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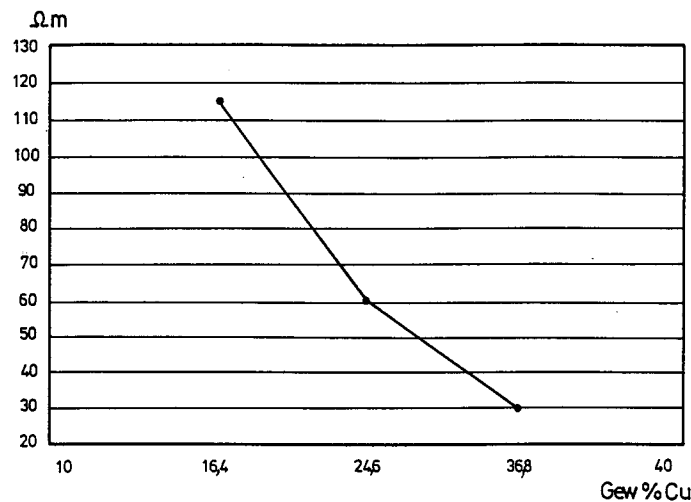
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D-20308 Hamburg (DE)54 **Electrical conductor having an insulation of plastic material.**

57 An electrical conductor comprising an insulation of plastic material, characterized by an integral body made of a mixture of said plastic material and a content of metallic fibers, said fibers having a small cross-sectional dimension relative to the length, said body being molded by injection molding or extrusion, respectively, such that during said molding process said metallic fibers substantially concentrate in the central portion in view of the flowing direction of the molding process whereby a well-conductive conductor portion is formed.

**FIG. 1****EP 0 674 326 A2**

The invention refers to an electrical conductor having an insulation of plastic material.

BACKGROUND OF THE INVENTION AND PRIOR ART

5 Electrical cable connections for the low and medium voltage range are located in housings or enclosures which are to meet a plurality of requirements. The most important is to provide for an electrical insulation between the components of the connection and the outer side of the housing. A further condition is that upon deterioration or mechanical damage of the housing a short current path is to be established for security reasons. To this purpose, a sufficient conductivity is to be provided. In the state of the art, these
10 conditions are met by various structural solutions.

It is known to enclose an electrical connection by a metallic housing which is coated with an insulating material. It is also known to make a housing of plastic material conductive by coating the inner side with metal by a flame plating process. It is further known to place the metallic housing into an injection mold and to coat the outer side with plastic material by an injection molding process. It is further conceivable to cover
15 a grid or a net of metallic material with plastic material. A metallic housing for an electrical connection can be also wrapped with an insulation tape. Alternatively, a plastic housing can be wrapped with an electrically conductive tape.

All known embodiments require several production steps and thus are correspondingly expensive.

It has been further become known to make plastic material conductive to a limited extent by the
20 addition of carbon black, metallic powder, metallic fibers or the like. Such plastic material can be used for shielding signal conductors, electronic components or the like. The specific resistance of such shieldings is relatively high. Therefore, such conductive plastic material cannot be used for the conduction of larger currents as is required in case of housings for cable connections for the low or medium voltage range. The desired short currents are in the range of kiloampere.

25 Semiconductive synthetic materials having a relatively large specific resistance are used for anti-electrostatic purposes. They serve to discharge electrostatic charges. The currents occurring are relatively small.

From the JP60 (1985)162778 it has become known to make plastic material conductive by the addition of particles having a conductive coating. The synthetic material achieved thereby serves for shielding
30 purposes.

From the JP63(1988)277279 and the JP63(1988)251468 it has become known to coat conductive fibers, e.g. of copper, with thermoplastic resin and to add the coated fibers to a plastic matrix together with a metallic powder, a low melting metal and a flow promoter in order to achieve a conductive plastic material for shielding purposes. The metallic fibers, in particular copper, are collected to a bunch and are drawn
35 through a bath or a mold for coating purposes. Thereafter, the bunch is cut into granulate material, e.g. to a length of 6 mm. This method leads to a relatively small specific resistance in the range of 3×10^{-3} ohmcm with improved shielding properties. Such a plastic material, however, is not suited to conduct a current in the range of amperes or even kiloamperes. This requires a specific resistance in the range of 10^{-3} ohmcm.

