A crimp (40a, 40b) for joining copper wires (18a, 18b) in a telecommunications exchange (1), the crimp comprising a cylindrical wall of material comprising an alloy containing copper, iron, nickel, and manganese, and preferably having a composition conforming to BS CN102.

FIGURE 3A
The present invention relates to apparatus for repairing wiring and related aspects. In particular but not exclusively, the invention relates to apparatus, such as a crimp, suitable for repairing wiring in a high density wiring environment where several wires and cables are very close proximity to each other. Such environments include, for example, apparatus for repairing wiring connected to and located within telecommunications exchange apparatus.

High-density wiring environments require wiring and wiring repairs to have characteristics to meet various criteria which may be set by one or more standards bodies for wiring and wiring repairs in a particular environment. The criteria may indicate that wiring repairs have appropriate electrical properties and have certain other physical characteristics, for example, the amount of stress and strain (e.g. compressive, lateral, and longitudinal) the repair is robust against. For example, lateral and longitudinal movement of as well as elongation forces applied to wiring/cabling located in a high-density wiring environment can result in considerable frictional forces being exerted on the cabling (and the wiring housed within cabling) and thus wire repairs in such locations must be appropriately resilient. Examples of high-density wiring environments include duct space and main distribution frames within telecommunications exchanges.

For example, within a telephone exchange, extremely thin diameter wiring (wiring with a cross-sectional area of approximately 1mm² or less) must be able to withstand a relatively high amount of longitudinal strain (i.e., strain along the longitudinal axis of the wire), for example, 40 N or more. An idea of the levels of wiring density in a high-density wiring environment can be obtained by considering a typical number of wires per meter squared on the horizontal portion of a MDF which can be thousands. An MDF bearer can approximately 500mm in cross-sectional diameter across with the depth of the jumper wires within the bearer being 200mm across. On a vertical MDF section there can be between 200 wires per block in a bottom block and 2000 wires per top block (e.g. 200 wires per block x 10 blocks). Thus in a high-density wiring environment such as a telephone exchange, where wiring (and repairs to wiring) can also be subject to compressive forces which apply pressure to a wire in an inwards axial direction (for example, compression arising simply from the weight of the surrounding wiring), and where wiring repairs could be deformed/loosened and/or other degrade over time, forming repairs appropriately is extremely important. Any loss of contact between wires in a repair which is detrimental to the electrical transmission characteristics of the wiring can degrade the signal transmission characteristics of the repaired wire resulting in a further repair being required.

Accordingly, in a high-density wiring environment such as a telecommunications exchange MDF, all wiring and wiring repairs are required to have characteristics which to meet certain operational
requirements. These repair requirements include those imposed by standard bodies for the telecommunications exchange environment. The wiring is required to meet thermal and conductivity criteria specifications at installation and to maintain performance specifications for these characteristics over a period of time as well as other physical specifications. For example, wiring must not become too brittle as it ages.

Unlike environments in which, when a wire breaks, the choice of method used to repair the wire is determined simply by the most convenient method, the choice of repair method within a telephone exchange environment should therefore meet certain regulatory standards. For example, a repair should result in the repaired joint being sufficiently strong and the repair should not negatively affect the electrical and/or signal transmission properties of the wire to which the repair has been applied and/or electrical and/or signal transmission properties of the surrounding wiring and/or cabling.

To achieve this, it is desirable if a repair can be performed in such a way that the cross-section of the repair joint has a low profile compared to the cross-section of each individual wire being joined so that the joint formed by the repair does not increase the outer diameter of the cabling and/or wiring by more than a minimal amount. It is also desirable if the tensile strength of the cabling/wiring is at least maintained at a level comparable with that of each individual wire in the join, so that the repair joint does not form a point of weakness, or focal point, for subsequent breakage if the repaired wire is subsequently to strain.

When a wire or cable breaks in a high wiring density environment where there is very little space between adjacent cables and/or wires and/or wire pairs it is very desirable for the repair to be formed in a manner which restores the wire as closely as possible to its original condition. However, the close proximity of other wires and/or cables means that any repair must be capable of being carried out in a small space and ideally result in a repair which does not dramatically increase the diameter of the wire/cable at the break point (as this could cause the cable to catch or snag when being moved longitudinally and/or affect adjacent wiring) and ideally ensure that the repaired wire maintains a relatively high tensile strength compared to its original tensile strength. If not, then there is a chance that the wire will simply break again at the point of the repair if subjected to a similar amount of strain as that which caused the break in the first place.

