Dec. 6, 1955 I. W. EDWARDS 2,725,615

METHOD OF MAKING AN ELECTRICAL CONNECTOR

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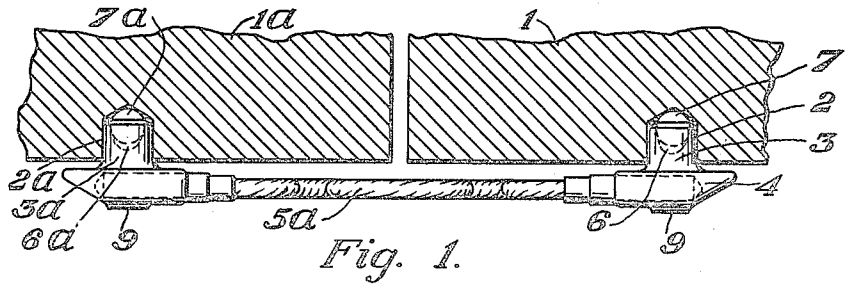


Fig. 1.

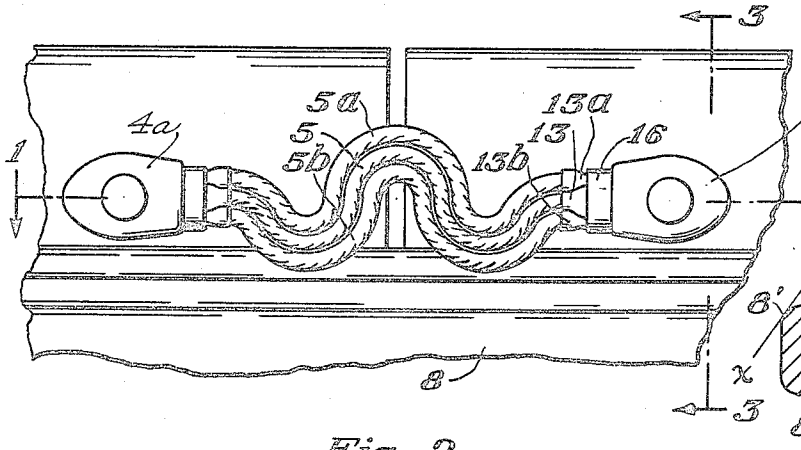


Fig. 2.

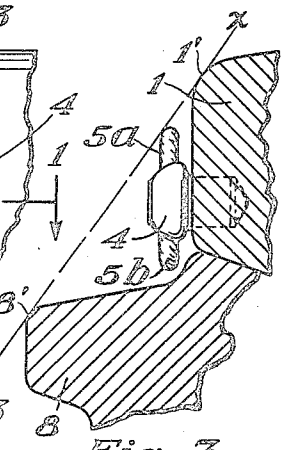


Fig. 3.

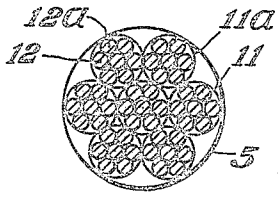


Fig. 4.

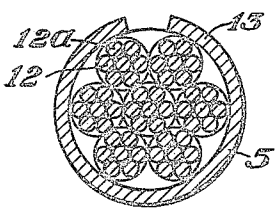


Fig. 5.

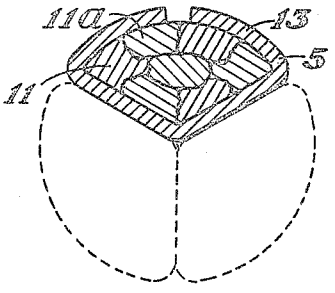


Fig. 6.

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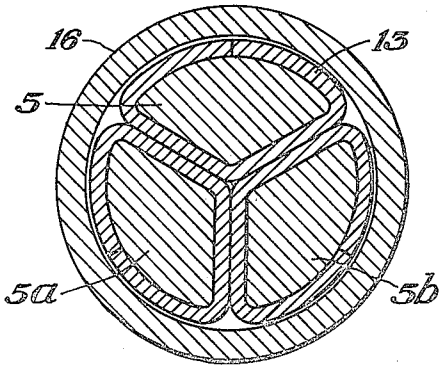


Fig. 7.

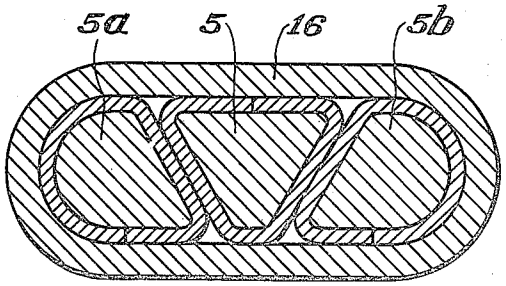


Fig. 8.

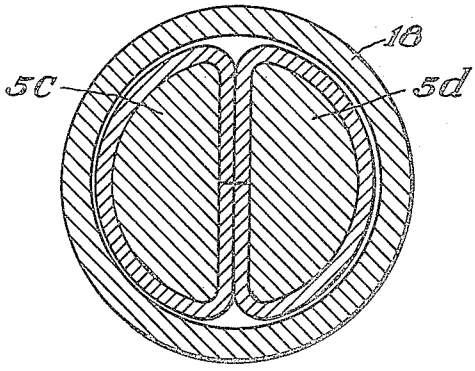


Fig. 9.

