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(54) CABLE SHIELDING TAPE AND CABLE

(71) We, THE DOW CHEMICAL COMPANY, a Corporation organised and existing under the laws of the State of Delaware, United States of America, of Midland, County of Midland, State of Michigan, United States of America do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:

This invention relates to new and useful improvements for electrical cables adapted for use in supplying electrical power and communications and, more particularly, to an improved corrosion resistant cable shielding tape forming a part of such cables. More specifically, the present invention relates to cable shielding tapes comprising a relatively thin metal strip with one or more layers of polymeric resinous material adhered to at least one side thereof.

In the art of designing and constructing electrical cables, especially telecommunication cables such as telephone cables, it is known to assemble insulated conductors in a core and surround them by shield and jacket components. A well known telephone cable design of such construction is referred to in the art as an "Alpeth" cable. This type of cable is more fully described in the F. W. Horn et al paper "Bell System Cable Sheaths Problems and Designs" in A.I.E.E. Proceedings 1951, Volume 70. The shielding tape of the "Alpeth" cable is formed of a layer of bare aluminum having a thickness of about 8 mils which is usually corrugated transversely prior to being wrapped about the cable core. The corrugations impart greater flexibility to the cable and permit bending of the cable without wrinkling or rupturing of the shielding tape.

The term "shield, screen, or shielding tape" as used herein means a relatively thin layer of any metal, bare or coated, which can provide mechanical protection and electrostatic and electromagnetic screening for the conductors in the core of electrical power and communication cables.

When telephone cables are installed underground by being buried directly in soil, the outer jacket of such cables, which is formed of a polymeric resinous material such as polyethylene, may be subjected to damage due to the rigors of installation; rocks; rodents; lightning; frost; or dig-ins. The underlying shielding tape can thus be exposed to sub-surface water or brine and the attendant potential for corrosion.

Where the outer jacket of such cables is formed from a polymeric resinous material, the jacket is not well adhered to the shielding tape of bare metal. The outer plastic jacket is known to slip over the shielding tape and to fold up into shoulders as the cables are pulled through ducts or placed into trenches. The shielding tape is also known to kink, curl or twist during installation causing fatigue in the tape and, in extreme cases, rupture of the tape because of mechanical bending stresses exerted thereon.

In order to improve the corrosion resistance of a shielding tape of bare metal, a special adhesive polyethylene film may be applied to cover one or both sides of the metallic strip as taught in U.S. Patent Nos. 3,233,036 and 3,795,540. Such shielding tapes are widely used in the manufacture of electrical power and communications cables. The adhesive polyethylene used for this film contains reactive carboxyl groups which have the ability to develop film adhesion to the metallic strip and also to the overlying polyethylene jacket. The metal component of such shielding tapes provide electrostatic screening and mechanical strength to the cable; the polymeric resinous material coating, e.g., ethylene acrylic acid (EAA) copolymer coating, provides bondability, sealability and corrosion protection to the metal component. A metallic strip, such as aluminum, which is protected by the adhesive

polyethylene film normally has higher resistance to corrosion.

When a polyethylene jacket is extruded over the metallic strip coated with the adhesive polyethylene film, the heat from the semi-molten polyethylene jackets bonds the film coated metal strip to the jacket, forming a unitized component which combines the strength of the metal strip with the elongation and fatigue resistance of the polyethylene jacket component. Such cable construction is referred to in the art as a "Bonded Jacket" cable design. If the heat imparted to the jacket-forming polyethylene is sufficiently high, the shielding tape would become hot enough so that the overlapped portions of the shielding tape bond together at the seam, thereby forming a sealed tube or pipe around the core of the cable. The "Bonded Jacket" cable with a sealed seam has improved resistance to moisture penetration into the cable core. This cable construction also has been shown to have greater mechanical strength necessary to withstand repeated bending of the cable, i.e. kinking and fatigue failures of the shielding tape, resulting from bending stresses during installations. Further, the stresses induced by the temperature cycles under service conditions are reduced.

The plastic coating protects the metal to some degree from corrosion by limiting the area over which such corrosion can occur or by preventing contact between the metal and water or brine. The coating should be tightly bonded to the metal to resist significant delamination therefrom during exposure to the corrosive water and the mechanical forces exerted by the formation of voluminous metal corrosion products, thereby restricting the path of corrosive attack to the exposed metal edges of the shielding tape.

Recently, examination of several commercial cables utilizing polymeric resinous material coated shielding tapes representative of the prior art has revealed, however, that the coatings on such tapes are damaged during cable manufacture exposing numerous corrodible bare spots on the surfaces of the metal strip, more specifically, when a polyethylene jacket is extruded over a plastic coated shielding tape, the heat from the molten polyethylene jacket softens or melts the polymeric resinous material coating to obtain a bond to the jacket and a sealed seam. While the coating is in such softened or molten state, it is penetrated or abraded by the smooth, corrugated or embossed core wraps, by the seams of the tape, by the binder tapes, and/or by the weight of the core itself, thereby exposing numerous corrodible bare spots on the surfaces of the metal strip. As a result, the corrosion rate at the damaged spots is accelerated due to an unfavorable ratio of the anodic and cathodic areas of bare and coated metal. Furthermore, corrosion propagates between damaged spots and prematurely destroys the longitudinal continuity of the shielding tape which, in turn, can render the cable inoperative. Since telephone cables are expected to have a long service life, corrosion of shielding tapes which can lead to premature cable failures is indeed a serious technical and financial problem for the wire and cable industry. The problem of coating damage has not been recognized until the present invention because of the industry's preoccupation with other major problems. One of such problems was the need to develop thermal barrier materials to protect the cable core from heat damage. Another problem was associated with the introduction of fully-filled telephone cable designs wherein the cable core is filled with a grease-like compound to prevent ingress and migration of water.

The corrodible bare spots may occur on either side of the shielding tape but the problem is particularly critical with the use of corrugated metallic strips where it has been observed that the penetration and/or abrasion damage exposing the bare metal is concentrated on the raised corrugated surfaces of the shielding tape disposed toward the core. A corrosive attack on this type of circumferentially concentrated damage area of the corrugated metal strip will quickly destroy the longitudinal electrical function of the shielding tape. In order to maintain the prior art criterion of restricting corrosion to the shielding tape edges, it is now recognized that penetration and/or abrasion resistance of the plastic coatings is required, in addition to delamination resistance, to insure that corrosion is generally confined to the edges of the shielding tape instead of being extended over the entire surface thereof.

Although there is no known prior art directly concerned with overcoming the above identified problems, the following prior patents specifically referred to hereinbelow and in Table II illustrate the closest known prior art in the plastic coated shielding tape technology. U.S. Patent No. 3,586,756 and U.S. Patent No. 3,950,605 (Example 3 and 6 - Table II) disclose shielding tapes comprising a metal strip having an adhesive polymer coating adhered to at least one side of the metal strip. However, these prior patents do not provide for a deformation resistant layer of a polymeric resinous material composition having a deformation temperature of at least 130°C as hereinafter described in this specification. The coating on such tapes will be deformed during cable manufacture exposing numerous corrodible bare spots on the surfaces of the metal strip.

U.S. Patent No. 3,507,978 (Example 4 - Table II) teaches a shielding tape comprising a metal foil having layers of a copolymer such as ethylene/acrylic acid chemically bonded to both sides of the metal foil and an additional layer of high density polyethylene bonded to one of the copolymer layers. However, there is no teaching or suggestion in U.S. Patent No.

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3,507,978 of the damage problem overcome by the present invention and examination of commercial cables incorporating such a shielding tape also illustrates that penetration and/or abrasion of the high density polyethylene layer occurs at current cable manufacturing and service use conditions.

U.S. Patent No. 3,379,824 (Example 8 - Table II) teaches a shielding tape comprising a three layer structure with an aluminum foil laminated between two polypropylene layers or a polypropylene layer and a polyethylene terephthalate layer. Again, there is no teaching or suggestion of the damage problem overcome by the present invention. In addition, although these plastic layers will resist penetration and abrasion, they do not provide corrosion protection when a corrosive environment is present in a cable since both polypropylene and polyethylene terephthalate are highly inert and can develop only a poor mechanical bond to the metal strip based on friction adhesion. Therefore, both the polypropylene and polyethylene terephthalate layers will easily delaminate under exposure to corrosive conditions and the mechanical forces exerted by metal corrosion products.

