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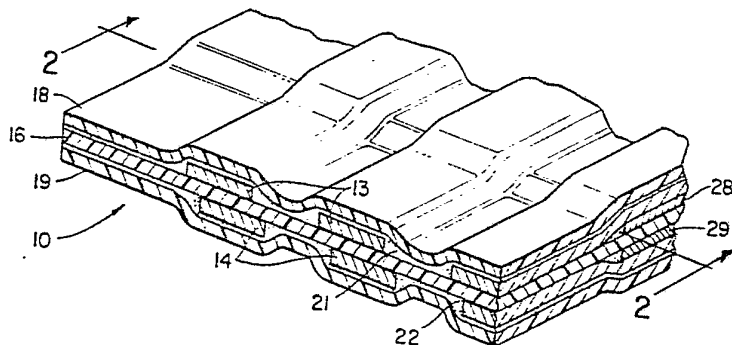
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(54) Title: MULTI-CONDUCTOR FLAT CABLE AND METHODS AND APPARATUS FOR THE MANUFACTURE AND CONNECTORIZATION OF SAME

(57) Abstract

Several flat cable embodiments (10, 10', 10'', 10''', 10''') are disclosed, as are methods and apparatus (30) for the selective manufacture and connectorization of same. In accordance with one preferred flat cable embodiment (10), adapted for telephone under carpet applications, two precisely offset arrays of rectangularly shaped conductors (13, 14) are separated by a center film (16), with each array being adhesively bonded through an associated adhesive coating (21 or 22) to only the respectively adjacent one of two outer films (18 or 19). The laminating apparatus (30) includes a first pair of laminating rollers (31, 32), one (31) being both internally and externally heated, and having a smooth peripheral surface formed of a layer (68) of resilient material, the other (32) having a steel peripheral surface formed with a plurality of specially dimensioned conductor-receiving grooves (72), and a second pair of finishing rollers (37, 38), each being unheated and having a smooth, peripheral surface formed of a layer (37a or 38a) of resilient material. It has been found that by utilizing a center film (16) with no adhesive coating initially on either side thereof, and the specially constructed laminating apparatus (30), when used in conjunction with properly chosen laminating pressures, temperatures and feed rate, the resultant fabricated cable (10) exhibits excellent bond strength, and consistently and precisely maintained conductor spacings. In accordance with another aspect of the invention, isolating strips (28, 29) are at least lightly secured on opposite sides of, and extend transversely across, the center film (16) at predetermined spaced terminating points therealong so as to facilitate the termination of the cable (FIGS. 8-12), and the subsequent connectorization of the terminated conductor ends (13a, 14a) thereof to a connector (25).



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MULTI-CONDUCTOR FLAT CABLE AND METHODS AND APPARATUS
FOR THE MANUFACTURE AND CONNECTORIZATION OF SAME

Field of the Invention

This invention relates to multi-conductor flat
5 cable and, in particular, to methods and apparatus for the
manufacture and connectorization thereof.

Background of the Invention

Flat flexible cable is finding ever increasing
use in the telecommunications industry, and in such
10 applications it is important that such cable exhibit
extremely high crosstalk rejection, be of minimum
thickness, and be capable of being folded back upon itself,
so as to be applicable for telephone under-carpet cable,
TUCC[®], applications (a registered trademark of the Western
15 Electric Company).

Flat cable, particularly of the 25 pair type
designed for telephone system wiring, has taken a number of
different forms heretofore, particularly in order to reduce
crosstalk to tolerable levels. One of the earliest forms
20 of such cable was comprised of a woven ribbon of twisted
pair conductors. Disadvantageously, such cable was
relatively thick (on the order of 2 mm), and when folded
back upon itself so as to allow the cable to change
direction when laid under carpet, for example, produced
25 intolerable bumps that were found objectional from even an
esthetic standpoint.

Another approach taken to reduce troublesome
crosstalk in flat cable heretofore has involved forming
so-called pseudo-twists (or crossovers) at predetermined
30 spaced intervals therealong. In the latter type of cable,
the conductors are normally initially fabricated along a
common plane, with the zig-zag patterns of the respective
conductors being spaced apart and arranged relative to each
other in distinct groups so that when the fabricated cable
35 is folded back upon itself in the longitudinal direction,



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the then respectively associated pairs of overlying-underlying conductors in the two groups effectively cross-over each other in a pseudo-twist manner. Unfortunately, when such a once folded cable is again folded back upon
5 itself to effect bends therealong, it too exhibits undesirable thickness, particularly in the areas of the bends when required in under-carpet applications. Moreover, it has also been found quite difficult to manufacture the latter type of flat cable with crosstalk
10 losses in excess of 100db, particularly in end use lengths greater than 3 to 5 meter.

The criticality of crosstalk in telephone system wiring may perhaps be most readily appreciated when it is realized that the human ear can detect and interpret voice
15 information at signal levels of nearly 100db-five orders of magnitude down from, or only 0.001 percent of, the desired voice signal. In contradistinction, the crosstalk rejection requirements for flat cable used in computers, as well as in other digital systems, is far less demanding.
20 For example, in such applications, the digital hardware can typically ignore up to one percent crosstalk (20db loss). It is thus seen that flat cable when used in telephone voice applications must be 100 times more effective with respect to signal crosstalk rejection than when used in
25 digital transmission applications.

Other attempts to reduce crosstalk in flat cable, particularly when the conductors are in overlying-underlying arrays, have involved the use of metallic shields, specially constructed and positioned screens, that
30 separate groups or pairs of conductors, and ground planes. The purpose of such auxiliary members, of course, is to establish desirable capacitive-decoupling electric and magnetic field boundaries about either pairs or groups of conductors within the cable. While such flat cables
35 generally exhibit excellent crosstalk rejection characteristics, they disadvantageously are likewise relatively thick, often are quite inflexible, and are



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costly to manufacture.

Still another approach taken to reduce crosstalk heretofore has been to vary the spacing between either adjacent conductors forming a given pair, or the spacings
5 between pairs, while lying in a common plane. In many telephone wiring applications, where 25 conductor pairs are generally desired, such cables must necessarily be considerably wider than when the conductors are arranged in two overlying/underlying arrays, with only 25 conductors in
10 each array.

As a result of the aforementioned crosstalk, dimensional and cost problems involved in the manufacture of flat cable for telephone applications heretofore, a completely different approach to attacking these problems
15 evolved in the design of a cable wherein two peculiarly aligned, and precisely offset, overlying/underlying arrays of conductors are fabricated in a common insulative medium, such as in an extruded plastic carrier or, in separate flat cables which are thereafter bonded together or, more
20 preferably, are interleaved and laminated between three plastic films.

Considered more specifically, it has been found in such a cable that capacitive decoupling, which gives rise to a very significant reduction in crosstalk, can be
25 substantially completely effected provided adjacent conductor pairs therein are geometrically spaced and spatially arranged to satisfy the following so-called geometric decoupling equality:

$$(1) \quad d_{13} d_{24} = d_{14} d_{23}$$

30 where the subscripts 1 and 2 represent the conductors of the first conductor pair, and the subscripts 3 and 4 represent the conductors of the second pair.

While it can be shown mathematically that the standard "quad" and "Tee" configurations most ideally
35 satisfy the above decoupling equality, with certain assumptions, other quadrilateral geometric configurations, such as the parallelogram, equilateral trapezoid, and

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general quadrilateral, can all be shown to at least substantially satisfy the above decoupling equality. However, only the parallelogram configuration is of primary concern herein, because it advantageously allows two
5 overlying/underlying arrays of conductors to be much more closely spaced than in the case of a true "quad", or square geometry. In addition, a parallelogram configuration of adjacent conductor pairs advantageously exhibits an "open" decoupled characteristics, i.e., the decoupling locus
10 thereof, which can be readily derived algebraically, is such that any number of adjacent decoupled conductor pairs can be employed in a multi-pair, multi-arrayed flat cable.

For purposes of this invention, it will suffice to simply state that in a flat cable of the type in
15 question, it has been found that crosstalk is most effectively minimized when a family of parallelograms are chosen that not only satisfy the aforementioned decoupling equality ($d_{13} d_{24} = d_{14} d_{23}$), but further satisfy the following decoupling locus equation therefor:

20
$$(2) \quad X = (2 \cos 2 \alpha)^{1/2},$$

where α is the skew angle, i.e., the acute angle between adjacent sides of the parallelogram, and $X = 2b/a$, where $2b$ is the length of each side of one pair of parallel sides and a is the length of each side of the other pair of
25 parallel sides. The angle α approaches $\pi/4$ as the vertical spacing between conductors becomes very close, or conversely, as the pair spacing increases.

It can be shown from a calculated plot of Near End Crosstalk (NEXT) versus conductor offset, that for a
30 skew angle α close to $\pi/4$, and a vertical spacing between the conductors in each pair of approximately 0.1 mm, for example, that the expected loss peak will occur for an offset approximately equal to 0.3 mm. The particular offset required in any given cable of the type
35 in question will depend, of course, on not only the thickness and dielectric constant of the material chosen to separate the upper and lower arrays of conductors, but on



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the cross-sectional configuration of the latter. As such, it is appreciated that in actual cable manufacture, less than perfect dielectric homogeneties and boundaries will selectively negate the realization of absolute zero

5 crosstalk in any practical flat cable embodiment.

Nevertheless, a flat cable of the type of concern herein is capable of producing crosstalk loss in excess of 120db for cable lengths of 35 feet or more.

For a more detailed theoretical discussion of
10 such a unique cable, reference is made to an article entitled "Geometrically Decoupled Balanced Pairs", by Mr. D. P. Woodard, of Bell Telephone Laboratories, presented at the proceedings of the International Wire and Cable Symposium, November 1978.

15 In connection with the manufacture of one particular form of the last mentioned type of cable for use in telephone under-carpet applications, wherein 25 adjacent pairs of conductors are each arranged in a parallelogram configuration, and wherein the upper and lower conductors
20 are laminated between a common double adhesive-backed center film, and respectively associated adhesive-backed outer films, a very serious problem has arisen in maintaining not only the spacing between conductors in each array, but the very critical offset between the
25 respectively associated conductors in the two arrays, within stringent limits.

More specifically, it was found that the requisite offset between the two arrays of conductors tended to cause the respectively associated pairs of
30 overlying/underlying conductors to randomly shift laterally while the conductors and films were fed through a pair of laminating rollers during the fabrication of the cable. Unfortunately, it was further found that even extremely small lateral displacements of the conductors, particularly
35 with respect to the offset dimension, could not be tolerated in a cable designed for telephone voice transmission applications. The criticality of the



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conductor offset dimension can perhaps best be appreciated by the fact that in one particular type of flat cable, where the nominal offset dimension is 0.25 mm, even several lateral conductor deviations greater than ± 0.05 mm in a given length of cable as short as 3 meter, can produce a drastic decrease in crosstalk loss from a range from 110-120db down to an unacceptable level well under 100db.

