

PATENT SPECIFICATION

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(54) HEAT-RECOVERABLE CLOSURE METHOD AND CLIP

(71) We, RAYCHEM CORPORATION, a Corporation organized according to the laws of the State of California, United States of America, of 300 Constitution Drive, Menlo Park, California 94025, 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 a method of protecting a substrate, especially an elongate substrate such for example, as a cable, a pipe or a connector:

Many attempts have been made to solve the problems involved in forming a protective closure member around an elongate substrate when access to neither end of the substrate is possible. Dimensionally heat-unstable polymeric materials have been utilized in a number of "wrap-around" closure articles and methods with varying degrees of success in specific applications. As examples, there may be mentioned the following patent specifications which all relate to aspects of forming a wrap-around protective closure using heat-recoverable polymeric material, and which are incorporated as part of the disclosure of this application by reference herein:

Conde	U.S. Pat. No. 3,379,218
Ellis	U.S. Pat. No. 3,455,336
Wilson	U.S. Pat. No. 3,530,898
Muchmore	U.S. Pat. No. 3,542,077
Tanaka	U.S. Pat. No. 3,574,313
Evans et al.	U.S. Pat. No. 3,770,556
Evans	U.S. Pat. No. 3,847,721
Sovish et al.	U.S. Pat. No. 3,899,807
Clabburn et al.	U.K. Pat. No. 1,219,768
and	DT-OS 2,543,358
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It is evident from the patent specifications listed above that a great deal of effort has been expended in the attempt to devise a wrap-around closure member which is simple and economical to fabricate and quick and easy to install. While the various devices and methods referenced above satisfactorily accomplish the functions for which they were designed, each in some way requires a more or less involved manufacturing or installation technique or results in a closure member which suffers from at least one disadvantage.

The present invention provides a method of protecting a substrate using a sheet of

cross-linked polymeric material at least a part of which sheet is dimensionally heat-unstable, which comprises wrapping the sheet about the substrate, clamping between the jaws of a reusable installation tool portions of the sheet along a to-be-formed bond line with one part of the face of the sheet that is closer to the substrate in contact with a second part of the face; at least said parts of the face of the sheet being of material self-bondable on heating, applying heat by means of an external heat source to at least the portions to bond them and applying heat to cause recovery of at least part of the sheet, and removing the tool from the sheet.

The present invention also provides a method of forming a closure cap about a truncated end of an elongate substrate using a sleeve of cross-linked, dimensionally heat unstable polymeric material comprising the steps of:

sliding a portion of the length of said sleeve over said truncated end of said elongate substrate:

clamping collapsed, overhanging, laid-together portions of said sleeve disposed along a to-be-formed bond line between cooperating parallel jaws of a reusable installation tool to form an assembly enveloping said truncated end of said elongate substrate;

heating parts of said assembly with an external heat source thereby bonding the materials clamped between said cooperating parallel jaws and shrinking selected portions of said sleeve around said substrate; and

removing said reusable installation tool from along said bond line, thereby forming said closure cap.

It will be seen from the above that the present invention broadly provides methods of forming a closure member about a substrate using a sheet of cross-linked, dimensionally heat-unstable polymeric material comprising wrapping the sheet about the substrate; clamping laid-together portions of the sheet disposed along a to-be-formed bond line between cooperating parallel jaws of a reusable installation tool to form an assembly, which is advantageously generally tubular, around the substrate; heating parts of the assembly with an external heat source thereby bonding the materials clamped between the cooperating parallel jaws and radially shrinking selected portions of the sheet around the substrate; and removing the reusable installation tool from along the bond line, thereby forming the closure member. The selected portions may, of course, constitute the whole, or practically the whole, of the sheet.

Advantageously the removal tool used in the method comprises a modular clip assembly including at least two clip modules each of which possesses first and second parallel jaws, first and second handles connected to the jaws, hinge means for allowing the jaws to move cooperatively into and out of engagement with each other in longitudinally parallel relationship, and spring means for urging the jaws into mutual engagement. Flexible linking means interconnecting the at least two clip modules are employed for maintaining a selected longitudinal relationship between the modules thereby facilitating the hand installation of the modular clip assembly along the to-be-formed bond line.

Preferably, there is used a clip having a pair of longitudinally parallel jaws formed with cooperating plates, spring means urging the jaws toward a closed position in which the jaws are in contact with each other, and manually operable means for urging the jaws away from the closed position, the pair of jaws each possessing a gripping flange disposed inwardly at the terminal portion of each cooperating plate, each gripping flange and associated plate having a generally L-shaped cross-section, the short arms of the L's which correspond to the gripping flanges being substantially collinear in the closed position, the portions of the plates having the cross-section corresponding to the long arms of the L's being provided with a plurality of ventilating apertures adjacent to the gripping flanges.

For specific applications, the parallel jaws of each clip module can be configured to conform to that portion of a selected to-be-formed curved bond line corresponding to the module's position in the longitudinal assembly.

The method of the invention employs sheets of which at least the portion to be clamped at the bond line to be formed is a self-bonding polymeric material. Preferably the whole of the sheet is of a self-bonding polymeric material.

Although many commonly used, cross-linked dimensionally heat-unstable polymeric materials such as, for example, high density cross-linked polyethylene, do not exhibit significant self-bonding at their recovery temperatures, some polymeric materials suitable for use with the method of this invention are known. The amount of self-bonding a given polymeric material exhibits can be measured objectively to determine if it is suitable for use with the present invention.