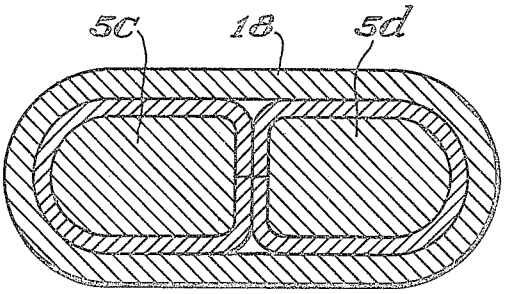


Fig. 10.

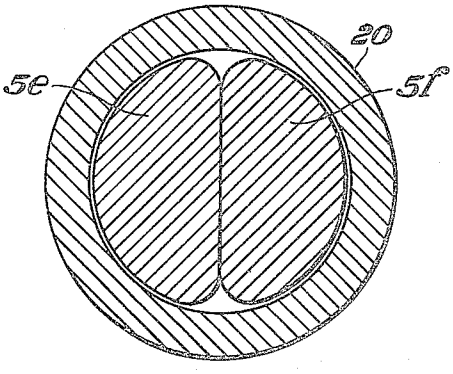


Fig. 11.

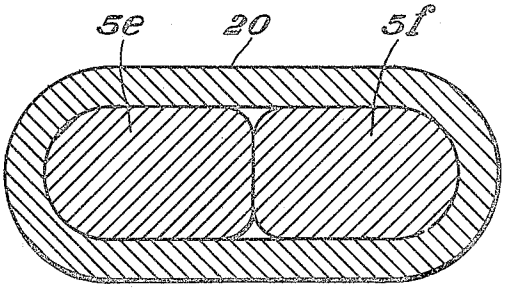


Fig. 12.

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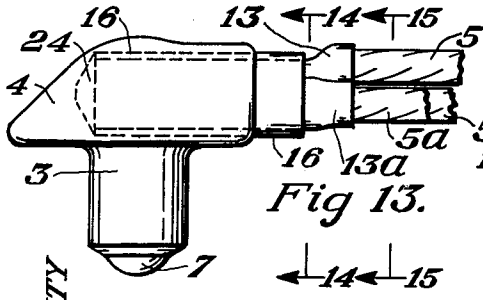


Fig 13.

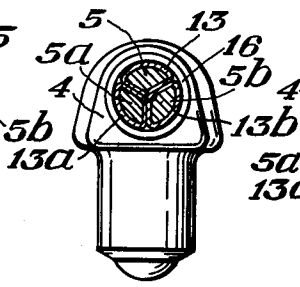


Fig. 14.

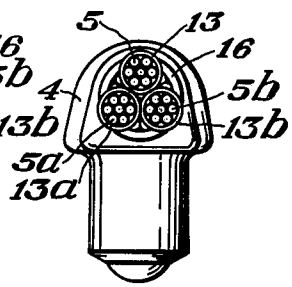


Fig. 15.

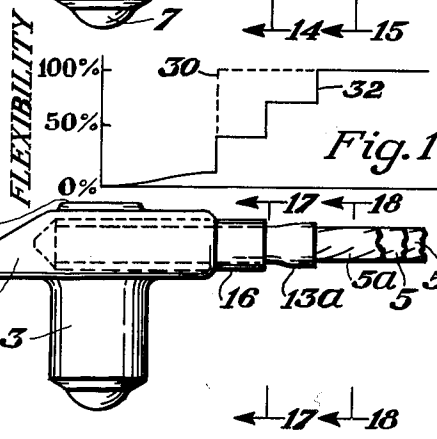


Fig. 19.

Fig 16.

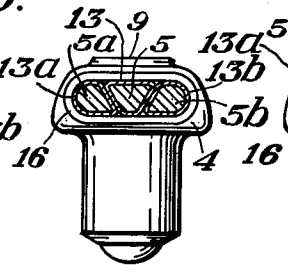


Fig. 17.

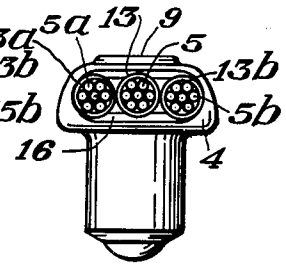


Fig. 18.



Fig. 20.

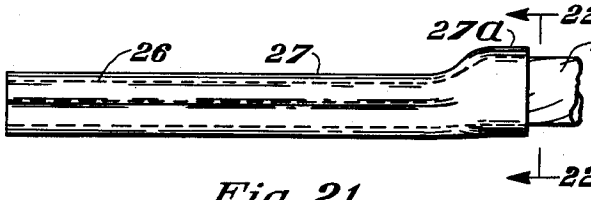


Fig. 21.

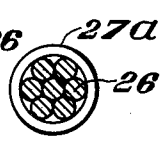


Fig. 22.

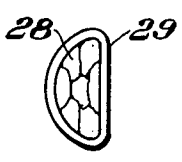


Fig. 23.

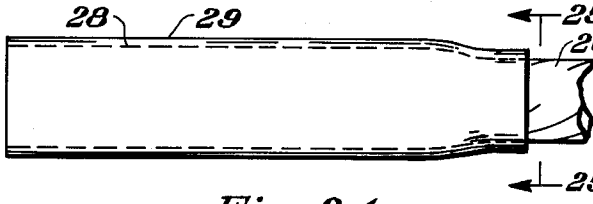


Fig. 24

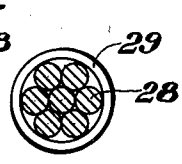


Fig. 25.

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Fig. 26.