United States patent application US2002/0057985 entitled "Copper Alloys for use as connector materials having high resistance to stress corrosion cracking and a process for producing the same" describes an copper alloy suitable for use as a connector material which has sufficient strength to withstand crimping which contains 17-32 wt% Zn, Sn and S and lists a range of other contents whose sum is 0.01 to 5wt%, provided that S is present in an amount up to 30ppm, the
elements comprising at least one of the group consisting of: 0.01-3 wt% Fe, 0.01-5 wt% Ni, 0.01-3 wt% Co, 0.01-3 wt% Ti, 0.01-2 wt% Mg, 0.01-2 wt% Zr, 0.01-1 wt% Ca, 0.01-10% wt Mn, 0.01-3 wt% Cd, 0.01-5 wt% Al, 0.01-3 wt% Pb, 0.01-3 wt% Bi, 0.01-3 wt% Be, 0.01-1 wt% Te, 0.01-3 wt% Y, 0.01-3 wt% La, 0.01-3 wt% Cr, 0.01-3 wt% Ce, 0.01-5 wt% Au, 0.01-5 wt% Ag and 0.01-5 wt% P.

United States patent 4, 442,182 describes a one-piece composite electrical connector having a cast-aluminium bronze alloy CDA 955 at the mechanical connection end which includes as a percentage of the alloying elements in copper 10.0 to 11.5 % Al, up to 3.5 % Mg, 3.0 to 5.0 % Fe, and 3.0 to 5.5 % Ni.

International patent application WO01/68928 describes Be-Cu alloys including Be, Ni and/or Co, Pb, and Cu alloy components with respective operable wt% of 0.15 to 0.5, 0.40 to 1.40, 0.2 to 1.0, balance; respective typical wt% of: 0.2 to 0.4, 0.5 to 1.25, 0.2 to 0.60, balance; and respective more typical wt% of 0.25 to 0.35, 0.60 to 0.80, 0.25 to 0.50, and balance. In addition, the alloys can contain a total of 0.50 wt% of one or more of the following ingredients, typically as impurities: Fe, Al, Si, Cr, Zn, Sn, Ag, Mn, Mg, Ti, and Zr.

European Patent Application EP10505094 entitled Copper Alloy with improved resistance to cracking describes a copper alloy having improved resistance to cracking due to localized plastic deformation. The alloy consists essentially of: from 0.7 to 3.5 weight percent nickel; from 0.2 to 1 weight percent silicon; from 0.05 to 1 weight percent tin; from 0.26 to 1 weight percent iron; and the balance copper and unavoidable impurities. The copper alloy has a local ductility index of greater than 0.7 and a tensile elongation exceeding 5 %.

EP10505094 further describes one alloy in which nickel is from 1.2 to 2.8 weight percent, silicon is from 0.3 to 0.7 weight percent, tin is from 0.2 to 0.6 weight percent, iron is from 0.28 to 0.7 weight percent and the alloy further includes an effective amount of manganese for improving hot workability up to 0.15 weight percent and another alloy in which nickel is from 1.5 to 2.5 weight percent, silicon is from 0.35 to 0.55 weight percent, tin is from 0.3 to 0.5 weight percent, iron is from 0.3 to 0.5 weight percent and manganese is from 0.02 to 0.1 weight percent.

The invention seeks to provide in its various embodiments a method and means to repair wiring, particular, copper wiring locating in a high-density wiring environment, in which the resultant repair was found to have unexpectedly improved properties over known repair apparatus and methods for such environments. The invention seeks to be useful for repairing one or more of a plurality of wires located in a high wiring density environment where it is important that the external diameter of the cabling sheath is increases as little as possible by the repair. Such high-density wiring
environments include cables comprising a plurality of wires housed within a cabling sheath, such as, for example, the cables which run within and to and from a telephone exchange main distribution frame (MDF). In addition, the material used to form a repair to copper wiring according to one or more embodiments of the invention is sufficiently malleable enough to permit forming the repair without exerting too much compressional force. Exerting too much compression when forming the crimp could affect the conductive properties of the repair, for example, by damaging the wires by overly reducing the cross-sectional area of the wiring within the repair or even severing a wire) when using a crimping tool.