A well known, standard procedure for measuring the peel strength of adhesive bonds is described by the American Society for Testing and Materials "T-Peel Test" A.S.T.M. designation: D 1876-72 which is incorporated herein by reference. Although the T-peel test is concerned with adhesive bond strengths, the test apparatus described in the standard can

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be used to measure the T-peel strengths of bonds formed between clamped surface portions of self-bonding polymeric materials. Briefly, two 1 inch (25.4 mm) wide strips of cross-linked dimensionally heat-unstable polymeric sheet material are cut from an unrecovered sheet. The strips are oriented in the sheet such that the direction of maximum heat instability in the sheet lies parallel to the longitudinal axis of each strip. The strips are then laid together in registry and clamped with a force of 60 pounds per square inch (4.2 kg/cm²) between a pair of 1/8 inch (3.1 mm) wide parallel jaws which have smooth, flat contacting faces. The jaws define a straight 1 inch (25.4 mm) long, 1/8 inch (3.1 mm) wide, to-be-formed bond line disposed at right angles to the longitudinal axis of the strips. Those portions of the strips not clamped between the jaws are separated from each other to avoid self-bonding. The clamped portions of the strip are heated externally to the recovery temperature of the material, thereby forming a bond line and shrinking portions of the strips adjacent the clamped portions. The strips are allowed to cool to room temperature and then the clamping jaws are removed. Free ends of the bonded strips are clamped in a pair of linearly separable test grips of an Instron (Trade Mark) Tensometer tension testing machine. When properly clamped in the test apparatus, the bonded strips have a generally T-shaped, cross-sectional configuration wherein the bond line is positioned at right angles to the line of test grip motion so as to be peeled apart by the separation of the test grips. Self-bonding materials which are preferred for use with the method of this invention will exhibit a peak T-peel bond strength reading of at least 0.071 kg per linear mm (4 pounds per linear bond inch) at a constant test grip separation rate of 50.8 mm (2 inches) per minute.

A family of presently preferred self-bonding polymeric materials suitable for forming cross-linked dimensionally heat-unstable sheets which are in turn suitable for practicing the method of the invention is described in a U.S. Patent No. 4,001,065. More specifically, the presently preferred self-bonding sheets of polymeric material comprise a cross-linked copolymer of an ethylenically unsaturated hydrocarbon and a carboxylic acid ester having ethylenic unsaturation. The ethylenically unsaturated hydrocarbon is preferably ethylene or an α -ethylenically unsaturated aliphatic hydrocarbon. The carboxylic acid ester may be derived either from an unsaturated alcohol and a saturated carboxylic acid or from a saturated alcohol and an unsaturated carboxylic acid. As examples, there may be mentioned vinyl acetate, butyrate and propionate; esters (for example methyl and ethyl esters) of fumaric, maleic and itaconic acids, including the mono- and di-esters; and esters of acrylic or methacrylic acid.

It will be understood that the copolymers may be derived from more than one member of each of the above-mentioned groups; in addition, the copolymer may contain units derived from monomers other than those within the groups. For example, some vinyl acetate units of an ethylene-vinyl acetate copolymer may be saponified to yield alcoholic groups, while partial saponification of an ethylene-ethyl acrylate copolymer yields a polymer containing carboxylic acid groups. Alternatively the copolymer may be a terpolymer, ethylene-vinyl acetate-unsaturated carboxylic acid copolymers being examples of effective materials. Blends of a polymer as described above may also be employed, including blends of two or more such polymers as well as blends of one or more such polymers with polymers other than those described above. As polymers outside those described above especially suitable for such blends there may be mentioned copolymers of ethylene with ethylenically unsaturated carboxylic acids, for example with acrylic, methacrylic, maleic, fumaric or itaconic acids. In cases where acid groups are present in the polymer or the blend they may be neutralized in whole or in part by metals, for example the alkali metals, alkaline earth metals, zinc, magnesium or aluminium. For example ionomers (for example those sold under the trade mark "Surlyn" by E.I. Du Pont de Nemours & Co. Inc.) may be employed in the blends. In the case of trivalent salts, for example aluminium, cross-linking usually occurs and the method of crosslinking the sheet whereby aluminium alkoxides (for example aluminium butoxide or isopropoxide) is diffused into the system is to be regarded as an alternative to radiation or other chemical methods of cross-linking discussed hereinafter.

Preferably, the proportion by weight of the polymer (or, where a blend, of the polymers in the blend) of units derived from ethylenically unsaturated hydrocarbons is at least 50%, preferably at least 60%; preferably the proportion is at most 90%. At too-low hydrocarbon ranges the polymer tends to be insufficiently crystalline to have recovery properties. If the hydrocarbon range is too high, the self-bonding adhesion of the sheet tends to suffer. It will be apparent that the most preferred proportions within the range will differ from one copolymer to another and it will also be apparent that it is but a matter of routine experiment to determine optimum ratios in any particular case.

The polymers may be blended with tackifying or adhesion-improving substances, for example, phenol-aldehyde adducts, ketone-aldehyde adducts, partially hydrolyzed silanes (for example, those described in British Patent Specification No. 1,255,493) or mixtures thereof.

The polymer may also be admixed with another polymer to improve chemical or physical characteristics, for example, flexibility. As examples of "flexibilizing" polymers, there may be mentioned rubbers, for example an ethylene-propylene rubber. Especially suitable are oil extended ethylene-propylene copolymers containing 50% to 80% of ethylene, the preferred oil being a naphthenic oil when the material is to be used in connexion with high voltage equipment. Preferably, the "flexibilizing" additive is present in a proportion of up to 20% by weight of the polymer mixture.

The flexibility is also affected by the melt index of the polymer; in general the melt index may be from 1 to 500, preferably 2 to 200. The higher the index, the more flexible the polymer.

The base polymers may optionally also contain the usual additives such for example as fillers, flame retardants, anti-oxidants, stabilizers and pigments. Typical of these classes of material are carbon blacks; metallic oxides, for example, ferric oxide, zinc oxide, titanium dioxide; silicas and silicates, alumina, hydrated alumina, barium sulphate or calcium sulphate, phenolic or amine anti-oxidants; stabilizers, for example, dibasic lead phosphite and dibasic lead fumarate; pigments, for example, phthalocyanines, lead molybdate, cobalt blue and chrome green.

The materials may be blended by methods generally used in the plastics industry, for example, in a two-roll mill or Banbury mixer. The material may then be fabricated into a tube or flat sheet by any of the usual fabrication processes, for example extrusion. The material can subsequently be cut to the desired dimensions; cutting is preferably carried out after expansion.