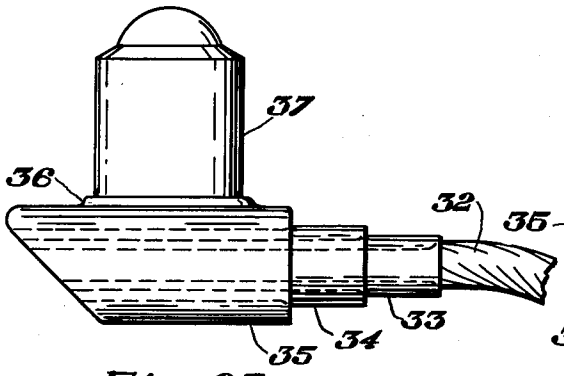


Fig. 27.

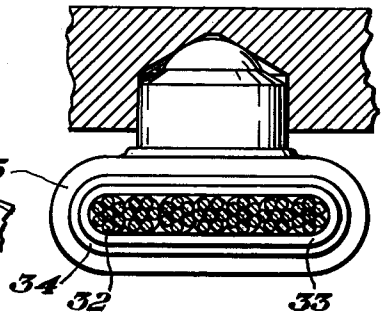


Fig. 28.

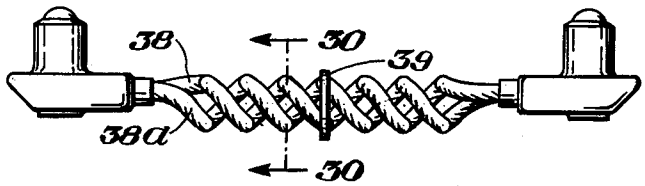


Fig. 29.

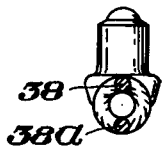


Fig. 30.

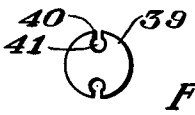


Fig. 31.

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United States Patent Office 2,725,615 Patented Dec. 6, 1955

2,725,615

METHOD OF MAKING AN ELECTRICAL CONNECTOR

Irving W. Edwards, Detroit, Mich.

Application August 30, 1947, Serial No. 771,524

1 Claim. (Cl. 29—155.55)

This invention relates to electrical connecting conductors, and more particularly to the conductors of the type commonly known as jumpers or straps for establishing electrical connections or continuity; and the invention is especially applicable to railbonds.

This application is a continuation in part of my copending application Serial No. 605,319, filed July 16, 1945, issued as Patent No. 2,579,227, on December 18, 1951.

Connectors of this type ordinarily comprise one or more terminal members with a flexible conductor attached to or between the terminal members. When such conductors or connectors are used for connecting abutting rails of a railroad track they are commonly called railbonds; although they are not limited to use with rails, but may be used in other analogous applications such as for grounding or connecting steel frames, bus bars, pipes and the like. Such connecting conductors or bonds ordinarily comprise a flexible conductor attached to the terminal member or post which is fastened to the thing to which connection is to be made.

A principal object of the present invention is to provide an improved electrical linkage, or railbond, which can maintain circuit continuity for long periods of time and which shall be resistant to shock, vibration, weathering, and other factors which are experienced in the operation of railways, or in other adaptations, which tend to impair or loosen the connection.

It has long been understood that for the efficient, continuous and safe operation of railroads, signal stations must be maintained with the utmost durability in spite of the adverse conditions which are encountered in railroad operations. The track circuit which is commonly used for railroad signal circuits is the heart of the signal system. For this purpose, it is required that abutting rails be electrically joined to each other and maintained. This circuit continuity is commonly maintained by railbonds comprising a terminal post or stud forced into the side of the abutting rail head and with a flexible electrical conductor joining the terminal posts. Such railbonds are subject ot hard use which tend to loosen the stud and to wear out or break the flexible conductors; and many improvements have been suggested to increase the life and reliability of such railbonds in order that the desired circuit continuity shall be maintained.

In spite of numerous proposals which have been made to improve such railbonds, they are still subject to injury, loosening and breakage. The flexible conductors, for example, are becoming more and more subject to failure due to being struck by dragging equipment on the railroad track, and vibrational stresses, incident to the increase of weight and speed of rolling stock, as well as to duration and increased frequency of the periods of stress.

In order to allow for this vibration and also to allow for the expansion and contraction of rails which changes the spacing between the abutting rails, it is a practice to provide enough length of conductor between the terminal studs in the adjacent rail heads to allow for about a one inch takeup. This involves some form of looping or bending of the conductor. Such looped conductors are extremely subject to the above mentioned hazards; and for this purpose it is desired to confine the loop or curvature within a restricted locality.

It has heretofore been proposed and attempted to accommodate the excess length or looping of the conductor by arranging it in a serpentine configuration; and for this purpose, the conductor was made of laminated strips or ribbons of copper or the like. This was at one time a common practice, and still is used to some extent for some types of heavy capacity bonds, for example, on electric railway systems wherein heavy currents are carried. It was quickly found, however, that for rail head, high speed train operations, such a serpentine laminated conductor was short lived and subject to mechanical deterioration; and owing to its general impracticability it was abandoned for that purpose. The short life of cables of this type was due mainly to the tearing stresses in the plane of lamination. While the laminations will bend easily in the direction transverse to the plane of the lamination, it is resistant to bending in the plane of lamination and consequently tends to tear in that direction. In consequence, there was substituted a single rope type of cable made up of strands of copper or the like and this had the advantage of being equally flexible in all planes normal to its longitudinal axis. But it has the disadvantage that a substantially large diameter cable is required to take care of the current to be carried; and since it is necessary to provide considerable bend in the cable to take care of the joint expansion slack, it was subject to considerable "bird-caging," that is, a spreading of the strands. This permitted only a single bend in the cable with perhaps secondary bends adjacent its terminals; and to accommodate the required amount of slack the single main bend varied an excessive distance from the line betwen the terminal members, with the consequent danger of being caught by moving objects or dragging equipment.