U.S. Patent No. 3,325,589 (Example 9 to 11 - Table II) discloses a plastic coated metal shielding tape comprising a metal strip having an adhesive layer immediately adjacent to the metal strip and an additional Mylar ® or polypropylene layer adhered to one side of the metal strip. Such a shielding tape was subjected to simulated conditions of cable manufacture and a laboratory corrosion test. It was found that the tape did not provide satisfactory corrosion resistance to the metal, i.e., the path of corrosive attack was not confined to the exposed metal edges. The adhesive layer was deformed from pressure exerted through the polypropylene of Mylar ® layer thereby exposing bare aluminum spots. Corrosion ® = Registered Trademark was taking place on these bare spots after subjecting the cable to a standard corrosion test with sodium hydroxide, as hereinafter defined in this specification, due to the infiltration of the NaOH between the adhesive layer and the polypropylene (PP) or Mylar ® layers.

U.S. Patent No. 3,790,694 (Example 8 - Table II) discloses a polypropylene layer adhesively bonded to a metal strip. The patent does not specify the use of any particular adhesive. Since ethylene acrylic acid (EAA) copolymer is the best known metal adhesive in the industry today, the shielding tapes made according to the teachings of that patent were found to give similar results to those of U.S. Patent No. 3,325,589. The patent teaches bonding of the jacket, a screen, and composite tapes together during extrusion of the cable jacket. Since the thermoplastic coatings on the screen and composite tapes must be above its melting point to effect bonding they were found to be damaged a priori. Thus, this prior art patent also failed to recognize the problem of coating damage on shielding tapes. U.S. Patent Nos. 3,325,589 and 3,790,694, are related to a heat resistant core wrap (thermal barrier) and a fully filled cable, respectively.

U.S. Patent No. 3,321,572 (Example 13 - Table II) and U.S. Patent No. 3,622,683 (Example 8 - Table II) disclose, inter alia, shielding tapes comprising a metal strip having a polymeric resinous material coating adhered to at least one side thereof and capable of resisting deformation at an elevated temperature. However, these shielding tapes were found to fail the adhesion requirement of the present invention. In these tapes, it was found that the path of corrosive attack was not confined to the exposed edges of the metal strip because of the infiltration of corrosive element between the polymer coating and the metal strip.

U.S. Patent No. 3,484,539 teaches the adhesion of a heat sealable layer, such as, for example, polyvinyl chloride to a polymer layer capable of resisting deformation at cable-forming temperatures. However, the polymer layer of this patent, having adhered thereto a heat sealable layer, is not "tightly bonded" to the metal strip and is thus open to corrosive attack due to the infiltration of corrosion causing liquids when the cable jacket is damaged.

None of the prior art patents hereinabove discussed shows or suggests that a deformation resistant layer can be used in a shielding tape to prevent damage to the protective coating during cable manufacture, installation or service use. Furthermore, none of the polymer coatings on the shielding tapes disclosed in the prior patents meet both the bonding or adhesion and deformation resistance requirements of the present invention to provide satisfactory corrosion resistance to the shielding tapes by restricting the path of corrosive attack to the exposed metal edges.

Although the "bonded jacket" cables have improved resistance to moisture penetration into the cable core and have greater mechanical strength necessary to withstand repeated bending thereof, some problems have also been encountered in terminating and splicing the cables. More specifically, it is cumbersome to separate the jacket from the shielding tape for the purpose of making electrical connections to the tape. While it is possible to terminate and splice the "bonded jacket" cables without separating the jacket from the shielding tape, it has been shown that the quality of electrical connections is not as good as that with the jacket removed. More particularly, the electrical properties of the connections to the shielding tape are known to change less with time than the connections to the shielding tape and bonded

jacket of electrical cables.

The present invention is an improved corrosion resistant cable shielding tape comprising a metal strip having a deformation resistant layer of polymer resinous material tightly bonded (as hereinafter defined) to at least one side thereof, said deformation resistant layer having a deformation temperature of at least 130°C.

In another embodiment, a second deformation resistant layer and/or other layers of polymeric resinous materials is included in the shielding tape thereby providing a multilayered structure having a combination of desirable functional characteristics. For example, deformation resistant layers of polymeric resinous material are tightly bonded to both sides of the metal strip, if desired, to provide penetration and/or abrasion resistance on both sides of the shielding tape.

In a further embodiment, adhesive layers of polymeric resinous materials having good bonding characteristics to both the metal strip and the deformation resistant layer or layers are used to tightly bond the deformation resistant layer to the metal strip when direct adhesion of the same is insufficient to adequately provide corrosion protection for the metal strip.

In another embodiment, heat seal layers of thermoplastic polymeric resinous material are included in the shielding tape of this invention to provide a hermetically sealable shield seam in the cable structure and to provide a good bond between the cable shielding tape and outer plastic jacket of the cable.

In a further embodiment, an adhesive/heat seal layer of thermoplastic polymeric resinous material having both good metal bonding and heat seal characteristics is tightly bonded directly to one side or to opposite sides of the metal strip.

The combined layers of polymeric resinous materials described above have high electrical resistivity, high resistance to chemicals and moisture and exceptionally good bonding to the metal strip thereby being able to withstand the rigors of manufacturing processes as well as penetration and/or abrasion when in use without delamination in a corrosive environment.

The shielding tape of this invention must meet both the adhesion or bonding and deformation resistance requirements to provide satisfactory corrosion protection to the shielding tape by restricting the path of corrosive attack to the exposed metal edges of the metal strip.

The present invention also provides a cable shielding tape to which an outer jacket is firmly bonded and wherein the jacket is easily removed to facilitate the splicing and grounding procedures and yet provides corrosion protection in all areas of such shielding tape by allowing removal of the jacket in such a manner that a tightly bonded adhesive layer remains on the metal component of the tape after stripping of the jacket.

More specifically, such a shielding tape has a bond between a metal strip and an adhesive layer tightly bonded thereto which bond is stronger than the interlayer bond of other tightly bonded layers of polymeric resinous material. By judicious selection of the types and proportions of polymer composition for the deformation resistant layer, the bond of the deformation resistant layer to the adjacent layers of polymeric resinous material is made weaker than that of the adhesive layer to the metal strip. The interlayer bond must be capable of withstanding delamination under conditions of normal use but which will separate prior to delamination of the adhesive layer from the metal strip.

More specifically, as herein defined, "metal strip" means a relatively thin layer of any metal which has good electrical or mechanical properties useful in electrical power and communications cables.

As herein defined, the term "tightly bonded" means restricting the path of corrosive attack to the exposed metal edges of the shielding tape by chemically and/or mechanically bonding the deformation resistant layer to the metal strip, either directly or indirectly with an adhesive layer, or by bonding an adhesive/heat seal layer directly to the metal strip, to prevent significant delamination of the deformation resistant and adhesive/heat seal layers from the metal strip under exposure to corrosive conditions and the resulting mechanical forces exerted by the metal corrosion products. The degree of adhesion between plastic layers, and between a plastic layer and the metal strip of the shielding tape of this invention, which will satisfy the requirement for "tightly bonded" is at least 1 kg/2.54 cm of tape width, preferably at least 2 kg/2.54 cm. after immersion of a tape sample in deionized water maintained at a temperature of 70°C for a period of 7 days.

"Adhesive layer", as herein defined, means a layer of polymeric resinous materials having good bonding characteristics with the metal strip and deformation resistant layer and the plastic jacket of the electrical cable.

"Heat seal layer", as herein defined, means a layer of thermoplastic polymeric resinous materials having a sealing temperature of 121°C or lower and, preferably, 110°C or lower which will easily seal to itself, or other polymeric resinous materials such as, for example, those materials forming the outer plastic jacket of a cable.

"Adhesive/heat seal layer", as herein defined, means a layer of thermoplastic polymeric

resinous materials having both good metal bonding and heat seal layers which will tightly adhere to the metal strip.

"Deformation resistant layer", as herein defined, means a layer of polymeric resinous materials that substantially resist penetration and/or abrasion at deformation temperatures of at least 130°C. and pressures normally associated with cable manufacture, installation and/or service use.