The material may be cross-linked before or after expansion; cross-linking may be by chemical means or by irradiation. As chemical cross-linking agents there may be mentioned peroxide catalysts and Claisen condensation catalysts. Typical examples are 2,5-dimethyl-2,5-di(tert.butyl peroxy)hexane, 2,5-dimethyl-2,5-di(tert.butyl peroxy) hexyne-3, dicumyl peroxide, di tert. butyl peroxide, dibenzoyl peroxide, tert. butyl peroctoate, tert. butyl perbenzoate, tert.butyl percrotonate, tert. butyl perpivalate, diisopropyl peroxy dicarbonate, hexylene glycol benzoate perbenzoate, lauroyl peroxide and propionyl peroxide. Suitable Claisen catalysts include sodium hydroxide, potassium hydroxide, sodium ethoxide.

Radiation cross-linking may be achieved by means of ultraviolet or high energy electron irradiation, or a γ -ray source, for example, cobalt 60, with or without the presence of polyfunctional monomers, for example, divinyl benzene, allyl methacrylate, trimethylol propane or triallyl cyanurate. In the absence of such monomers, the dose may be, for example, 1 to 50 Mrad., preferably 2 to 30 Mrad. The dose required in any particular case is reduced by the addition of the monomer. Where ultraviolet radiation is employed, one of the usual sensitizers, for example benzophenone, is added. Preferably, the sheet will be approximately 0.01 to 1.0 cm thick, for example about 0.1 cm, although the thickness will depend to some extent on the strength of the material, its degree of expansion and the application for which it is intended. Although the materials may be expanded by up to three or four times the original dimensions, normally an expansion of 1.25 to 2.0 is preferred.

If desired, an additional bond may be formed between the juxtaposed, clamped and heated portions of the inside surface of the sheet by using separate adhesive materials. These adhesive materials can be disposed as a layer on a portion of the inside surface along at least a part of the to-be-formed bond line to be sandwiched between the clamped portions of the sheet. Depending on the type of adhesive and the type of polymeric sheet material used, in some embodiments it will be desirable to dispose a layer of adhesive on both contacting portions of the inside surface which will be juxtaposed, clamped and heated. As a manufacturing expedient or for other considerations in some embodiments it will be desirable to form an adhesive layer on substantially all of the inside surface. In other embodiments, a liquid adhesive such as, for example, those comprising cyano acrylate esters, or a liquid activator for an adhesive coating already on a portion of the inside surface will be spread between the juxtaposed portions of the sheet prior to the clamping and heating steps. In one embodiment, a strip of hot melt adhesive, supplied separately in the form of a tape, may be interposed between the laid-together portions of the sheet along the to-be-formed bond line prior to the clamping and heating steps. An example of a hot melt adhesive which can be supplied as a tape and which satisfactorily bonds cross-linked high density polyethylene is Versalon (trade mark) 1140 which is available from General Mills Chemical Division, Minneapolis, Minn., U.S.A.

Although many adhesives are known, those which are suitable for use with a selected polymeric material in the practice of the present invention can be determined objectively through a test procedure. The test procedure is analogous to the one described for determining the suitability of self-bonding polymeric materials. The standard adhesive bonding test described in A.S.T.M. D 1876-72 is not completely reliable for determining

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the suitability of an adhesive because of the heat-shrinkable nature of the bonded test strips. For example, a given adhesive may satisfactorily bond test strips of a selected polymeric material at room temperature before the strips are subjected to the heat required for their recovery. However, the same bond may be unable to withstand the temperature and stresses associated with heat recovery. Those adhesives which are suitable for use with a selected polymeric material in the practice of this invention will, when tested as described above, exhibit a peak T-peel bond strength reading of at least 4 pounds per linear bond inch (0.071 kg/linear mm) at a constant test grip separation rate of 2 inches (50.8 mm) per minute.

The method of the invention allows sheet material to be cut and clamped in close conformation with irregularly shaped objects thereby allowing sheet materials with lower shrink ratios to be used. Bond lines formed by the method of the invention require no permanent clips, pins, channels or the like and are therefore nonconductive if the polymeric material is non-conductive and can be relatively flexible. For field use, self-bonding heat shrinkable material can be supplied in tubular form and either used as such or slit longitudinally and installed according to the invention. A number of sheet segments can be clamped together to form larger closure members.

Several ways of carrying out the method of, and installation tools for use in the method of the invention will now be described by way of example with reference to the accompanying drawings, in which:

Figure 1 is a perspective view of a sheet of heat-shrinkable polymeric material partially installed with reusable clamps around a substrate to form a tubular assembly;

Figure 2 is a perspective view of the assembly of Figure 1 showing the reusable clamps partially removed after heat has been applied to form a bond between clamped portions of the sheet and to shrink the sheet around the substrate;

Figure 3 is a cross-sectional view of the assembly of Figure 1 as seen through the lines 3-3;

Figure 4 is a cross-sectional view through the lines 4-4 in Figure 1 showing additional adhesive strips positioned for clamping between laid-together portions of the sheet;

Figure 5 is a partial cross-sectional view through the lines 5-5 in Figure 2 which shows a portion of the completed closure member with the reusable clamp removed;

Figure 6 is a cross-sectional view through the lines 6-6 in Figure 2 which shows a portion of the bonded and heat-shrunk sheet with a reusable clamp still in place;

Figure 7 is a cross-sectional view through the lines 7-7 in Figure 2 which shows the clamped, bonded and heat-shrunk tubular assembly with an additional adhesive disposed between the clamped and bonded portions of the sheet;

Figure 8 is a perspective view of an irregularly shaped connector so positioned that no access is possible to its ends;

Figure 9 is a perspective view of a sheet of heat-shrinkable polymeric material which has been wrapped around the connector of Figure 8 and clamped with a reusable installation tool to form a tubular assembly;

Figure 10 is a partial cross-sectional view of the assembly of Figure 9 as seen through the lines 10-10;

Figure 11 is a perspective view of the tubular assembly shown in Figure 9 after the assembly has been heated to form a bond between clamped portions of the sheet and to shrink the tubular assembly around the connector;

Figure 12 is a partial cross-sectional view through the lines 12-12 in Figure 11 which shows a portion of the bonded and heat-shrunk sheet with the jaws of the reusable installation tool still in place; and

Figure 13 is the partial cross-sectional view shown in Figure 12 with the reusable installation tool removed.