40 SUMMARY OF THE INVENTION

The invention provides an electrical conductor which can be easily manufactured with an outer configuration adapted to desired space requirements.

45 The invention provides an integral body which is made from a mixture of plastic material and a content of metallic fibers having a small cross-sectional dimension relative to their length by injection molding or extrusion, respectively. It is made such that the metallic fibers with respect to the flow direction during the molding process substantially concentrate on the central or medium area so that a high conductive conductor portion is formed.

The invention makes use of the observation that during injection molding or extrusion in the mentioned
50 composition the metallic fibers do not distribute uniformly in the molded body, rather concentrate on an area which lies in a plane wherein the material exits from the extrusion or injection nozzle. By the publication "Plastics" 74 (1984) "Fiber orientation during the molding of thermoplastic materials reinforced with short fibers", pages 271 to 277, it has become known to achieve the described distribution and orientation in connection with plastic glass fibers. It is understood that the configuration and the sizes of the
55 gates of the tools influence the flowing behaviour of the fibers. The expert is regarded in a position to simply investigate the optimum geometry and the sizes of the respective gate.

If for example a plate-like body is to be molded, the metallic fibers concentrate substantially in the medium area of the plate-like body so that a good conductivity is achieved for orthogonal directions while in

a direction perpendicular to this plane, the insulation of the plastic material becomes effective.

With the invention, an integral conductive body is achieved which can be manufactured in a single working step. With a corresponding high concentration of metallic fibers, conductivity values can be achieved in the order of magnitude of metallic conductors.

5 The invention has also the advantage that the external configuration of the conductor can be chosen arbitrarily in adaptation to desired requirements. If for example a housing for a cable connection is to be made, the molding of the housing or parts of the housing of suitable plastic material a suitable conductive portion can be molded in conjunction therewith which is in a position to conduct a high current in case of a short circuit current. On principle, the applicability of the conductor according to the invention is unlimited.
10 A primary application can be seen where relatively small lengths, e.g. 1 to 100 mm are required for the transmission of energy and/or signals.

The metallic fibers used for the conductor of the invention are essentially circular or oval in cross section and have to have a relatively large length, e.g. 5 to 15 mm. On the other hand, they have a relatively small thickness or diameter, e.g. 35 to 200 μm . The ratio between length and diameter is in the
15 overall range of 50 to 500, particularly 240.

According to an embodiment of the invention, the metallic fibers are of a compound material wherein the fibers are extending substantially parallel and are bonded to each other by a polymeric adhesive substance. Thereafter defined lengths are cut. Such a granulate is known from the DE 38 10 598. The following materials would be suitable as coating agents: polyamide 6, glass-fiber reinforced polyamide, polycarbonate polymers, acrylonitril-butadiene-styrene or the like. It serves for the production of molded parts
20 for the shielding of electromagnetic radiation. In the invention, however, plastic material and metallic fibers are used for the production of an electrical conductor having a resistivity preferably smaller than 10^{-3} ohmcm.

The matrix material is to be compatible with the used coated metallic fibers and suited to be mixed with the fibers. It is preferred to use polyamides, specifically polyamide 6.6, polyamide 6, polyamide 4.6, or polyamide 10 or polyamide 11. Alternatively, polyester, terephthalate such as PBT or PET, polycarbonates or aromatic polyamides could be used. The matrix material influences the electrical conductivity.

According to a further embodiment of the invention, the metallic fibers are of a metal of high conductivity in the range of 10 to 60 $\text{m}/\text{mm}^2 \Omega$ and preferably of Cu, Ag, Fe, Ni, Co or of alloys thereof also
30 in conjunction with other metals. It is particularly advantageous to use copper fibers.

For the manufacture of the conductor, a relatively large content of metallic fibers is necessary. For the conduction of relatively high currents it is appropriate to add coated metallic fibers up to 50 weight per cent. For conventional application purposes, e.g. the production of housings for cable connections, it may be sufficient to limit the content of coated metallic fibers between 20 to 35 weight per cent.