Improved cables adapted for use in supplying electrical power or communications can be constructed with the improved corrosion resistant cable shielding tape described above. Such cables comprise a core of at least one insulated conductor, a shield of the improved corrosion resistant cable shielding tape surrounding the core, and an outer plastic jacket surrounding the tape. The deformation resistant layer of the shielding tape may be positioned in the direction of the core, in the direction of the outer jacket or in both directions to overcome penetration and/or abrasion damage during manufacture and/or during service of the cable.

The invention is further understood by reference to the accompanying drawings in which like characters of reference designate corresponding materials and parts throughout the several views thereof, in which:

Figure 1 is a partial cross-sectional view of a plastic coated metal shielding tape constructed according to the principles of the present invention;

Figures 2-9 are partial cross-sectional views illustrating modified plastic coated metal shielding tapes constructed according to the principles of the present invention;

Figure 10 is a cross-sectional view of a typical power cable with three insulated conductors, a plastic coated metal shield and an outer plastic jacket; and

Figure 11 is a cut-away perspective view of an end of a communications cable with multi-pair insulated conductors in the core, plastic coated metal shield and plastic outer jacket.

Referring now to the drawings, Figure 1 illustrates an improved corrosion resistant cable shielding tape 10 comprising a metal strip 12 having a deformation resistant layer 14 formed of a polymeric resinous material such as a blend of 50 weight percent polypropylene and 50 weight percent ethylene/acrylic acid copolymer tightly bonded to one side thereof. In order to provide corrosion protection for the metal strip 12, shielding tape 10 should be used in cable constructions having a plastic outer jacket formed of an adhesive composition which will tightly bond to the metal strip 12 on the side opposite to that of layer 14.

Figure 2 illustrates a modified cable shielding tape 20 having a deformation resistant layer 24 like layer 14 of Figure 1 tightly bonded to metal strip 12. Layer 25 which is tightly bonded to the opposite side of strip 12 may be a deformation resistant layer like layer 24 or may be an adhesive/heat seal layer formed of an ethylene/acrylic acid copolymer.

Figure 3 illustrates another modified cable shielding tape 30. The metal strip 12 may have a deformation resistant layer 34 like layer 14 of Figure 1 tightly bonded to one side thereof and a heat seal layer 36 formed of low density polyethylene adhered to layer 34. Alternatively, layer 36 may be a deformation resistant layer formed of a material such as nylon which will not tightly bond directly to the metal strip 12 with sufficient adhesion to provide corrosion protection and layer 34 may be an adhesive layer formed of a material such as an ethylene/acrylic acid copolymer. Like shielding tape 10 of Figure 1, shielding tape 30 should be used in cable constructions which have a plastic outer jacket formed of an adhesive composition to insure corrosion protection for the metal strip 12.

Figure 4 illustrates still another modified cable shielding tape 40. There are four possible structures of shielding tape 40 useful in accordance with this invention. Layer 45 may be a deformation resistant layer like layer 14 of Figure 1 for two of the possible structures or an adhesive/heat seal layer like layer 25 of Figure 2 for the other two structures. Layer 44 may also be a deformation resistant layer like layer 14 of Figure 1 when it will tightly bond directly to the metal strip 12 or it may be an adhesive layer formed of an ethylene/acrylic acid copolymer which in turn is used to tightly bond a deformation resistant layer 46 like layer 36 of Figure 3 that will not tightly bond directly to the metal strip 12. When layer 44 is a deformation resistant layer tightly bonded to the metal strip 12, layer 46 is beneficially a heat seal layer like layer 36 of Figure 3.

Figure 5 illustrates still another modified cable shielding tape 50. There are three possible structures of tape 50 useful in accordance with this invention. First, two deformation resistant layers 56 and 57 like layer 36 of Figure 3 which will not tightly bond directly to the metal strip 12 may be tightly bonded to the strip 12 with adhesive layers 54 and 55 like layer 34 of Figure 3. Second, the remaining two possible structures may be a deformation resistant layer 55 like layer 14 of Figure 1 tightly bonded to the metal strip 12 and a heat seal layer 57 like layer 36 of Figure 3 bonded to layer 55. On the opposite side of the metal strip 12 there may be a deformation resistant layer 54 like layer 14 of Figure 1 tightly bonded directly to the strip 12 and a heat seal layer 56 like layer 36 of Figure 3 bonded to layer 54 or, in the alternative, there

may be a deformation resistant layer 56 like layer 36 of Figure 3 which will not tightly bond directly to the metal strip 12 that is tightly bonded to the strip 12 with an adhesive layer 54 like layer 34 of Figure 3.

Figure 6 illustrates a further modified cable shielding tape 60. A deformation resistant layer 66 like layer 36 of Figure 3 which will not tightly bond directly to the metal strip 12 is tightly bonded to the strip 12 with an adhesive layer 64 like layer 34 of Figure 3. A heat seal layer 68 formed of an ethylene/acrylic copolymer is bonded to layer 66. Like shielding tapes 10 and 30, shielding tape 60 should be used in cable constructions which have a plastic outer jacket formed of an adhesive composition to insure corrosion protection for the metal strip 12.

Figure 7 illustrates a still further modified cable shielding tape 70. The adhesive layer 74, deformation resistant layer 76 and heat seal layer 78 are the same as the corresponding layers 64, 66 and 68 found in Figure 6. Layer 75 may be a deformation resistant layer like layer 14 of Figure 1 or, in the alternative, an adhesive/heat seal layer like layer 25 of Figure 2 tightly bonded directly to the metal strip 12.

Figure 8 illustrates a still further modified cable shielding tape 80. The adhesive layer 84, deformation resistant layer 86 and the heat seal layer 88 are the same as the corresponding layers 64, 66 and 68 found in Figure 6. On the opposite side of the metal strip 12 there may be a deformation resistant layer 85 like layer 14 of Figure 1 tightly bonded directly to the strip 12 and a heat seal layer 87 like layer 36 of Figure 3 bonded to layer 85 or, in the alternative, there may be a deformation resistant layer 87 like layer 36 of Figure 3 which will not tightly bond directly to the metal strip 12 that is tightly bonded to the strip 12 with an adhesive layer 85 like layer 34 of Figure 3.

Figure 9 illustrates a final modified cable shielding tape 90. The adhesive layers 94 and 95, deformation resistant layers 96 and 97, and the heat seal layers 98 and 99 are the same as the corresponding layers 64, 66 and 68 found in Figure 6.

Referring now to Figures 10 and 11, a typical three-conductor power cable 100 and multi-pair conductor communications cable 110 are illustrated. The power cable 100 has low resistance metal conductors 101, which can be solid or stranded, usually of copper or aluminum, which are each insulated, usually with an extruded plastic cover 102 of, for example, polyvinyl chloride, polyethylene or rubber. Space fillers 103 of, for example, natural fibers or foamed plastic are used to provide a substantially circular core assembly which is enclosed in a shielding tape 104 formed from any one of the shielding tape structures illustrated in Figures 1-9. The shielding tape 104 is preferably a longitudinally folded tube with an overlapping seam that may be hermetically sealed by heat sealing the plastic coating of the shielding tape together in the overlapping seam during cable manufacture. An outer plastic jacket 105, usually extruded polyethylene containing stabilizers and carbon black, is beneficially bonded to the shielding tape 104. The communications cable 110 includes an inner core of many pairs of insulated conductors 111 (e.g. plastic coated copper wires) bundled in a plastic core wrap 112 of, for example, polypropylene or polyethylene terephthalate which is securely bound with a binder tape 113. The bundle is enclosed in a shielding tape 114 formed from any one of the shielding tape structures illustrated in Figures 1-9. Like the shielding tape 104 of power cable 100, shielding tape 114 is preferably a longitudinally folded tube with a hermetically sealed overlapping seam. An outer plastic jacket 115 preferably of polyethylene is extruded over the shielding tape 114 and is advantageously bonded to the same.

The metal strip which is used in accordance with this invention may have a thickness from 0.2 to 25 mils and, more preferably, from 2 to 15 mils. The metal strip may be formed, for example, from aluminum, aluminum alloys, alloy-clad aluminum, surface modified copper, bronze, steel, tin free steel, tin plate steel, aluminized steel, stainless steel, surface modified copper-clad stainless steel, terneplate steel, galvanized steel, chrome or chrome treated steel, lead, magnesium or tin. These metals may also be surface treated or have thereon surface conversion coatings.