A crimp joint according to the various embodiments of the invention comprises deformed material (i.e. the compressed or crimped material) which forms the repair resulting in a repair joint which has a narrow cross-sectional area but which is strong enough to withstand additional compressive forces and lateral strain exerted by movement of the repaired wiring or by the movement of other elements which come into contact with the wiring.

Thus at least one of the various embodiments of the present invention seeks to provide a method of repairing wiring in a high-density wiring environment such as a telephone exchange, in particular, but not exclusively for repairing the wiring which is connected to and runs within a main distribution frame in a telephone exchange environment.

By experimentation, an alloy has been found for constructing of cylindrical crimps which comprises a copper, iron, manganese, and nickel alloy composition. As the material properties are very suitable for forming tubular or cylindrical crimps, not only is the method of manufacturing the crimps very simple, but in addition, the crimps can be formed to have dimensions which make them very suitable for repairing electrical wiring in high-density wiring environments where frictional forces can be applied to repaired joints as well as compression forces. The material was found to yield quite unexpected results which met the criteria for crimp repairs to wiring in a telecommunications MDF environment, and to any other environment where wiring is present in very high wiring densities.

Embodiments of the present invention seek to obviate and/or mitigate unnecessary wastage of material and enable a faster repair to be performed than in known in the art.

Aspects of the invention are as set out below and by the accompanying claims in which the dependent claims represent preferred embodiments of the invention. The invention also comprises any suitable combination of the aspects and preferred embodiments of the invention which are apparent to those of ordinary skill in the art.
A first aspect of the invention seeks to provide a crimp joint forming an electrical connection between two electrically conductive wires, the crimp joint comprising:

- a crimp comprising a cylindrical tube of material composed of an alloy comprising copper, iron, nickel and manganese, wherein, within the tubular portion of the crimp body, a length of the first end of one of said wires is adjacent to a length of the other wire to overlap with said other wire in a longitudinal direction within the cylindrical crimp body.

The crimp may comprise a substantially copper alloy including about 10 to 13 % by weight in total of iron, nickel and manganese. The iron may be present in quantities of about 9 to 10%wt. The nickel may be present in quantities of about 1 to 2%wt. The manganese may be present in quantities of about 0.3 to 1%wt.

The electrically conductive wires may have a substantially copper composition.

Each of said two electrically conductive wires may remain fixedly attached at a far end when a near end of each said wire is inserted into said cylindrical crimp body, and wherein the near end of each said wire is inserted into the same aperture of said crimp body.

Each of said two electrically conductive wires remains fixedly attached at a far end when a near end of each said wire is inserted into said cylindrical crimp body, and wherein the near end of each said wire is inserted into a different aperture of said crimp body and each said wire is pushed into said cylindrical crimp body sufficiently far to overlap with the other wire along the longitudinal axis of the crimp body.

The electrically conductive wires may lie substantially parallel to each other along the entire length of the crimp body.

The crimp may be comprised of an alloy having a manganese content of the alloy comprises 0.3 to 1% by weight of the alloy content.

The crimp joint may be comprised of an alloy which comprises about 90% copper and 10% of an alloy of iron, nickel and manganese. The alloy may consist only of copper, iron nickel and manganese. The quantities may vary by a small fraction of the stated values or be exact. Trace quantities of elements may be present, for example, as impurities.

The crimp joint may be comprised of an alloy of iron, nickel and manganese which comprises about 9 to 11% iron, 1 to 2% nickel, and 0.3 to 1% manganese. The quantities may vary by a small fraction of the stated values or be exact. Trace quantities of elements may be present, for
example, as impurities.

The crimp joint may be composed of an alloy conforming to the CN102 BS composition.

The crimp joint may have an internal diameter of 1.1 mm in cross-section.

Each of said wires in a said crimp may have a cross-sectional area of 1 mm², and the external diameter of the joint formed by the crimp around the two wires of 1mm² which overlap along the longitudinal axis of the cylindrical body of the crimp may range between 1.35 and 1.39 mm.

The thickness of the cylindrical wall of the crimp body may range between 0.35 and 0.39 mm.

The crimp joint may be used to repair a severed wire in a telecommunications exchange.

Each wire end may substantially comprise copper and have a diameter of at least 1mm². The external diameter of the crimp joint may range between 1.35 and 1.39 mm. The crimp joint may retain each wire when one, each or both wires are subjected to a tensile force of at least 50N.

