

Dec. 6, 1960

V. F. DAHLGREN

2,963,538

FLAT CABLES

Filed April 11, 1957

3 Sheets-Sheet 1

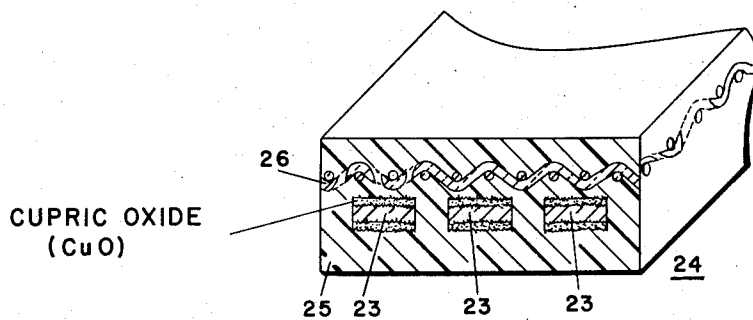


Fig. 2

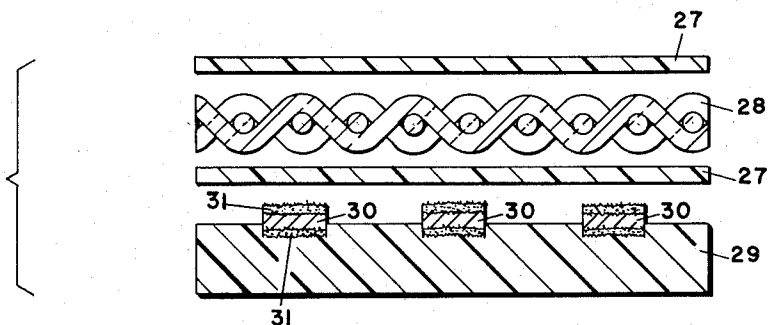


Fig. 3

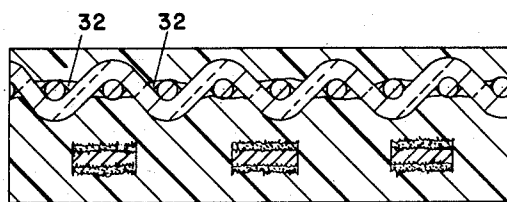


Fig. 4

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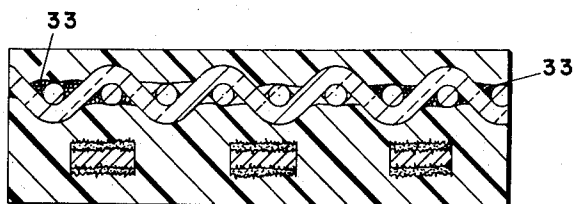