In an effort to reduce the conductor spacing deviations in question, a number of different types of conventional flat cable laminating apparatus, and process techniques, have been tried, but with no success. In this regard, different combinations of laminating roller assemblies, in particular, were tried wherein the rollers, for example, comprised either two steel or one steel and one rubber-covered roller, either selectively or both internally heated, and heated in different ways, for laminating two offset arrays of ribbon-shaped conductors between three polyester plastic films, wherein the two outer films were adhesive-backed on the inner side, and the center film was adhesive-backed on both sides. Such a combination of adhesive-backed films was considered important so as to achieve a reliable and high degree of bond strength, and very precisely positioned, permanently bonded and completely encapsulated conductors between the center and associated outer films. Concomitantly, the laminating temperature, pressure and feed rate employed were also varied over wide ranges, selectively, in attempts to maintain conductor spacing uniformity within the necessary stringent limits.

Unfortunately, however, it was found that no prior conventional laminating apparatus, nor any particular choice of laminating operating parameters employed in conjunction therewith, would consistently maintain the requisite conductor spacings and offset within an acceptable range of $\pm$ deviations and, particularly, while at the same time producing satisfactory bond strength between the three films of the composite cable. Indeed,



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not even a change in the type of plastic films employed, or changes in the thickness thereof, or in the composition or thicknesses of the adhesive coatings, proved beneficial in maintaining either the conductor spacing or offset within
5 the required tolerances.

In addition to the aforementioned problems experienced heretofore in manufacturing a cable of the type of concern herein, another problem also arose with respect to terminating such a cable for connectorization. More
10 specifically, because of the utilization of two arrays of conductors, with each laminated between an outer and center film, both adhesive-backed, the interposed conductors were firmly bonded to both films. As such, whenever short terminating segments of the outer films were removed, such
15 as through the use of a conventional material grinding or abraiding operation, so as to expose the outer surfaces of the terminated conductors, they still remained firmly secured to the center film. This, of course, made complete insulation stripping of the terminating conductor ends
20 quite difficult and time consuming.

For similar reasons, the prior use of conductor masking or separating tapes, disposed transversely across, and on opposite sides of, a single array of conductors, so as to facilitate the separation of two opposite side cover
25 films from the conductor, likewise would not prove effective in terminating the flat cable in question for connectorization. More specifically, in accordance with the prior disclosed uses of such tapes, they would not be effective in separating two underlying/overlying arrays of
30 conductors from a normally inaccessible center film (as distinguished from cover films) bonded to both arrays of conductors.

U. S. patent 4,149,026 discloses another technique employed heretofore to separate the terminating
35 ends of two underlying/overlying arrays of conductors when interleaved and laminated between two respectively associated adhesive backed outer carrier members and an



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inner adhesive member. As disclosed in that reference, the inner adhesive member is dimensioned such that it does not extend to both marginal edges of the outer carrier members. One longitudinally disposed edge of each carrier member is thus readily accessible for peeling the conductors bonded thereto from the inner member, provided the conductors are initially bonded more firmly to the carrier members than to the inner adhesive member. Disadvantageously, such a cable construction does not allow the two arrays of conductors to be completely hermetically sealed between the outer carrier members, as is desired, if not required, in many flat cable wiring applications.

In view of the foregoing, there has been an urgent need for an improved type of underlying/overlying multi-conductor flat cable, and of a method and apparatus for the manufacture thereof, that will allow adjacent conductor pairs therein to be consistently spaced within extremely stringent limits, while positioned in the aforementioned, and advantageous, parallelogram type of geometric configuration, desired for high crosstalk rejection. A solution has also been sought for such an improved cable which at the same time will allow for the simplified termination and connectorization thereof.

Summary of the Invention

It, therefore, is an object of the present invention, to provide a flat, thin, flexible cable, particularly adapted for low cost telephone under carpet applications, and which exhibits excellent and consistent crosstalk characteristics, is readily connectorized, and involves simplified, reliable and low cost methods and apparatus for the manufacture and connectorization of same.

In accordance with the principles of the present invention, the above and other objects are realized in one preferred flat cable and method for its manufacture wherein two precisely offset arrays of rectangularly shaped conductors are separated by a center polyester film, with each array of conductors being adhesively bonded directly



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to only the adjacent inner surface of the associated one of two adhesive-backed outer films.

Considered more specifically, in accordance with several significant aspects of the invention, it has been found that by utilizing a combination of two peculiarly constructed and heated laminating rollers, and three properly chosen polyester films, with only the two outer films having an adhesive coating (of a predetermined type and thickness) on the inner facing surfaces thereof, together with a properly chosen laminating temperature, pressure and feed-through rate, the requisite conductor spacings and offset within the cable can be very reliably and consistently maintained during manufacture. In addition, the conductors remain permanently positioned and encapsulated between the respectively associated laminated films such that no lateral displacement and shifting thereof is possible after fabrication, - one of the critical accomplishments of this invention - even when the cable may be subsequently folded back on itself to effect any necessary bends when installed under carpets, or for any other purpose, in a telephone system wiring installation.

With respect to the pair of laminating rollers, it has been found very important that one roller be of metal, especially steel, formed with a plurality of specially dimensioned conductor-receiving grooves in the cylindrical peripheral surface thereof, and internally heated. The other roller, also of metal, has a smooth, resilient, cylindrical peripheral surface, such as formed by a layer of silicone rubber, and is both internally and externally heated in a unique manner.

With respect to the three laminating films, it has been found to be very important, particularly when the geometric configuration of the multi-arrayed conductors interleaved therebetween involves an offset, that only the outer films, have an adhesive coating thereon, with the center film being bare, and preferably of polyester



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material, such as Mylar[®] plastic. The outer films are also preferably of polyester material, such as Mylar plastic, with heat-activated, flame retardant polyester adhesive coatings on the inner surfaces thereof, as fabricated.

5 In connection with the heating of the laminating rollers, it has also been found very important to utilize a peculiarly configured heated shoe not only to externally heat an arcuate portion of the rubber-covered laminating roller, but the associated array of conductors, and outer
10 film, immediately before they pass through the nip of the laminating rollers.

In accordance with another aspect of the invention, the aforementioned cable attributes are further enhanced by feeding the laminated cable, with the plastic
15 films still in a somewhat pliable state, through the nip of a second pair of unheated finishing rollers, each having a smooth, resilient, cylindrical peripheral surface, such as formed by a layer of silicone rubber. The finishing rollers have been found to reduce some of the tension
20 otherwise exerted on the cable while in a somewhat pliable state, as a result of being frictionally fed through the nip of the first pair of laminating rollers. The finishing rollers further function to eliminate any possible air pockets in the cable, and to force the still very soft
25 adhesive into any possible remaining voids that may exist between adjacent conductors in the same array.

In accordance with still another aspect of the present invention, termination and connectorization of a preferred embodiment of the flat cable is greatly
30 facilitated by preferably lightly or permanently bonding a spaced array of isolating strips, such as of plastic material, on each side of, and extending transversely across, the bare center film, in aligned pairs, prior to the laminating operation to fabricate the cable. The
35 isolating strips are preferably positioned at predetermined possible spaced cable termination points, for example, at five, ten or fifteen foot intervals along the cable. Such



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isolating strips may be of a material, or have properly chosen double-backed adhesive coatings thereon, that will cause the strips to either bond or not bond to the respectively associated outer films, and when bonded thereto, with controlled adhesion relative to the center film. As such, the terminating ends of the conductors may be selectively stripped from the center film, and/or the respectively associated outer films, as desired, or required, to facilitate connectorization of the terminated conductor ends to either solder or solderless type connectors in a simplified and reliable manner.

Detailed Description of the Drawings

FIG. 1 is a fragmentary, perspective view of a flat flexible cable wherein two offset arrays of conductors, separated by a thin, non-adhesive backed center plastic film, are laminated between opposite sides of the center film and two respectively associated outer films, together with two aligned and center film-separated arrays of isolating strips, in accordance with one preferred illustrative embodiment of the invention;

FIG. 2 is a fragmentary, detailed, cross-sectional view of the cable of FIG. 1, taken along the line 2-2 of that FIG., showing a pair of terminating isolating strips incorporated therein in greater detail;

FIG. 3 is a side elevational view, partially in section, of a flat cable assembly wherein the cable of FIG. 1 has the terminated conductor ends stripped of insulation and solder-connected to respectively associated contacts of a connector;

FIG. 4 is a schematic view illustrating in greater detail the offset relationship between the conductors in each of two adjacent pairs thereof in the cable of FIG. 1, which cable typically includes 25 such pairs;

FIG. 5 is a schematic representation of the geometric parallelogram relation established between the conductors of two adjacent pairs, arranged as depicted in



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FIG. 4, together with the designated spacings therebetween that are used to define a significant capacitive decoupling equality based on the spatial relationship of the conductors;

5 FIG. 6 is a schematic view of one preferred embodiment of the apparatus employed to fabricate the cable depicted in FIG. 1, in accordance with the principles of the present invention;

10 FIG. 7 is an enlarged, detailed, fragmentary sectional front view of the laminating rollers in the apparatus of FIG. 6, taken along the line 7-7 of that FIG., together with the center and outer laminating films, and the two arrays of conductors, while positioned in the nip defined between the two rollers;

15 FIG. 8 is a fragmentary, side elevational view of a terminated end section of the flat cable of FIG. 1, with end portions of the outer films having been removed, and with each of the isolating strips remaining bonded to the center film, preparatory to the conductor ends being
20 secured to either a solder or solderless type connector;

 FIG. 9 is a fragmentary, side elevational view of a terminated end section of the flat cable of FIG. 1, wherein the conductor ends in each array remain laminated between the respectively associated outer film and
25 isolating strip, with at least the major portion of the latter being separated from the center film, so as to allow connectorization of the conductors to an insulation displacement type connector;

30 FIG. 10 is a fragmentary, side elevational view of a flat cable similar to that of FIG. 9, but distinguishing therefrom by having the terminated end portions of the outer cable films removed from the conductors, as in FIG. 8, so as to expose the outer surfaces of the latter for connectorization to either
35 solder or solderless type connectors, but with the isolating strips remaining bonded to the conductors rather than to the center film so as to facilitate conductor



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alignment during connectorization of the cable.

FIG. 11 is a fragmentary, side elevational view of an alternative flat cable embodiment wherein four isolating strips are initially laminated in an interleaved manner as part of a cable of the general type depicted in FIG. 1, so as to facilitate the complete stripping of the insulation manually from the conductor ends in preparation for their connectorization to either a solder or solderless type connector, and

FIG. 12 is a fragmentary, side elevational view of a flat cable similar to that of FIG. 9, or optionally FIG. 10, but further including an insulative auxiliary spacing member bonded to opposite sides of the exposed forward end of the center film, upon termination of the cable, so as to provide greater dielectric material separation between the two arrays of terminated conductors, particularly desired if they are again compressed through the interposed isolating strips against the spacing member to facilitate insertion of the terminated cable end in a female type connector.

Detailed Description of the Invention

With particular reference now to FIGS. 1-3, there is depicted a flat cable 10 adapted particularly for telephone under-carpet wiring applications. The cable is fabricated with two precisely offset arrays of flat, ribbon-like conductors 13, 14, separated by a center film 16, with each conductor array, and the exposed areas of the associated side of the center film, being adhesively bonded to the inner surface of the associated one of two outer films 18, 19, each having an adhesive coating, or backing 21, 22, respectively, on one major side thereof.