Each wire may be subjected to a tensile force of at least 51N. Each wire may be subjected to a tensile force of at least 51.5N.

The crimp joint may be in a telecommunications exchange and each wire may be provided as a wire in a cable comprising a plurality of wire pairs. Each wire in the cable may be able to resist a pull-out force of 51N applied in a longitudinal direction along the crimp joint. Each wire may be connected at one end to a main distribution frame in said telecommunications exchange. The plurality of wire pairs may comprise five wire pairs.

A crimp for use in forming a crimp joint according to the first aspect, the crimp comprising a cylindrical tube of material composed of an alloy comprising copper, iron, nickel and manganese, and capable of receiving within the tubular portion of the crimp body at least two wires.

The alloy may have a composition conforming to the British Standard CN102.

The preferred embodiments of the invention will now be described with reference to the accompanying drawings which are by way of example only and in which:

Figure 1 shows a schematic view of a main frame in a telecommunications exchange according to a first embodiment of the invention;
Figure 2A shows schematically a crimp joint rejoining the ends of two wires having a first wiring repair configuration;

Figure 2B shows schematically the crimp joint shown in Figure 2A with the joined ends of the wires removed;

Figure 2C shows schematically a crimp joint rejoining the ends of two wires having a second wiring repair configuration;

Figure 2D shows schematically the crimp joint shown in Figure 2C with the protruding ends of the rejoined wires removed;

Figure 2E shows schematically a cross-section through a crimp joint as shown in any of Figures 2A to 2D;

Figure 2F shows a cross-sectional view of the wiring within a cable comprising five pairs of wires;

Figure 3A shows a side-ways schematic view of a section of a cable 16 repaired according to an embodiment of the invention;

Figure 3B shows an enlarged schematic side-ways view of the location of a wire fault in a cable 16 according to an embodiment of the invention;

Figure 4A shows an enlarged schematic side-ways view of a crimp joint repairing in situ the wire fault in a cable 16 shown in Figures 3A and 3B;

Figure 4B shows an enlarged schematic cross-sectional view of the crimp joint shown in Figure 4A; and

Figure 4C shows schematically an enlarged view of the cross-section shown in Figure 3C.

The best mode of the invention will now be described with reference to the accompanying drawings.

Those of ordinary skill in the art will be aware that for clarity the description may omit to directly refer to features of the invention whose inferred presence is apparent to one of ordinary skill in the art. Elements of the invention shown in Figures 4A,B,C retain the numbering scheme shown in the previous drawings.
Figure 1 of the accompanying drawings shows an example of a high-density wiring environment 1, a telephone exchange comprising an MDF 2. A typical MDF 2 in a telephone exchange may support the termination of hundred of thousands of connections to the premises of telecommunications service subscribers, although only a few are shown for the sake of clarity in Figure 1. Most subscriber premises receive telecommunications services via a pair of copper wires which run from the local exchange to the subscriber premises. As a result, at the local exchange, hundreds of thousands of wires have to be accommodated and to do this the wires are packed tightly together, which forms the high-density wiring environment 1 in which duct space is very limited. The term high-density wiring environment is defined herein to imply an environment in which a sufficient amount of wires and/or cables are confined to a predetermined area to result in the movement of any one wire and/or cable resulting in a pressure change on one or more adjacent wires and/or cables.

In Figure 1, MDF 2 has on a "D-side" a series of horizontal banks 4a..4d of termination blocks 6 on one side of a supporting frame (not shown) receives wiring 8 which comprises pairs of copper wires which connect subscriber premises to the exchange via an access network (not shown). On the other side of the frame, known in the art as the "E-side" of MDF 2, a series of vertical arrangements 10 of termination blocks 12 are provided to connect wiring to other equipment housed within the exchange via which other communications networks can be accessed. As shown in Figure 1, the wiring from the E-side of the MDF comprises a plurality of cables. In a typical UK telephone exchange environment, five wire pairs 14a,b,c,d,e are bundled together to form a cable 16. Within the MDF, a jumper 30 comprising a twisted pair of copper wires form an internal connection between the D-side termination blocks 6 and the E-side termination blocks 12 for each subscriber.

As the duct space is so limited the wires and cables in a cable run/duct are so tightly packed that it is not normally possible to remove a long stretch of wire/cable if that wire/cable is damaged and/or is cut in two. Accordingly, it is very important for the wire/cable to be repaired effectively in situ and for the repaired wire to have as low a profile as possible, to ensure that it is less likely to snag on something if moved. In addition, it is important that the repair is as strong as possible against "pull-out" forces, these being forces which compel the wires to moved in such a way that they would soon work loose from any join repairing them.