Fig. 5

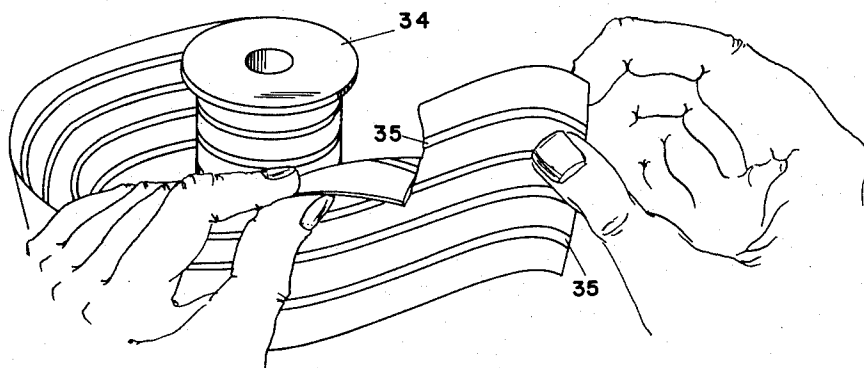


Fig. 6

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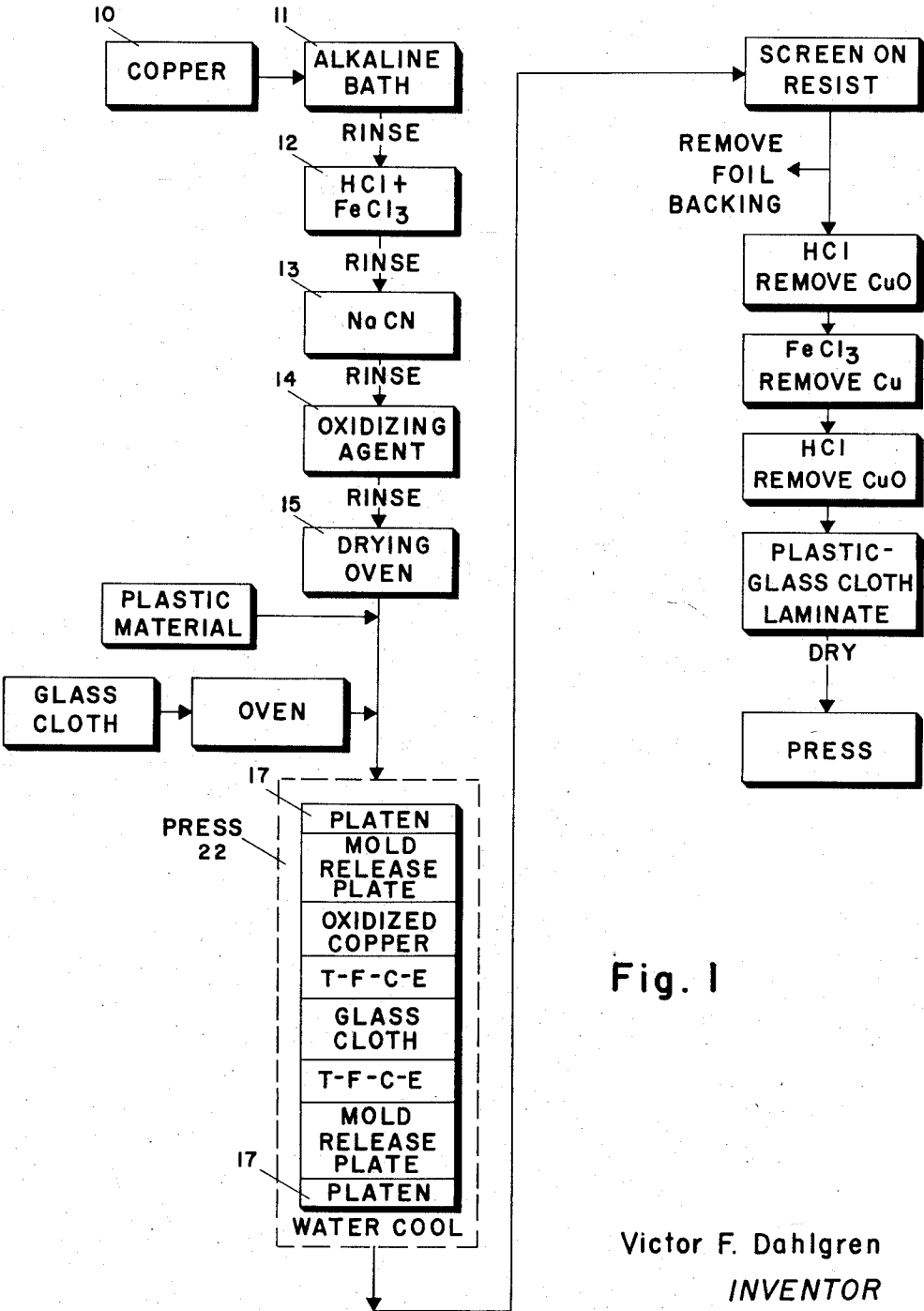
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3 Sheets-Sheet 3



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2,963,538

FLAT CABLES

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6 Claims. (Cl. 174-117)

The present invention relates to plastic-copper articles and, more particularly, to printed circuit type articles such as flat flexible cabling utilizing copper conductors bonded to a wide range of plastic materials such as trifluoro-chloro-ethylene. The invention also relates to the method of manufacture of articles of this type. The present application is a continuation-in-part of the copending application Serial No. 598,170, filed July 16, 1956, by the same inventor.