In accordance with one aspect of the invention, in order to manufacture the cable 10 with the requisite conductor spacings and offset maintained within exceedingly stringent limits, it has been found to be very important that the center film 16 initially be bare, i.e., have no adhesive coating or backing on either side thereof. As



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such, the conductors 13, 14, in each array are only directly bonded to the respectively associated outer films 18, 19, with opposite sides of the center film 16 being respectively bonded thereto only in the exposed, longitudinally extending areas defined between conductors of the associated overlying/underlying arrays, and along the co-extensive border regions.

In accordance with one aspect of the invention, spaced pairs of non-conductive and aligned isolating strips 28, 29 are uniquely positioned between the center film 16 and the respectively associated arrays of conductors 13, 14. As will be described in greater detail hereinbelow, in connection with the methods and apparatus for fabricating and connectorizing the subject cable 10, the isolating strips 28, 29 are employed to facilitate the separation of the conductor ends from the center film 16 for cable termination and connectorization.

The center film 16 and outer films 18, 19 are preferably of polyester material, such as polyethyleneterephthalate, one form sold under the aforementioned tradename Mylar plastic. The adhesive backing on each of the outer films 18, 19 preferably comprises a heat-activated, flame retardant polyester material, with one preferred form of such an adhesive being available from the Sheldahl Company under the code name GT-340. The isolating strips are preferably of Teflon[®] plastic or of polyester adhesive backing on the side facing the center film.

Depending on the type of plastic material employed to form the isolating strips 28, 29, and the nature of the adhesive backing thereon, they may be either lightly or permanently bonded selectively to the center film 16, or to an associated outer film 18 (or 19), or to both, with different predetermined degrees of adhesion. Such selective bonding of the isolating strips advantageously makes it possible to effect different types of cable terminations and connectorizations, one such connection, to an illustrative connector 25, being depicted



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in FIG. 3, and described in greater detail hereinafter in connection with FIGS. 8-12.

With respect to typical structural dimensions of the various elements forming the composite cable 10, it will be appreciated that the thickness dimension of the center film 16, and of the outer films 18, 19, will depend to a great extent on the size and shape of the conductors 13, 14, as well as on the composition of both the films, and of the adhesive coatings applied to the outer films. In addition, a flat cable utilizing offset conductors arranged in the geometric configuration of primary concern herein, the thickness of the center film 16, for the reasons discussed above, is also dependent on the conductor offset dimension, or skew angle, required in order to optimize crosstalk loss in the cable.

With the significance of such factors being understood, the conductors would typically have a thickness in the range of 0.075 to 0.2 mm, a width in the range of 0.62 to 1 mm, and a center line-to-center line spacing of 2 mm to 2.2 mm, with the offset dimension normally being in a range of 0.05 to 0.2 mm, and the outer films 18, 19 would normally each have a thickness in the range of 0.05 to 0.12 mm, with an adhesive coating thereon having a thickness in the range of 0.02 to 0.12 mm.

By way of a more specific example of one preferred embodiment of the cable 10, wherein the conductors 13, 14 were of flat rolled, annealed copper, measuring approximately 0.15 x 0.8 mm in cross section, the offset between the two arrays of conductors measured approximately 0.25 mm, the center film 16 was of bare Mylar plastic, measuring approximately 0.12 mm in thickness, and the two outer films 18, 19 were also of Mylar plastic, measuring approximately 0.075 mm in thickness, with the aforementioned type of polyester adhesive coatings 21, 22 on the outer films measuring approximately 0.075 mm in thickness, the cable exhibited very high crosstalk loss, in excess of 110db in lengths up to 12 m. Equally important



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is the fact that when using the cable laminating apparatus embodied herein, in conjunction with the specified processing temperatures, laminating pressures and feed rates described in detail hereinbelow, the critical conductor offset chosen of 0.25 mm, did not vary more than ± 0.05 mm on either side thereof during cable fabrication, and the cable also exhibited excellent bond strength, evidenced by a peel force exceeding 1,44 kg/cm between any two adjacent films.

As previously noted, the respectively associated conductors in the two arrays could be arranged in quadrilateral geometric configurations other than the parallelogram to effect a significant reduction in crosstalk. However, some of the other spatial conductor geometries would require a considerably greater vertical spacing between the two arrays of conductors, which normally is not desirable because of the resulting thickness of the cable. For that reason, in particular, it is very advantageous to fabricate the cable 10 in accordance with a prescribed family of parallelograms wherein the respectively associated conductors 13, 14 in each pair are offset by a critical dimension, the specific dimension being chosen to minimize undesired capacitive coupling between adjacent pairs (inductive coupling normally being negligible).

The desired parallelogram-defined spatial relationship desired between two adjacent pairs of conductors in the cable 10 is illustrated in greater detail in FIG. 4, with the dimension d_1 and d_2 indicating the center line-to-center line spacing between adjacent conductors in a common array, and the offset spacing between conductors of each pair, respectively.

FIG. 5 further illustrates schematically the geometric relationship between the conductors of FIG. 4, with one pair of conductors being represented by the points designated 1 and 2, and the other pair of conductors being represented by the points designated 3 and 4. The



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significant distances between the various conductors involved in satisfying the geometric decoupling equality ($d_{13} d_{24} = d_{14} d_{23}$), discussed hereinabove and identified as equation (1), are correspondingly identified in FIG. 5.

- 5 Also shown are the particular sides of the parallelogram involved in satisfying the aforementioned locus equation (2) for the desired family of parallelograms, namely, $X = (2 \cos^2 \alpha)^{1/2}$, where α is the skew angle, and $X = 2b/a$. As will be recalled, and as identified in
- 10 FIG. 5, $2b$ is the length of each side of one pair of parallel sides, and a is the length of each side of the other pair of parallel sides of a desired conductor-defined form of parallelogram. It can be shown mathematically that the angle α approximates $\pi/4$ as the vertical spacing
- 15 between the conductor arrays advantageously becomes very close. From a calculated plot of Near End Crosstalk (NEXT) loss versus conductor offset, for a skew angle close to $\pi/4$, and a vertical spacing between the conductors in each pair of approximately 0.12 mm, as in the one preferred
- 20 embodiment of the cable 10 described above, the expected peak in crosstalk loss will occur when the offset approximately equals 0.25 mm.

It should be appreciated, however, that variations in conductor shapes and dielectric

25 inhomogeneties and boundaries will slightly alter the actual offset that should be used in any given cable. In addition, such variations will prevent the attainment of zero crosstalk between adjacent conductor pairs because of less than perfect electric and magnetic decoupling being

30 achievable simultaneously in practice. Nevertheless, excellent crosstalk rejection has been made possible by arranging two overlying/underlying arrays of flat cable conductors in accordance with the geometrically decoupled quadrilateral configurations defined above and, in

35 particular, the parallelogram configuration, analyzed and described in the aforementioned article by D. P. Woodard. In that regard, the conductors have been found to be most

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reliably and precisely positioned in the desired parallelogram configuration when the cable of which they form a part is fabricated in accordance with the principles of the present invention.

5 Attention is now directed to FIG. 6, which schematically illustrates one preferred embodiment of a laminating apparatus 30 for manufacturing the multi-conductor arrayed flat cable 10 depicted in FIG. 1, and described in detail hereinabove. The laminating apparatus
10 includes a pair of heated laminating rollers 31, 32, a specially constructed heated shoe 34, and a pair of unheated forming rollers 37, 38. Following the latter rollers are a cable splitter 41, a counter 43, a light box conductor gauging platform 44 and a printer 46. The latter
15 three structural elements are optional and only schematically shown, as they may be of a conventional type, and selectively used in practice.

Also associated with the laminating apparatus 30 are two conductor supply reels 47, 48 for the
20 conductors 19, a film supply reel 58 for the center film 16, and a take-up reel 59, driven by a motor 61, shown only schematically, for the completely fabricated cable 10.

Considering now the laminating rollers 31, 32 in greater detail, the upper roller 31, internally heated, is
25 preferably made of steel, with a smooth, resilient cylindrical peripheral surface, such as formed by a relatively thin outer layer 68 of silicone rubber. One preferred type of such rubber, is characterized by having a resiliency of 60 Durometer, and an upper useable
30 temperature limit of at least 200°C. It has been found that for manufacturing one preferred embodiment of the cable 10, the outer layer 68 of rubber may have a thickness in the range of 0.2 mm to 25 mm, however, a thickness of approximately 19 mm has been found most effective in
35 attaining the bond strengths desired, while at the same time affording more accurate control over the conductor spacing and the associated offset during the fabrication of



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the cable. The roller 30 is controllably biased relative to the roller 32, such as pneumatically, as indicated symbolically by a double acting pneumatic cylinder 69.

Laminating roller 31, as well as roller 32, are
5 both internally heated, preferably by a re-circulated supply of hot oil 71 fed into and out of oil retaining interior cavities of the rollers. The oil is initially heated to the desired temperature in a container 73, preferably having a suitable heater element 74 therein,
10 depicted as of the filamentary type, and is then fed under pressure, by means of a pump 76, through a main conduit 77 and two conduit branches 78a and b to the interior cavities of the rollers 31, 32, respectively. The re-circulated oil is returned from the rollers to the heated container 73
15 through two respective conduit branches 79a and b and a main conduit 81. The container 73, heater element 74 and pump 76 may all be of conventional design.

While the oil may be supplied to the interior cavities of the rollers in a number of different ways, one
20 preferred way, as schematically illustrated, is through the use of journaled rotating unions that form a part of the axial bearing assemblies of the rollers. The incoming oil may be simply fed into the roller cavities or, more preferably, sprayed outwardly toward the periphery of the
25 rollers through an axially disposed conduit (not shown) having an array of spray orifices formed therein. The somewhat cooled excess oil is preferably returned from the rollers 31, 32 to the heated container through an overflow outlet port (not shown) associated with the rotating union
30 forming a part of each roller. The significance of utilizing oil to internally heat the rollers 31, 32 is that it is has been found to provide a very effective medium with which to accurately and uniformly establish a desired temperature on the peripheral surfaces of the rollers.

35 For manufacturing a cable 10 of the type embodied herein, the peripheral steel surface of the roller 31, i.e., at the interface with the rubber layer 68, is



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generally heated to a temperature in the range of 182°C to 210°C, which establishes a temperature at the periphery of the rubber layer in the range of about 127°C to 171°C.

The lower laminating roller 32, also preferably
5 formed of steel, is internally heated by the aforementioned re-circulated hot oil 71 such that the cylindrical peripheral surface thereof also attains a temperature in the range of 182°C to 210°C. With such laminating roller operating temperatures, the compressive force exerted on
10 the three films 16, 18 and 19, and the two interleaved arrays of conductors, at the bias-controlled nip of the rollers, would normally be in a range of 7 to 35 Kg/cm², with the cable feed rate typically being in a range of 1 to
15 6 meter per minute, in order to fabricate a cable with the desired physical and electrical characteristics described hereinabove. The reason for the seemingly wide range for the laminating pressures resides in the fact that it is very difficult to accurately measure the pressure exerted on the composite cable independently of the pressure also
20 exerted between the rollers 31, 32. This follows from the fact that the rollers extend beyond opposite sides of the cable, and along such regions the peripheries of the rollers are also in biased, rotating contact with each other.

