LOW NOISE CORD WITH NON-METALLIC SHIELD

Inventors: Byron B. Giffel, Richmond, Ind.; Robert B. Cole, New Westville, Ohio

Assignee: Belden Corporation, Chicago, Ill.

Filed: Mar. 30, 1973

Appl. No.: 346,600


Int. Cl. .................. H01b 9/02


References Cited

UNITED STATES PATENTS

3,037,068 5/1962 Wessel .................. 174/69
3,100,240 8/1963 McKirdy .................. 174/69

Primary Examiner—A. T. Grimley
Attorney, Agent, or Firm—William E. Anderson

ABSTRACT

A low noise flexible multiconductor electric cord having a number of insulated electrical conductors, at least one of which has a non-metallic electrically conductive material enveloping the same to define an electrical shield, a grouping of relatively small exposed electrical drain or ground strands positioned generally parallel to and in intimate contact with the shield of each of the shielded primary conductors to provide electrical continuity between the grounding strands and the shielding material, and an outer insulating jacket enveloping all of the conductors and ground strands.

9 Claims, 2 Drawing Figures
This invention generally relates to flexible electric cords or cables and, more specifically, to miniature multiconductor shielded electric cords that may be either retractile cords or straight bulk cordage.

Although retractile or coiled cords as well as the uncoiled cords or bulk cordage have long been manufactured incorporating one or more shielded conductors, i.e., such shielded conductors have a suitable electromagnetic and/or electrostatic shielding material that envelopes the electrical insulating material covering the metallic conductors. The function of the shielding material is to preclude extraneous voltages or signals being picked up and carried by one or more of the conductors which may detrimentally affect the signal being transmitted by the shielded conductors.

Previous constructions of cable shields have consisted of low coverage copper or tinsel or copper alloy braids, serves, aluminum-polyester tapes as well as semiconducting fabrics. All these shields exhibit one or more of the disadvantages of high self-generated noise, large diameters, high cost, poor shielding, or reduced flex life in addition to reduced initial flexibility.

For relatively small diameter multi-conductor cords, commonly referred to as miniature or sub-miniature cords which are used in the telephone headset industry, and for microphone cables of tape recorders, medical instrumentation, etc., undesirable hum and self-induced or tricob-electric noise are important factors that contribute to the operational performance of a cord during use. Additionally, since such cords are typically subjected to considerable flexing during normal usage, it is also important that the cord be capable of being flexed over an extended period of time without breaking the conductors or grounding strands therein or without detrimentally affecting the operational characteristics of the cord.

Accordingly, it is a primary object of the present invention to provide a miniature multi-conductor cord that includes at least one shielded conductor and exhibits excellent flexibility and extended flex life, as well as improved operational characteristics including substantially lower self-induced noise and hum.

It is another object of the present invention to provide a cord having the aforementioned desirable attributes which is suited for fabrication as either straight, bulk cordage or in a coiled retractile configuration.

Still another object of the present invention lies in the provision of having at least one shielded conductor in the cord wherein the shield comprises a layer of semiconductive plastic material overlying the insulating sheath that envelopes the conductors and also includes a group of extremely small exposed or uninsulated grounding strands positioned generally parallel to and in intimate contact with the conductive plastic shielding material so that electrical continuity between the shielding material and grounding strands is maintained, thereby reducing the probability of the shield becoming open circuited.

A related object lies in the provision of extruding the conductive shielding material around an insulated conductor which results in significantly increased production speeds compared to serving and other comparable procedures and thereby favorably affects production costs.

A more specific object of the present invention lies in the provision of having a group of small diameter uninsulated strands in intimate contact with the shielding material to provide drain or ground strands that may be easily processed at a point of termination, with the combination of the grounding strands and shielding material also providing improved electrical operational characteristics.

Yet another specific object of the present invention is to provide a cord having the above desirable attributes wherein the shielding material for the shielded conductor is easily applied and may have a thin wall thickness which is helpful in producing a small overall cord diameter.