As more fully disclosed in the copending application, printed circuit articles have been developed providing, in printed circuit form, the equivalent of the conventional multi-conductor cables. The printed circuit type of cable assumes the form of a flat, relatively thin sheet of plastic material having flat, thin conductors all in the same plane or at most in a few superimposed planes. In one form of such cable, the conductors are of uniform width and separated by a uniform distance. The problems of bonding conductors to the different plastic materials used and the methods employed to solve these problems are fully disclosed in the copending application and, to some extent, are also considered herein. The present invention is directed to improvements on the concepts disclosed in the copending application which provide solutions for problems arising from the nature of the plastic materials employed.

In forming plastic cabling of the printed-circuit type there arise, among others, the problem of maintaining dimensional stability or relative spacing of the copper conductors in the plastic material during all phases of manufacture and use. For example, if the conductors are terminated in critically spaced terminals, it is of extreme importance that the spacing between these terminals and that the configuration or pattern of terminals remain fixed during all the manufacturing processes and later when the cabling is in use. Additionally, in utilizing plastic cable there is the problem of cutting or otherwise separating it into desired lengths. For example, arbitrary lengths of cabling may be needed from a much longer length or reel of cable. The present invention is primarily directed to providing the dimensional stability needed and to facilitating the severing of the cabling into arbitrary lengths.

It is therefore an object of the present invention to provide new and improved plastic-copper articles which do not have the limitations or deficiencies of prior such articles.

It is a further object of the present invention to provide a new and improved plastic-copper article which has a degree of dimensional stability surpassing that of prior such articles.

It is a further object of the present invention to provide new and improved plastic-copper articles, particularly flat flexible cabling, which may be simply and easily severed into desired lengths.

It is also an object of the present invention to provide

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new and improved flat cabling which is rippable and provides a clean, regular edge when ripped.

In accordance with the present invention, there is provided a thin, flat, flexible, laminated cable comprising a base of thermoplastic material. A flexible planar conductor is laminated to the base for providing a base laminate. An insulating cover layer including a layer of glass fibre fabric and insulating thermoplastic material is laminated to the base laminate. The glass fibre fabric has fibres bonded to and encapsulated by the thermoplastic insulating material. In addition, the glass fibre fabric extends to the edges of the laminate, and has a total thickness no greater than the base for providing a laminated cable no greater than .015 inch thick.

As used herein the term "plastic" means a synthetic organic material whose principal component is a resinous cellulose derivate binder organic compound. The term "thermoplastic" is intended to apply to all those plastic materials which tend to flow at given temperatures. The term "fusible thermoplastic" means those plastic materials which reach a heat distortion point or no-strength condition before being substantially decomposed under the influence of heat. The term "ethylene" includes all those plastic materials retaining the ethylene radical substantially intact and the term "vinyl" includes all those plastic materials in which at least one of the hydrogens is displaced by an electro-negative element or radical.

For a better understanding of the present invention, together with other and further objects thereof, reference is made to the following description taken in connection with the accompanying drawings and its scope will be pointed out in the appended claims.

In the drawings:

Fig. 1 is a flow chart illustrating the preferred process for manufacturing articles in accordance with the present invention;

Figs. 2, 3, 4 and 5 are sectional views of a sheet of copper bonded to a plastic-fiber-fabric laminate in accordance with the invention; and

Fig. 6 is a perspective view illustrating an aspect of a plastic-fiber-fabric-copper laminate.

TRI-FLUORO-CHLORO-ETHYLENE-COPPER
ARTICLE

Referring now to the drawings and with particular reference to Fig. 1, a method of manufacturing a trifluoro-chloro-ethylene-copper article including glass cloth layers will be described. The method is carried out in detail in the following manner:

Sheets of copper 10 are:

(1) Immersed in a mild alkaline bath 11 such as Dy-Clene EW metal cleaner, as manufactured by MacDermid, Inc., of Waterbury, Connecticut for five seconds;

(2) Rinsed in cold, running water for five seconds;

(3) Dipped for 15 seconds in a 10 percent solution of hydrochloric acid (HCl) 12 containing a small amount of ferric chloride (FeCl_3);

(4) Rinsed in cold, running water for five seconds;

(5) Immersed in a 10 percent solution 13 of sodium cyanide (NaCN) for 15 seconds and then rinsed;

(6) Immersed for 10 minutes at 190° F.-210° F. in an oxidizing agent 14, such as an aqueous solution of 1½ pounds per gallon of water of Ebanol "C" Special, as manufactured by Enthone Company, New Haven, Connecticut. The oxidizing agent is preferably a hot aqueous solution consisting essentially of an alkali selected from the group consisting of sodium hydroxide and potassium hydroxide and a chlorite selected from the group consisting of sodium chlorite and potassium chlorite;

(7) Immersed in cold, running water;

(8) Rinsed in hot, running water for 10 to 20 seconds; and

(9) Baker in a preheated oven 15 at a temperature above 212° F. until all traces of moisture are removed.