25 It should also be understood that the particular temperatures, pressures and feed rates associated with the bonding rollers 31, 32 will depend on a number of factors, such as the particular physical dimensions and compositions of the conductors, plastic films and adhesives employed in
30 manufacturing a given flat cable in accordance with the principles of the present invention.

In order to consistently limit deviations on either side of the critical offset dimension, when having a desired nominal value of 0.25 mm, to within ± 0.05 mm, in
35 one preferred embodiment of the subject flat cable, it has also been found necessary to construct the lower laminating roller 32 with a laterally disposed array of conductor-



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receiving grooves 72 in the cylindrical peripheral surface thereof, as best seen in FIG. 7. These grooves are dimensioned to accommodate not only the width dimension of the lower array of conductors 14, but the thickness of the outer film 19 on either side of a nested conductor, and preferably some of the adhesive material 19a, upon all of these elements being heated, under pressure, while being advanced through the nip of the laminating rollers 31, 32. With respect to the film 19, a certain degree of shrinkage thereof, upon being heated, must also be taken into account in dimensioning the grooves 72. By way of example only, in one preferred embodiment of the flat cable 10 having the specific structural dimensions set forth above in connection with a description of the cable per se, each groove measured approximately 1 mm x 0.25 mm in width and depth, respectively.

While both laminating rollers 31, 32 could be directly driven, it is preferred that only the steel roller 32 be directly driven, such as by a motor 84, shown only schematically in FIG. 6. With the upper roller 31 then being indirectly driven by only frictional engagement with the advancing composite cable, there is no problem of having to precisely match the peripheral speed of the two rollers, which can vary a small amount not only because of the resilient peripheral surface of the roller 31, but because of slight variations in the diameters of the two rollers as constructed.

Inasmuch as the rubber layer 68 on the upper roller 31 does not function very effectively as a heat conductor, it has been found necessary, as previously mentioned, to utilize the internally heated shoe 34, constructed with arcuate surfaces 34a, 34b. The former surface is formed with a radius of curvature that allows it to be positioned immediately adjacent an appreciable peripheral portion of the upper roller 31 in a region near the nip defined between the two rollers 31, 32. The arcuate surface 34b of the shoe is located so as to allow

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the non-adhesive backed side of the upper film 18 to pass thereover immediately prior to being fed through the nip of the laminating rollers. As configured, the heated shoe also preferably allows the upper array of conductors 13 to pass over a portion of the outer arcuate surface 34b just prior to being advanced through the nip of the rollers 31, 32. In fabricating a flat cable of the type of primary concern herein, the shoe 34 is preferably internally heated by the same heated oil 71 employed to heat the laminating rollers 31, 32, so as to likewise provide a temperature at the arcuate surfaces thereof typically in a range between 182°C to 210°C. A spray tube 82 mounted within the shoe 34, and formed with a plurality of orifices, effectively sprays the inlet oil outwardly against the arcuate surfaces 34a, b of the shoe. The oil 71 is recirculated through the shoe 34 by means of a coupled extension 77c of the conduit 77, and a coupled outlet conduit branch 78c, the latter being coupled to the oil container 73 through the common conduit 81.

Downstream of the laminating rollers 31, 32 are the aforementioned unheated forming rollers 37, 38. Both of these latter rollers have smooth, cylindrical resilient peripheral surfaces, such as formed by layers 37a, 38a of the same type of silicone rubber employed in laminating roller 31. Such rubber layers may typically also have a thickness in the range of 0.25 mm to 25 mm, with 19 mm being preferred in the fabrication of one preferred embodiment of the cable 10. For that purpose, the roller 37 is controllably biased relative to the roller 38, such as pneumatically, as indicated symbolically by a double acting pneumatic cylinder 88, to exert a compressive force on the cable in the range of 3.5 to 35 kg/cm².

As will be described in greater detail in connection with a description of the operation of the laminating apparatus 30, the rollers 37, 38 tend to minimize tensile forces otherwise exerted on the three films while in a somewhat pliable state, by the laminating



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rollers 31, 32, and further contribute to minimizing or eliminating any voids or air pockets that may possibly still remain in the cable after passing through the nip of the laminating rollers. As in the case with the laminating rollers 31, 32, only one of the rollers 37, 38 is preferably directly driven, such as the upper roller 37, coupled to a motor 83, shown only schematically in FIG. 6.

The aforementioned cable splitter 41 may be of conventional construction comprising, for example, a different pair of cutter wheels positioned on each side of the laminated cable so as to trim the latter to any desired finished width.

As previously mentioned, the counter 43, light box gauging platform 44 and printer 46 are all optional. The counter 43 when used may be of a conventional type including a contact roller 43a that rotatably engages the cable at a point preferably opposite an optional idler roller 91. Such a counter, of course, is used to accurately measure and provide a readout of the linear running feet of the fabricated cable.

The light box conductor gauging platform 44, when used, allows the spacings and offset between the conductors in the two arrays to be visually examined from the upper side of the fabricated cable, as a result of an illuminated light source 44a being directed against the cable from the underside thereof.

As for the printer 44, when used, it may also be of a conventional type. As shown, it is positioned to operate opposite an associated idler roller 93.

Attention will now be directed to a typical flat cable laminating operation to fabricate one preferred embodiment of the cable 10. Initially, the two outer plastic films 18, 19, each having a flame retardant polyester adhesive coating 21 or 22 on the inner-facing side thereof, are respectively advanced from the supply reels 56, 57, together with the two arrays of conductors 13, 14 from the supply reels 47, 48, and the



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non-adhesive backed center plastic film 16. Also advanced with the center film 16 are the upper and lower spaced arrays of isolating strips 28 and 29, preferably previously bonded to the center film while in roll stock form in accordance with an aspect of the invention. During such advancement of the composite cable elements, not only the non-adhesive coated side of the upper film 18, but the upper array of conductors 13 are preferably brought into contact with and pre-heated by the arcuate surface 34b of the heated shoe 34, immediately prior to their being fed through the nip of the laminating rollers. Such preheating has been found to facilitate the reliable bonding of not only the conductor array 13 to the upper film 18, but the latter to the center film 16 during the laminating operation. The need for such selective pre-heating is believed due to the fact that the outer rubber layer 68 on the upper roller 31 is not nearly as efficient in conducting, retaining and supplying heat as the lower steel roller 32, even though the heated shoe 34 is also employed to externally heat a portion of the peripheral resilient surface of the roller 31.

In this connection, it should be readily apparent, however, that both arrays of conductors could be pre-heated by similar means, or selectively preheated by other means, such as by the use of one or more internally heated rollers comprising part of the conductor tensioning and guide roller assemblies 51 and 52, and/or by the use of separate heating ovens (not shown). Likewise, not only the center film 16, but the films 18 and 19 could likewise be selectively pre-heated, if desired, by similar or other means, such as by independent heating ovens, one such optional oven 81 being shown in phantom in FIG. 6. For the particular cable of concern herein, however, it has been found to be not only advantageous but very important, to utilize only the uniquely heated laminating rollers 31, 32 and heated shoe 34, in conjunction with the aforementioned preferred temperatures, pressures and feed rates associated

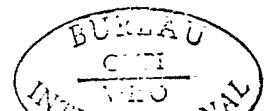
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therewith, to effect the bond strengths, as well as conductor spacing uniformity, desired in the fabricated cable. In regard to the two outer films 18, 19, it should also be appreciated that the adhesive coatings 21, 22 thereon could be applied, such as in liquid form, with conventional applicators immediately before those films were advanced through the nip of the laminating rollers. The present method and apparatus, however, is believed to afford greater simplicity and control over the cable laminating operation.

Regardless of how the adhesive coatings 21, 22 are applied to the outer films 18, 19, it is preferable to fabricate the cable with the width of the center film 16 initially being slightly wider than that of the outer films. As such, the mutually disposed borders of the center film, as laminated, will effectively mask the longitudinally disposed edges of the outer films from the otherwise immediately adjacent peripheral surface portions of the rollers 31, 32, thus preventing the latter from coming in contact with any adhesive that may tend to seep out of the outer film-center film border interfaces during the laminating operation.

FIG. 7, taken along the line 7-7 in FIG. 6 as previously noted, depicts the cross-section of the various cable elements at the point of maximum bonding force exerted thereagainst when confined between the nip of the laminating rollers 31, 32. It is seen that the adhesive coatings 21, 22 on the outer films 18, 19, while heated to a very soft state, are forced by the rollers 31, 32, to flow into and substantially completely fill the otherwise established voids defined between the edges of each conductor in each array and the desired longitudinally disposed regions of contact between the associated outer and center films. Such fillet-shaped areas filled with adhesive, together with some seepage of the adhesive between the conductors and the center film, result in the firm bonding of the conductors to the latter film as well



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as to the associated outer film, except in the regions of the isolating strips. It is also seen that the resilient peripheral surface 68 of the upper laminating roller 31 advantageously essentially acquires the same peripheral surface profile as the lower steel roller 32, notwithstanding the fact that only the latter roller is formed with the conductor-receiving grooves 72 in the periphery thereof. It should be appreciated that it is the combination of a smooth-surfaced resilient roller and a groove-surfaced steel roller, together with a specially configured heated shoe, that makes possible the attainment of high bond strength between films, while simultaneously affording precise control over the critical conductor spacings and offset, particularly with respect to the latter when the center film of the cable is non-adhesive backed.

After passing through the nip of the laminating rollers 31, 32, the then completely fabricated cable 10, with the adhesive coatings still in a very soft state, are preferably drawn through nip defined between the aforementioned unheated, and resilient finishing rollers 37, 38. These rollers insure that the composite cable elements remain in precise, laminated relationship until the adhesive coatings have sufficiently solidified. As previously noted, the rollers 37, 38 also tend to reduce the tensile forces otherwise exerted on the three films by the laminating rollers 31, 32, and further tend to smooth out any air pockets and eliminate any possible voids that may possibly still exist in the cable after having passed through the nip of the laminating rollers. Such voids or air pockets could possibly prove particularly troublesome in a given telephone under-carpet cable (TUCC) wiring installation, for example, should they occur at points where the cable is folded back upon itself to effect bends, or occur in regions near the terminating end of a cable, where moisture or foreign contaminant problems could develop between the center film and a given one of the



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outer films, in the vicinity of one or more conductors of the cable. In addition, air pockets or voids can adversely affect the electrical characteristics of the cable because of the significant difference in air versus adhesive dielectric constants.

After the completely fabricated cable 10 passes through the nip of the rollers 37, 38, the cable 10 is trimmed to the desired finished width by the slitter 41, before passing by and in contact with the aforementioned optical counter 43, light box conductor gauging platform 44 and printer 46, and then before being wound upon the take-up reel 59.