Other objects and advantages of the present invention will become apparent upon reading the following detailed description, while referring to the attached drawings, in which:

FIG. 1 is a cross sectional view, partially in perspective, and illustrating a cord construction embodying the present invention, and particularly illustrating three primary conductors; and

FIG. 2 is a sectional view of a cord construction also embodying the present invention, and particularly illustrating a six primary conductor configuration.

While the present invention is susceptible of various modifications and alternative constructions, certain preferred embodiments are shown and described herein. It should be understood, however, that it is not intended to limit the invention to the specific forms disclosed. On the contrary, it is intended that all substitutions, equivalents and modifications be covered as may be included within the spirit and scope of the present invention as expressed in the appended claims.

Turning now to the drawings and specifically FIG. 1, a short length of electric cord 10 embodying the present invention is shown. Broadly stated, the cord 10 is shown to include three primary electrical conductors indicated generally at 12, 14 and 16, with each of these conductors having one or more electrically conductive central strands 18 and an insulating sheath 20. The conductor 12 also has a layer 22 of non-metallic, electrically conductive shielding material applied to and enveloping the insulating material 20. Positioned generally parallel to and in intimate contact with the shielding material 22 is a grouping of uninsulated or exposed strands 24 which are in electrical contact with the material and provide a ground or drain wire which may easily be processed or terminated at terminating points. A pair of non-conductive textile filler strands 26 are also provided in the construction illustrated to provide for more even overall symmetry and balance in the resulting cord so that during normal use, the cord will not be prone to flex repeatedly in a specific direction which would tend to reduce the overall flex life of the cord. An outer jacket 28 is shown to surround all of the interior components of the cord. While a cross sectional view of the cord taken any where along its length would result in the same relative positions of the interior components relative to one another, it should be understood that the conductors and strands are twisted along their length and the jacket 28 is applied to maintain the twist of the interior components as is conventional practice.

The foregoing broad description of the electric cord embodying the present invention, while appearing to be similar to existing configurations, nonetheless belies the
significant advance in the art, particularly in terms of its operational characteristics and flex life, which will be clearly set forth hereinafter. More specifically, the various parameters that are used to measure the operational effectiveness of an electric cord will be set forth and the significant improvements that result from the present invention will become readily apparent.

In keeping with the present invention, the size of the miniature cords to which the present invention is primarily directed and particularly the three conductor construction shown in FIG. 1 may of course vary, but may be on the order of 0.130 inches (130 mils) diameter for straight or bulk cordage, the diameter being slightly increased to about 0.150 inches (150 mils) diameter in the event a retractile cord is produced. The slightly increased diameter for the retractile cord is largely a function of increased jacket thickness that is desirable to provide the requisite elasticity or resiliency for the coiled configuration. With such outside diameters, the individual conductors 14 and 16 are typically about 37 mils in diameter including the insulating sheath 20 and the shielded conductor 12 is of slightly increased diameter due to the additional thickness of the shield and is preferably about 47 ± 2 mils diameter. The grouping of drain or ground strands 24 may of course vary depending upon the number of individual strands that are incorporated into the cord, but with a grouping of 10 drain strands 24, the effective diameter approximates 29–30 mils, it being realized that the grouping is not perfectly symmetrical. With the conductors 12, 14 and 16 being arranged in a generally triangular configuration, the grouping of ground strands 24 is positioned immediately adjacent the shielded conductor 12 preferably in the valley between either the conductor 14 or 16 and the shielded conductor 12. In the shown configuration, it is then preferable that filler material such as a textile thread or cotton strand or the like be placed in the two remaining valleys to gain the desirable symmetry and fill out the configuration to approach circularity in the overall outer configuration.