The deformation resistant layer which is used in accordance with this invention may have a thickness from 0.1 to 15 mils and, more preferably, from 0.5 to 2.0 mils. Beneficially, the deformation resistant layer may be formed from any polymeric resinous material which will provide a layer deformation temperature of at least 130°C such as, for example, polypropylene, carboxyl modified polypropylene, polyamides, polyethylene terephthalate, fluoropolymers, 1-4 di-methyl pentene polymers, ethylene/propylene copolymers, stereo regular polystyrene, flexible thermoset polymeric resinous materials, Saran®, or irradiated carboxyl modified olefin polymers. These polymeric resinous materials may be blended with, for example, low or high density polyethylene, ethylene/ethyl acrylate copolymers, ethylene/vinyl acetate copolymers, carboxyl modified ethylene polymers, ethylene/acrylic acid copolymers, ionic olefin polymers, or chlorinated polyethylene, provided the layer deformation temperature is at least 130°C. Flexible thermoset polymeric resinous materials

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such as, for example, polyurethanes may also be used provided their deformation temperature is at least 130°C.

The adhesive layer may have a thickness from 0.1 to 10 mils, preferably from 0.3 to 2.5 mils. Such layer may be formed from any thermoplastic polymeric resinous material which will tightly bond the deformation resistant layer to the metal strip. Copolymers of ethylene and ethylenically unsaturated carboxylic acids readily form a strong adhesive bond with aluminum and are preferred in achieving beneficial results of the present invention. The adhesive polymer which is beneficially used in accordance with this invention is a normally solid thermoplastic polymer of ethylene modified by monomers having reactive carboxylic acid groups, particularly a copolymer of a major proportion of ethylene and a minor proportion, typically from 1 to 30, preferably from 2 to 20, percent by weight, of an ethylenically unsaturated carboxylic acid. Specific examples of such suitable ethylenically unsaturated carboxylic acids (which term includes mono- and polybasic acids, acid anhydrides, and partial esters of polybasic acids) are acrylic acid, methacrylic acid, crotonic acid, fumaric acid, maleic acid, itaconic acid, maleic anhydride, monomethyl maleate, monoethyl maleate, monomethyl fumarate, monoethyl fumarate, tripropylene glycol monomethyl ether acid maleate, or ethylene glycol monophenyl ether acid maleate. The carboxylic acid monomer is preferably selected from α,β -ethylenically unsaturated mono- and polycarboxylic acids and acid anhydrides having from 3 to 8 carbon atoms per molecule and partial esters of such polycarboxylic acid wherein the acid moiety has at least one carboxylic acid group and the alcohol moiety has from 1 to 20 carbon atoms. The copolymer may consist essentially of ethylene and one or more of such ethylenically unsaturated acid comonomers or can also contain small amounts of other monomers copolymerizable with ethylene. Thus, the copolymer can contain other copolymerizable monomers including an ester of acrylic acid. The comonomers can be combined in the copolymer in any way, e.g., as random copolymers, as block or sequential copolymers, or as graft copolymers. Materials of these kinds and methods of making them are readily known in the art.

Beneficially, the heat seal layer may have a thickness from 0.1 mil to 10 mils and, preferably, from 0.3 mil to 1 mil. The heat seal layer may be formed from, for example, low or high density polyethylene, ethylene/ethyl acrylate copolymers, ethylene/vinyl acetate copolymers, carboxyl modified ethylene polymers, or blends of the above.

The adhesive/heat seal layer may have a thickness from 0.1 mil to 10 mils and, more preferably, from 1 mil to 3 mils. The adhesive/heat seal layer may be formed from, for example, carboxyl modified olefin polymers, ionic olefin polymers, blends of carboxyl modified olefin polymers or blends of ionic olefin polymers.

Deformation resistance of a layer of polymeric resinous material is normally tested by means of a penetrometer. However, known penetrometers are designed for coatings (comprising one or more layers of synthetic resinous material) 60 to 125 mils (1.52 to 3.17 mm) thick and data therefrom do not apply to the coating thicknesses on cable shielding tapes or temperatures and pressures associated with the cable manufacture or use. Therefore, a special penetrometer test was developed to evaluate the ability of relatively thin coatings, i.e., coatings having a thickness of 10 mils (0.254 mm) or less, on plastic clad metals to resist deformation at elevated temperatures. The special penetrometer consists of a metal block weighing 1.68 kg onto which a circular ring has been machined. The ring has an outside diameter of 38.1 mm and a thickness of 25 mils. The cutting edge of the ring in contact with the coated shielding tape sample is rounded to a 0.79 mm radius which applies a pressure to the sample of 35 pounds per square inch (24.6 gm/mm²). The testing procedure consists of placing the sample of shielding tape on a base such as a metal plate and then positioning the special penetrometer on the sample with the ring in contact with the coating thereon. An electrical circuit, open because of the coating, is connected between the penetrometer and the metal strip of the sample. Thereafter, the entire assembly is placed in a circulating air oven preheated to 218°C which increases the temperature of the shielding tape being tested at a rate of approximately 10°C per minute. When the ring penetrates the coating the electrical circuit is completed and the temperature of the coating, determined by a thermocouple or other means, is recorded. This temperature is the deformation temperature, for the coating being tested. It has been found that the conditions of this test correlate well with the temperatures and pressures associated with cable manufacturing and/or service use. It has been found that the deformation resistant layer should have a deformation temperature of at least 130°C and preferably at least 138°C to resist the temperatures and pressures normally associated with cable manufacturing and/or service use. The degree of adhesion is determined by preparing a 6 inch wide by 6 inch long by 60 mil (15.24 cm x 15.24 cm x 3.175 mm) thick molding of a plastic jacketing material using a procedure similar to that described in the United States Department of Agriculture Rural Electrification Administration (REA) specification PE-200. A sheet of shielding tape of the same dimensions (6 in. x 6 in.) was placed over the molding. A strip of polyester film of 1 mil (0.0254 mm) thickness was placed

between the shielding tape and the molding of the jacketing material to prevent bonding to one end of the jacketing material to form a "tab" for use in a tensile strength testing machine. The shielding tape was bonded to the molding using a compression molding press and a molding temperature of 190°C. The molding pressure was 300 pounds per square inch (0.2 kg/mm²). The heating cycle was as follows: 3 minutes to reach temperature with no pressure; 2 minutes under pressure; and 5 minutes to cool to room temperature. After the shielding tape/jacketing material laminate was prepared one inch (2.54 cm) wide samples for bonding tests were cut on a sample cutter. The samples were placed on a tensile testing machine and tested for bond strength as follows: the unbonded portion of the shielding tape was folded back 180°C; the sample was inserted into the tensile testing machine with the shielding tape in the upper jaw and the molding of jacketing material in the lower jaw; a rigid metal plate was placed behind the molding to maintain the peeling angle at 180°; and the shielding tape was then separated from the rigid molding of the jacketing material at a crosshead speed of 5 inches per minute. The required force to separate the shielding tape from the molding was recorded as a measure of adhesive strength. The separation can occur at the metal strip/plastic layer interface, or plastic layer/plastic layer interface or plastic layer/jacketing material interface.

Several shielding tapes of plastic coated aluminum were prepared and were tested for corrosion resistance thereof. More specifically, test samples of the shielding tapes having an area of 5.08 cm x 5.08 cm were first subject to a simulated jacketing test, as described hereinafter, and were then immersed in one (1) normal sodium hydroxide (1N NaOH) solution for 24 hours. Bare aluminum spots on the surfaces of the shielding tapes, which had been exposed by damage to the plastic coatings thereon during the simulated jacketing test, were thereby corroded. The number of corroded spots, which were easily identifiable in the test sample of shielding tape, were counted and recorded as a corrosion damage index thereof. An index of 0 indicates that no corrosion spots are present while a given number indicates the number of corrosion spots which can be counted on the sample. Shielding tapes having poorly bonded plastic coatings thereon resulted in total dissipation of the metal often accompanied by delamination of the coatings.