By way of further specific example with respect to the operating parameters employed in using the apparatus 30 of FIG. 6 to fabricate one preferred embodiment of the cable 10, having the specific structural dimensions set forth above in connection with a description of the cable per se, the peripheral steel surfaces of the laminating rollers were both preferably heated to a temperature of approximately 200°C, as were the arcuate surfaces 34a and b of the shoe 34, with the peripheral surface of the rubber layer 68 on the roller 31 acquiring a temperature of approximately 160°C. When utilizing a rubber layer 68 on the laminating roller 31 measuring approximately 19 mm in thickness, the compressive laminating force exerted on the cable in passing through the nip thereof measured approximately 21 kg/cm². With the rollers 37 and 38 having similarly dimensioned rubber layers 37a, 38a, a compressive force exerted on the fabricated cable in passing through the nip thereof measured approximately 21 kg/cm². The feed rate in this specific operation example was approximately 2 m/min.

As thus fabricated, the one preferred illustrative cable embodiment 10, with 25 pairs of conductors, as previously mentioned, exhibited crosstalk loss in excess of 110db for lengths up to 10 meters, and excellent bond strengths between adjacent laminated films,



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as evidenced by a peel force in excess of 1,44 kg/cm. It should be understood, of course, that the exceptionally high crosstalk loss experienced in the cable 10 was also only made possible by the unique construction thereof, in
5 conjunction with the method and apparatus for its manufacture.

With respect to the connectorization of the completely fabricated cable 10, as previously briefly described, terminating end sections 18a, 19a of the outer
10 films, shown in phantom only in FIG. 8, can be readily abraided away so as thereafter facilitate the separation of the conductor ends 13a, 14a from the bare center film 16. This allows the conductor ends to be suitably connected to a connector of either the solder or solderless type, the
15 aforementioned illustrative connector 25 depicted in FIG. 3 being of the former type, having U-shaped conductor-receiving solder cups 25a.

As also previously mentioned, prior to the present invention it was quite difficult and time consuming
20 to strip the otherwise bare conductor ends 13a, 14a from the center film 16, because of not only the adhesive backing on the latter film, but because of the adhesive coatings from both the center and outer films filling the fillet-shaped voids, defined between the edges of adjacent
25 conductors in each array. Even when the center film 16 is bare, in accordance with an aspect of the present invention, the outer film coatings 21, 22 also substantially completely fill the voids adjacent the edges of the conductors, as desired for cable integrity, as best
30 seen in FIGS. 1 and 7. Such desired adhesive-filled areas, together with some seepage of such adhesive between the underside of the conductors and the center film, results in the conductors remaining substantially secured to the center film 16, as well as to the associated outer film, if
35 it were not for the uniquely positioned isolating strips 28, 29 described briefly hereinabove.



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Considering the significance of the isolating strips 28, 29 now in greater detail, each spaced array thereof is preferably bonded, or otherwise secured, to each side of the center film 16 so as to extend transversely thereacross in aligned pairs, as best seen in FIGS. 1-3 and 8-12. These isolating strips are located, as previously mentioned, at predetermined possible spaced cable termination points, for example, 2, 4 or 6 meter intervals.

The isolating strips 28, 29 may be of any suitable non-conductive material that bonds firmly, lightly, or not at all to the outer films 18, 19 and to the center film, selectively, thus allowing the terminating ends of the conductors 13a, 14a, as seen in FIGS. 8-10, for example, to be selectively stripped from the isolating strips, or from the associated outer films, or both, as desired or required to facilitate connectorization to either solder or solderless type connectors.

In those situations where it is desired that the conductor ends be freely separated from the isolating strips, it is apparent that the latter may either remain secured to the center film 16, or be peeled therefrom. This will depend on the degree of adherence established therebetween, which adherence can be readily controlled not only by the proper selection of the isolating strip and adhesive backing materials, but by the bonding pressures and/or temperatures employed both at the time of initial securement of the isolating strips to the center film, and at the time of cable fabrication.

By way of further example, when the center and outer films are of Mylar plastic, and the adhesive coatings thereon are of a polyester composition, isolating strips of Teflon plastic, having a heat-activated adhesive backing, such as of polyester, on only the side thereof which faces the center film 16, will not bond or even lightly adhere to the associated outer film 18 or 19, or to the associated array of conductors. Depending on the nature of the



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adhesive backing, such Teflon isolating strips may be either lightly or permanently bonded to the center film. Alternatively, the isolating strips 28, 29 may be of polyester plastic, with the adhesive backing thereon chosen
5 of a material that will result in the isolating strips adhering much more firmly to the respectively associated outer films than to the center film.

In addition to the aforementioned isolating strip materials, it should be appreciated, of course, that such
10 strips may be made out of many other materials not necessarily of a plastic composition, to provide the same desired functional results. For example, such isolating strips may also be made out of certain types of non-conductive fibrous material, rubber or paper when treated,
15 as required, to be flame retardant.

The width of the isolating strips 28, 29 may be chosen such that they either substantially coincide with the longitudinally disposed terminating portions 18a, 19a of the outer films normally removed from the cable for
20 connectorization, or allow for a rearward portion remaining anchored between the outer and center films, as desired. The latter type of cable termination would be most practical, of course, if the isolating strips are at least lightly bonded to the outer films, as well as to the center
25 film, as is represented in the illustrative embodiment of FIG. 9.

In any event, it may often be desired or necessary to trim back an end portion of the exposed center film 16, together with all, or the co-extensive forward end
30 portion, of the isolating strips 28, 29 secured thereto, so as to more completely free the exposed conductor ends 13a, 14a for connectorization to a conventional connector of either the solder or solderless type, the former type being illustrated in FIG. 3. In FIG. 8, the dashed line 96
35 represents the point to which the center film and isolating strips would be trimmed back for connectorization in FIG. 3.



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As for positioning the isolating strips 28, 29 at the desired spaced terminating points along the cable, it should be understood that they may be either permanently or temporarily secured to the center film 16 either manually or in an automated manner, and as an independent operation, so as to be a part of the film 16 when used in roll stock form, as described in connection with the operation of the apparatus 30 of FIG. 6. Alternatively, the isolating strips may be positioned manually or in an automated manner, on opposite sides of the center film 16, just prior to the latter being fed through the nip of the laminating rollers 31, 32, together with the outer films 18, 19 and the two interleaved arrays of conductors 13, 14. In this latter case, as well as in the former case, the isolating strips 28, 29 need not be of a material that would even lightly adhere to the center film 16, as long as the strips were properly aligned and positioned laterally relative to the center film, and with each lower isolating strip 29 being suitably maintained in proper registry with the respectively associated upper strip prior to, and during passage of, the films, conductors, and strips through the nip of the laminating rollers.

This could be effected, for example, by employing isolating strips dimensioned to extend a short distance beyond the opposite edges of the finished cable, and of type capable of being temporarily lightly bonded or otherwise secured at their common mating ends so that each pair of aligned strips would remain in proper registry during the cable laminating operation. It is generally desired, however, that the isolating strips be dimensioned such that the laterally disposed ends thereof either coincide with, or are confined within, the respective marginal edges of the finished cable. In the latter case, any given pair of isolating strips that were not used to terminate the cable would remain hermetically sealed between the inner and outer laminated films.



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It will also be appreciated, of course, that when the isolating strips 28, 29 are positioned across the width dimension of the center film 16 just prior to the cable laminating operation, this advantageously allows the strips and, hence, the thus defined terminating regions along the fabricated cable, to be located at any desired or variably spaced intervals, as in contrast to fixed predetermined intervals when the strips form a part of the center film as used in roll stock form. In this connection, it should also be noted that the strips could take the form of suitable coatings, such as of non-adhering resinous material applied to the center film "on the fly", such as by a spraying or brushing operation.

From the foregoing, it is seen that depending on the nature of the isolating strips 28, 29, and how they are positioned and secured within the cable 10, a number of different unique cable terminations may be effected which, in turn, are selectively conducive to effecting different types of cable connectorization, as will now be described in greater detail with respect to FIGS. 9-12.

In these last mentioned FIGS., like, but primed, reference numerals will be used to identify corresponding structural elements of the basically common fabricated cable 10.

With specific reference now to FIG. 9, the terminated end of a cable 10' includes a pair of isolating strips 28', 29' that may be of a material, or have an adhesive backing, of the type that will permanently bond to the outer terminating film ends 18a', 19a', and associated conductor ends 13a', 14a', but not to the center film end portion 16a'. Such isolating strips are seen to allow the terminated conductor ends 13a', 14a' to be readily separated from the center film, if desired, while remaining hermetically sealed between the respectively associated and co-extensive portions of the outer films and isolating strips. For this purpose, it may be desirable that the isolating strips be adapted to at least lightly bond to the



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center film 16', so as to also provide an effective hermetic seal for the conductors near the rearward edges of the isolating strips, as illustrated. Such a terminated cable is particularly adapted for connectorization to
5 solderless type connectors, i.e., of the insulation displacement type. Isolating strips made of polyester plastic, with properly chosen adhesive backings, such as of polyester or acrylic compositions, are particularly advantageous for this purpose. The leading end
10 portions 16a' of the center film 16' would normally be trimmed back, such as to the point indicated by the dashed line 97.

FIG. 10 illustrates the terminated end of a flat cable 10'', similar to that of FIG. 9, but distinguishing
15 therefrom by having outer terminating portions 18a'' and 19a'' of the outer films removed by any suitable means so as to expose the outer surfaces of the conductor ends 13a'', 14a'' for connectorization to either a solder or solderless type connector. In effecting such a
20 connectorization, the exposed center film end portion 16a'' would normally be trimmed back, such as to the point indicated by the dashed line 98, unless the terminated end of the cable was to be used as a male type member for insertion within a female type connector.

FIG. 11 illustrates the terminated end of a flat cable 10''' wherein four isolating strips are employed, one pair 28a''', 29''' being respectively bonded to opposite
25 sides of the center film end portion 16a''', as in FIG. 8, with each of a second pair 101, 103 being initially bonded between the associated outer film end portion 18a''' (or 19a''') and the associated conductor ends 13a''' (or 14a'''). As illustrated, the strips 101, 103, together
30 with the co-extensive film portions 18a''', 19a''', have been peeled from the associated conductors, with such
35 peeled sections thus being in positions to be severed from the cable, if desired.



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Depending on the bonding characteristics of the four isolating strips, the terminating ends of each array of conductors may advantageously either be manually separated from the contacting isolating strips, as illustrated, or such conductor ends may remain hermetically sealed between such isolating strips while either positioned adjacent to, or separated from, the center film, as required for a particular type of cable connectorization. In the former illustrated case, of course, no time-consuming mechanical or chemical operation is required to remove the terminating end portions of the outer films for connectorization. Obviating the need for a mechanical abraiding operation, in particular, also eliminates problems that can otherwise possibly arise, such as with respect to foreign debris, and physical damage to the conductor ends when of fragile and minute size. As in the case of the embodiment of FIG. 8, the exposed forward end portion 16a''' of the center film, and major forward portions of the isolating strips 28''', 29''' would normally be trimmed back, such as to the dashed line 106, unless the terminated cable end was to be used as a male type member for insertion within a female type connector.