35 According to a further preferred embodiment of the invention, glass fibers having a length smaller than 1 mm are added to the composition of a plastic matrix and metallic fibers. The content of glass fibers can be up to 30 weight per cent. Preferably, in a manner known per se the glass fibers are coated with a suitable coating agent, e.g. silane.

It has turned out that also the glass fibers substantially concentrate on a medium area and do not arrive
40 at the surface of the body molded. Furthermore, glass fibers appear to have the property to improve the contacting of the individual copper fibers during the mixing and the molding process. Basically, a good balance between the metal fibers and the glass fibers is to determine. The glass fibers prevent a separation of the metal fibers and allow to obtain a more homogenous component. The flowing characteristics of the matrix should not be too good because in this case the metal fibers and glass fibers would be separated.
45 For a good homogeneity it is necessary to avoid any separation effect.

The following table is indicating the relationship between the matrix material and the resistance or resistivity, respectively:

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Table 1

Material Name	Material Identification	Cu fibers % by weight	Resistance m Ω	Resistivity Ω cm
Pocan B4235	Polybutylentheraphthalat 30% Glass	16.4	25	$2 \cdot 10^{-3}$
		24.6	10	$8 \cdot 10^{-4}$
		36.8	5	$4 \cdot 10^{-4}$
IXEF 1503	Polyarylamid 30% Glass	16.4	56	$4 \cdot 10^{-3}$
		24.6	14.5	$1 \cdot 10^{-3}$
		36.8	7.4	$6 \cdot 10^{-4}$

15 BRIEF DESCRIPTION OF THE DRAWINGS

The invention is subsequently explained with reference to the accompanying drawings, wherein

Fig. 1 is a diagram, wherein the specific resistance of a test bodies made according to the invention is shown in dependence of the content of copper fibers;

Fig. 2 shows a test body having the features according to the invention;

Fig. 3 is a diagram, wherein the voltage in dependence of the current in a test body according to the invention is depicted;

Fig. 4 shows the surface temperature of the test body in dependence of the current; and

Figs. 5 to 7 show embodiment examples for a conductor according to the invention.

25 DETAILED DESCRIPTION OF THE DRAWINGS

Rectangular and circular plates are made for test purposes. The rectangular plates had the sizes 152x76x3.2 mm. The circular plate had a diameter of 140 mm and a thickness of 3.2 mm. For the manufacture, a matrix of polyarylamide is used added by 30 weight per cent short glass fibers (length smaller than 1 mm). In a standard mixing procedure, this matrix material is mixed with copper fibers which are made according to the German patent specification 38 10 598, e.g. coated with a polyamide. This is a compound granulate material provided with parallel extending metallic fibers, e.g. copper fibers which are bonded by a polymeric adhesive substance. These copper fibers are coated with a suitable plastic material, examples thereof described in the mentioned publication. The mixing ratio is between 16 and 36 weight per cent of pure copper, with the content of the coating is substantial 13% weight per cent.

The plates achieved are measured according to DIN 53.482 VDE. It can be derived from Fig. 1 that with a content of 30 weight per cent copper, the resistivity is significantly below 50 ohmm.

With the plates having a diameter of 140 mm, the following values have been measured according to DIN 53.482:

Material	Conductivity in ohm m	
	in flowing direction	perpendicular to the flowing direction
IXEF 1503, 16.4 % Cu	73	41
IXEF 1503, 24.6 % Cu	19	10
IXEF 1503, 36.8 % Cu	9	6
Steel plate 1 mm thickness	0.6	0.6
Aluminum plate 1 mm thickness	0.12	0.12
IXEF 1503 is an aromatic polyamide of Solvay.		

From the table it can be derived that the conductivity of the conductor according to the invention is only one order of magnitude smaller than that of steel.

It is to be mentioned that the test plates are made by injection molding process. With this process, test bodies are produced which are shown in Fig. 2. With these test bodies, the copper fibers are completely embedded by the plastic matrix so that the test body is a completely insulated electrical conductor, e.g. an insulated cable. The copper fibers do not define a solid conductor rather, the conductive portion can be

compared with a so-called braided conductor.

A voltage is applied to the probe body at a distance of 115 mm. The current flowing has been measured, with such measurement shown in Fig. 3. The upper curve corresponds to a content of 36 weight per cent of copper while the lower curve corresponds to a content of 24.6 weight per cent of copper fibers.