The simulated jacketing test was designed to simulate temperature and pressure conditions normally encountered inside a cable, during and following the jacketing operation, in order to study the effects thereof on cable components. The test is particularly well suited to study the effect of the temperature and pressure conditions on the plastic coating or plastic coated shielding tapes. In order to conduct this test, a cylindrical section of a cable having a length of about 5.0 cm is converted into a rectangular configuration having planar surfaces. The test is carried out using the following procedure: A sample of molded jacketing material of about 5.08 cm x 5.08 cm and weighing 13 grams and having a thickness of 100 mil (2.54 mm) was heated in an oven to a temperature of 218°C; the jacketing material was removed from the oven after 6 to 7 minutes and within a period of 5 seconds a sample of corrugated shielding tape (5.08 cm x 5.08 cm) was placed on the jacketing material; a corrugated core wrap of polyester film, a section of a cable core having a generally rectangular configuration and weighing 218 grams, and a 2000 gram weight were then successively stacked on top of the shielding tape; and finally, the entire assembly was placed on a large aluminum block (weighing 955 grams) to cool while the temperature of the core wrap/-shield interface was recorded through a thermocouple placed therebetween. The aluminum block provides a heat sink and thereby simulates the cooling bath located downstream of the extruder head.

The temperature-time relationships for the shield obtained with this test correlate to those obtained with cables containing a large number of conductor pairs during extrusion of the jacket. R.C. Mildner, P. C. Woodland, H. A. Walters, and G. E. Clock, entitled, "A Novel Form of Thermal Barrier for Communication Cables," presented at the 14th International Wire and Cable Symposium, Atlantic City, New Jersey, 1965.

Heat sealability was determined on film samples of the coatings by means of a special seal test. Two samples of film 50.8 mm wide are placed in contact with each other in a heat sealer apparatus such as a Sentinel Brand, Model 24AS, or equivalent. The temperature of the sealer bar is increased in 5°C increments from 88°C to a temperature sufficient to seal the films together. The temperature at which the films seal to each other is recorded as the minimum seal temperature. The dwell time in seconds for the sealer bar is equal to 26.25 times the film thickness in mm. The air pressure on the sealer bar is set to 28 g/mm².

The effect of "fillers" for the cable core was tested with samples of plastic coated shielding tapes in which coatings on both sides thereof were exposed to petrolatum filling compounds (Witco 5B) and floodant (Witco 4) at 115.5°C for two seconds. A percent swell was calculated based on the amount of filler picked up by the coating as follows after the surface thereof is wiped clean of any filler compound: The original weight of the coating was subtracted from the weight of the coating after exposure and this difference was divided by the original weight. This number was multiplied by 100 to obtain percent swell. The results of

event bonding to testing machine. The press and a square inch (0.2 with no pressure; after the shielding tapes for bonding using machine and tape was folded the shielding tape rigid metal plate the shielding tape ahead speed of 5 the molding was metal strip/plastic material

I were tested for tapes having an est, as described ide (1N NaOH) tapes, which had ed jacketing test, dentifiable in the n damage index a given number . Shielding tapes of the metal often

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this test are listed in Table IX.

In a "connector stability" test, coated metal samples approximately 50 mm x 150 mm were corrugated. Then two Griplok ® connectors were attached to each longitudinal end of the samples. The initial resistance in milli-ohms was measured across the connectors using a Kelvin Bridge. The samples were then given 50 temperature cycles from -40°C to +60°C, with each cycle being of an 8 hours duration, and the resistance was measured again. The results of these tests are listed in Table X.

In a jacket bond strength and bend performance test, a bonded jacket gas pipe was fabricated on a cable jacketing line using lengths of corrugated laminates. The laminates were oriented such that the multilayer coated side contacted the extruded jacket. Samples of the pipe were then collected for determination of jacket bond strength and bend performance. The results of these tests are listed in Table XII.

The following additional test methods were used:

1. Physical properties of the coating were determined by ASTM D-638.
2. Elmendorf Tear was determined by ASTM D-1922.
3. Melt Index was determined by ASTM D-1238.

Representative examples of the present invention along with deformation temperatures and corrosion index test results, are shown in Table I. The examples were formed by extruding the plastic layers, each of about one mil thickness, and then laminating them to a hot metal strip having a temperature of about 190°C.

Bonded jacket cables incorporating these examples were fabricated on commercial cable manufacturing lines under normal processing conditions.

The penetrometer test for deformation resistance was used to obtain the deformation temperature.

Examples 8-11 in Table I show the use of three component blends as the deformation resistant layer.

Example 12 establishes the use of a four component blend as the deformation resistant layer.

Example 13 establishes the lower limit for deformation temperature of a blend of polyethylene with polypropylene of 130°C.

Example 14 illustrates the use of an adhesive jacket to substantiate the utility of single side coated metals according to Figures 1, 3 and 6.

Example 15 illustrates an embodiment in which polypropylene is used as a deformation resistant layer. An EAA-PP blend is used as a second adhesive layer to bond the deformation resistant layer to a first adhesive layer of EAA. A second EAA-PP blend layer and a heat seal layer of EAA can be successively applied to the PP layer to obtain low temperature sealability.

Examples 16-18 are comparative examples and were prepared in the same manner as the examples of this invention. However, the composition of the blend in the deformation resistant layer was selected where it was not sufficient to provide a deformation temperature of at least 130°C.

Example 19 illustrates a particular blend in the deformation resistant layer which falls within the desirable range of deformation temperature and corrosion index.

Example 20 illustrates a functional example with copper. Since copper degrades an EAA coating in the presence of moisture, a copper stabilizer, OABH (oxalic acid bis (benzylidene hydrazide)), has been added to the EAA.

Example 21 illustrates a functional example with ionomer (Surlyn ® 1652, 11%MAA) as the metal adhesive layer.

Example 22 illustrates a functional example with an EAA-polyethylene blend as the metal adhesive layer.

Examples 23-25 illustrate functional examples with crosslinked coatings which were unusual in that they maintained their bondability, sealability, and corrosion protection qualities after irradiation.

Examples 26 and 27 illustrate functional examples with Saran as the heat deformation resistant layer. These structures are not illustrated in the drawings. Like Example 15, a second adhesive layer consisting of a blend or a suitable polymer is used to tightly bond a heat deformation layer to metal. The basic structures would be: Metal/Adhesive layer/Second Adhesive layer/Deformation layer; Metal/Adhesive layer/Second Adhesive layer/Deformation Resistant layer/Heat Sealable layer (EVA); or Metal/Adhesive layer/Second Adhesive layer (blend)/Deformation layer/Second Adhesive layer (blend)/Sealable layer.

A comparative analysis of Tables I and II demonstrates the damage that occurs to the plastic coated shielding tape of the prior art as measured by the number of corrosion spots counted on a 25 cm² sample. It also demonstrates the need for a deformation resistant layer having a deformation temperature of at least 130°C and tight bonding to prevent the occurrence of bare spots on the surface of the tape and the attendant potential for corrosion

thereon.

Examples 9-11 in Table II illustrate that damage to lower melting point coatings on metal can occur through a deformation resistant layer. Without tight adherence between a deformation layer and a metal adhesive layer, or with bonds between the two that are water sensitive, corrosion can occur at the defects in the adhesive coating on the metal.

Example 12 illustrates the non-functionality of this patent construction for corrosion protection.

Example 13 illustrates the need for tight adherence of coatings to metal.

Table III and IV illustrate the initial bond strengths and bond strengths after aging for 7 days in 70°C deionized water. Two sets of numbers are given in Table III because multilayer coatings may not necessarily fail at the interface of the metal and an immediately adjacent plastic layer during bond strength tests. If the metal bond exceeds the bond of the various plastic layers to each other, then bond failure occurs at the weakest interface thereof. (The example numbers refer to those in Table I and Table II where the detailed shielding tape constructions are shown.) The minimum bond strength is 1.0 kg/2.54 cm regardless of whether the bond strength refers to a metal/polymeric layer bond or to a polymeric layer/polymeric layer bond. For the former, corrosion resistance and mechanical performance will be deficient below the minimum bond strength. For the latter, the ability to withstand handling without delamination will also be impaired below this minimum bond strength.

From Table III, it can also be seen that the judicious selection of the types and proportions of polymer compositions will provide a bond between the metal strip and adhesive layer which is stronger than the interlayer bond of the other layers of polymeric resinous materials while still providing a minimum bond strength of 1.0 kg/2.54 cm between the polymeric coating/polymeric coating bond.