Two different wiring configurations can be repaired using a crimp which permits the wires which are to be joined to overlap each other in a longitudinal direction within the crimp joint formed, for example, contrast the embodiment of a crimp joint shown in Figures 2a,b with the embodiment of a crimp joint shown in Figure 2c,d respectively.

Figures 2A to 2E show a crimp joint which comprises a cylindrical crimp 40 which is used to join
two wires 18a, 18b referred to also in the drawings as Wire A and Wire B. Wire A 18a comprises a copper core wire 24a surrounded by an insulating sheath 22a. Wire B 18b comprises a copper core wire 24b surrounded by an insulating sheath 22b.

In Figure 2A, the insulating sheath 22b has been removed from the ends of the two wires 18a, 18b, to expose the copper cores 24a,24b and the exposed ends are slid into the same end of crimp 40 so that exposed copper wires 24a, 24b lie alongside each other aligned generally along the longitudinal axis of the crimp 40 according to an embodiment of the invention. The exposed ends of the two wires 24a, 24b are in electrical contact with each other and the cylindrical body of the crimp 40. Preferably, the crimp joint is formed by exerting pressure laterally on the crimp body, for example, by using a Knipex™ crimp tool. Figure 2B shows a resultant crimp joint, in which the ends of the copper wires A, B have been cut away so that all exposed copper is within the crimp 40. Not shown in Figures 2a or 2b is the presence of an insulating sheath which would be placed around the crimp 40 to ensure its electrical isolation from other potential electrical contacts.

Figure 2C shows an alternative embodiment of the invention in which the crimp joint is formed by sliding the two wires in opposing directions into the body of the crimp 40 so that the exposed copper cores 24a, 24b lie alongside each other aligned generally along the longitudinal axis of the crimp 40. The exposed ends of the two wires 24a, 24b are in electrical contact with each other and the cylindrical body of the crimp 40. Preferably, the crimp joint is formed by exerting pressure laterally on the crimp body, for example, by using a Knipex™ crimp tool. Figure 2B shows a resultant crimp joint, in which the ends of the copper wires A, B have been cut away so that all exposed copper is within the crimp 40. Not shown in Figures 2a or 2b is the presence of an insulating sheath which would be placed around the crimp 40 to ensure its electrical isolation from other potential electrical contacts.

Within the telecommunications exchange high-density wiring environment 1 shown in Figure 1, the crimp is suitable for use in repairing jumper wires, or copper twisted pair. However, the crimp joint formed in Figures 2d is less preferred than that shown in Figures 2b as the crimp joint is capable of being more easily snagged, whereas the crimp joint shown in Figure 2d is less likely to do so as it is formed in longitudinal alignment with the two copper wires it is repairing.

Figure 2E shows an expanded cross-sectional view of a pair of wires such as that shown above in Figure 2A. In Figure 2E, a wire 14 comprises a twisted copper pair of wires 18a,18b which are enclosed within an insulating sheath 20. Each individual wire 18a, 18b comprises an insulating sheath 22a,22b respectively surrounding a signal conducting core 24a,24b respectively.

Figure 2E shows an expanded cross-sectional view of cabling 16 shown in Figure 1. As shown in
Figure 1, cable 16 comprises an insulating sheath 26 surrounding five wire pairs 14a,…,14e. As shown in Figure 1, cable 16 runs from other equipment located in the exchange to the E-side of the termination block 12 of MDF 2. In Figure 1 and 2F, cable 16 is shown in cross-section as comprising five pairs of copper wires 14a,b,c,d,e known in the art as a five-pair fan-out tail. Each wire pair 14 forming a five-pair fan-out tail is terminated at a termination point 12 as shown in Figure 1 using individual termination points. An example of an E-side termination block 12 is a JT47 block and a wire pair 14 typically has a sheath 20 diameter of approximately 0.1 mm² in cross-sectional area.

Figure 3A is a schematic diagram showing a high wiring density environment 32 in which a plurality of cables 16 are packed tightly together, for example, within a cable run or duct (not shown). Figure 3A shows an exemplary fault 34 affecting wire pair 14c (shown emerging from the cable as a dashed line in Figure 3A) which requires one or more wires located within a cable 32 to be repaired. Figure 3B shows a cross-section of a cable 16 housing a faulty wire 18b in which a length l₁ of the cable sheath 26 has been cut away to expose the faulty wire 18b.