5 For both compositions, temperature measurements have been made at the locations a, b and c. The course of the surface temperature is shown in the diagram of Fig. 4. From Fig. 4 it can be derived that in the range of some amperes the rise of temperature is below 10 °C if referred to an environmental temperature of 20 °C. In case of substantially higher currents, a rise of temperature beyond 60 °C can be observed.

10 Fig. 5 shows an injection molded conductor 10 having a circular cross section produced from a mixture of copper fibers 12 and plastic material 14 (Examples for the materials are indicated above). The optimum plate arrangement for the manufacture of the conductor would be to use a circular gate in the middle of the circular end of the conductor. The diameter should be in the range of 0.5 to 1.0 mm. This would allow to make a conductor of a diameter of 5 mm and a length of 300 mm.

15 Fig. 6 shows an injection molded flat conductor 18 rectangular in cross section having copper fibers 20 and a plastic material 22. In both cases, it can be clearly seen that the fibers 12 or 20, respectively, concentrate on the central portion while the outer skin 24 or 26, respectively, is free from fibers. The optimum gate in this case would be to produce a so-called "film gate" which is a gate of a rectangular dimension arranged at the rectangular small side of the conductor, preferably on the upper edge, extending
20 over the entire width with a thickness of 0.5 to 1.0 mm. This, for instance, would allow to make a conductor of a rectangular cross section with a width of 20 mm and a height of 2 mm and a length of 200 mm.

In Fig. 7, a corner 28 of a housing is shown in a perspective view which is also made by injection molding, with the wall portions of plastic material 30 and copper fibers 32. The copper fibers 32 concentrate on the medium plane while the outer skin 34 has no fibers. This is a more complex configuration and here
25 necessitates either a combination of small circular gates as well as several film gates could be thought of.

Claims

- 30 1. An electrical conductor comprising an insulation of plastic material, characterized by an integral body made of a mixture of said plastic material and a content of metallic fibers, said fibers having a small cross-sectional dimension relative to their length, said body being molded by injection molding or extrusion, respectively, such that during said molding process said metallic fibers substantially concentrate in the central portion with respect to the flowing direction of the molding process whereby a well-conductive conductor portion is formed.
- 35 2. The electrical conductor of claim 1, wherein the metallic fibers have a length of 5 to 15 mm.
3. The electrical conductor of claim 2, wherein the metallic fibers have a length of 8 to 12 mm, preferably 10 mm
- 40 4. The electrical conductor of claim 1, wherein the metallic fibers have a diameter or a thickness of 35 to 200 μm .
- 45 5. The electrical conductor of claim 1, wherein the ratio of the length and the diameter or thickness of said fibers is between 50 and 500, preferably approximately 240.
6. The electrical conductor of claim 1, wherein the metallic fibers are coated with a thermoplastic material.
- 50 7. The electrical conductor of claim 1, wherein the metallic fibers are part of a compound material, wherein the fibers are extending parallel and are bonded by a polymeric adhesive substance and cut into defined lengths thereafter.
8. The electrical conductor of claim 1, wherein the metallic fibers are of a metal having a high electrical conductivity with a range of 10 to 60 $\text{m}/\text{mm}^2 \Omega$, particularly of Cu, Ag, Fe, Ni, Co or of alloys thereof or in conjunction with other metals.
- 55 9. The electrical conductor of claim 1, wherein the content of coated metallic fibers is up to 50 weight per cent, preferably between 20 and 35 weight per cent.

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10. The electrical conductor of claim 1, wherein glass fibers are added having a length smaller than 1 mm.

11. The electrical conductor of claim 10, wherein the content of glass fibers is up to 30 weight per cent.

5 **12.** The electrical conductor of claim 10 or 11, wherein the glass fibers are coated with a coating agent.

13. The electrical conductor of claim 1, wherein the specific resistance is smaller than 10^{-3} ohmcm.

14. The electrical conductor of claim 1, wherein said body is shaped as a plate, a block or a rod.

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15. The electrical conductor of claim 1, wherein the plastic material is resilient.