Table V and VI show that the multilayer coatings have improved ultimate tensile strength, elongation, and tear strength when compared to coatings of the presently known art. The example numbers refer only to the improved coating structure shown in Table I and not to the coated metal structure.

Tables VII and VIII show actual cable data wherein the cables are made using several shielding tapes described in Tables I and II. The same example numbers are used.

Table IX shows that the improved coatings of this invention have increased resistance to adverse effects of filling and flooding compounds. The attribute is also of benefit in extending the service life of filled cables.

Table X shows that the connector stability to coated metal is improved with the improved coating since the increase in resistance over the initial value is smaller.

Table XI shows that the electrical breakdown strength and resistance to permeation is improved with the new coating. The electrical strength of the new coating may be used to advantage in filled cable designs by elimination of the standard electrical barrier which is wrapped about the core. The reduced rates of permeation may serve to improve corrosion resistance.

The bond strength figures of Table XII reflect the levels of interlayer bond of the multilayer samples. These bond values are approximately 1/2 that of the prior art example 5 of Table II. However, the interlayer failure provides a means for controlling the level of bond between the polymer layers of the shielding tape and the jacket i.e. a bond strong enough to provide good mechanical properties while allowing easy stripping of the jacket for splicing. Moreover, at least the adhesive layer of the multilayer coating remains intact on the metal strip to provide continued corrosion protection.

The bend performance values are surprising since the multilayer samples, at half the bond strength, exhibited bend performance equivalent to the control sample. These results tend to suggest that bend performance requires a moderately high jacket bond strength but perhaps even more important is the ability to relieve stresses. The multilayer film provides a means of stress relief via the lower interlayer adhesion.

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TABLE I. THIS INVENTION

Example Number	Layer Construction	Deformation Temperature, °C	Corrosion Index
1	EAA (1)/A1/EAA (1)/50% EAA (1)-50% PP/EAA (1)	144	0
2	EAA (1)/A1/EAA (1)/40% EAA (1)-60% PP/EAA (1)	164	0
3*	EAA (1)/A1/EAA (1)/30% EAA (1)-70% PP/EAA (1)	164	0
4	EAA (1)/A1/EAA (1)/50% LDPE-50% PP/EAA (1)	164	0
5	EAA (1)/A1/EAA (1)/100% Nylon/EAA (1)	>199	0
6	50% EAA (2)-50% PP/A1/50% EAA (2)-50% PP	166	0
7	EAA (1)/TPS/EAA (1)/50% HDPE-50% PP/EAA (1)	163	0
8	EAA (1)/A1/EAA (1)/34% HDPE (1)-64% PP -2% LDPE/EAA (1)	163	0
9	EAA (1)/A1/EAA (1)/39% HDPE (1)-59% PP -2% LDPE/EAA (1)	160	0
10	EAA (1)/A1/EAA (1)/44% HDPE (1)-54% PP -2% LDPE/EAA (1)	154	0

TABLE I. THIS INVENTION (Continued)

Example Number	Layer Construction	Deformation Temperature, °C	Corrosion Index
11	EAA (1)/A1/EAA (1)/49% HDPE (1)-49% PP-2% LDPE/EAA (1)	151	0
12	EAA (1)/A1/EAA (1)/19% HDPE (1)-19% EAA (1)-2% LDPE/60% PP/EAA (1)	158	0
13	EAA (1)/A1/EAA (1)/70% HDPE-30% PP	136	0
14	0.254 mm Jacket of EAA (1)/A1/EAA (1)/35% HDPE (1) 65% PP/EAA (1)	163	0
15	EAA (1)/A1/EAA (1)/50% EAA (1)-50% PP/PP	164	0
16*	EAA (1)/A1/EAA (1)/90% HDPE-10% PP/EAA (1)	124	94
17*	EAA (1)/A1/EAA (1)/80% HDPE-20% PP/EAA (1)	128	86
18*	EAA (1)/A1/EAA (1)/70% EAA (1)-30% PP/EAA (1)	111	35
19	EAA (1)/A1/EAA (1)/60% EAA (1)-40% PP/EAA (1)	131	7

TABLE I. THIS INVENTION (Continued)

Example Number	Layer Construction	Deformation Temperature, °C	Corrosion Index
20	EAA (3)/Cu/EAA (3)/Nylon/EAA (1)		
21	Ionomer/A1/Ionomer/50% PP-50% HDPE	>199	0
22	70% EAA (1)-30% HDPE/A1/70% EAA (1)-30% HDPE/50% PP-50% HDPE	154	0
23	EAA (1)/A1/EAA (1) (Irradiated 10 megarads)	163	0
24	EAA (1)/A1/EAA (1) (Irradiated 10 megarads)	>210	0
25	EAA (1)/A1/EAA (1)/LDPE (Irradiated 5 megarads)	>210	0
26	EAA (1)/A1/EAA (1)/50% EVA-50% EAA/Saran	>210	0
27	EAA (1)/A1/EAA (1)/EVA/-Saran/EVA/EAA (1)	160	0
		161	0

*Samples prepared for comparison

1 - All blend percentages on weight basis.

A1 - Electrical Grade Aluminum Layer (0.203 mm thick)

TABLE I. THIS INVENTION (Continued)

EAA	(1)	- Ethylene/Acrylic Acid Copolymer Layer, 8% by weight Acrylic Acid
EAA	(2)	- Ethylene/Acrylic Acid Copolymer Layer, 12% by weight Acrylic Acid
EAA	(3)	- Ethylene/Acrylic Acid Copolymer Layer, 8% by weight Acrylic Acid with 0.1% Copper Stabilizer
PP	-	Polypropylene, Melt Flow 9.0, Density 0.905
PP	(1)	- Polypropylene, Melt Flow 7.0, Density 0.908
HDPE	-	High Density Polyethylene, Melt Index 3.6-4.4, Density 0.963-0.967
HDPE	(1)	- High Density Polyethylene, Melt Index 5.0, Density 0.964
LDPE	-	Low Density Polyethylene, Melt Index 1.95, Density 0.919
Nylon	-	Nylon 6 Layer
EVA	-	Ethylene/Vinyl Acetate Copolymer - 28% by weight Vinyl Acetate
TPS	-	Tin Plate Steel Layer, 0.152 mm thick
Cu	-	Copper Layer, 0.127 mm thick

All layer interfaces are indicated by the slanted symbol "/".

TABLE II. PRIOR ART

Example Number	Layer Construction	Deformation Temperature, °C	Corrosion Index
1	LDPE/Adh (1)/Al/Adh (1)/LDPE	106	77
2	Ternary Copolymer/Al/Ternary Copolymer	108	60
3	LDPE/EEA (1)/Al/EEA (1)	106	92
4	HDPE/EEA (1)/Al/EEA (1)	122	14
5	EEA (1)/Al/EEA (1)	102	99
6	EVA/Ionomer/Al/Ionomer/EVA	112	39
7	EEA (2)/Al/EEA (2)	102	*
8	PP/Al/PP	163	*
9	0.127 mm PP/EEA (1)/Al/EEA (1)	163	41
10	0.025 mm Mylar/EEA (1)/Al/EEA (1)	>209	36
11	0.0762 mm Mylar/EEA (1)/Al/EEA (1)	>209	38
12	LDPE/Al/LDPE	106	*
13	Mylar/Al/EEA (1)	>209	*

*Metal completely dissipated during test: Corrosion resistance insufficient

** -H. Ishikawa, et al "A New Method of Manufacturing Laminated Aluminium Polyethylene Sheath Cable", 21st International Wire and Cable Symposium, Atlantic City, New Jersey, 1972, p. 153.