These steps result in providing a sheet of copper having a cupric oxide surface obtained by utilizing a chemical agent rather than by applying heat as in the prior art. The cupric oxide obtained in the manner described in steps 1 to 9 above is quite different from that obtained by heating. It appears as a homogeneous, velvety black coating. The black is intense. Under a microscope of greater than 300 power, the crystals of oxide appear fine and needle-like and are much smaller than those obtained when copper is heated. Further, and probably most important, this cupric oxide differs from that obtained by heating in that it is tightly bonded to the copper and will not flake off.

The copper sheets obtained by means of steps 1 to 9 above are now ready for lamination to a plastic and glass cloth combination. The lamination process is, for example, as follows:

(10) Place a sheet of thin, metallic-foil mold release plate, such as aluminum, on the platen of a press 22, such as manufactured by Wabash Press Company, Wabash, Indiana; the aluminum foil is used to prevent adherences between the tri-fluoro-chloro-ethylene and the platen;

(11) Place a lamination of a sheet of plastic material, a sheet of glass cloth and another sheet of plastic material on the platen 17 of the press 22. This lamination may have as many layers as desired, for reasons to be considered more fully hereinafter, alternating plastic and glass cloth but having outside layers of plastic. The plastic may be, for example, tri-fluoro-chloro-ethylene and each sheet may be, for example, 6 inches long, 2 inches wide and 2 mils thick. Prior to use in the laminate, the glass cloth is heated to remove all organic and contaminating material. The temperature of the oven is, for example, 400° C.;

(12) Place a sheet of copper, coated in accordance with steps 1 to 9 on top of a tri-fluoro-chloro-ethylene layer of the laminate and apply an initial pressure of approximately 5 pounds per square inch, gradually increasing the pressure;

(13) Bake under pressure at 216° C. to 219° C. for 40 seconds;

(14) Remove the copper clad plastic from the press and quench in cold water; and

(15) Remove the aluminum foil.

This process provides a plastic copper clad which may be used for any of a number of purposes. Though definite pressures and temperatures are mentioned above, the pressures, times and temperatures are interrelated and vary also with the thickness, area and type of plastic material used. Generally, the temperature is in the range of 215° C.-300° C., the initial pressure being of the order of 5 pounds per square inch but building up to higher pressures which may be of the order of hundreds of pounds per square inch. The parameters are time-temperature, primarily and, to some degree, time and temperature, in terms of the pressure applied, may be interchanged.

The plastic can, of course, be copper clad on both sides merely by placing sheets of copper both above and below the plastic. Similarly, a number of sheets of plastic may be intermixed with cupric oxide coated sheets of copper to form a laminated structure. The glass cloth provides dimensional stability assuring accurate and constant positioning of the copper and also provides an article which is relatively impervious to accidental damage but which will rip cleanly and neatly along a path between glass fibers. The copper conductors are not damaged by the ripping. This feature is exemplified in Fig. 6.

Another method for effecting the bond involves the use of a rotary press. The rollers are heated to a tem-

perature of 215° C. to 250° C. and thermostatically maintained. The copper-plastic bond is effected by covering a sheet of plastic, such as tri-fluoro-chloro-ethylene with two sheets of cupric oxide coated copper and introducing the composite article between the rollers. Preferably, the rollers are spaced so as to apply a positive pressure greater than 5 pounds per square inch, and are rotated at such a rate as to provide a linear speed of, for example, 10 inches per minute, to the sheets.