In accordance with my invention, I have overcome the disadvantages of prior connectors by the provision of flexible connectors or cables, so formed and arranged with the terminal members as to enable the connectors to be maintained in a restricted area and out of the way of moving members such as dragging equipment and the like which might injure it. In the case of a railbond the desired restricted area or region will usually be a region closely adjacent the side of the rail head, and considerably below its top. This maintenance of the connectors within a desired restricted area is accompanied at the same time by the provision of means for taking up vibration and variations in distance between the ends of the connectors.

According to a feature of my construction, I construct my connecting cables of a plurality of strands of wire and arrange them in a serpentine configuration. By this arrangement the bends of the serpentine can be held within a relatively small range of a straight line joining the terminal members. A related feature is the provision of sleeves around the cables or connectors at the places where they attach to the terminal posts, thereby providing a desirable support for the cables and securing them at the terminals against undue bending, while permitting desired increased bending further from the terminal.

Another related feature of my invention is a flattening of the connecting cable or cables where they join the terminal members, this serving further to maintain the connector or cable within the desired restricted region. In carrying out this feature, I may provide an assembly of two or more connecting cables at the terminal posts, this having the advantage of a reduction in diameter of the individual cables. All of the cables may be thus flattened, if desired, so as to result in the desired restriction of the area occupied by the cable.

According to another feature of my invention I obtain the desired restriction in the area occupied by the cables by the formation of the individual cables of the bond into

a loosely wound helix or helices. This enables the cables to be made to lie within the restricted area and close to a railhead while still providing means for taking up variations in distance between terminal members due to vibration and other causes.

The foregoing and other features of the invention will be better understood from the following detailed description and the accompanying drawings of which:

Fig. 1 is a section taken on the line 1—1 of Fig. 2, showing the terminal posts affixed to a pair of adjoining rails and the connecting cables joining the terminal posts;

Fig. 2 is a side elevation of the connector of the invention used as a rail bond;

Fig. 3 is a sectional end elevation taken on the line 3—3 of Fig. 2;

Fig. 4 is a cross-section of a single cable which may be employed in the rail bond as shown in Fig. 2;

Fig. 5 shows the cable of Fig. 4 as provided with a sleeve;

Fig. 6 shows a cross-section of the cable of Fig. 5 shaped in the form of 120° sector;

Fig. 7 is a sectional elevation of three sectors, such as the one shown in Fig. 6 enclosed within a sleeve;

Fig. 8 is a sectional elevation of the assembly of Fig. 7 flattened in the direction of the vertical transverse axis;

Fig. 9 shows an alternate construction wherein a pair of cables are shaped into 180° sectors and are provided with a sleeve;

Fig. 10 is a sectional elevation of the assembly of Fig. 9 flattened in the direction of the vertical transverse axis;

Fig. 11 is a sectional elevation of an alternative embodiment of the invention wherein the individual cables are formed but not separately sleeved;

Fig. 12 is a sectional elevation of the assembly of Fig. 11 flattened in the direction of the transverse axis;

Fig. 13 is a plan view of one of the terminals as shown in Fig. 2 with three cables inserted therein;

Fig. 14 is a sectional elevation taken on the line 14—14 of Fig. 13;

Fig. 15 is a sectional elevation taken on the line 15—15 of Fig. 13;

Fig. 16 is a plan view of the terminal of Fig. 13 after the same has been flattened in the direction of its horizontal axis;

Fig. 17 is a sectional elevation taken on the line 17—17 of Fig. 16;

Fig. 18 is a sectional elevation taken on the line 18—18 of Fig. 16;

Fig. 19 is a graphic portrayal of the linear change in flexibility of the cables mounted in the manner shown;

Fig. 20 is an end elevation of a cable provided with a seamless sleeve and having a cross-section in the shape of a 120° sector;

Fig. 21 is a side elevation of the sleeved cable of Fig. 20;

Fig. 22 is a sectional elevation taken on the line 22—22 of Fig. 21;

Fig. 23 is an end elevation of a single cable provided with a seamless sleeve having a cross-section in the shape of 180° sector;

Fig. 24 is a side elevation of the cable of Fig. 23;

Fig. 25 is a sectional elevation taken on the line 25—25 of Fig. 24;

Fig. 26 is a top view of the rail bond made according to my invention, showing the connecting cable arranged in a horizontal serpentine;

Fig. 27 is an enlarged partial view of an undriven rail bond according to my invention, showing the attaching stud welded to sleeves which enclose the cable;

Fig. 28 is a view partially in cross-section showing a short connecting stud adapted for connection with a relatively thin metallic member or the like, and showing, a multiple cable entry into the sleeving attached to the stud;

Fig. 29 is a plan view of the rail bond according to my invention, showing multiple cables in helical formation.

Fig. 30 is a sectional elevation on line 30—30 of Fig. 29; and

Fig. 31 shows the disc used as a cable spacer in the apparatus of Fig. 29.

Figs. 1, 2 and 3 show the device of the invention employed as a rail bond connecting the rails 1 and 1*a* in electrically conductive relationship. In the embodiment shown, the abutting rails 1 and 1*a* are drilled at the head portion thereof, to a proper depth, diameter and location according to good practice to form the bores or receptacles 2 and 2*a*.