Figure 4A shows again the break of length l₁ in the cable sheath 26 of cable 16 which has been removed to provide access to repair the faulty wire 18b. In order to comply with regulations, the sheath of cable 16 must be repaired using a cylindrical section of material shown in Figure 4A as new cable repair sheath 18, which requires all of the wire pairs 14a…14e housed by cable 16 to be severed. Figure 4A shows two of the wire pairs 14b and 14c which have been repaired using a crimp according to an embodiment of the invention.

As shown in Figure 4A, a cylindrical, tubular, crimp 40 is used to re-join the severed ends of a wire. Figure 4B shows in more detail a side-ways cross-section of a crimp joint of length l₁ₓₚₓ which is joining the two severed ends of wire 18a according to an embodiment of the invention.

The crimp joint shown in Figure 4B was formed by a crimping tool which exerts crimping pressure at a plurality of pressure points spaced distally along the longitudinal axis of the crimp, for example, the Knipex 97 52 08 crimp tool can be used to form the crimp joint.

The crimp according to one embodiment of the invention comprises a copper, nickel and manganese metal alloy. For example, in one embodiment the composition of the alloy comprises 90% copper and 10 % nickel-iron alloy by weight. The copper-nickel-iron alloy preferably comprises 9-11%wt nickel, 1-2%wt (e.g. 1 to 1.8%wt) iron, which trace amounts of manganese, for example, 0.3 to 1.0%wt (e.g. 0.5-1.0%wt) manganese with the remainder copper. Very small quantities of lead and trace impurities may be present. The preferred alloy has the CN102 BS specification or equivalent. CN102 BS is a copper nickel iron alloy with a small alloy content of
BS2874 CN102 has the ISO designation CuNiI OFeIMn and has the international equivalents EN12163 CW, 352H ASTM, B121 C70600. Its chemical composition is listed by Wt.% and is given as Ni% 10-11, Mn% 0.5-1, Fe%1-2, Pb 0-0.01%, Impurities 0.3 max, with the remainder Cu%. In one embodiment of the invention, the crimp has this chemical composition.

This alloy is known to have excellent resistance to sea and brackish water and combines easy fabrication with good mechanical properties between -100 and 300 degrees Celsius. The iron and manganese content of the alloy improve the mechanical properties and its resistance to corrosion and erosion. This material has been found to be sufficiently malleable and to have a sufficient tensile strength to enable its extrusion about a bore into a tubular or cylindrical form from which, by severing lengths of the extruded material, cylindrical crimps can be obtained which have surprisingly useful material properties suitable for the purpose of repairing copper wires.

Figure 4C shows in more detail a cross-section through crimp joint 40. The crimp joint 40 shown in Figure 4C comprises a cylindrical sheath 42 of the crimp which forms a boundary around the ends of wire 18a. Each severed part of wire 18a is placed within the crimp joint 40 so that they overlap with each other along the longitudinal direction of the crimp joint within the crimp sheath 42. This shortens the severed part of wire 18a by at least \( l_{crimp} \).

The crimp which is shown in a used state in Figure 4C has an overall external diameter \( E \), and internal diameter \( l \), and a sheath thickness \( D \). Typical figures for a crimp joint formed according to one embodiment of the invention are:

\[
E = 1.45 \text{ to } 1.49 \text{mm} \\
l = 1.0 \text{ to } 1.1 \text{mm} \\
D = 0.35 \text{ to } 0.49 \text{mm}.
\]

Thus, a crimp according to an embodiment of the invention has sufficient deformability and strength to enable the overlapping ends of the wires being repaired within the crimp to be suitably compressed when forming the crimp joint.

The crimp was subject to an accelerated ageing testing using test conditions which heated a crimp joint in a range of dry and humid conditions at various temperatures. For example, a crimp was subjected to a test cycle of 20 hours dry at 70°C, followed by 4 hours at 40°C and 93% relative humidity (RH), for four cycles, to give the overall test conditions of 80 hours in 70°C dry heat and for 16 hours at 40°C with a relative humidity of 93%.
manganese.