The bonding time varies with the mass of the supporting plate in the press and the starting temperature of the press. By using very thin material, very small coils of transmission line, transformers and chokes may be produced. For example, a strip of the material 7/4 inches long by .002 inch thick with a .00135 inch copper conductor, may be rolled into a coil having a diameter of 3/16 of an inch. In one application of the present invention, a cable one inch wide contains 21 conductors with 42 separate terminations at either end. In this application the conductors were encapsulated in tri-fluoro-chloro-ethylene affording an extremely tough and flexible cable though easily rippable into desired lengths.

A modified form of the improved method of bonding tri-fluoro-chloro-ethylene to copper involves the use of powdered tri-fluoro-chloro-ethylene which is spread on top of a sheet of cupric oxide covered copper. For un-plasticized powder of high molecular weight the operating temperature range may be as high as 300° C. After placing the powder in contact with the copper (and, if desired, applying another sheet of copper on top of the powder), the press is closed at the rate of .2 inch per minute until the desired thickness is obtained as determined by gauge blocks. By shining a light through the material a color change will be observed from pink to white. After the white light appears the press is held in place for 15 to 30 seconds, depending upon the thickness of the material desired. The composite sheet thus obtained is then quenched in cold water or transferred to a cold press. In both processes immediate quenching produces crystallization and thus a relatively high degree of transparency. The glass cloth and other layers of plastic can be added as desired.

The bond strengths obtained as measured by delaminating a one inch strip of copper from the tri-fluoro-chloro-ethylene are consistently greater than 8 pounds per inch. Bond strengths of 18 pounds per inch and higher are obtainable. For example, laminates prepared by starting with the tri-fluoro-chloro-ethylene powder as indicated above are characterized by bond strengths which are consistently in excess of 15 pounds per inch.

To manufacture a component of an electric circuit, the copper of the article prepared in the manner described above may be treated as indicated in the remainder of the flow chart of Fig. 1. A resist is placed on the copper in the pattern of a desired configuration and the excess removed by a suitable etching technique. The remaining resist is removed and the circuit may then be encapsulated by placing a sheet of plastic-glass cloth laminate in contact with the coated copper and sealing by means of pressure in the manner described above.

TETRA-FLUORO-ETHYLENE—COPPER ARTICLE

Using the same apparatus and general procedure as outlined in Fig. 1, and differing only in the plastic to copper bonding process, a thin sheet of Teflon, for example under .010 inch thick, is placed in contact with a sheet of cupric oxide coated copper foil, for example, 2 ounce copper, and placed in the press 22. The plastic-copper laminate is preheated at approximately 700° F. for several minutes and then pressed at that temperature and in the order of 250 pounds per square inch pressure for about 6 minutes. The laminate is then water cooled in the press under continued pressure. Bond strengths have been observed as high as 8 pounds per inch.

A number of compounds which typify large classes of plastic materials have been laminated to cupric oxide coated copper in the manner suggested above. The temperature, pressure, preheat time under slight pressure, heating time under pressure, the thickness of copper used, the thickness of the plastic and the resultant peel strengths are tabulated below for a number of materials utilized.

Parameters for bonding copper to plastic

	Temperature of Materials (°C.)	Pressure (Lbs./In. ²)	Time of Preheat (Minutes)	Minimum Time in Press (Minutes)	Thickness of Copper (10 ⁻³ In.)	Thickness of Plastic (10 ⁻³ In.)	Peel Strength (Grams/Inch)
Ethylenes:							
Polyethylene.....	127	70-80	1	4	1.35	-----	² >3,000
Kel-F.....	234	120-150	5	6	1.35	10	4,200
Teflon ¹	380	120-150	5	6	2.70	10	1,650
Vinyls:							
Polyvinyl Chloride.....	220	120-150	1	4	1.35	10	3,100
Polyvinyl Butyral.....	193	120-150	1	4	2.70	8.5	3,300
Polyvinyl Acetate.....	200	120-150	1	4	2.70	10	3,100
Polyvinyl Alcohol ¹	205	325-350	1	4	2.70	11	5,500
Saran:							
Polyvinylidene Chloride.....	180	120-150	1	4	2.70	12	(³)
Polyvinylidene Styrene.....	205	120-150	5	6	2.70	31	2,500
Polyamides:							
Nylon NC-10 ¹	250	325-350	5	6	1.35	Crystals	4,000
Celluloses:							
Cellulose Acetate ¹	193	120-150	1	4	2.70	30	7,260
Acrylics:							
Methyl Methacrylate (Plexiglas) ¹	250	325-350	5	6	2.70	66	2,000
Rubber Hydroxide ¹	122	120-150	1	4	1.35	9	Decomposes

¹ Press—water cooled.