The terminals 4 and 4*a* of the rail bond connecting the two rails are, according to common railroad bonding practice, provided with studs 3 and 3*a*, respectively adapted to be placed in the bores to establish electrical contact. To provide necessary binding effect of the studs within the bores, means for achieving the binding is provided. In Fig. 1, the arrangement shown is that described in my said copending application and comprises the respective taper recesses 6 and 6*a* in the studs 3 and 3*a* into each of which is set a ball 7 and 7*a*, with part of the ball protruding from the front of the stud. In accordance with conventional practice, the stud is expanded in the bore at the railhead by hammering on the head 9 of the terminal 4, for example, thereby forcing the part of the ball which protrudes from the recess into the conical end of the bore and thereby forcing the ball back into the recess and forcing the end of the stud against the side of the bore.

In the embodiment shown in Figs. 1, 2 and 3, the terminals 4 and 4*a* are joined by electrical conductive cables 5, 5*a* and 5*b* placed side by side and extending into the terminal heads. The cables are made of strands of wires arranged in a tight helix, and are formed into a serpentine or multiple bend, this being shown as a double S bend, with the several cables lying parallel to each other and to the side of the railhead. By reason of this multiple bend, the displacement of the bent cable from the straight line joining the terminal members is greatly reduced; and the conductors are caused to lie within a restricted area defined, as shown in the sectional elevation of Fig. 3, by a line X—X drawn between the upper portion of the head at the rail 1 and the outer edge 8′ of the splice bar 8. Restriction of the cable displacement is accordingly accomplished without reducing the desired slack which according to standard railroad practice is one inch. The use of multiple cables instead of only a single cable enables the diameters of the individual cables of the multiple assembly to be made much smaller than in the case of a single cable, for a given conductance or a given current carrying capacity; and the small size of the individual cables permits manufacture with the multiple bends as illustrated in Fig. 2. As shown in Figs. 1 and 2, the ends of the conductor cables are housed within a bore in the heads of the respective terminals 4 and 4*a* and preferably each cable has placed around each of its ends an individual sleeve such as the sleeves 13, 13*a*, 13*b* (see Fig. 14) respectively of conductive material and all of sleeves 13, 13*a*, 13*b* are placed within an outer conductive sleeve 16, the outer sleeves being lodged within the bores of the respective terminals.

The advantage of restricting displacement of the cables is apparent by reference to the sectional elevation of Fig. 3 taken on the line 3—3 of Fig. 1 wherein it is seen that any dragging equipment would not interfere with the rail bond inasmuch as it would not normally project into the area enclosed by the line X—X.

Furthermore, the provision of a plurality of relatively small cables instead of a single larger cable permits the multiple bending shown in Fig. 2. This would not be possible if a single large cable were employed because of the consequent bird-caging or wire spreading which results when a large cable is bent in this manner. Bird caging is undesirable because of the infiltration of dirt and grit which is permitted when the wires are thus

spread. Although the serpentine bend is shown in Figs. 1, 2 and 3 to lie in a vertical plane it may be also satisfactory to bend the cables on a horizontal or an oblique plane which still will lie within the area defined by the line X—X of Fig. 3. Such a horizontal serpentine is shown in Fig. 26.

A feature of my connectors is the means of affixing the cables 5, 5*a* and 5*b*, or a greater or lesser number of such cables, to the terminal posts 4 and 4*a* whereby the lateral protrusion of these posts beyond the head of the rail is reduced to a minimum. In prior bonds of the type using a single round connecting cable, affixed to the terminal posts either by an extension of the terminal head itself, drilled to receive the cable, or by butt-welding the cable to the terminal face, undesirably great protrusion of the terminal posts from the rail face has resulted due to the relatively large dimensions of the single cable.

As illustrated in Figs. 4 to 30 I have devised a unique method of joining the plurality of cables employed in my rail bond to the terminal posts whereby the protrusion of the posts from the rail is greatly reduced. In Fig. 4 there is shown in sectional elevation a single cable such as for example, the cable 5 shown in Fig. 2. The cable 5, as here shown is a conventional type, known as a 7 by 7 type, that is, comprising seven strands 11, 11*a*, etc., each of which consists of seven individual wires 12, 12*a*, etc. For facility of construction and handling and for the protection of the fine wires 12 and 12*a* of the individual strands 11, 11*a*, etc., of the cable 5 at the points where vibration changes in degree and resonance, I enclose this cable 5 in a conductive sleeve 13 shown in the sectional elevation view of Fig. 5. The sleeve 13 may be either in the form of a tube press-fitted onto the cable or as indicated in Fig. 5 as a wrapped-on sleeve.

To avoid the mechanical difficulty of making an irregular receptacle in the terminal to receive a plurality of cables such as the cable 5 or the alternative procedure of drilling a series of round holes in alignment and adjacent to each other in such a terminal, I alter the configuration of the ends of each of the plurality of cables to adapt them for insertion into a round receptacle or drilled hole formed in the terminal. In Fig. 6 there is shown in sectional elevation the end of cable 5 provided with the sleeve 13, the cable end having been deformed in cross-section, as shown in Fig. 6 so as to assume the shape of a 120° sector. The dotted lines in Fig. 6 represent a configuration of the cable ends presented in sectional elevation when three cables similar to cable 5 are placed together. These sectors may be formed in a suitable die, for example. It will be understood that preferably no portion of the cable other than the sleeved ends should be thus deformed.

