circular wire is not the best configuration for the fuse element due to its poor ratio of surface area to volume. If a section is chosen which gives a larger ratio of surface area to volume, the cooling of the element is improved and this means that a small cross section of active material can be used to carry a given current with a consequent improvement in the fuse blowing time. In the case of heavy current fuses, this can be achieved by the use of fuse material in flat ribbon form, but a more convenient system for lower currents is the use of the fuse material in the form of a thin film on a supporting insulator.

A diagram of a fuse of this type is shown in FIGURE 2. Here a small sheet of mica 1 has lead-out wires 2 attached to it by rivetting or other suitable means. The surface of the mica is coated with a controlled thickness of a suitable metal or alloy by vacuum deposition, sputtering or any of the conventional insulator plating processes with a controlled thickness of the insulator plating processes. Silver or tin are particularly suitable metals. The whole is enclosed in a glass or ceramic tube 3 with metal end caps 4 and three quarters filled with the dielectric

liquid 5. The mica is provided with a central narrow neck and the fuse rating is determined by the width of this neck and the thickness of the plating.

It will normally be preferred to have the container sealed so as to be air-tight. Where the fuse is to be subjected to considerable vibration it may be preferable to fill the container completely with the dielectric liquid.

I claim:

1. In an electric fuse, a thin metallic film fusible element connected between two end terminals, an insulating support supporting said thin metallic film fusible element, said thin metallic film element having a narrow portion between two broad portions, the narrow portion thereof being dimensioned to control the current carrying capacity of the fuse with said broad portions being connected to said end terminals, a container containing said element and supporting said terminals, in said container a heat dissipating dielectric liquid immersing the element and whose temperature of vaporisation is below the temperature of fusion of the said element and which liquid vaporises to produce a vapour of high heat and electrical resistance.

2. In an electric fuse, a thin metallic film fusible element connected between two end terminals, an insulating support for supporting said thin metallic film element, a container surrounding said element and supporting said terminals, in said container a fluorocarbon liquid immersing said element and whose temperature of vaporisation is below the temperature of fusion of said element.

3. An electric fuse according to claim 2 wherein the liquid occupies only a part of the volume of the container.

4. In an electric fuse for an electrical circuit having semiconductor devices therein,

a thin metallic fuse element connected between two end terminals, said thin metallic fuse element having a high ratio of surface area to volume,

a closed container surrounding said element,

in said container a heat dissipating dielectric liquid immersing said thin metallic fuse element, said heat dissipating dielectric liquid having a temperature of vaporization below the temperature of fusion of said thin metallic fuse element,

said container having a large surface area relative to that of said thin metallic fuse element so as to rapidly dissipate heat from the dielectric liquid to maintain the temperature of the liquid dielectric below the boiling point thereof when current through the fuse is below the rated capacity of the fuse,

whereby, as current through said fuse element is increased to the rated capacity thereof the liquid dielectric boils vigorously on the surface of said thin metallic fuse element and large bubbles are formed which thermally insulate the said fuse element from the liquid dielectric and the cooling effect of the dielectric, to allow the fuse to melt with extreme rapidity.

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