Figure 14 is a stylized perspective view of a modular clip assembly usable in the method of the invention possessing curved cooperating parallel jaws for forming a selected curved bond line;

Figure 15 is a perspective view of a further clip assembly one embodiment for use in the method of the invention;

Figure 16 is an end view of a form of modular clip shown with the cooperating parallel jaws in the closed position;

Figure 17 is a side view of the clip shown in Figure 16;

Figure 18 is an end view of the clip of Figure 16 shown with the cooperating parallel jaws in an open position; and

Figure 19 is a view looking into the closed jaws of the improved modular clip shown in Figure 17.

Referring now generally to the drawings and specifically to Figure 1, a sheet of cross-linked, dimensionally heat-unstable polymeric material 10 is shown partially wrapped about an elongate substrate 12. The substrate 12 may comprise for example, a conductor, a

pipe, or a connector. Moreover, the substrate 12 need not be of constant cross-section as is shown in Figures 1 through 7. The heat instability of the sheet 10 and its orientation with respect to the substrate 12 are preferably such that the sheet is shrinkable around the circumference of the substrate and most preferably such that the sheet is shrinkable around the circumference of the substrate without a substantial change in length along the longitudinal axis of the substrate. A particularly economical sheet with the preferred heat instability characteristics can be fabricated by simply extruding a tube and rendering it heat shrinkable by the method of Cook et al. U.S. Pat. No. 3,086,242. The heat recoverable tube is then slit longitudinally to form the desired sheet.

The sheet 10 possesses a pair of primary surfaces 14 and 16 which will for convenience be referred to as the outside surface and the inside surface respectively. It is of course obvious that the relative positions of the primary surfaces 14 and 16 can be easily interchanged by wrapping the sheet 10 "inside-out" around the substrate 12. After the sheet 10 has been wrapped about the substrate 12, portions of the inside surface 16 are laid together in contact with one another to form a generally tubular structure around the substrate 12. The portions of the sheet which are laid together as described and shown are said to be arranged in lay-up lap seal configuration. This configuration of the sheet 10 is distinguished from an overlap seal configuration wherein a portion of the inside surface 16 is juxtaposed with a portion of the outside surface 14 again forming a generally tubular structure which surrounds the substrate 12. The importance of using a lay-up lap seal configuration rests in the ability of the protruding laid-together portions of the sheet 10 to be clamped on the outside of the resulting tubular structure. It is clear that more complex laid-together configurations of the sheet 10 involving combinations of a lay-up lap seal and an overlap seal also possess the ability to be clamped externally.

A reusable installation tool, shown in Figures 1 and 2 as a modular clip assembly indicated generally by reference numeral 18 formed with a plurality of clip modules indicated generally by reference numeral 20 longitudinally interconnected by a flexible cable 22 is installed as shown in Figure 1. A pair of retaining beads 23 disposed one at each end of the flexible cable 22 confines the individual clip modules 20 on the cable 22. Thus confined, the hand installation of the clip modules 20 is facilitated, since the next module to be installed is always close at hand. Each clip module 20 possesses a pair of cooperating jaws 24.

The parallel jaws 24 of each modular clip 18 are installed in substantial longitudinal abutment with one another to define a substantially continuous to-be-formed bond line. Although Figures 1 and 2 show the parallel jaws 24 of the modular clip assembly 18 installed to form a straight bond line, it is to be understood that curved, substantially continuous bond lines can also be formed. Curved bond lines are particularly useful for forming closures around irregularly shaped substrates, such as, for example, where a to-be-covered substrate changes from a small cross-section at one end to a larger cross-section in the middle and then back to a small cross-section at the other end. A substantially continuous curved bond line can be formed from straight bond line segments using the modular clip assembly 18 shown in Figures 1 and 2. Alternatively, special purpose modular clip assemblies can be fabricated with each module having curved parallel jaws that conform to the curvature of the underlying substrate at the location corresponding to the module's position in the assembly. Clamping laid-together portions of the sheet 10 with the reusable installation tool 18 as shown and described forms a tubular assembly 26 which is ready for heating.

The next step in forming a closure member involves heating portions of the tubular assembly 26 with an external heat source (not shown) thereby bonding the materials clamped between the cooperating parallel jaws 24 and shrinking selected portions of the sheet 10 radially around the substrate 12. Suitable external heat sources include for example, electric hot air heat guns, open flame torches and infra-red electric lamps.

It is to be understood that in the formation of a closure member the entire sheet 10 need not be completely recovered. In some applications, where for example a closure member is to be formed around a hand-wired connector block used to splice a pair of jacketed multi-conductor telephone cables, it is specifically desired that the sheet 10 be bonded along the clamped bond line, recovered snugly and preferably bonded to the cable jackets at opposite ends of the closure and loose fitting around the wire connector itself. This arrangement functions to protect the connections at the connector block from stress when the cable is in tension by allowing the tension to be transmitted around the connector through the closure member. This protection is provided without subjecting the individual conductors and connections to the full heat required to recover the central portion of the closure member.

After the tubular assembly 26 has been heated to form the bond line and to shrink selected portions of the sheet 10, the tubular assembly is preferably allowed to cool to room

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The final step in the method of the invention requires that the reusable installation tool (shown as the modular clip assembly 18) be removed from along the bond line 32 as is shown in Figure 2 thereby forming a finished closure member indicated generally by reference numeral 34. Those skilled in the art will appreciate that it is not always necessary to allow the tubular assembly to cool to room temperature before removing the reusable installation tool. The exact temperature to which the assembly must be allowed to cool depends upon the specific properties of the polymeric sheet material and the adhesive (if any) used to form the closure member 34.

Figure 3 is a cross-sectional view of the tubular assembly 26 which employs a sheet 10 of self-bonding polymeric material as seen through the lines 3-3 in Figure 1.

Figure 4 is a cross-sectional view through the lines 4-4 in Figure 1 which illustrates the optional adhesive layer 28 and the strip of hot melt adhesive tape 30 positioned for clamping between laid-together portions of the sheet 10. Figure 5 is a partial cross-sectional view through the lines 5-5 in Figure 2 which shows a portion of the completed closure member 34. When a self-bonding polymeric material is used for the sheet 10 the clamped, laid-together portions tend to coalesce along the bond line 32 making the bonded portions appear locally integral in cross-section as is shown. Figure 6 is a cross-sectional view through the lines 6-6 in Figure 2 which shows a portion of the bonded and heat shrunk sheet 10 with a clip module 20 in place. This view illustrates how the cooperating parallel jaws on the clip module 20 are configured to avoid interference with the recovery of the clamped portions of the sheet 10. Figure 7 is a cross sectional view through the lines 7-7 in Figure 2 illustrating the clamped, bonded and heat shrunk tubular assembly with a stylized adhesive 36 bonding the clamped portions of the sheet 10.