Fig. 7 is a sectional elevation of three cables 5, 5*a* and 5*b* shaped in cross-section as 120° sectors inserted in a sleeve 16. After insertion of the sleeve 16 within a terminal post such as the terminal 4 (Figs. 1 and 2) the terminal is compressed or flattened in the manner hereinafter set forth and the sleeve 16 containing the cables 5, 5*a* and 5*b* is flattened in the form shown in Fig. 8. By flattening the sleeve 16 within the terminal the cables 5, 5*a* and 5*b* are caused to assume the general shape and position shown in the sectional elevation of Fig. 7, i. e. the center cable 5 is wedged between the cables 5*a* and 5*b*.

An alternative embodiment of the invention is shown in Fig. 9 wherein two cables such as the cables 5*c* and 5*d* are fitted into a sleeve 18 by shaping each of the cables in the form of 180° sectors.

The sleeved cables of Fig. 9 when inserted in the receptacle of the terminal, such as the terminal 4 of Fig. 2, and compressed as hereinafter described, will assume the shape shown in sectional elevation in Fig. 10.

In Fig. 11 there is shown a sectional elevation of another embodiment of the invention wherein the cables 5*e* and 5*f* are not separately sleeved adjacent their ends and are simply compressed and formed in the shape of

180° sectors and inserted in the sleeve 20. When the sleeve 20 is inserted in one of the terminal posts and compressed, the assembly shown in Fig. 11 will assume the shape shown in sectional elevation in Fig. 12. The advantage of the embodiment shown in Figs. 11 and 12 besides economy in the elimination of the individual cable sleeves is that it permits the use of larger cables without increasing the required size of the terminals.

The means of joining the plurality of cables as shown, for example, in Figs. 1, 2 and 3 to one of the terminals is shown in Figs. 13 to 18. Fig. 13 is a plan view of one end of the rail bond including the terminal 4 and the individual cables 5, 5*a* and 5*b* provided with the individual sleeves 13, 13*a* and 13*b* (shown in Figs. 14 and 15). As shown in Fig. 7 the individual cables 5, 5*a* and 5*b* provided with the sleeves 13, 13*a* and 13*b*, respectively, are formed adjacent to their ends into 120° sectors whereby they may be compactly inserted in the sleeve 16. The sleeve 16 may then be inserted within the bore 24 of the terminal 4 shown in Fig. 13.

Fig. 14 which is a section taken on the line 14—14 of Fig. 13 shows the three cables 5, 5*a* and 5*b* in cross-section in relation to the sleeve 16 and the terminal post 4. A portion of Fig. 14 including the sleeve 16 and the three cables inserted therein is identical to the enlarged view of Fig. 7.

Fig. 15 which is a section taken on the line 15—15 of Fig. 13 shows the cables 5, 5*a* and 5*b* being of circular cross-section throughout the portion of their length not confined in the sleeves 13, 13*a* and 13*b*.

In the construction of the rail bond of the invention, the sleeve 16 into which has been inserted the individual cables 5, 5*a* and 5*b*, provided at the point of insertion with the sleeves 13, 13*a* and 13*b* respectively, and shaped so as to fit snugly into the sleeve 16, is inserted in the receptacle 24 formed in the head of the terminal member 4. To reduce the protrusion of the head of the terminal 4 from the side of the rails 1 or 1*a* as shown in Figs. 1 and 2, and to accomplish the efficient gripping and low resistance contacting of the cable in the terminal, the head is compressed or flattened in the direction of the rail as shown in Fig. 16, so as to assume a relatively flat shape. Thus, Fig. 16 is a plan view of the terminal 4 (as shown in Fig. 16), after it and the cables have been compacted and flattened as described. Similarly, Fig. 17 which is a section taken on the line 17—17 of Fig. 16, and Fig. 18 which is a section taken on the line 18—18 of Fig. 16, correspond respectively to Figs. 14 and 15 showing the relationship of the cables 5, 5*a* and 5*b* after compression of the terminal 4.

As shown in Fig. 17, the individual cables 5, 5*a* and 5*b*, after crimping of the terminal, assume the positions shown in Fig. 8 within the sleeve 16 and the relative position shown in Fig. 18 without the sleeve 16.

In one embodiment of the invention as hereinbefore described, and particularly with reference to Fig. 5, individual cables 5, 5*a* and 5*b* have been provided with sleeves which are wrapped on the cable, as for example, sleeve 13 of Fig. 5. Alternatively the sleeves of the individual cables may be seamless tubes swaged onto the cable as shown in Figs. 20 to 25.

Fig. 20 is an end view of a cable 26 provided with a seamless tube 27 shaped mainly in the form of a 120° sector similar to the cables 5, 5*a* and 5*b* as shown in Fig. 7. The tube 27 shown in elevation in Fig. 21 is swaged onto the cable 26. To avoid mutilation by crushing of the cable as it leaves the sleeve, the sleeve 27 is formed with one end 27*a* of circular cross-section as shown in Fig. 22 which is a section on the line 22—22 of Fig. 21.

In Figs. 23, 24 and 25 there is shown an alternative embodiment in which the cable 28, shown as an end view in Fig. 23, is provided with a seamless sleeve 29 shaped under compression in the manner shown in the side elevation view of Fig. 24 and the sectional elevation of Fig. 25 as taken on the line 25—25 of Fig. 24.

Although the cable of Fig. 2 is shown with the double-S bend, it will be understood that more or less bend might be used, and this general form of bending I call herein a serpentine bend.

Fig. 26 shows an embodiment of my rail bond or connector having the connecting cable arranged in serpentine manner, and in a horizontal plane, with more bends than simply the double-S bend shown in Fig. 2.