16. The electrical conductor of claim 1, characterized by its application to housings, casings or the like having conductive walls, in particular for cable connections in the low and medium voltage range.

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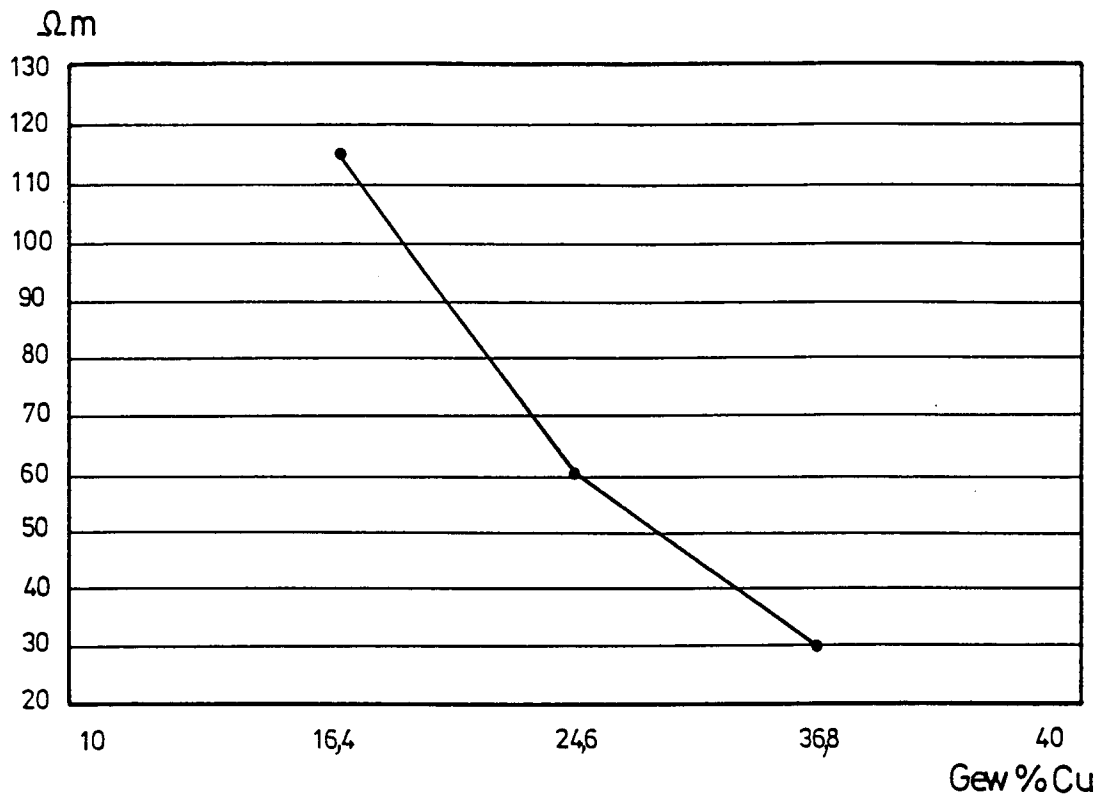