Figures 8 through 13 illustrate another application of the method of the invention. Figure 8 is a perspective view of an irregularly shaped coaxial connector indicated generally by reference numeral 50 positioned between a pair of electronic component housings 52 and 54. The connector 50 possesses a pair of end portions 56 and 58 of circular cross section and a central portion of hexagonal section 60. The component housings 52 and 54 restrict access to the coaxial connector 50. Therefore, in order to form a closure around the connector 50 a wrap-around closure article which does not require a locking channel that is slid on longitudinally must be employed. The method of the present invention can be used to form such a closure member.

First, as is shown in Figure 9, a sheet 62 of self-bonding, cross-linked, dimensionally heat unstable polymeric material is wrapped about the connector 50. Portions of the inside surface 64 of the sheet 62 are juxtaposed and clamped between a pair of cooperating parallel jaws 66 of a reusable installation tool 68. The reusable installation tool 68 is shown in Figures 9 and 11 as a pair of specially modified "Vicegrip" pliers. The reusable installation tool 68 and the clamped sheet 62 together form a tubular assembly indicated generally by reference numeral 70 about the connector 50. The parallel jaws 66 possess a recessed central portion 72 which allows the jaws 66 to conform to the tubular end portions 56 and 58 and the hexagonal central portion 60 of the connector 50. Figure 10 is a partial cross-sectional view of the assembly of Figure 9 along the lines 10-10.

Next, heat is applied to the assembly 70 from an external heat source (not shown). The heat bonds the laid-together portions of the sheet 62 clamped between the cooperating parallel jaws 66 and shrinks the remaining portions of the sheet into conformation with the exterior surfaces of the connector 50, resulting in the structure shown in Figure 11.

After the bonded portions of the sheet 62 clamped between the cooperating parallel jaws 66 have been allowed to cool beneath their crystalline melting temperature the bonded portions of the sheet 62 appear integral as is shown in Figure 12.

Removing the reusable installation tool 68 completes the formation of a closure member 74 as shown in Figure 13.

The foregoing discussion has focussed on a presently preferred use of the modular clip assembly 18 in the formation of a wrap-around closure member 34 from a single sheet 10. Nevertheless, it is to be understood that the scope of the invention's utility is broader. For example, the method of the invention can be used with a sheet of cross-linked, dimensionally heat-unstable polymeric material to form an end closure around a truncated substrate. Such a closure may be formed by positioning the sheet formed in a generally tubular configuration to overhang the truncated end of the substrate and by extending the bond line normally disposed along the longitudinal axis of the substrate around the truncated end to seal off the overhanging tubular portion. Similarly, the method of the invention using a modular clip assembly can be used to form an end closure cap by forming a bond line at one end of a tubular section of cross-linked, dimensionally heat-unstable polymeric material.

Figure 14 is a perspective view of a stylized modular clip assembly indicated generally by

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reference numeral 80 which illustrates the structural elements of the invention. A first manually operable clip module 82 possesses first and second parallel jaws 84 and 86 respectively. These jaws are connected respectively to first and second handles 88 and 90. A hinge means, shown generally at 92, allows the jaws 84 and 86 to move cooperatively into and out of engagement with each other in longitudinally parallel relationship. A spring means, shown as a coil spring 94, urges the jaws 84 and 86 into engagement. The assembly includes a second manually operable clip module 96 which possesses elements corresponding to those of the first manually operable clip module 82. Flexible linking means, shown as a chain 98, interconnects the first and second clip modules 82 and 96. The chain 98 functions to maintain the selected longitudinal relationship shown, thereby facilitating the hand installation of the modular clip assembly 80 along the to-be-formed bond line. It will be apparent that the use of a flexible linking means, to which the clip modules are attached, preferably with the contact lines of their jaws generally parallel to the axis of the portion of the flexible connecting means to which they are attached, imparts great versatility to the assembly of the invention. The linking means is substantially free from rigidity, e.g., it has the properties of a chain or a piece of string, to allow any desired configuration to be freely taken up. Third and fourth manually operable clip modules 100 and 102 respectively, are shown in Figure 14 to illustrate the advantages of longitudinally interconnecting individual clip modules. The parallel jaw pairs on each of the four modules shown 82, 96, 100 and 102 are specially configured to conform to a portion of a selected to-be-formed curved bond line corresponding to the module's position in the longitudinal assembly of modules 80. The chain 98 maintains the selected longitudinal relationship shown between the four modules thereby ensuring that the proper jaw pairs are installed at each location along the selected to-be-formed curved bond line.

Figure 15 is a perspective view, before installation, of the same modular clip assembly 18 that is shown partially installed in Figures 1 and 2. Although the modular clip assemblies shown in Figures 1, 2, 14 and 15 are each formed with four clip modules, it is to be understood any number of modules greater than two may be longitudinally interconnected to form an assembly of any desired length.

Figures 16 through 19 are four views of an embodiment of a clip module 20. The clip is an improvement on that described in U.S. Patent No. 1,474,102. The module 20 is formed with a pair of substantially identical plates 104 of generally T-shaped configuration as is best seen in Figure 17. Each plate possesses an inside surface 106, an outside surface 108, a jaw portion 110 corresponding to the upper horizontal part of the notional T and a handle portion 112 corresponding to the upright of the T. Two projections 114 on the jaw portion 110 are disposed parallel to and on opposite sides of the handle portion 112. These projections are cupped on their inside surfaces 106 to form spherical bearing seats 116. The plates 104 are juxtaposed as shown with a pair of ball bearings 118 disposed between aligned bearing seats 116 thereby forming two joints about which the plates 104 may rock. Two tubular clamping springs 120 are disposed around the joints to hold the plates 104 together and to urge the jaw portions 110 into engagement with one another.