In Figs. 27 and 28 I show a cable arrangement comprising a single seven-strand rope cable the strands of which are laid out flat at the terminal to comprise seven strands or groups of wires, **32**, laid side by side. Preferably, the strands **32** are arranged so that the lays of the cable wires are alternately right-lay and left-lay. In this way, the outer individual wires of contiguous strands lie in the same general direction, thereby increasing contact areas and thus reducing wear under vibration which might otherwise occur if the wires of the lays were crossing each other where they made contact. They also nest or fit against each other and thus reduce their spread as indicated in Fig. 28. These are placed within the oval-shaped sleeve **33** which is telescoped within the larger similar shaped sleeve **34**. The two sleeves are telescoped within the head **35** of the stud which in this embodiment has an oval cross-section similar to that of the sleeves. These sleeves are preferably compacted and sweated together to assure solidity and consequent efficiency in driving, particularly in the region of the studs. The stud **37** may be soldered, sweated, brazed or welded at its solid end as indicated at **36** to the head **35** of the terminal **37**.

A further embodiment of my invention as shown in Fig. 29 is the restriction of the displacement of the prescribed slack in the cable or cables to the area indicated by clearance line X—X in Fig. 3 by means of a loose, free helical wind of the cables, shown here for example where two cables **38** and **38***a*, in spiral but parallel conformation, are free to vibrate or extend with a minimum of internal stress. Being non-contiguous each with the other, these cables are less subject to mechanical wear against each other. Permissible joint expansion according to railroad standards is obviously provided for by the normal reductions in the helical radii. The central clearances between cables, shown in Fig. 30 as normally spiralled, are usually assured, but for further protection against chaffing and wear and to insure more positive clearances between the different cables, I prefer to use a spacer disc **39** inserted between the cables in Fig. 29 and shown in detail in Fig. 31. This disc is supplied with tightly fitting slots **40** for the insertion of the cables in the respective close-fitting recesses **41**. These discs may be of rubber, plastic, wood, fibre, or the like, as desired with due consideration to their functioning not only as spacers but for the dampening of any oscillations that may be inherent in the cables.

A further deterrent to resonance of this nature may be secured by the use of dissimilar metals respectively in cables **38** and **38***a*, with one cable having a resonant period out of synchronism or frequency with the second, or any others in the group. It should be noted that while a single cable in place of my multiple cables could be used in this helical embodiment it would be impossible without objectionable bird-caging to restrict the helical radius of such a single cable to the degree that can be safely used by two or more smaller cables of equal sectional area and at the same time provide the spare or slack in the extended cable length required for rail joint expansion. I prefer to use a disc of rubber or plastic of a non-rigid or energy absorbing nature where my cables have like resonance periods, while more rigid spacer material may be used to tie together cables of different resonances, as with one bronze cable and another steel cable.

My arrangement of multiple-connecting cables arranged in a parallel row and attached by the telescoped sleeves, is of particular advantage in the application to

which I put these connectors. In rail bond signal work, it is a very important consideration to be able to detect a broken cable before the continuity of the electrical circuit is interrupted. If only a single cable connector were used, this breakage would disrupt the electrical system. If, however, multiple cables are used, the breakage of one of the cables can usually be detected before the continuity of the signalling system is interrupted.

My use of parallel cable wires has a further advantage in that is possible to obtain a serpentine effect of the cable as shown in Figs. 2 and 26 or a helical configuration as shown in Fig. 29 by use of multiple cables whereas by the use of only a larger single cable only a single loop of the cable would be practical. The ability to form into the compact serpentine or the helical shape is of considerable advantage, which resides in the fact that a given over-all length of cable can be brought closer to the rail itself than when only a single loop is used. It is an advantage to have the cable and the terminal head hug close to the rail, as in this way it is less apt to be damaged by extraneous devices or tools brought in proximity to it, or by vehicles with cleats passing over the track or dragging equipment over the rails and cables.

Another advantage of my invention flows from the use of a plurality of cables and consists of the possibility of forming one of the cables of metal of high vibrational fatigue resistance and mechanical strength without appreciably increasing the electrical resistance of the bond. Metals such as stainless steel for example, which exhibit great mechanical strength are apt to be of high resistance which is an undesirable feature in a conventional rail bond. However, by forming one of my two or more cables from high strength though high resistivity metal, I am able to insure at least satisfactory conductivity for such a period as to permit inspection, discovery and replacement of the entire bond before actual interruption of the signal circuit occurs, in the event that the weaker and more conductive cables are broken. This feature is a great advantage in keeping signals, and consequently trains, in continuous operation. A single cable bond when it fails, on the other hand, means a complete signal failure and consequent train stoppage.

Obviously the tough cable, i. e. the cable to be made of stainless steel, for example, can be placed, if desired, at the top position (Fig. 2), that being the most vulnerable. However, I prefer to have a weaker cable in that location to indicate rupture earlier. Furthermore a hard, tough cable lends itself more readily to the wedging action as described and shown in Figs. 7 and 8 and clearly is a feature of this method of manufacture and assembly.

While I prefer to use material of good vibrational characteristics such as bronze for the high conductance cables, the conductivity of these can be improved by the use of pure copper or aluminum. Use of such materials becomes particularly feasible if a cable of greater mechanical strength, such as exhibited by galvanized steel or stainless steel, or high strength bronze, is used for the second or third cable.