While each of the primary conductors 12, 14 and 16 are shown to have a total of four strands 18, it should be understood that a greater or small number may be utilized depending upon the size and kind of strands that are used. For example, each of the strands 18 may comprise fine metal wires or tinsel which is a small textile strand or cord such as polyester or the like, around which one or more ribbons of a copper cadmium alloy or other low resistance metal are wrapped, with each of the ribbons typically having a cross sectional area of 1 mil by 9 mils. Thus, with a total of four of each strands 18, with each strand having 2 ribbons therein, it is seen that 8 electrically conductive ribbons would be present. The insulating material 20 is preferably extruded to the strands 18 and is preferably comprised of polypropylene or other flexible high resistance electrical insulating material.

In accordance with an important aspect of the present invention, and referring to the shielded conductor 12, it is noted that the construction of this conductor is substantially similar to the other conductors 14 and 16, except for the application of an electrically conductive shielding material to the outer surface of the electrical insulation 20. The electrically conductive shielding layer 22 is preferably extruded over the insulation so as to provide a homogeneous layer of electrically conductive material, such as semi-conductive polyvinyl chloride, for example. It has been found that semi-conductive polyvinyl chloride having the volume resistivity of up to 12.5 ohm centimeters is sufficiently conductive to adequately shield the conductor, although it is preferred that volume resistivities be within the lower end of the range, such as 4.8 ohm centimeters, for example. In this connection, a semi-conductive polyvinyl chloride having a volume resistivity of 4.8 ohm centimeters is sold under the trade name of "ABBEY-100" by the Abbey Plastic Corporation of Hudson, Mass. Using a conductive polyvinyl chloride shielding material with a wall thickness of about 5 mils, only increases the diameter of the conductor 12 by about 10 mils over the diameter of the other primary conductors 14 and 16 and therefore does not appreciably alter the symmetry of the overall cord configuration. Extrusion of the plastic shielding material 22 over the insulation 20 of the conductor 12 permits the use of high speed extruders and thereby eliminates the use of relatively slow serving machines, and may result in considerable production cost reductions.

While the conductive polyvinyl chloride is preferred for the shield, it should be understood that other semi-conductive plastic materials may be used, such as a semi-conducting polyethylene, for example. However, it is believed that polyethylene is principally somewhat inferior because it does not have favorable aging characteristics, and its electrical resistivity often increases with time. It is also preferred that the conductive shielding material 22 be dissimilar to the insulating material 20 so that the two materials will not bond together at the interface which would inhibit easy stripping of the shield by a user at a termination point. Thus, a semi-conductive polyvinyl chloride for the shielding material has been found to be readily strippable relative to a polypropylene insulating material 20.

In accordance with yet another aspect of the present invention, the group of uninsulated drain or grounding strands 24 are shown to be generally parallel to and immediately adjacent the conductive shielding material 22 so as to be in electrical contact with it. The individual drain or ground strands 24 are preferably made from a ribbon of conventional size, such as 1 mil by 9 mil cross sectional area wrapped around a polyester thread or the like to form a single strand. The construction of FIG. 1 illustrates a total of 10 of such strands 24 in the grouping and, while this number is not particularly critical, it is preferred that at least 8 to 10 and preferably at least 10 of such strands be used. If more than 10 strands 24 are used, the positive effect that may be gained would probably not justify the additional cost. However, if fewer than 10 of such conductors are used, it has been found that the flex life of the cords as a whole may be appreciably reduced. This is partially due to the manner in which the flex life is measured. It is preferred that the flex life is determined by flexing the cable until there is an increase in the measured resistance of 25 percent within the grouping of the drain strands, when they and the strands of the primary conductors are connected in series with one another, due to breakage of the individual strands. It is seen that if a total of eight wires are in the group, only two need to break before the critical limit of 25 percent increased in resistivity is achieved. On the other hand, if 10 of such strands are used, it is seen that three wires need to break before the 25 percent increase is reached and,
in actual use, it has been found that the use of 10 of such grounding strands is preferred from the standpoint of overall cord flex life. The group of grounding strands 24 are shown to be positioned in the valley between the conductors 12 and 14, with the inside of the outer extruded jacket 28 effectively maintaining the grounding strands 24 into intimate contact with the shielding material 22. In this connection, the outer insulating jacket 28 is preferably of a flexible plastic material such as polyvinyl chloride, or other flexible insulating material. The outer jacket is extruded under sufficient radially inward pressure so as to urge the group of grounding strands 24 into intimate contact with the shielding material 22 so as to provide electrical continuity between them. Under such conditions, the probability of an open shield along the length of the cord is greatly reduced due to the combination of the conductive drain or grounding strands and the extruded semi-conductive polyvinyl chloride shield material. Additionally, the operational characteristics have been significantly improved, in terms of the factors such as hum and self-induced noise.