The jaw portions 110 of the plates 104 are provided with a pair of bond line gripping flanges 122 which are disposed inwardly at substantially right angles to adjacent jaw portions of the plates. Each bond line gripping flange 122 and adjacent jaw portion 110 has a generally L-shaped cross-sectional configuration which is best seen in Figure 18. When the jaws of the module 20 are in the closed position, as is shown in Figure 16, the short arms of the L's which correspond to the section of the gripping flanges 122 are substantially collinear. The jaw portions 110 of the plates 104 which in section correspond to the long arms of the L's are provided with a plurality of ventilating apertures 124 adjacent the gripping flanges 122 as best seen in Figures 17 and 19. The ventilating apertures 124 provide passageways for hot air and/or radiant heat from the external heat source to reach the laid-together materials clamped between a pair of gripping faces 126 on the bond line gripping flanges 122. The apertures 124 also allow a craftsman heating clamped materials to observe their heat recovery as it progresses.

The optimum dimensions and specifications for the clip module 20 just described are, of course, a function of clip's intended use and engineering constraints. Generally, a larger percent ratio of aperture surface area to total jaw portion surface area is desirable as it facilitates a more rapid heating and cooling of the clamped materials. This percent ratio is, of course, limited by structural considerations. Preferably, the percent ratio is between about 10% and about 90%. For the clip to be easily hand installable, it is preferred that the pressure applied by squeezing the handle portions 122 between thumb and forefinger as shown in Figure 1 need not exceed 10 pounds (4.5 kg), preferably, the force required to open the jaws being between about 3 pounds (1.4 kg) and about 5 pounds (2.3 kg). The thermal conductivity of the clip is preferably greater than that of the material to be bonded. The gripping faces 126 on the bond line gripping flanges 122 are preferably smooth so as to

not cut or otherwise damage the clamped materials. The force per unit area exerted on clamped materials depends in part on the longitudinal length of the clip, shown in Figure 17 as the dimension "A"; the thickness of the gripping flanges 122, shown in Figure 17 as the dimension "B"; the distance of the gripping flanges from the ball-bearing joints, shown in Figure 18 as the dimension "E" and the placement and characteristics of the tubular clamping springs 120. The clamping force per unit area must be sufficient to hold the materials to be bonded in intimate contact initially and throughout the heating and cooling cycle. The flange depth, shown as the dimension "D" in Figure 18, is advantageously equal to one-half the internal jaw clearance, shown as the dimension "C" in Figure 16. The internal jaw clearance "C" is preferably equal to or greater than the composite thickness of the laid-together, bonded and fully recovered materials with which the clip module 20 is to be used. Such a clearance prevents the inside surfaces 106 of the plates 104 from interfering with the recovery of the clamped materials.

By way of example, a few dimensions and specifications are given for a presently preferred clip module 20 intended for use with a longitudinally slit section of Raychem type MS-251 self-bonding, heat shrinkable tubing in the formation of a wrap-around closure member such as is shown in Figures 1 and 2. The wall thickness of this tubing is initially about .030 inches (0.8 mm) and has a fully recovered thickness of about .090 inches (2.1 mm). This tubing is available from Raychem Corporation, Menlo Park, California, U.S.A. The plates 104 are stamped from low carbon steel sheets about .040 inches (1 mm) thick and chromium-plated. The approximate values for the dimensions represented in Figures 16, 17 and 18 by the letters A, B, C, D, and E are as follows:

- A = 2 inches (51 mm)
- B = .040 inches (1 mm)
- C = .180 inches (4.5 mm)
- D = .090 inches (2.2 mm)
- E = 1 inch (25 mm)

Each gripping face 126 has a surface area of about .08 square inches (51.6 sq. mm) and exerts a clamping force of about 40 pounds per square inch (2.8 kg/cm²). The apertures 124 are formed with a plurality of mutually parallel slots, each 1/2 inch (13 mm) long x 1/8 inch (4 mm) wide disposed on 1/4 inch (7 mm) centers substantially as shown in Figure 17.

Advantageously, the portions of the surfaces of the jaws of the clips that contact the surfaces of the sheet have a low tendency to stick to the sheet surfaces; preferably the surface has a coating of polytetrafluoroethylene.

WHAT WE CLAIM IS:

1. A method of protecting a substrate using a sheet of crosslinked polymeric material at least a part of which sheet is dimensionally heat-unstable, which comprises wrapping the sheet about the substrate, clamping between the jaws of a reusable installation tool portions of the sheet along a to-be-formed bond line with one part of the face of the sheet that is closer to the substrate in contact with a second part of the face, at least said parts of the face of the sheet being of material self-bondable on heating, applying heat by means of an external heat source to at least the portions to bond them and applying heat to cause recovery of at least part of the sheet, and removing the tool from the sheet.

2. A method as claimed in claim 1, wherein the whole of the sheet is of self-bondable material.

3. A method as claimed in claim 1 or claim 2, wherein the whole of the sheet is heat-shrinkable.

4. A method as claimed in any of claims 1 to 3, wherein the bond line is substantially straight.

5. A method as claimed in any one of claims 1 to 4, wherein the substrate is generally tubular.

6. A method as claimed in any one of claims 1 to 5, wherein the jaws are parallel.

7. A method as claimed in any one of claims 1 to 6, wherein the bond formed has, at room temperature, a T-peel strength of at least 0.071 kg/linear mm at a separation rate of 50.8 mm per minute.

8. A method as claimed in any one of claims 1 to 7, wherein the self-bondable material is a crosslinked copolymer of an ethylenically unsaturated hydrocarbon and a carboxylic acid ester having ethylenic unsaturation.

9. A method as claimed in claim 8, wherein the hydrocarbon is ethylene or an α -ethylenically unsaturated aliphatic hydrocarbon.