I prefer to assemble the connectors of my invention as follows: In the three-cable rail bond of Figs. 1 and 2, three circular cables may be initially sleeved at both ends thereof, and the sleeve portions formed in the shape of 120° sectors either prior to, simultaneously with, or after insertion as in the sleeves; or they may be formed without any such sleeves, for economy. In a three-cable construction each sleeve portion is formed in the shape of a 120° sector (Fig. 7) and in two cable construction each sleeve portion is formed in the shape of a 180° sector (Fig. 9). Similarly if four cables are desired each may be shaped, at the sleeved ends, into 90° sectors. The corresponding sector-shaped sleeved ends of the cables are then inserted in a circular outer sleeve adapted to receive compactly all sectored ends and this outer sleeve is inserted in a circular bore in the terminal post. The

terminal head is crimped or pressed so as to distort the outer sleeve and consequently the sleeved ends of the cable within the outer sleeve so as to cause the same to assume a relatively flat shape (Fig. 17).

The arrangement of telescoped connecting sleeves has particular advantage in rail bond work wherein the cables are subjected to heavy vibration, because the sleeves tend to protect the cable against damage from the vibration. By reason of the use of a plurality of telescoped sleeves, with the inner sleeves extending further out along the cable than the outer sleeves which terminate near the head, the rigidity of the cable connection or termination is increased toward the head. This progressive increase in rigidity or increase of stiffness toward the connector head plays a very important part in absorbing vibrations. In addition to the function of allowing more flexibility toward the outer end of the inner sleeve than at the head itself, these telescoped connector sleeves have the additional advantage of increasing the vibration dampening effect. The reason for this is that individual vibration resonance frequencies of the several telescoped sleeves will be different and in consequence they will not all vibrate naturally at the same period.

As indicated above, the telescoping attained by this type of construction causes the flexibility of each of the cables to change gradually from a minimum value at the point of anchorage in the terminal to a maximum value where the cables are free from each other. In Fig. 19 there is shown in graph form this change in flexibility and consequent change in vibration absorption. The ordinate of Fig. 19 represents the relative degree of flexibility between an arbitrary zero exhibited at the point of anchorage in the terminal and an arbitrary 100% as exhibited by a free cable. The abscissae of the graph of Fig. 19 represent distances along the sleeving on the cable and is related to the distances along the cable shown in Fig. 16 immediately below Fig. 19. The vibration imparted to the cable would be abrupt as indicated by the dotted line **30** if no sleeving were used. Such abrupt vibration change is analogous to that experienced by bending a piece of metal in the jaws of a vice. In my successively multipled or telescoped sleeving, I am able to increase the life of the cable by reducing the abruptness of the transition from complete rigidity, as for example, at the axis of the stud **3**, to what is arbitrarily called 100% flexibility of each cable as it emerges from the outermost sleeve such as the sleeve **13**. The step-wise increase in flexibility is shown in Fig. 19 by the solid line **32**. This beneficial feature of my invention is incident to the type of construction thereof, and to increase this effect, I may increase the number of sleeves beyond that necessary to obtain the structure described, or slit sleeves **13** and **16** part way at circumferential intervals so as to smooth out the corners of the steps shown in Fig. 19. For this purpose it is preferable to form the sleeves from tough material such as stainless steel or the like, although such is not a necessary requirement of the invention.

Another feature which may be incorporated in the rail bond of my invention is the provision of spiral scoring on the inside of the sleeves forming the bond. In a preferred form both the sleeve contacting the cable and the outer sleeve are scored, the former preferably in a direction opposite to the lay of the cable and the latter in a direction opposite to the inner sleeve scoring. This provides additional locking means for preventing pulling out of the cable without too much mutilation in compressing. What is to be avoided in such mechanical connections of the cable to the terminal through scored sleeves is cable breakage within the tube should the rail separate in excess of the 1-inch of tolerated joint gap expansion. Breakage within the terminal is exceedingly difficult to discover whereas breakage of the cables between the terminal posts or outside of the sleeves is relatively simple to discover, by track inspection.

In an alternative method of assembly of the rail bond of the invention, I may form the cables as described, place them in the enclosing sleeve and compress the sleeve with or without the assistance of dies and subsequently insert the group in a hole in the terminal post which was originally drilled round and mechanically flattened to the shape of the pressed sleeved cable group. This procedure suffers the disadvantage of requiring an additional manufacturing operation but is nevertheless included within the contemplation of the invention.

While I have contemplated the use of sleeves for my assembly and for vibrational fatigue dampening and elimination, it is obvious that where economy dictates, and where vibration is not encountered, as on buried pipe lines, and in the grounding of steel structures, etc., my cables without sleeves can be compacted to the essential sector-shaped cross-sectional areas and inserted directly into the bore in the terminal and therein compacted and swaged in accordance with the general procedure described.

It is apparent from the foregoing description and illustrations that I have provided an electrical connector, described with particular reference to use as a rail bond, which is adapted to provide means for assembling multiple cable connectors to terminal posts in proper alignment, means of protecting the vulnerable junctures of cables and terminals by multiple graded sleeving and to provide a rail bond cable attachment adapted to be crimped or compressed whereby a good electrical and mechanical juncture is assured and mechanical interference by dragging equipment is practically eliminated.

Modifications in the specific embodiments in the invention herein illustrated and described may occur to those skilled in the art without departing from the scope of the invention as set forth in the foregoing description and the following claim.

I claim:

The method of forming a connection between the corresponding ends of a plurality of wire conductor cables and a terminal post receptacle, said ends of the cables being initially round, including the steps of deforming said round ends under pressure to form said ends into sector shape having similar flat and round portions, assembling said ends together with the flat portions thereof in juxtaposition to provide substantially a round cable structure, fitting said structure into a sleeve, inserting said sleeve into the terminal post receptacle, and flattening said terminal post receptacle to deform said sector shape cable ends and sleeve within said receptacle.

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