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Al -Electrical Grade Aluminum Layer, .203 mm thick

LDPE -Low Density Polyethylene Layer

Adh (1) -Thermoplastic Adhesive Layer, as disclosed in U.S. Patent 3,809,603

Ternary Copolymer -Ethylene, Vinyl Acetate and Methacrylate or Glycidyl Acrylate Layer

EAA (1) -Ethylene/Acrylic Acid (Random) Copolymer Layer

HDPE -High Density Polyethylene Layer, Melt Index 6.0-9.0, Density 0.962-0.966

EVA -Ethylene/Vinyl Acetate Copolymer Layer

Ionomer -Ethylene/Methacrylic Acid Copolymer Layer with the acid partially neutralized by metal ions

EAA (2) -Ethylene/Acrylic Acid Graft Copolymer Layer

Mylar -Polyethylene Terephthalate

TABLE III. THIS INVENTION

Bond Strength in Kg/25.4 mm

Table I Example Number	To Metal		To Plastic	
	Initial	After Aging	Initial	After Aging
1	7.95	9.08	3.27	4.09
2	7.95	9.11	1.04	1.09
3*	7.95	9.08	.54	.68
4	7.90	8.99	2.60	2.59
5	7.95	9.09	4.63	2.95
6	2.77	2.93	2.81	2.92
7	15.44	12.94	4.27	5.09
8	6.45	6.04	1.05	1.00
9	6.36	6.18	1.34	1.36
10	6.36	6.68	2.36	2.13
11	6.45	6.59	3.13	3.09
12	6.45	6.63	1.34	1.32
13	7.95	8.90	8.40	8.42
14	7.55	8.35	1.07	1.05
15	7.95	8.77	2.31	2.30
16*	8.95	9.12	8.18	9.54
17*	8.95	9.17	7.45	6.13
18*	8.90	9.13	8.72	7.13
19	8.92	9.15	4.54	4.51
20	11.20	10.50	4.26	4.28
21	7.84	7.90	1.43	1.45
22	8.29	9.12	2.90	2.93
23	9.64	10.05	8.45	8.90
24	6.68	7.53	6.95	6.93
25	8.07	9.50	4.27	4.31
26	8.40	9.15	1.81	1.78
27	8.42	9.23	3.86	3.91

*Comparative Examples

TABLE IV. PRIOR ART

Bond Strength in Kg/25.4 mm

To Metal

Table II Example No.	Initial	After Aging
1	4.31	5.18
2	7.18	3.73
3	5.45	6.14
4	6.72	8.30
5	8.00	8.86
6	>4.59 CNS	>6.63 CNS
7	2.68	3.72
8	0	0
9	7.95	9.14
10	7.94	8.74
11	7.92	8.62
12	0.50	0
13 (Mylar side)	0.17	0
13 (EAA side)	7.26	7.93

CNS - could not be separated

TABLE V. THIS INVENTION

Table I Example Number	Direction	Tensile (Kg/mm ²)		Elongation (Percent)	Elmendorf Tear (gms)	Minimum Seal Tem- perature °C
		Yield	Ultimate			
1	MD	.96	2.68	580	634	113
	CD	.97	2.16	555	672	
2	MD	.99	2.57	605	525	113
	CD	.95	2.22	656	717	
4	MD	1.32	2.58	685	307	113
	CD	1.30	2.36	685	442	
5	MD	1.70	4.65	600	166	110
	CD	1.80	4.56	540	150	
8	MD	1.38	2.82	770	480	104
	CD	1.32	2.58	795	576	
9	MD	1.37	2.64	775	295	104
	CD	1.36	2.58	755	499	
10	MD	1.41	2.65	695	262	107
	CD	1.35	2.49	750	486	
11	MD	1.32	2.60	760	352	110
	CD	1.29	2.50	800	538	
12	MD	1.38	2.84	715	416	110
	CD	1.27	2.47	740	589	

TABLE VI. PRIOR ART

Table II Example Number						
1	CM	1.13	1.90	300	170	110
	CD	1.06	1.58	450	190	
5	MD	.74	1.79	450	244	107
	CD	.71	1.83	560	308	

Tensile and Elongation: ASTM D-882

MD - Machine Direction

CD - Cross Machine Direction

Elmendorf Tear: ASTM D-1922

TABLE VII. ACTUAL CABLE DATA, THIS INVENTION

Table I Example No.	Cable Size	Jacket Melt Temperature, °C	Line Speed Meter/Min	Corrosion Index
2	100 pr, 22 AWG, Air Core	221	18.0	0
3	100 pr, 22 AWG, Air Core	221	18.0	0
5	150 pr, 24 AWG, Air Core	218	15.2	0
5	75 pr, 24 AWG, Filled Core	232	30.5	0
9	100 pr, 22 AWG, Air Core	235	24.4	0

TABLE VIII. ACTUAL CABLE DATA, PRIOR ART

Table II Example No.	Cable Size	Jacket Melt Temperature, °C	Line Speed Meters/Min	Corrosion Index
3	25 pr, 22 AWG, Air Core	199	30.5	49
4	100 pr, 22 AWG, Air Core	199	18.0	36
5	25 pr, 22 AWG, Air Core	199	30.5	97
5	150 pr, 22 AWG, Air Core	218	15.2	76
5	75 pr, 24 AWG, Filled Core	232	30.5	22
5	100 pr, 22 AWG, Air Core	221	18.0	78

TABLE IX. FILLER AND FLOODANT RESISTANCE

Coated Metal Structure ^(A)	Percent Swell ^(B)	
	Filler ^(C)	Floodant ^(D)
EAA (1)/50% EAA (1)-50% PP/EAA (1)/Al/ EAA (1) 50% EAA (1)-50% PP/EAA (1)	5.2	10.2
EAA (1)/40% EAA (1)-60% PP/EAA (1)/Al/ EAA (1)/40% EAA (1)-60% PP/EAA (1)	5.2	11.1
EAA (1)/50% HDPE-50% PP/EAA (1)/Al/ EAA (1)/50% HDPE-50% PP/EAA	5.0	10.1
Example 5 (Table II)	10.5	13.8

(A) See Table I for Description of Materials

(B) Weight increase after exposure to filler and floodant at 115.5°C for 2 seconds

(C) Mixture of 92% petrolatum and 8% polyethylene

(D) Mixture of 75% petrolatum and 25% atactic polypropylene

TABLE X. CONNECTOR STABILITY

Table I Example No.	Resistance in Milliohms ⁽¹⁾	
	Initial	After Cyclizing ⁽²⁾
2	0.6663	1.187
10	0.6912	1.702
18	0.7353	1.7825
5 ⁽³⁾	0.6750	2.727

¹ Two connectors were attached to 50 mm by 140 mm sample of coated metal; the resistance of the assembly was measured with a Kelvin Bridge² Resistance after 50 -40 to +60 °C temperature cycles, each cycle of 8 hours duration³ Example No. 5 from Table II

TABLE XI. COATING PROPERTIES

	This invention ¹	Prior Art ²
Breakdown Strength, Kilovolts/CM	1360	1100
<i>Permeability</i>		
N ₂ , cc-mil/24 hrs/100 in ² /Atm	334	525
O ₂ , cc-mil/24 hrs/100 in ² /Atm	1130	1580
H ₂ O, g-mil/24 hrs/100 in ² /Atm	0.74	1.28

¹ Example 10, Table I² Example 5, Table II

TABLE XII

JACKET BOND STRENGTH AND BEND PERFORMANCE OF
BONDED JACKET GAS PIPE⁽³⁾

Shield Laminate	Jacket Bond Strength, lb/in Width	Bend Performance ⁽¹⁾ , Cycles With R/D ⁽²⁾ of		
		5	6	8
Ex. 10 - Table I	9.1	16	30	40
Ex. 5 - Table II	16.1	13	22	38

⁽¹⁾Number of reverse bends around the indicated mandrel required to cause a fracture in shield. 1 cycle = 2 bends.

⁽²⁾R/D = Radius of Mandrel/Diameter of pipe

⁽³⁾Jacket thickness was approximately 60 mils. Pipes were filled with lead shot to provide internal support.

From the foregoing detailed description, it can be seen that the present invention provides an improved corrosion resistant cable shielding tape for use as a shield in electrical power and communications cables.

Specifically, the present invention resides in an improved corrosion resistant cable shielding tape comprising a metal strip having a deformation resistant layer of polymeric resinous material tightly bonded (as hereinbefore defined to at least one side thereof, the deformation resistant layer having a deformation temperature of at least about 130°C. The shielding tape must meet both the adhesion and deformation resistance requirements simultaneously to provide satisfactory corrosion protection to the shielding tapes by restricting the path of corrosive attack to the exposed metal edges.

The deformation resistant layer of polymeric resinous material must therefore resist penetration and/or abrasion exposing the metal strip at the temperatures and pressures normally associated with cable manufacturing and/or service use.

The present invention also provides a plastic coated cable shielding tape which includes layers of polymeric resinous material other than the deformation resistant layer thereby forming a multilayered structure having a combination of desirable functional characteristics.