10. A method as claimed in claim 8 or claim 9, wherein the ester is vinyl acetate, vinyl butyrate or vinyl propionate.

11. A method as claimed in claim 8 or claim 9, wherein the ester is a fumaric, maleic,



not cut or otherwise damage the clamped materials. The force per unit area exerted on clamped materials depends in part on the longitudinal length of the clip, shown in Figure 17 as the dimension "A"; the thickness of the gripping flanges 122, shown in Figure 17 as the dimension "B"; the distance of the gripping flanges from the ball-bearing joints, shown in Figure 18 as the dimension "E" and the placement and characteristics of the tubular clamping springs 120. The clamping force per unit area must be sufficient to hold the materials to be bonded in intimate contact initially and throughout the heating and cooling cycle. The flange depth, shown as the dimension "D" in Figure 18, is advantageously equal to one-half the internal jaw clearance, shown as the dimension "C" in Figure 16. The internal jaw clearance "C" is preferably equal to or greater than the composite thickness of the laid-together, bonded and fully recovered materials with which the clip module 20 is to be used. Such a clearance prevents the inside surfaces 106 of the plates 104 from interfering with the recovery of the clamped materials.

By way of example, a few dimensions and specifications are given for a presently preferred clip module 20 intended for use with a longitudinally slit section of Raychem type MS-251 self-bonding, heat shrinkable tubing in the formation of a wrap-around closure member such as is shown in Figures 1 and 2. The wall thickness of this tubing is initially about .030 inches (0.8 mm) and has a fully recovered thickness of about .090 inches (2.1 mm). This tubing is available from Raychem Corporation, Menlo Park, California, U.S.A. The plates 104 are stamped from low carbon steel sheets about .040 inches (1 mm) thick and chromium-plated. The approximate values for the dimensions represented in Figures 16, 17 and 18 by the letters A, B, C, D, and E are as follows:

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Advantageously, the portions of the surfaces of the jaws of the clips that contact the surfaces of the sheet have a low tendency to stick to the sheet surfaces; preferably the surface has a coating of polytetrafluoroethylene.

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1. A method of protecting a substrate using a sheet of crosslinked polymeric material at least a part of which sheet is dimensionally heat-unstable, which comprises wrapping the sheet about the substrate, clamping between the jaws of a reusable installation tool portions of the sheet along a to-be-formed bond line with one part of the face of the sheet that is closer to the substrate in contact with a second part of the face, at least said parts of the face of the sheet being of material self-bondable on heating, applying heat by means of an external heat source to at least the portions to bond them and applying heat to cause recovery of at least part of the sheet, and removing the tool from the sheet.

2. A method as claimed in claim 1, wherein the whole of the sheet is of self-bondable material.

3. A method as claimed in claim 1 or claim 2, wherein the whole of the sheet is heat-shrinkable.

4. A method as claimed in any of claims 1 to 3, wherein the bond line is substantially straight.

5. A method as claimed in any one of claims 1 to 4, wherein the substrate is generally tubular.

6. A method as claimed in any one of claims 1 to 5, wherein the jaws are parallel.

7. A method as claimed in any one of claims 1 to 6, wherein the bond formed has, at room temperature, a T-peel strength of at least 0.071 kg/linear mm at a separation rate of 50.8 mm per minute.

8. A method as claimed in any one of claims 1 to 7, wherein the self-bondable material is a crosslinked copolymer of an ethylenically unsaturated hydrocarbon and a carboxylic acid ester having ethylenic unsaturation.

9. A method as claimed in claim 8, wherein the hydrocarbon is ethylene or an α -ethylenically unsaturated aliphatic hydrocarbon.

10. A method as claimed in claim 8 or claim 9, wherein the ester is vinyl acetate, vinyl butyrate or vinyl propionate.

11. A method as claimed in claim 8 or claim 9, wherein the ester is a fumaric, maleic,



* C L N S *

itaconic, methacrylic or acrylic acid ester.

12. A method as claimed in claim 11, wherein the ester is a methyl or ethyl ester.

13. A method as claimed in claim 8, wherein the copolymer is an ethylene-vinyl acetate copolymer.

5 14. A method as claimed in any one of claims 8 to 13, wherein the copolymer comprises from 50% to 90% by weight of units derived from the hydrocarbon.

15. A method as claimed in claim 14, wherein the copolymer comprises about 60% by weight of units derived from the hydrocarbon.

10 16. A method as claimed in any one of claims 8 to 15, which comprises at least two such copolymers.

17. A method as claimed in any one of claims 1 to 16, wherein at least the self-bonding portion of the sheet also comprises tackifying agents or adhesion-promoting agents.

18. A method as claimed in any one of claims 1 to 17, wherein an adhesive layer is positioned between juxtaposed surfaces of said sheet at the to-be-formed bond line.

15 19. A method as claimed in claim 1, carried out substantially as described with reference to and as illustrated by any one or more of the accompanying drawings.

20. A substrate whenever covered by a method as claimed in any one of claims 1 to 19.

21. A method as claimed in any one of claims 1 to 19, wherein the tool comprises a clip assembly

20 a first manually operable clip possessing first and second jaws, first and second handles connected respectively to said first and second jaws, hinge means for allowing said jaws to move cooperatively into and out of engagement with each other in longitudinally parallel relationship, and spring means for urging said jaws into mutual engagement;

25 a second manually operable clip possessing elements corresponding to those of said first manually operable clip; and

25 flexible linking means interconnecting said first and second clips for maintaining a selected longitudinal relationship between the clips thereby facilitating the hand installation of said clip assembly along said to-be-formed bond line.

30 22. A method as claimed in claim 21 wherein said first and second parallel jaws belonging to one of said manually operable clips engage in a plane, the line of engagement being a straight line therein.

23. A method as claimed in claim 21, wherein said first and second parallel jaws belonging to one of said manually operable clips engage in a plane, the line of engagement being a curved line therein.

35 24. A method as claimed in claim 21, wherein said first and second parallel jaws belonging to one of said manually operable clips engage along a curved line extending across the intersection of two cylindrical surfaces.

25. A method as claimed in claim 24, wherein the axes of the cylinders are parallel.

40 26. A method as claimed in any one of claims 21 to 25, wherein said flexible linking means comprises a cable.

27. A method as claimed in any one of claims 21 to 25, wherein said flexible linking means comprises a chain.

45 28. A method as claimed in any one of claims 21 to 27, wherein said first and second parallel jaws belonging to one of said manually operable clips comprise a pair of cooperating plates.