Turning now to an important aspect of the present invention, and referring to the following Tables I and II which vividly illustrate the comparison of the operational characteristics of the cord embodying the present invention as compared to a cord having similarly sized primary conductors, but which includes a served conductive shield comprising uninsulated tinsel strands. In other words, the cord having a served tinsel shielded conductor was tested along with a cord substantially identical to the structure shown in FIG. 1 and the test results are evident from the following Tables.

It should be noted that the cord designated as "A" in the Tables is a three-conductor cord having metallic strands served around the insulation for the shielded conductor to define the shield, and cord "B" is a three-conductor cord embodying the present invention and having the extruded non-metallic electrically conductive polyvinyl chloride shield and a total of ten grounding strands have been positioned generally parallel to and in intimate contact with the shielding material. Cord "B" is substantially the construction illustrated in FIG. 1.

### TABLE I

<table>
<thead>
<tr>
<th>Test</th>
<th>Cord A</th>
<th>Cord B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hum Freq. (Hz)</td>
<td>60</td>
<td>26 mv</td>
</tr>
<tr>
<td>400</td>
<td>58 mv</td>
<td>32 mv</td>
</tr>
<tr>
<td>1 k</td>
<td>1.1 v</td>
<td>38 mv</td>
</tr>
<tr>
<td>5 k</td>
<td>1.5 v</td>
<td>42 mv</td>
</tr>
<tr>
<td>7 k</td>
<td>1.6 v</td>
<td>46 mv</td>
</tr>
<tr>
<td>9 k</td>
<td>1.7 v</td>
<td>48 mv</td>
</tr>
<tr>
<td>11 k</td>
<td>1.7 v</td>
<td>49 mv</td>
</tr>
<tr>
<td>13 k</td>
<td>2.2 v</td>
<td>48 mv</td>
</tr>
<tr>
<td>15 k</td>
<td>1.6 v</td>
<td>49 mv</td>
</tr>
</tbody>
</table>

As is evident from the measurements shown in Table I, cord "B" embodying the present invention has greatly improved characteristics and exhibits on the order of 7.5 times better hum suppression than cord "A" at 60 Hz, almost 2 times better at 400 Hz and on the order of 30 times better for frequencies measured between 1 k Hz and 15 k Hz. It is noted that the hum test was made by placing the two cords within a brass tube approximately 18 inches long and having an inside diameter of about % to % inch, wherein an oscilloscope was connected to a cord and a variable frequency generator connected to the brass tube with a 700 VAC signal being applied. The test essentially measures the amount of signal that penetrates the shielding material and appears on the shielded conductor itself.

With respect to self-induced noise, it was found that the cord "B" had an average of 9.5 peak to peak millivolts as compared with a measurement of 114 millivolts average for cable "A," which shows an improvement on the order of 12 times better for cord "B" embodying the present invention. The self-induced noise test was made following the method described in MIL-C-17 which is also a National Bureau of Standards test procedure and is not set forth in detail for that reason.

With respect to the flex life of cord "B" embodying the present invention, it was tested by bending the cord 60° each side of vertical around a ½ inch radius at the rate of 85 cycles per minute. The test was terminated when the measured electrical resistance of the primary conductor strands and group of grounding strands connected in series, increased 25 percent, due to breakage of individual strands within the group. It has been found that the average flex life of cord "B" is at least 200,000 cycles and measurements approaching 800,000 cycles have been experienced. It is noted that if less than 10 grounding strands are incorporated into the cord, that the flex life decreases. In this connection, when a total of only 8 wires were incorporated into the design, the flex life was found to drop to an average of about 160,000 to 170,000 cycles on the average.