In the final illustrative embodiment of the invention, a terminated end of a cable 10'''' is shown, which includes the use of isolating strips 28'''', 29'''', similar to those used in the terminated cable of FIG. 10, but distinguishing therefrom by also using an auxiliary non-conductive spacing member 108. The latter member is secured to opposite sides of the exposed end portion 16a'''' of the center film, after termination of the cable. Such a spacer member provides greater dielectric material separation between the two arrays of conductor ends 13a''', 14a''', particularly if they are again compressed against the spacing member 108, through the interposed isolating strips, so as to form a male-type member adapted for insertion in a female type connector (not shown). In the latter case, the increased separation

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established between the two arrays of conductor ends at the point of termination, because of the presence of the auxiliary spacer member 108, would normally satisfy even the most stringent d-c voltage breakdown requirements specified in most, if not all, demanding telephone system wiring applications.

While the spacer member 108 is depicted as a U-shaped strip of material, it is apparent that such a member could actually comprise a second pair of isolating strips bonded, or otherwise secured, to the center film end portion 16a'''' either at the time of cable termination, or during the manufacture of the cable, as in the case with the cable embodiment of FIG. 11.

With respect to cable termination of the types depicted in FIGS. 8, 10 and 12, where it is normally desired to remove the terminating end portions 18a, 19a of the outer films from the cable for connectorization, it should be understood that the cable can be initially severed at a number of different points relative to a pair of isolating strips 28, 29, to accomplish this result. More specifically, by severing the cable at a point that bisects a pair of isolating strips, the terminating end portions 18a, 19a of the outer films may then be removed, such as by longitudinally directed displacement of a grinding apparatus, for example, relative to the terminated cable, along at least the co-extensive regions of each remaining half of the original full width pair of isolating strips. This advantageously allows two cable terminations to be made for each original pair of isolating strips.

Alternatively, the cable could initially be severed a short distance in front of the laterally disposed forward edges of a pair of isolating strips 28, 29. The cable could then be readily clamped between the severed end and a region rearward of a pair of isolating strips so as to allow the outer terminating film portions 18a, 19a to be removed, with the ultimately exposed arrays of conductors being more firmly positioned over the lengths thereof that



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are co-extensive with an adjacent isolating strip. In this latter case, the initially severed and normally clamped end of the cable would normally be trimmed back to the laterally disposed forward edges of the then exposed pair
5 of isolating strips.



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Claims

1. A flat cable of the type wherein at least two overlying/underlying conductor arrays are spaced apart and laminated between two outer, adhesive-backed insulative plastic films,

CHARACTERIZED BY

a non-adhesive insulative center film (16), being interposed between the two conductor arrays (13, 14), of a width that allows longitudinally disposed border regions thereof to extend a predetermined distance beyond the respective longitudinally disposed edges of said conductor arrays,

and wherein each outer film (18, 19) is dimensioned to extend coextensively with the center film, each of the outer films, being bonded both to the adjacent surfaces of the associated array of conductors (13, 14) and to the adjacent longitudinally disposed surface-regions of the center film.

2. A flat cable in accordance with claim 1, CHARACTERIZED IN THAT the center and outer films are of polyethylene terephthalate plastic, with each of the outer films having a flame retardant, heat-activated polyester adhesive coating on the side thereof facing the center film.

3. A flat cable in accordance with claims 1 or 2,

CHARACTERIZED IN THAT

the offset spacing between the respectively associated conductors in the two arrays thereof is in a range of 0.175 mm to 0.355 mm.

4. A flat cable in accordance with any of claims 1-3,

CHARACTERIZED IN THAT

the conductors are of annealed copper having a thickness in the range of 0.075 to 0.20 mm, and a width in the range of 0.625 to 1 mm, with the major



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surfaces of said conductors being oriented in the major plane of the cable, and wherein the center line-to-center line spacing between adjacent conductors in the same array is within a range of 20 to 22.5 mm.

- 5 5. A flat cable in accordance with any of claims 1-4,

CHARACTERIZED IN THAT

the center insulative film has a thickness in the range of 0.05 to 0.1 mm, wherein each of the outer
10 insulative films has a thickness in the range of 0.05 to 0.12 mm, and wherein the adhesive coating on the one side of each outer film has an initial thickness in the range of 0.025 to 0.12 mm.

- 15 6. A flat cable in accordance with any of claims 1-5,

CHARACTERIZED BY

a plurality of non-conductive isolating strips (28, 29) positioned transversely, and on opposite sides, of the center film in aligned pairs and positioned
20 at predetermined spaced cable termination points along the cable.

7. A flat cable in accordance with claim 6,
CHARACTERIZED IN THAT
the isolating strips comprise thin plastic
25 tapes.

8. A flat cable in accordance with claims 6 and 7,

CHARACTERIZED IN THAT

the isolating strips are of a type adapted
30 to at least lightly bond to the center film, but not to the conductors, thus facilitating the separation of the coextensive end portions of the associated array of contacting conductors therefrom.

9. A flat cable in accordance with any of
35 claims 6-8,

CHARACTERIZED BY

a second pair (28', 29') of isolating strips



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located at each cable termination point and aligned with the first pair (28, 29), each isolating strip of the second pair being interposed between a different one of the arrays of conductors (13', 14') and the outer
5 film (18a', 19a') immediately adjacent thereto, said second pair of isolating strips being of a material that will not firmly bond to the associated outer film nor to the array of contacting conductors, thus allowing the
10 conductor ends of each array as thus interposed between and coextensive with two aligned and different isolating strips from the first and second pairs to be readily separated therefrom so as to allow the connectorization of the cable.

15 10. A flat cable in accordance with any of claims 6-9,

CHARACTERIZED IN THAT

a non-conductive auxiliary spacer member (108) is secured to opposite sides of the exposed
20 end of the center film (16) after the isolating strips have been separated therefrom, together with the respectively associated arrays of conductors, the spacer member allowing a greater insulative dielectric material separation between the two arrays of conductors at the
25 point of cable termination in situations when the isolating strips, together with the associated arrays of conductors bonded thereto, are to be subsequently brought into engagement with the spacer member.

30 11. A method of fabricating a flat cable in accordance with claims 1-10, with at least two arrays of conductors,

CHARACTERIZED BY

guiding a least two continuously advancing
35 arrays of parallel extending conductors into a precisely controlled offset relationship therebetween;

isolating at least the two arrays of conductors with a continuously advancing bare center



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plastic film of the type that will not directly bond to the conductors in response to normal laminating temperatures and pressures;

overlying each array of conductors with
5 a different continuously advancing, adhesive-backed outer insulative film;

passing the center film, two arrays of conductors and the two outer films through the nip of a pair of internally heated laminating rollers, one
10 roller having a peripheral metal surface formed with a plurality of conductor-receiving grooves therein, and the other roller having a smooth, resilient peripheral surface;

15 applying external heat at a predetermined temperature to an arcuate portion of the roller with the resilient peripheral surface in a region immediately adjacent the nip of the two laminating rollers, and

applying a predetermined biasing force
20 between the two laminating rollers which, in combination with the selective internal and external heating thereof, laminates the two arrays of conductors in an interleaved manner between, and within longitudinally disposed borders of the center film and the two outer films.

25 12. A method in accordance with claim 11,
CHARACTERIZED BY
the further steps of:

pre-heating to a predetermined temperature both the non-adhesive coated side of the particular outer
30, advancing film, and the associated array of conductors positioned on the same side of the center film as is the laminating roller with the resilient peripheral surface, the pre-heating occurring immediately prior to the last-mentioned film and array of conductors
35 being advanced into the nip of the laminating rollers, and

passing the laminated cable, after leaving



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the nip of the first pair of laminating rollers through the nip of a second pair of unheated finishing rollers, both of the latter rollers having smooth, resilient peripheral surfaces.

- 5 13. A method in accordance with claims 11 or 12,

CHARACTERIZED IN THAT

- the peripheral surface of the grooved laminating roller is internally heated to a temperature
10 in the range of 182°C to 210°C, wherein the resilient peripheral surface of the other laminating roller is heated to a temperature in the range of 127°C to 171°C, with the pressure exerted by the laminating rollers on the cable films and conductors being advanced there-
15 through being in the range of 7 to 35 kg/cm², with a feed rate in the range of 1 to 6 meter per minute.

14. A method in accordance with any of claims 11-13,

CHARACTERIZED BY

- 20 positioning and securing a spaced array of insulative isolating strips on opposite sides of, and extending transversely across, the center film at pre-determined spaced cable termination points prior to that film, together with the isolating strips thereon, being
25 advanced through the nip of the laminating rollers, the strips on each side of the center film being aligned in pairs and of a type of material that will allow the two arrays of conductors in the laminated cable to subsequently be readily separated from the center film for
30 connectorization.

15. A method in accordance with any of claims 11-14,

CHARACTERIZED IN THAT

- 35 the continuously advanced isolating film comprises a bare polyester film that initially is wider



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than the simultaneously advanced outer films, and which is positioned so as to mask the longitudinally disposed edges of the outer films from the peripheral surfaces of the first and second pairs of rollers when advanced therethrough, and wherein the method further comprises the step of:

trimming opposite sides of the advancing laminated cable to a predetermined finished width, which trimming operation includes removing the outwardly extending border regions of the isolating film that initially were not coextensive with the outer films.

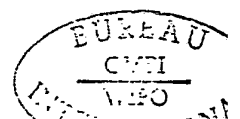
16. A method in accordance with any of claims 11-15,

CHARACTERIZED BY
the further step of:

pre-heating to a predetermined temperature the non-adhesive backed side of the continuously advanced outer film positioned on the same side of the isolating film as is the roller with the resilient surface.

17. An apparatus for the manufacture of multi-conductor flat cable in accordance with any of claims 1-10,

CHARACTERIZED BY
first and second rotatably mounted laminating rollers positioned to define a nip, and being adjustably biased so as to provide controllable laminating pressure therebetween, the first roller having a smooth, resilient cylindrical peripheral surface, and the second roller having a cylindrical peripheral surface of metal, and further including an array of laterally spaced, circumferentially disposed grooves of predetermined thickness and width to accommodate respective conductors of one array thereof when drawn through the nip of said rollers;



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means for internally heating the first and second rollers to a predetermined temperature;

means for rotatably driving at least one of the first and second rollers;

5 means for heating an arcuate portion of the resilient peripheral surface of the second roller to a predetermined temperature, and for heating a surface of a short length of a first insulative film to a predetermined temperature when advanced through a region
10 immediately adjacent the nip of the first and second rollers;

first and second payoff supply means for allowing the respective advancement of first and second
15 arrays of conductors through the nip of the first and second laminating rollers;

first and second conductor guiding and tensioning means positioned on the upstream side of the first and second rollers for precisely controlling
20 the alignment of the conductors in the first and second arrays when being advanced to the nip of the first and second rollers;

second and third payoff supply means for allowing the respective advancement of first and second
25 adhesive-backed insulative films through the nip of the first and second rollers while the first and second films are respectively positioned to overlies the first and second conductors arrays, respectively;

third payoff means for allowing the
30 advancement of a third insulative film through the nip of the first and second rollers while interposed between the first and second arrays of conductors, and

take-up means for receiving a cable after having been fabricated upon passing through the
35 nip of the first and second rollers.