In one preferred embodiment, the tape of the present invention has less than eight corrosion damage points in an area of 25.0 cm² following simulated jacketing and corrosion tests, conducted by the test method as hereinbefore defined.

In another preferred embodiment, the ultimate tensile strength in a cross machine direction of multiple layers of the polymeric resinous material including said deformation resistant layer positioned on one side of the metal strip only is at least 2.0 kg/mm² measured using the test method (ASTM D-882) as hereinbefore defined. Preferably, the elongation of said multiple layers is at least 500%.

In a further preferred embodiment, the percentage weight increase of the tape is less than 6.0% after exposure for two seconds in a cable filler composition comprising 92 weight percent petrolatum and 8 weight percent polyethylene maintained at a temperature of 115.5°C and after wiping off excess filler composition from the tape.

In yet a further preferred embodiment the electrical resistance of the shielding tape having a length of 14.0 cm and a width of 5.0 cm and having two connectors attached to each longitudinal end thereof is less than 2 milli-ohms following 50 cycles conducted over a temperature range of -40°C to +60°C and over a cycling period of 8 hours per cycle.

WHAT WE CLAIM IS:

1. Corrosion resistant cable shielding tape comprising a metal strip having a deformation resistant layer of polymeric resinous material tightly bonded (as hereinbefore defined) to at least one side thereof, said deformation resistant layer having a deformation temperature of at least 130°C.

2. Cable shielding tape as claimed in claim 1, including an adhesive/heat seal layer of thermoplastic polymeric resinous material tightly bonded to one side of the metal strip.

3. Cable shielding tape as claimed in claim 1 or claim 2, including a heat seal layer of thermoplastic polymeric resinous material tightly bonded to at least one said deformation resistant layer on the side of the deformation resistant layer opposite to that on which the



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TABLE XII

JACKET BOND STRENGTH AND BEND PERFORMANCE OF
BONDED JACKET GAS PIPE⁽³⁾

Shield Laminate	Jacket Bond Strength, lb/in Width	Bend Performance ⁽¹⁾ , Cycles With R/D ⁽²⁾ of		
		5	6	8
Ex. 10 - Table I	9.1	16	30	40
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⁽¹⁾Number of reverse bends around the indicated mandrel required to cause a fracture in shield. 1 cycle = 2 bends.

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⁽³⁾Jacket thickness was approximately 60 mils. Pipes were filled with lead shot to provide internal support.

From the foregoing detailed description, it can be seen that the present invention provides an improved corrosion resistant cable shielding tape for use as a shield in electrical power and communications cables.

Specifically, the present invention resides in an improved corrosion resistant cable shielding tape comprising a metal strip having a deformation resistant layer of polymeric resinous material tightly bonded (as hereinbefore defined to at least one side thereof, the deformation resistant layer having a deformation temperature of at least about 130°C. The shielding tape must meet both the adhesion and deformation resistance requirements simultaneously to provide satisfactory corrosion protection to the shielding tapes by restricting the path of corrosive attack to the exposed metal edges.

The deformation resistant layer of polymeric resinous material must therefore resist penetration and/or abrasion exposing the metal strip at the temperatures and pressures normally associated with cable manufacturing and/or service use.

The present invention also provides a plastic coated cable shielding tape which includes layers of polymeric resinous material other than the deformation resistant layer thereby forming a multilayered structure having a combination of desirable functional characteristics.

In one preferred embodiment, the tape of the present invention has less than eight corrosion damage points in an area of 25.0 cm² following simulated jacketing and corrosion tests, conducted by the test method as hereinbefore defined.

In another preferred embodiment, the ultimate tensile strength in a cross machine direction of multiple layers of the polymeric resinous material including said deformation resistant layer positioned on one side of the metal strip only is at least 2.0 kg/mm² measured using the test method (ASTM D-882) as hereinbefore defined. Preferably, the elongation of said multiple layers is at least 500%.

In a further preferred embodiment, the percentage weight increase of the tape is less than 6.0% after exposure for two seconds in a cable filler composition comprising 92 weight percent petrolatum and 8 weight percent polyethylene maintained at a temperature of 115.5°C and after wiping off excess filler composition from the tape.

In yet a further preferred embodiment the electrical resistance of the shielding tape having a length of 14.0 cm and a width of 5.0 cm and having two connectors attached to each longitudinal end thereof is less than 2 milli-ohms following 50 cycles conducted over a temperature range of -40°C to +60°C and over a cycling period of 8 hours per cycle.

WHAT WE CLAIM IS:

1. Corrosion resistant cable shielding tape comprising a metal strip having a deformation resistant layer of polymeric resinous material tightly bonded (as hereinbefore defined) to at least one side thereof, said deformation resistant layer having a deformation temperature of at least 130°C.
2. Cable shielding tape as claimed in claim 1, including an adhesive/heat seal layer of thermoplastic polymeric resinous material tightly bonded to one side of the metal strip.
3. Cable shielding tape as claimed in claim 1 or claim 2, including a heat seal layer of thermoplastic polymeric resinous material tightly bonded to at least one said deformation resistant layer on the side of the deformation resistant layer opposite to that on which the



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4. Cable shielding tape as claimed in any one of the preceding claims, including an adhesive layer of polymeric resinous material, having good bonding characteristics to the deformation resistant layer and metal strip, disposed between and tightly bonded to the metal strip and at least one said deformation resistant layer.

5. Cable shielding tape as claimed in claim 4, wherein the bond between the metal strip and the adhesive layer tightly bonded thereto is stronger than the interlayer bond of other tightly bonded layers of polymeric resinous material.

6. Corrosion resistant cable shielding tape comprising (1) a metal strip having tightly bonded (as hereinbefore defined) to one side thereof a first adhesive layer comprised of a copolymer of ethylene and from 2 to 20 percent based on copolymer weight of an ethylenically unsaturated carboxylic acid; and (2) a first deformation resistant layer composed of a polymeric resinous material tightly bonded (as hereinbefore defined) to said first adhesive layer, said first deformation resistant layer having a deformation temperature of at least 130°C.

7. Cable shielding tape as claimed in any one of the preceding claims, wherein said tape has less than eight corrosion damage points in an area of 25.0 cm² following simulated jacketing and corrosion tests, conducted by the test method as hereinbefore defined.

8. Cable shielding tape as claimed in any one of the preceding claims, wherein the ultimate tensile strength in a cross machine direction of multiple layers of the polymeric resinous material including said deformation resistant layer positioned on one side of the metal strip only is at least 2.0 kg/mm² measured using the test method (ASTM D-882) as hereinbefore defined.

9. Cable shielding tape as claimed in claim 8, wherein the elongation of said multiple layers is at least 500%.

10. Cable shielding tape as claimed in any one of the preceding claims, wherein the percentage weight increase of the tape is less than 6.0% after exposure for two seconds in a cable filler composition comprising 92 weight percent petrolatum and 8 weight percent polyethylene maintained at a temperature of 115.5°C and after wiping off excess filler composition from the tape.

11. Cable shielding tape as claimed in any one of the preceding claims, wherein the electrical resistance of the shielding tape having a length of 14.0 cm and a width of 5.0 cm and having two connectors attached to each longitudinal end thereof is less than 2 milli-ohms following 50 cycles conducted over a temperature range of -40°C to +60°C and over a cycling period of 8 hours per cycle.

12. Cable shielding tape as claimed in claim 1 substantially as hereinbefore described in any one of Examples 1, 2, 4 to 15, and 19 to 27 in Table I.

13. Cable shielding tape as claimed in claim 1 substantially as hereinbefore described with reference to and as illustrated in any one of Figures 1 to 9 of the accompanying drawings.

14. Cable adapted for use in supplying electrical power and communications comprising a core of at least one insulated conductor, a shielding tape as claimed in any one of the preceding claims surrounding said core, and an outer plastic jacket surrounding the tape.

15. Cable adapted for use in supplying electrical power and communications comprising a core of at least one insulated conductor, a shielding tape as claimed in claim 5 surrounding said core, and an outer plastic jacket surrounding the tape, wherein the adhesive layer remains tightly bonded to the metal strip of the shielding tape following removal of the jacket.

16. Cable as claimed in claim 14 or claim 15 substantially as hereinbefore described with reference to and as illustrated in Figure 10 or Figure 11 of the accompanying drawings.

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