50 29. A method as claimed in claim 28, wherein each of said cooperating plates possesses a terminal portion disposed inwardly to form a pair of bond line gripping flanges, each gripping flange and associated plate having a generally L-shaped cross-section, the short arms of the L's which correspond to said gripping flanges being substantially collinear when said jaws are closed, the portions of said plates having the cross-section corresponding to the long arms of the L's being provided with a plurality of ventilating apertures adjacent to said gripping flanges.

30. A method as claimed in any one of claims 21 to 29, wherein the hinge means is positioned between the jaws and the handles.

55 31. A method as claimed in any one of claims 21 to 30, wherein at least one of said manually operable clips is formed with a pair of substantially identical plates of generally T-shaped configuration, each plate possessing a jaw portion corresponding to the upper horizontal part of the T, a handle portion corresponding to the vertical part of the T and a pair of projections on said jaw portion disposed parallel to and on opposite sides of said handle portion, said projections being cupped on their inside surfaces to form spherical-bearing seats, said plates being juxtaposed with a pair of ball bearings disposed between aligned bearing seats thereby forming two joints about which said plates may rock, the clip further possessing a pair of tubular clamping springs which embrace said joints holding said plates together and urging said jaw portions into engagement.

65 32. A method as claimed in claim 31, wherein the clip further comprises jaw portions of



acetate			said plates possessing a pair of bond line gripping flanges disposed inwardly at substantially right angles to adjacent jaw portions of said plates, each bond line gripping flange and adjacent jaw portion of said plate having a generally L-shaped cross-sectional configuration, the short arm of the L corresponding to said flange having a length of at least one-half the maximum composite thickness of fully heat-recovered materials intended to be clamped by said selected clip, the portions of said plate corresponding to the long arm of the L being provided with a plurality of ventilating apertures adjacent said flange.	
comprises	5	5	33. A method as claimed in any one of claims 21 to 31, wherein the jaws of each clip are provided with ventilating apertures.	5
60% by			34. A method as claimed in any one of claims 1 to 19, wherein the tool comprises a clip having a pair of longitudinally parallel jaws formed with a pair of cooperating plates, spring means urging said jaws toward a closed position in which said jaws are in contact with each other and manually operable means for urging said jaws away from said closed position wherein the jaws each possess a gripping flange disposed inwardly at the terminal portion of each said cooperating plate, each gripping flange and associated plate having a generally L-shaped cross-sectional configuration, the short arms of the L's which correspond to said gripping flanges being substantially collinear in said closed position, the portions of said plates having the cross-section corresponding to the long arms of the L's being provided with a plurality of ventilating apertures adjacent said gripping flanges.	10
two such	10	10	35. A method as claimed in any one of claims 1 to 19, wherein the tool includes a clip suitable for use in an assembly of similar clips laid side by side said clip being formed with a pair of substantially identical plates of generally T-shaped configuration, each plate possessing a jaw portion corresponding to the upper horizontal part of the T, a handle portion corresponding to the vertical part of the T and a pair of projections on said jaw portion disposed parallel to and on opposite sides of said handle portion, said projections being cupped on their inside surfaces to form spherical-bearing seats, said plates being juxtaposed with a pair of ball bearings disposed between aligned bearing seats thereby forming two joints about which said plates may rock, said clip further possessing a pair of tubular clamping springs which embrace said joints holding said plates together and urging said jaw portions into engagement characterized in that the jaw portions of said plates possess a pair of bond line gripping flanges disposed inwardly at substantially right angles to adjacent jaw portions of said plates, each bond line gripping flange and adjacent jaw portion of said plate having a generally L-shaped cross-sectional configuration, the short arm of the L corresponding to said flange having a length of at least one-half the maximum composite thickness of fully heat-recovered materials intended to be clamped by said clip, the portions of said plate having the cross-section corresponding to the long arm of the L being provided with a plurality of ventilating apertures adjacent said flange.	15
bonding agents.			36. A method as claimed in any one of claims 1 to 19, wherein the tool comprises a clip assembly comprising:	20
layer is			a first manually operable clip possessing first and second parallel jaws, each of said jaws possessing a terminal portion disposed inwardly to form a pair of bond line gripping flanges, each of said gripping flanges and said jaws forming a generally L-shaped cross-sectional configuration, first and second handles connected respectively to said first and second jaws, hinge means for allowing said jaws to move cooperatively into and out of engagement with each other in longitudinally parallel relationship, and spring means for urging said jaws into mutual engagement;	20
nd line.			a second manually operable clip possessing elements corresponding to those of said first manually operable clip and	25
ed with wings.	15	15	flexible linking means interconnecting said first and second clips for maintaining a selected longitudinal relationship between said clips thereby facilitating the hand installation of said clip assembly along said to-be-formed bond line.	25
1 to 19.			37. A method as claimed in claim 36, wherein the jaws have ventilating apertures.	30
ses a clip	20	20	38. A method as claimed in claim 36 or claim 37, wherein the hinge means of each clip is positioned between the handles and the jaws.	30
handles			39. A method as claimed in claim 21, substantially as described with reference to, and as illustrated by, any one or more of the accompanying drawings.	35
d jaws to y parallel	25	25	40. A method of forming a closure cap about a truncated end of an elongate substrate using a sleeve of cross-linked, dimensionally heat unstable polymeric material comprising the steps of:	35
said first			sliding a portion of the length of said sleeve over said truncated end of said elongate substrate;	40
aining a stallation	30	30	clamping collapsed, overhanging, laid-together portions of said sleeve disposed along a to-be-formed bond line between cooperating parallel jaws of a reusable installation tool to form an assembly enveloping said truncated end of said elongate substrate;	40
allel jaws gagement	35	35	heating parts of said assembly with an external heat source thereby bonding the materials	45
allel jaws gagement	40	40		45
allel jaws extending	45	45		50
parallel.				55
le linking	50	50		60
le linking				65
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possesses ages, each the short near when bonding to adjacent to	60	60		
e means is				
one of said of generally the upper the T and a des of said a spherical- ed between ck the clip bonding said	65	65		
portions of				



clamped between said cooperating parallel jaws and shrinking selected portions of said sleeve around said substrate; and removing said reusable installation tool from along said bond line, thereby forming said closure cap.

5 41. A substrate whenever covered by a method as claimed in any one of claims 21 to 40.

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