² Tearing of polyethylene.

³ Turned brown—tearing of material at 1500 grams.

The plastic-copper bonding mechanism is not thoroughly understood. However, as a result of much experimentation and analysis, it is believed that the bonding mechanism is essentially mechanical. One basic requirement seems to be that the plastic material must flow fairly readily without decomposing. As indicated in the previous table, some of the materials tend to decompose before the desired melt-viscosity is reached even though a satisfactory bond may still be obtained. In the case of some forms of Teflon the degree of plasticity increases with temperature, but the material tends to decompose or sublimate before it reaches a suitable flow point. It will be apparent, however, that while a degree of flow is necessary to cause the plastic material to fill the interstices formed by cupric oxide needles, more or less randomly oriented, a good bond is obtainable even though ideal flow conditions are not realized. In the case of the polyvinyl material it has been frequently observed that the bond is stronger than the plastic material itself. Thus, for polyvinyl chloride and polyvinyl acetate the peel strength is indicated on the order of 3000 grams. This is the pulling force at which the plastic material broke.

GLASS FIBER-PLASTIC COPPER LAMINATE

Referring now to Figs. 2-5, inclusive, there is here illustrated a copper-plastic article, for example a flexible printed circuit cable, in which a plurality of copper conductors 23 are embedded in contact with an insulating panel 24. The panel 24 is formed from a laminate of plastic material 25 such as Kel-F and a sheet of fiber fabric in the manner described above. As previously stated, the fabric is preferably formed from glass fibers. The plastic material is sealed through the interstices of the fabric 26 to provide an insulating panel substantially impervious to humidity. It has been found that a high quality seal is obtainable if the total thickness of fluorocarbon is greater than or equal to approximately the thickness of the glass fiber fabric. If the thickness of the fluorocarbon is substantially less than the thickness of the glass fiber fabric, either the fabric will be only partially encapsulated or an air space will exist between the layers of fluorocarbon. See,

for example, the space 32 in Fig. 4. This results from the fact that it is difficult to develop pressures high enough to make the plastic flow and fill the voids in the fiber. The degree of heat employed is also important. If the fluorocarbon is heated to a high temperature, for example 600° F., its viscosity decreases to approximately 10⁶ poises, a relatively low viscosity, and it flows into the interstices of the fabric to result in

partial encapsulation. This is evident by the flow identified at 33 in Fig. 5. If the lamination of fluorocarbon and glass fiber fabric occurs at 400° F., its viscosity is in the order of 10⁸ poises and only a limited degree of flow into the fabric takes place; hence, air spaces between the encapsulating layers of fluorocarbon are introduced. This permits humidity to permeate the laminate and reduce its insulation resistance. These spaces cannot be tolerated.

In Figs. 3, 4 and 5 a relatively thin layer of fluorocarbon 27, for example .002 inch, is laminated to a sheet 28 of glass fiber fabric which is relatively thick, for example .010 inch. Another layer 29 of fluorocarbon of the same thickness as the layer 28 is bonded to a plurality of copper conductors 30 having a thickness, for example, of .001 inch. A pair of surfaces of the conductors 30 are coated with cupric oxide 31 as shown. The oxide coatings are imprinted in the fluorocarbon to provide the bond.

A truly unobvious result is achieved when a suitable ratio of thickness of fluorocarbon and glass fiber fabric are laminated together. Sheets of fluorocarbon less than .005 inch are not easily torn without a cutting tool. Similarly, sheets of fiber glass fabric less than .005 inch are not easily torn. When a laminate is formed with outer layers of fluorocarbon each less than approximately .005 inch with a sheet of glass fiber fabric extending to edges of the laminate and being less than approximately .005 inch, the laminate is readily rippable into desired arbitrary lengths by hand as illustrated in Fig. 6. Here a coil 34 of flexible printed circuit cable is shown, formed for example from two sheets of fluorocarbon each .002 inch thick and a sheet of glass fiber fabric .005 inch thick. A plurality of cupric oxide coated conductors 35 are embedded in the insulating panel provided by the fluorocarbon and the glass fiber fabric. The segment of the cable thus removed may be readily connected by inserting pointed prongs of a connector through the fluorocarbon and fabric to contact the conductors 35. This type of pressure contact is well known in the art and available commercially in a variety of configurations.