Although it is shown from the foregoing that the flex life and self-induced noise characteristics are indeed superior for the cord embodying the present invention, Table II is set forth to illustrate other operational characteristics such as capacitance, D-C resistance of the shielded drain or grounding strands as well as cross talk between various primary conductors within the two cords and is included to complete the data for the comparison.

### TABLE II

<table>
<thead>
<tr>
<th>Test</th>
<th>Cord A</th>
<th>Cord B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cross Talk Freq. (Hz)</td>
<td>dB Isolation</td>
<td>dB Isolation</td>
</tr>
<tr>
<td>40 K</td>
<td>64</td>
<td>69</td>
</tr>
<tr>
<td>70 K</td>
<td>58</td>
<td>60</td>
</tr>
<tr>
<td>100 K</td>
<td>48</td>
<td>46</td>
</tr>
<tr>
<td>400 K</td>
<td>34</td>
<td>27</td>
</tr>
<tr>
<td>1 M</td>
<td>15</td>
<td>10</td>
</tr>
<tr>
<td>1.6 M</td>
<td>14</td>
<td>13</td>
</tr>
<tr>
<td>4.0 M</td>
<td>13</td>
<td>14</td>
</tr>
<tr>
<td>10 M</td>
<td>21</td>
<td>31</td>
</tr>
<tr>
<td>16 M</td>
<td>26</td>
<td>43</td>
</tr>
<tr>
<td>40 M</td>
<td>28</td>
<td>35</td>
</tr>
</tbody>
</table>

As is evident from Table II, the cross talk, capacitance and d-c resistance characteristics are comparable for the cords "A" and "B." It should be noted that the cross talk was measured according to the provisions of military specification MIL-C-23437 and MIL-C-23553.

In accordance with another aspect of the present invention and turning to FIG. 2 which illustrates another cord also embodying the present invention wherein six (6) primary conductors are incorporated into the con-
3,816,644

figuration, it should be understood that the construction is quite similar to that shown in FIG. 1, but includes four unshielded insulated primary conductors and two shielded insulation conductors as well as two groups of grounding strands. It is preferred that the shielded conductors be separated from one another and, in the illustrated embodiment, they are diametrically opposed relative to one another. Due to the symmetry of the configuration shown, it is preferable that a central textile core filler 30 having a diameter comparable to the diameters of the primary conductors be incorporated and it has been found that a cotton filler core is adequate for this purpose. Because of the inclusion of substantially similar components within the construction, the designator numbers of FIG. 1 are used in FIG. 2 since the individual primary conductors as well as the group of grounding strands are substantially identical to those shown in the configuration of FIG. 1. It should also be understood that while only three and six primary conductor cords are specifically illustrated in the drawings, cord configurations having 2, 4, or 5 primary conductors as well as even greater numbers of primary conductors may be produced in accordance with the present invention.

Thus, miniature electrical cords embodying the present invention have been described herein in detail which have many desirable attributes and have been shown to demonstrate superior operational characteristics in terms of hum and self-induced noise as well as in the flex life of the cord. One desirable aspect of the present invention is the improved processability that is achieved, since the shield is ready for termination merely by stripping off the conductive shielding material and terminating the drain wire. This and the other previously mentioned desirable attributes are believed to satisfy all of the objects and advantages that have been set forth herein.