FIG. 1

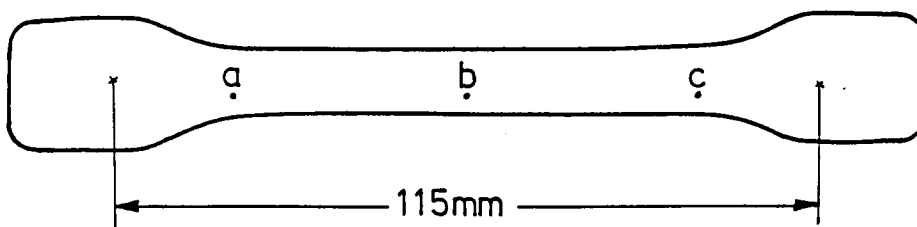


FIG. 2

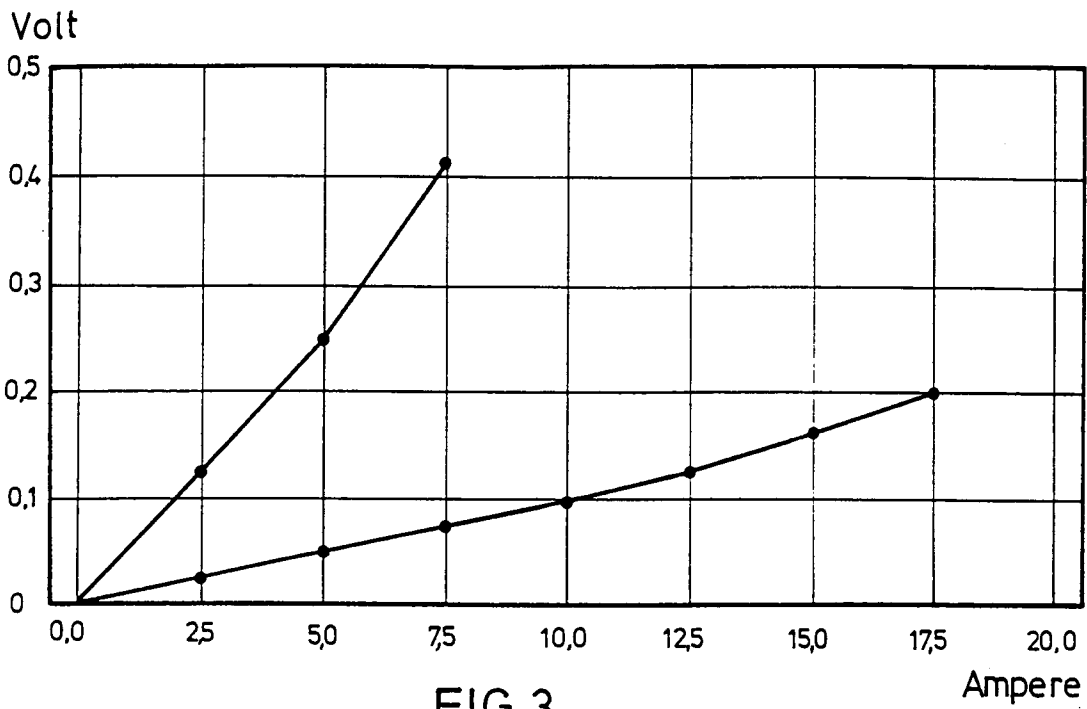


FIG.3

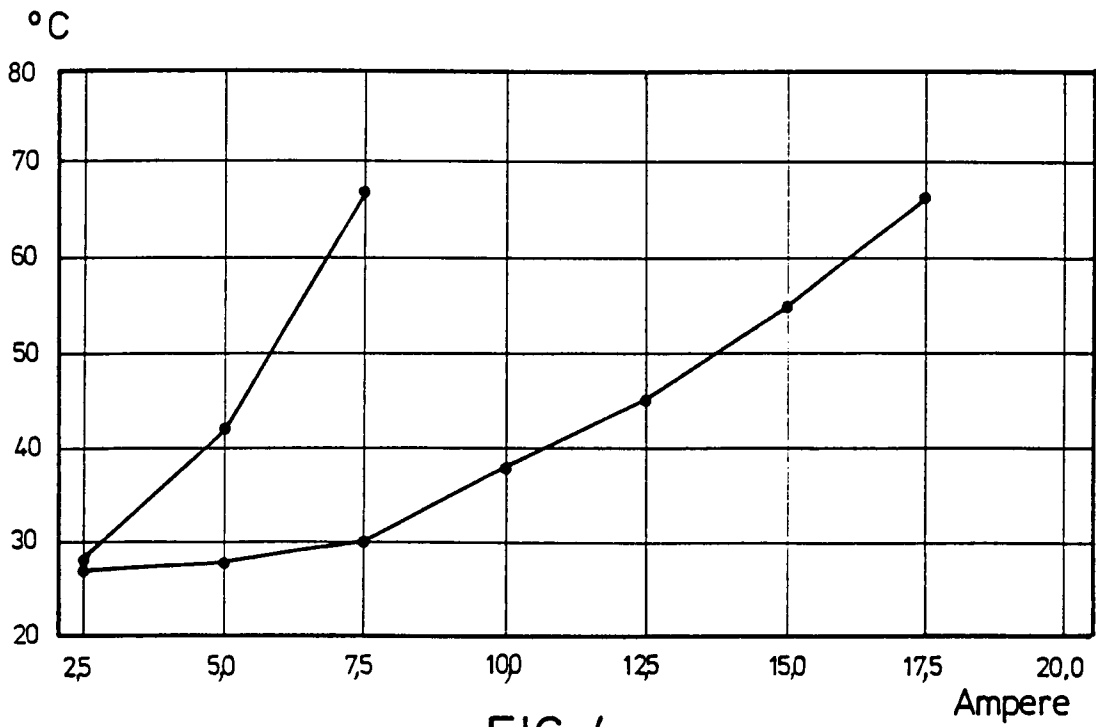