It is apparent from the above considerations that a plastic-copper article is prepared which has unusual di-

mensional stability and provides the desirable facility of being simply and easily rippable into lengths. Additional attractive features are the utilization of an exposed surface of glass cloth to provide an area readily adherent by conventional means to any desired surface.

While these has been described what is at present considered to be the preferred embodiment of this invention, it will be obvious to those skilled in the art that various changes and modifications may be made therein without departing from the invention, and it is, therefore, aimed in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of the invention.

What is claimed is:

1. A thin, flat, flexible, laminated cable comprising: a base of thermoplastic insulating material; a flexible planar conductor laminated to said base for providing a base laminate; and an insulating cover layer including a layer of glass fibre fabric and insulating thermoplastic material laminated to said base laminate, said glass fibre fabric having fibres bonded to and encapsulated by said thermoplastic insulating material, extending to the edges of said laminate, and having a total thickness no greater than said base for providing a laminated cable no greater than .015 inch thick.

2. A thin, flat, flexible laminated cable comprising: a base of thermoplastic insulating material less than .005 inch thick; a flexible planar conductor laminated to said base for providing a base laminate; and an insulating cover layer including a layer of glass fibre fabric having a thickness less than .005 inch and insulating thermoplastic material less than .005 inch thick laminated to said base laminate, said glass fibre fabric having fibres bonded to and encapsulated by said thermoplastic insulating material extending to the edge of said laminate and having a total thickness no greater than said base for providing a laminated cable no greater than .015 inch thick.

3. A thin, flat, flexible laminated cable comprising: a base of thermoplastic insulating material; a flexible sheet of conductive material laminated to said base, said conductive material being selectively removed to leave a conductor in a predetermined configuration and provide a base laminate; an insulating cover layer including a layer of glass fibre fabric and insulating thermoplastic material laminated to said base laminate, said glass fibre fabric having fibres bonded to and encapsulated by said thermoplastic insulating material extending to the edges of said laminate and having a total thickness no greater than said base for providing a laminated cable no greater than .015 inch thick.

4. A thin, flat, flexible laminated cable comprising: a base of thermoplastic insulating material; a flexible planar copper conductor having surfaces of substantially homogeneous black cupric oxide laminated to said base for providing a base laminate; and an insulating cover layer including a layer of glass fibre fabric and insulating

thermoplastic material laminated to said base laminate said glass fibre fabric having fibres bonded to and encapsulated by said thermoplastic insulating material, extending to the edges of said laminate and having a total thickness no greater than said base for providing a laminated cable no greater than .015 inch thick.

5. A thin, flat, flexible laminated cable, comprising: a base of thermoplastic insulating material less than .005 inch thick; a flexible sheet of conductive material laminated to said base, said conductive material being selectively removed to leave a conductor in a predetermined configuration and provide a base laminate; an insulating cover layer including a layer of glass fibre fabric having a thickness less than .005 inch and insulating thermoplastic material less than .005 inch thick laminated to said base laminate, said glass fibre fabric having fibres bonded to and encapsulated by said thermoplastic insulating material extending to the edges of said laminate and having a total thickness no greater than said base for providing a laminated cable no greater than .015 inch thick.

6. A thin, flat, flexible laminated cable comprising: a base of thermoplastic insulating material less than .005 inch thick; a flexible planar copper conductor having surfaces of substantially homogeneous black cupric oxide laminated to said base for providing a base laminate; and an insulating cover layer including a layer of glass fibre fabric having a thickness less than .005 inch and insulating thermoplastic material less than .005 inch thick laminated to said base laminate, said glass fibre fabric having fibres bonded to and encapsulated by said thermoplastic insulating material extending to the edges of said laminate and having a total thickness no greater than said base for providing a laminated cable no greater than .015 inch thick.

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