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The crimp which is shown in a used state in Figure 4C has an overall external diameter \( E \), and internal diameter \( I \), and a sheath thickness \( D \). Typical figures for a crimp joint formed according to one embodiment of the invention are:

\[
\begin{align*}
E & = 1.45 \text{ to } 1.49 \text{mm} \\
I & = 1.0 \text{ to } 1.1 \text{mm} \\
D & = 0.35 \text{ to } 0.49 \text{mm}.
\end{align*}
\]

Thus, a crimp according to an embodiment of the invention has sufficient deformability and strength to enable the overlapping ends of the wires being repaired within the crimp to be suitably compressed when forming the crimp joint.

The crimp was subject to an accelerated ageing testing using test conditions which heated a crimp joint in a range of dry and humid conditions at various temperatures. For example, a crimp was subjected to a test cycle of 20 hours dry at 70°C, followed by 4 hours at 40°C and 93% relative humidity (RH), for four cycles, to give the overall test conditions of 80 hours in 70°C dry heat and for 16 hours at 40°C with a relative humidity of 93%.
The results of the initial electrical resistance and the aged sample resistance for two copper wires of approximately 1\(\text{mm}^2\) cross-sectional area repaired with a crimp having a 1.1 mm internal diameter I according to an embodiment of the invention are shown below.

<table>
<thead>
<tr>
<th>Sample Number</th>
<th>Initial Resistance (mΩ)</th>
<th>Resistance of Aged Sample (mΩ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>13.53</td>
<td>14.51</td>
</tr>
<tr>
<td>2</td>
<td>13.16</td>
<td>15.89</td>
</tr>
<tr>
<td>3</td>
<td>13.58</td>
<td>26.48</td>
</tr>
<tr>
<td>4</td>
<td>12.92</td>
<td>14.54</td>
</tr>
<tr>
<td>5</td>
<td>13.62</td>
<td>26.04</td>
</tr>
</tbody>
</table>

Table 1 - resistance of aged samples.

Table 1 shows the resistance in milliohms (mΩ) of a 150 mm sample length of a copper wire 18a,b such as is known in the art to form a wire pair 14, where 5 wire pairs form a fan-out tail in a telephone exchange and before repair have a resistance of 12 mΩ. The initial resistance is the resistance of the 150 mm repaired jumper just after the repair is formed is shown in Column 2 and the aged resistance shown is the resistance after the full 80 hour test cycle as described herein above. The resistances shown comprise the overall resistance of the wires when repaired using a crimp according to an embodiment of the invention, for example a crimp comprising the CN102 metal alloy or other copper-iron alloy comprising a 0.1 to 1% manganese, and preferably 0.3 to 1% manganese alloy content.

A repair joint formed using a crimp having a copper-iron-manganese alloy composition such as CN102 according to an embodiment the invention was also tested for breakage when subjected to a pull-out force.

In one embodiment a crimp having a 1.1 mm internal diameter is used to form a crimp around two copper wires of approximately 1\(\text{mm}^2\) cross-sectional area. The results are set out below for a set of five-wire samples forming a typical 5 pair fan-out tail in a high-density environment such as a telephone exchange. The wires each have slightly differing electrical resistances which were subject to a tensile force along the longitudinal axis of the wires (a "pull-out force"):
Table 2, pull-out force for a five-pair fan-tail repaired by a crimp according to an embodiment of the invention.

Table 3 below shows for comparison the forces exerted on the crimp joint according to the invention which was used to repair wires in a fan-tail compared to the forces at which a crimp joint having the same internal diameter but a different composition broke at when subjected to strain.

The wire colours in Table 1 refer to the wires in an exemplary fan-tail in a telephone exchange environment. The crimps were all formed using the Knipex crimp tool.