FIG.4

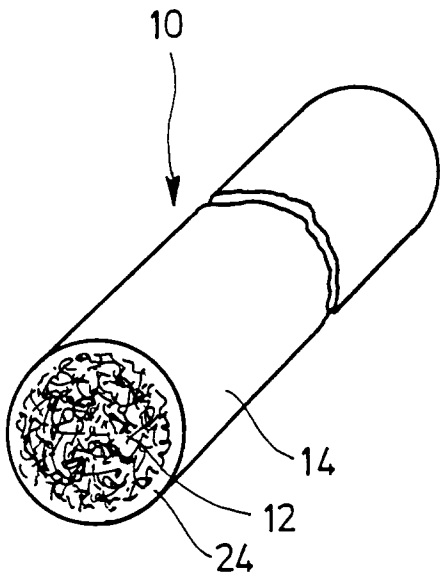


FIG. 5

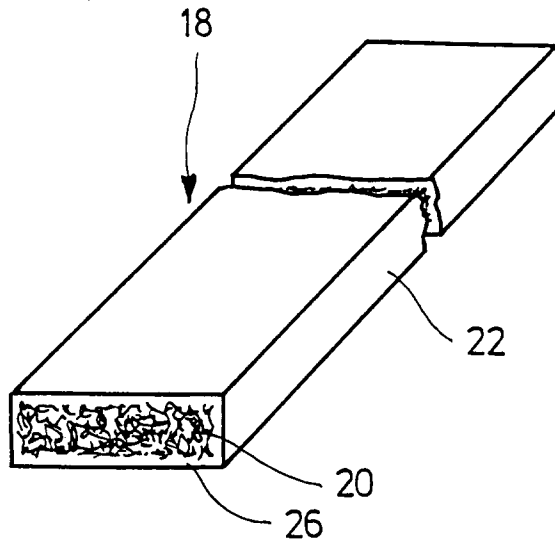


FIG. 6

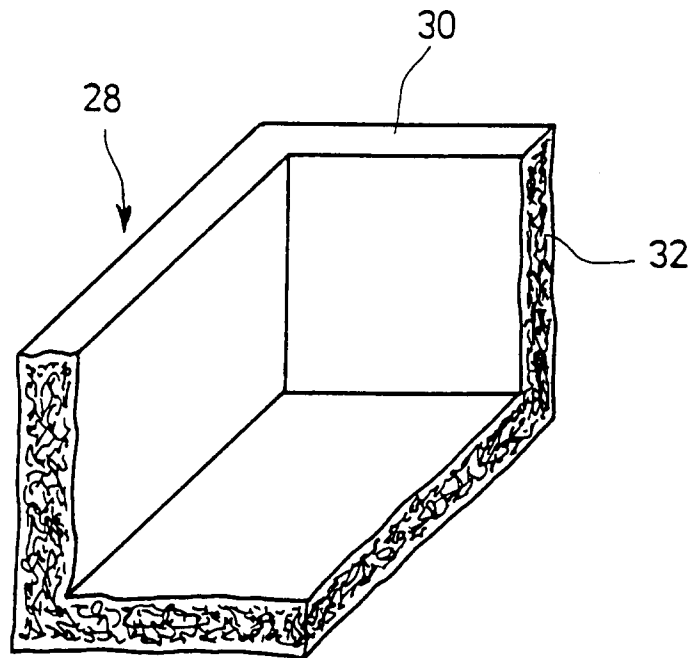


FIG. 7