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18. An apparatus in accordance with claim 17,
CHARACTERIZED IN THAT

the resilient peripheral surface of the
first roller comprises a layer of silicone rubber having
5 a thickness in the range of 0.2 to 25 mm, and wherein
the means to heat an arcuate peripheral portion of the
first roller, and a short length of a first film when
advanced through a region immediately adjacent the nip
of the first and second rollers comprises an internally
10 heated shoe formed with at least two arcuate surfaces,
one of the surfaces having a radius of curvature at
least substantially corresponding to the resilient surface
curvature of the first roller, with the other arcuate
surface of the shoe being adapted and oriented to allow
15 a continuously advanced first film to pass thereover in
a trajectory that directly leads to the nip defined
between the first and second rollers.

19. An apparatus in accordance with
claims 17 or 18, further comprising cable slitting means
20 positioned downstream of the first and second rollers
for trimming the edges of a fabricated cable to a
desired predetermined finished width after having been
advanced through the nip of the first and second rollers.

20. An apparatus in accordance with any of
25 claims 17-19,

CHARACTERIZED IN THAT

the first and second rollers are each
formed with a liquid medium-receiving cavity, including
an inlet and outlet port, and that the means for internally
30 heating the first and second rollers comprises a supply
of a liquid medium, and means for heating the liquid
medium to a predetermined temperature, and for re-circulating
said medium, under pressure, through the inlet ports,
cavities and outlet ports in succession of the first
35 and second rollers, respectively.



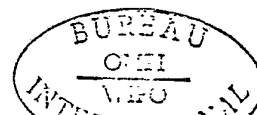
- 45 -

21. An apparatus in accordance with
any of claims 17-20,

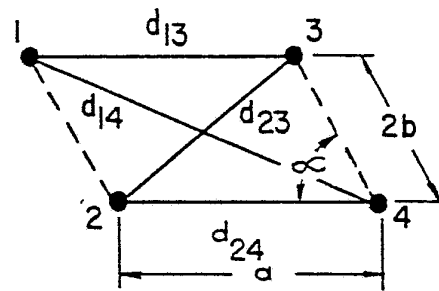
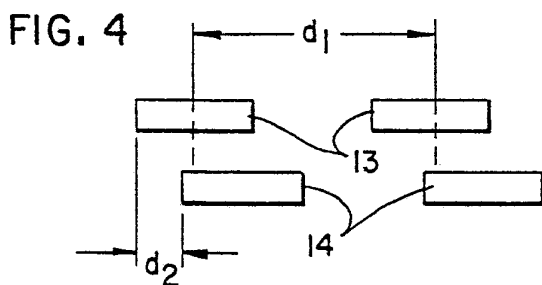
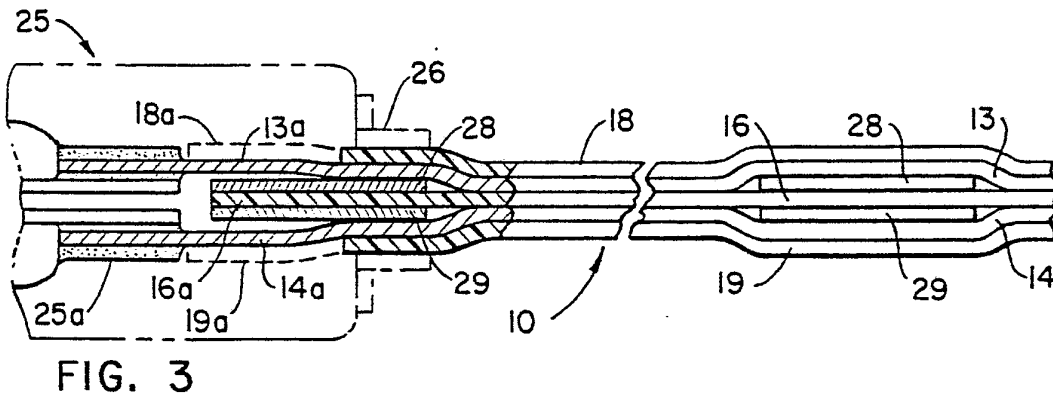
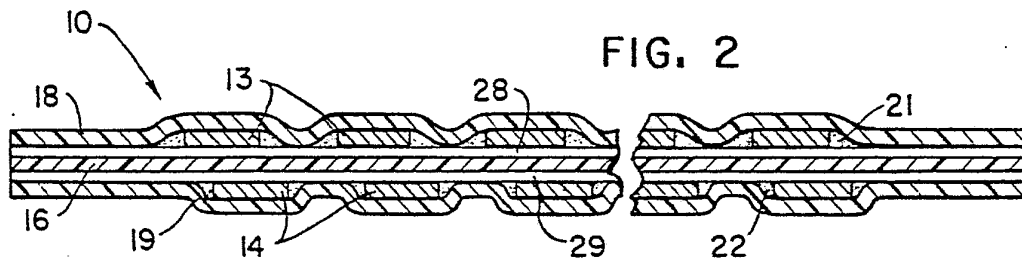
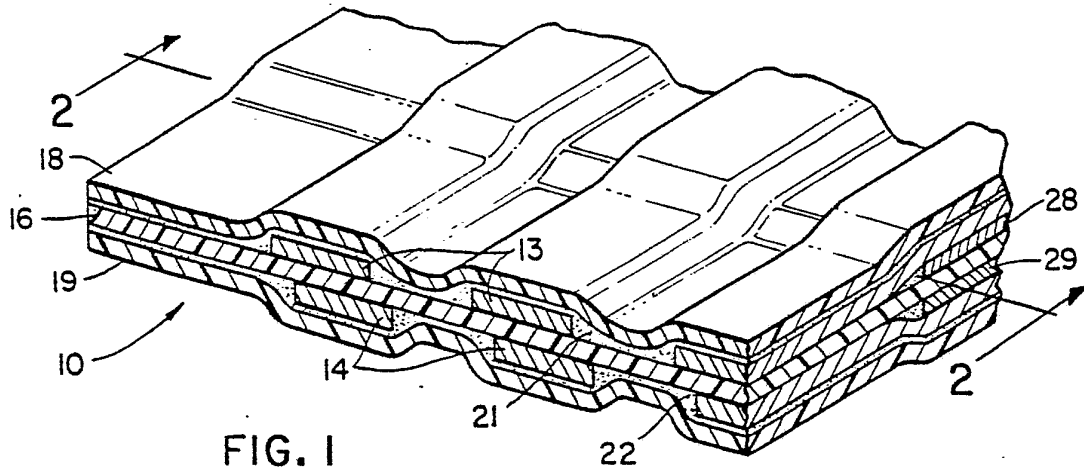
CHARACTERIZED BY

third and fourth rotatably mounted
5 finishing rollers positioned downstream from the first
and second rollers, and positioned to define a nip,
and being adjustably biased so as to provide controllable
pressure therebetween, the third and fourth rollers
both being unheated and having smooth, resilient,
10 peripheral surfaces, and
means for rotatably driving at least
one of the third and fourth rollers.

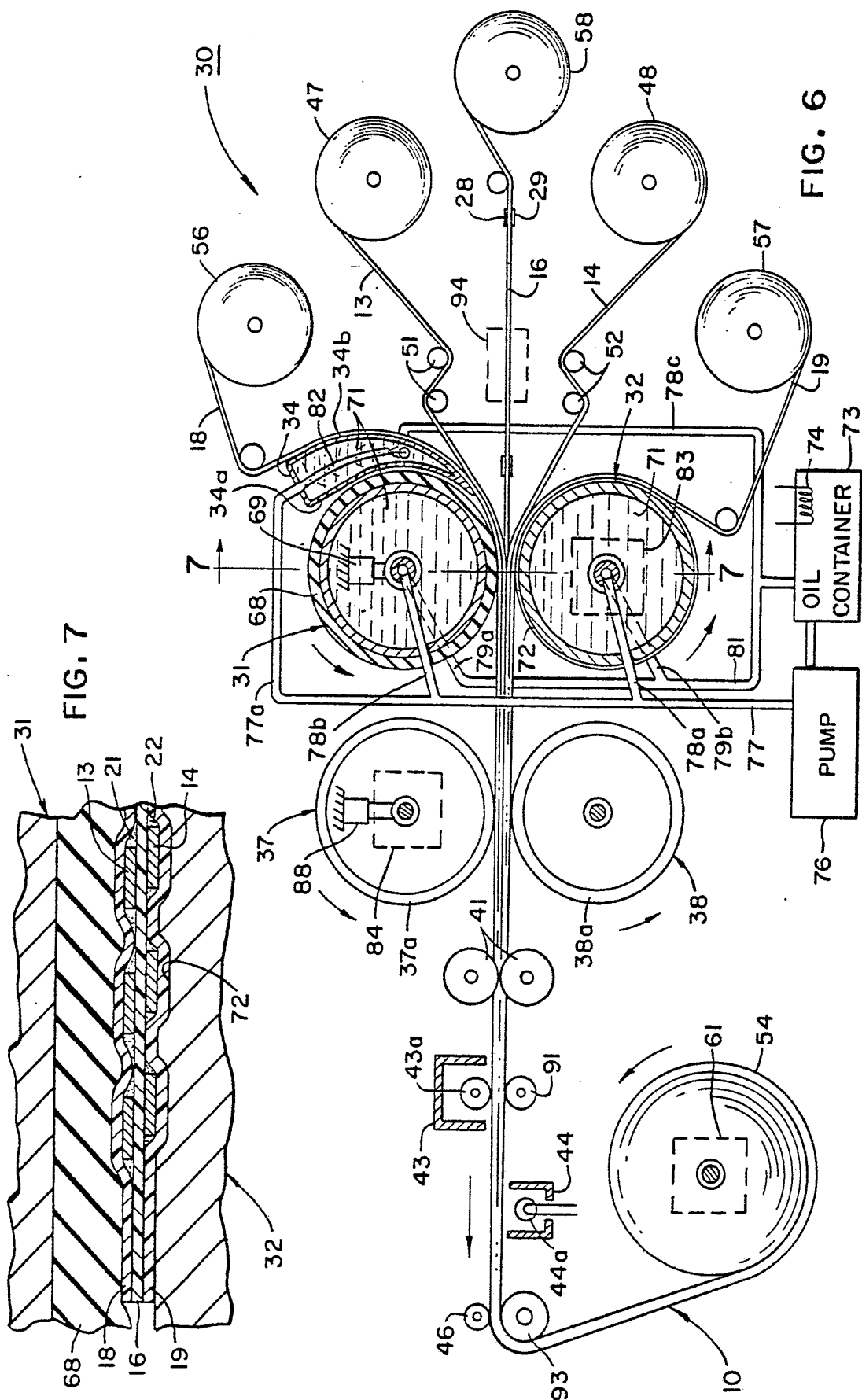
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1/3