What is claimed is:

1. A flexible, low noise miniature type cord, comprising, in combination:
   a plurality of flexible electrical conductors, each of which includes an electrically insulating sheath enveloping the same, each conductor comprising one or more strands, each strand comprising a nonmetallic thread and one or more electrically conductive metallic ribbons;
   at least one of said conductors having a non-metallic, flexible electrically conductive shielding material enveloping said insulating sheath to define an electrical shield;
   a plurality of at least eight flexible electrically conductive grounding strands positioned generally parallel to and in contact with each of said shielded conductors to provide electrical continuity between said grounding strands and said shielding material, each of said strands comprising a nonmetallic thread and one or more electrically conductive metallic ribbons twisted around one another; and
   an outer electrically insulating flexible jacket enveloping said conductors and grounding strands, said jacket having sufficient radial compression to maintain said grounding strands and shielding material in intimate contact with one another.
2. A cord as defined in claim 1 which includes three of said electrical conductors arranged in a generally tri-angular configuration, one of said conductors being said shielded conductor and said plurality of grounding strands being positioned in at least one of the valleys between said shielded insulated conductor and an adjacent insulated conductor, and textile filler strands extending along the remaining valleys.
3. A cord as defined in claim 1 including a central core of non-conductive textile material and six of said insulated conductors, two of which have said enveloping shielding material, said conductors being symmetrically arranged so that each of said conductors are immediately adjacent to other conductors and said core, said two shielded conductors being spaced from one another by one or more of said unshielded insulated conductors.
4. A cord as defined in claim 1 wherein said electrically conductive non-metallic material comprises electrically conductive polyvinyl chloride having a volume resistivity of up to about 12.5 ohms centimeters.
5. A cord as defined in claim 1 wherein said outer adjacent jacket comprises a flexible elastic insulating material and is set in the form of a series of self-retracting coiled convolutions, said coiled convolutions normally being adjacent one another in retracted relation and being spreadable relative to one another responsive to force being applied to extend the cord.
6. A cord as defined in claim 1 wherein each of said conductors comprises four of said strands, each of said strands including two of said ribbons, each ribbon having cross sectional dimensions of about 1 mil by 9 mils.
7. A cord as defined in claim 1 wherein said outer insulating jacket is extruded plastic material of uneven thickness, said jacket having a generally circular outer periphery and being of increased thickness in those locations where valleys occur between adjacent conductors and/or grounding strands and/or textile filler strands.
8. A cord as defined in claim 1 wherein said conductors comprise a plurality of electrically conductive strands, each strand being equal or smaller than the equivalent of about 22 gauge AWG.
9. A flexible multi-conductor miniature electric cord having superior low noise and extended flexibility life characteristics, comprising in combination:
   a plurality of flexible insulated primary electric conductors;
   at least one of said primary conductors having an electrically conductive non-metallic extruded material enveloping the same and defining an electric shield;
   a plurality of uninsulated electrically metallic grounding strands, each of said strands comprising a nonmetallic thread and one or more electrically conductive metallic ribbons twisted around one another, said plurality of grounding strands being grouped together and positioned generally parallel to and in intimate contact with said shielded primary conductor to provide electrical continuity between said grounding strands and said shielding material; and
   an outer insulating jacket surrounding said conductors and sized to provide sufficient tightness to maintain said grounding strands in intimate contact with said shielded primary conductors.
UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,816,644 Dated June 11, 1974

Inventor(s) Giffel, et al

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 2, line 67 - "nonetheless" should be --nonetheless--.
Column 8, line 20 - "adjacent" should be --insulating--.
Column 8, line 60 - "strains" should be --strands--.

Signed and sealed this 29th day of October 1974.

(SEAL)
Attest:

Mccoy M. Gibson Jr. C. Marshall Dann
Attesting Officer Commissioner of Patents
UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,816,644 Dated June 11, 1974
Inventor(s) Giffel, et al

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 2, line 67 - "nontheless" should be --nonetheless-- .
Column 8, line 20 - "adjacent" should be --insulating--.
Column 8, line 60 - "strains" should be --strands--.

Signed and sealed this 29th day of October 1974.

(SEAL)
Attest:

McCoy M. Gibson Jr. C. Marshall Dann
Attesting Officer Commissioner of Patents