2/3



3/3

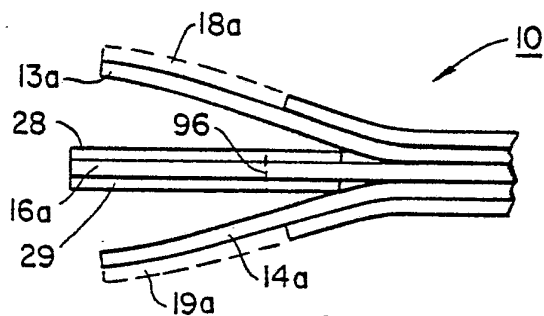


FIG. 8

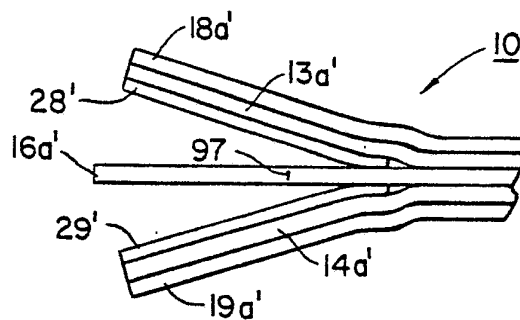


FIG. 9

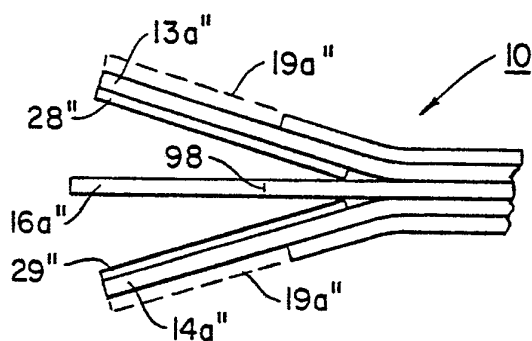


FIG. 10

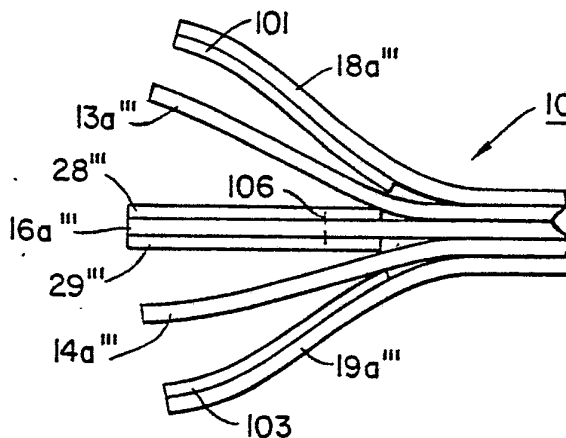


FIG. 11

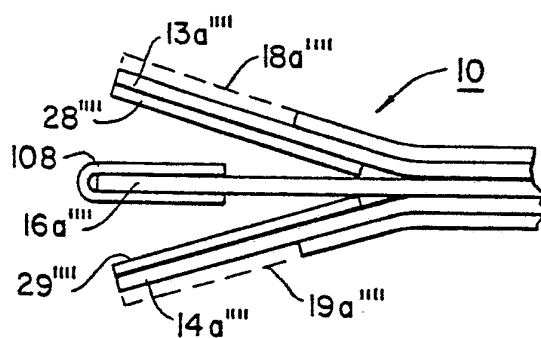


FIG. 12

INTERNATIONAL SEARCH REPORT

International Application No PCT/US 80/01656

I. CLASSIFICATION OF SUBJECT MATTER (If several classification symbols apply, indicate all) ³ According to International Patent Classification (IPC) or to both National Classification and IPC INT. CL. H 01 B 07/08; H 01 B 13/06; H 01 B 13/22 U.S. CL. 174/117ff; 156/55																										
II. FIELDS SEARCHED Minimum Documentation Searched ⁴ <table style="width: 100%; border: none;"> <tr> <td style="width: 20%; border: none;">Classification System</td> <td style="border: none;">Classification Symbols</td> </tr> <tr> <td style="border: 1px solid black; padding: 5px;">U.S..</td> <td style="border: 1px solid black; padding: 5px;">174/32,34,36, 117A, 117F, 117PC, 117FF</td> </tr> </table> Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched ⁴ none			Classification System	Classification Symbols	U.S..	174/32,34,36, 117A, 117F, 117PC, 117FF																				
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III. DOCUMENTS CONSIDERED TO BE RELEVANT ¹⁴ <table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="width: 10%;">Category ⁵</th> <th style="width: 60%;">Citation of Document, ¹⁶ with indication, where appropriate, of the relevant passages ¹⁷</th> <th style="width: 30%;">Relevant to Claim No. ¹⁸</th> </tr> </thead> <tbody> <tr> <td style="text-align: center;">X</td> <td>US, A, 3,764,727 Published 9 October 1973,</td> <td>1 to 10</td> </tr> <tr> <td style="text-align: center;">X</td> <td>US, A, 4,149,026 Published 10 April 1979,</td> <td>1 to 10</td> </tr> <tr> <td style="text-align: center;">X</td> <td>US, A, 3,703,604 Published 21 November 1972,</td> <td>1 to 10</td> </tr> <tr> <td style="text-align: center;">A</td> <td>US,A, 4,075,420 Published 21 February 1978,</td> <td>2 to 10</td> </tr> <tr> <td style="text-align: center;">A</td> <td>US, A, 3,057,952 Published 9 October 1962,</td> <td>2 to 10</td> </tr> <tr> <td style="text-align: center;">A</td> <td>US, A, 3,244,795 Published 9 April 1966</td> <td>1 to 10</td> </tr> <tr> <td style="text-align: center;">A</td> <td>GB, A, 1,086,823 Published 11 October 1967</td> <td>6 to 10</td> </tr> </tbody> </table>			Category ⁵	Citation of Document, ¹⁶ with indication, where appropriate, of the relevant passages ¹⁷	Relevant to Claim No. ¹⁸	X	US, A, 3,764,727 Published 9 October 1973,	1 to 10	X	US, A, 4,149,026 Published 10 April 1979,	1 to 10	X	US, A, 3,703,604 Published 21 November 1972,	1 to 10	A	US,A, 4,075,420 Published 21 February 1978,	2 to 10	A	US, A, 3,057,952 Published 9 October 1962,	2 to 10	A	US, A, 3,244,795 Published 9 April 1966	1 to 10	A	GB, A, 1,086,823 Published 11 October 1967	6 to 10
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¹⁵ * Special categories of cited documents: "A" document defining the general state of the art "E" earlier document but published on or after the international filing date "L" document cited for special reason other than those referred to in the other categories "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but on or after the priority date claimed "T" later document published on or after the international filing date or priority date and not in conflict with the application, but cited to understand the principle or theory underlying the invention "X" document of particular relevance																										
IV. CERTIFICATION <table style="width: 100%; border: none;"> <tr> <td style="width: 50%; border: none;">Date of the Actual Completion of the International Search ¹</td> <td style="width: 50%; border: none;">Date of Mailing of this International Search Report ²</td> </tr> <tr> <td style="border: 1px solid black; padding: 5px;">April 9, 1981</td> <td style="border: 1px solid black; padding: 5px; text-align: center;">16 APR 1981</td> </tr> <tr> <td style="border: none;">International Searching Authority ¹</td> <td style="border: none;">Signature of Authorized Officer ¹⁹</td> </tr> <tr> <td style="border: 1px solid black; padding: 5px;">ISA/US</td> <td style="border: 1px solid black; padding: 5px; text-align: center;">Richard J. Kuma</td> </tr> </table>			Date of the Actual Completion of the International Search ¹	Date of Mailing of this International Search Report ²	April 9, 1981	16 APR 1981	International Searching Authority ¹	Signature of Authorized Officer ¹⁹	ISA/US	Richard J. Kuma																
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INTERNATIONAL SEARCH REPORT

International Application No PCT/US 80/01656

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) ³		
According to International Patent Classification (IPC) or to both National Classification and IPC		
IPC ³ H01B 13/06 US. 156/55		
II. FIELDS SEARCHED		
Minimum Documentation Searched ⁴		
Classification System	Classification Symbols	
US	156/52,55,179,201,213,267,269,292,300,303,322,324, 475,499,551,554,555,582,583.1	
Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched ⁵		
NONE		
III. DOCUMENTS CONSIDERED TO BE RELEVANT ¹⁴		
Category ⁶	Citation of Document, ¹⁶ with indication, where appropriate, of the relevant passages ¹⁷	Relevant to Claim No. ¹⁸
A	US, A, 3,523,844 Published 11 August 1970, see Figure 3,4,5 and 10 and column 4, lines 22-75 and column 5 and column 6, lines 1-54, CRIMMINS ET AL	11-21
A	US,A, 4,000,348, Published 28 December 1976, see Figure 1 and column 5 lines 20-68 and column 6 and column 7, lines 1-48, HARLOW	11-21
A	US,A, 3,513,045, Published 19 May 1970, see Figures 1-4 and columns 3 to 5, EMMEL ET AL	11-21
A	US,A, 4,097,324, Published 27 June 1978, see Figures 1-6 and column 3 lines 34-68 and columns 4 to 6 and column 7 lines 1-15 EMMEL	11-21
A	US,A, 4,137,116, Published 30 January 1979, see Figures 5-6 and column 3, lines 59-68 and column 4 lines 1-31 MILLER	11-21
⁶ Special categories of cited documents: ¹⁵ "A" document defining the general state of the art "E" earlier document but published on or after the international filing date "L" document cited for special reason other than those referred to in the other categories "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but on or after the priority date claimed "T" later document published on or after the international filing date or priority date and not in conflict with the application, but cited to understand the principle or theory underlying the invention "X" document of particular relevance		
IV. CERTIFICATION		
Date of the Actual Completion of the International Search ²		Date of Mailing of this International Search Report ²
8 April 1981		16 APR 1981
International Searching Authority ¹		Signature of Authorized Officer ¹³
ISA/US		<i>Jerome W. Massie</i>

FURTHER INFORMATION CONTINUED FROM THE SECOND SHEET

V. ☒ OBSERVATIONS WHERE CERTAIN CLAIMS WERE FOUND UNSEARCHABLE ¹⁰

This international search report has not been established in respect of certain claims under Article 17(2) (a) for the following reasons:

1. ☐ Claim numbers _____, because they relate to subject matter ¹² not required to be searched by this Authority, namely:

(4 to 10)/(3 to 10) + dependent 11 to 21

2. ☒ Claim numbers A, because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out ¹³, specifically:

IMPROPER MULTIPLE DEPENDENT CLAIMS

VI. ☒ OBSERVATIONS WHERE UNITY OF INVENTION IS LACKING ¹¹

This International Searching Authority found multiple inventions in this international application as follows:

- I. Claims 1 to 10 to a flat cable in 174/117;
 II. Claims 11 to 16 to a method in 156/55;
 III. Claims 17 to 21 to apparatus in 156/475 or 29.

1. ☒ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims of the international application.
2. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims of the international application for which fees were paid, specifically claims:
3. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claim numbers:

Remark on Protest