<table>
<thead>
<tr>
<th>Copper Butt standard crimp</th>
<th>Copper wire resistance without crimp = 12.35mΩ</th>
<th>Tensile strength of copper wire = 51.8N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wire Colour</td>
<td>Resistance (mΩ)</td>
<td>Pull out / break force (N)</td>
</tr>
<tr>
<td>Blue</td>
<td>12.7</td>
<td>57.9</td>
</tr>
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<td>Orange</td>
<td>12.46</td>
<td>56.1</td>
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<td>Green</td>
<td>14.92</td>
<td>44.5</td>
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<tr>
<td>Brown</td>
<td>15.30</td>
<td>56.7</td>
</tr>
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<td>Slate</td>
<td>12.69</td>
<td>54.3</td>
</tr>
<tr>
<td>High</td>
<td>15.30mΩ</td>
<td>57.9 N</td>
</tr>
<tr>
<td>Average</td>
<td>13.614mΩ</td>
<td>53.9N</td>
</tr>
<tr>
<td>Low</td>
<td>12.46mΩ</td>
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<table>
<thead>
<tr>
<th>CN102 crimp drilled 1.1mm through joint</th>
<th>Resistance (mΩ)</th>
<th>Pull out force (N)</th>
</tr>
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<tbody>
<tr>
<td>Wire Colour</td>
<td>Resistance (mΩ)</td>
<td>Pull out force (N)</td>
</tr>
<tr>
<td>Blue</td>
<td>12.42</td>
<td>57.5</td>
</tr>
<tr>
<td>Orange</td>
<td>12.47</td>
<td>56.5</td>
</tr>
</tbody>
</table>
Table 3 comparison of pull-out forces exerted on crimps of different composition.

<table>
<thead>
<tr>
<th>Wire Colour</th>
<th>Resistance (mΩ)</th>
<th>Pull out force (N)</th>
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<tr>
<td>Blue</td>
<td>12.42</td>
<td>50.6</td>
</tr>
<tr>
<td>Orange</td>
<td>12.74</td>
<td>45.1</td>
</tr>
<tr>
<td>Green</td>
<td>13.25</td>
<td>49.1</td>
</tr>
<tr>
<td>Brown</td>
<td>12.41</td>
<td>53.0</td>
</tr>
<tr>
<td>Slate</td>
<td>12.42</td>
<td>50.6</td>
</tr>
<tr>
<td>High</td>
<td>13.25mΩ</td>
<td>53.0N</td>
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<td>Average</td>
<td>12.648mΩ</td>
<td>49.68N</td>
</tr>
<tr>
<td>Low</td>
<td>12.41mΩ</td>
<td></td>
</tr>
</tbody>
</table>

Brass Crimp drilled 1.1mm. Through joint.
Wire stripped with ITT cannon cable stripper 9mm long

<table>
<thead>
<tr>
<th>Wire Colour</th>
<th>Resistance (mΩ)</th>
<th>Pull out force (N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blue</td>
<td></td>
<td>56.3</td>
</tr>
<tr>
<td>Orange</td>
<td></td>
<td>50.8</td>
</tr>
<tr>
<td>Green</td>
<td></td>
<td>54.1</td>
</tr>
<tr>
<td>Brown</td>
<td></td>
<td>56.7</td>
</tr>
<tr>
<td>Slate</td>
<td></td>
<td>57.1</td>
</tr>
<tr>
<td>High</td>
<td></td>
<td>57.1N</td>
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<tr>
<td>Average</td>
<td></td>
<td>55.0N</td>
</tr>
<tr>
<td>Low</td>
<td></td>
<td></td>
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</tbody>
</table>
of the wires to withstand a higher force than any of the other crimps, for example, the lowest force at which a wire repaired using a crimp according to an embodiment of the invention broke at was 51.6 N.

The inventor has thus found that a crimp having an approximately 90% copper 10% iron by weight metal alloy composition which contains a small quantity of manganese (preferably 0.3 to 1%) and which has a wall thickness of 0.35 to 0.39 wall thickness and an internal cross-sectional diameter of 1.1 mm is sufficiently strong to withstand a pull-out force of over 50N, and preferably over 51N, and more preferably over 51.6N when used to repair copper wires of 1mm² for a longitudinal crimp cylinder length of 10mm.

The CN102 British Standard alloy is known for use in marine environments as the manganese content provides corrosion resistance in salt and brackish water, and is also known for use in fishing tackle. The CN102 alloy is based on copper and nickel with the minor addition of iron and manganese and is noted for its resistance to withstand sea water corrosion and erosion. The CN102 alloy is used widely for example in heat exchangers cooling plants, desalination treatment plants and other water treatment plants. The inventor found that by repurposing fishing tackle to have dimensions suitable for use as a crimp in a telecommunications exchange environment, the crimp joints formed had physical properties which were particularly advantageous when compared to crimps formed from more conventional materials, and which could be manufactured more cheaply.

Expressions of the type "about 'X' value " as used herein in the description and claims are provided to indicate that the quantity 'X' results in the unexpected and advantageous properties provided by the various embodiments of the invention described herein and that other quantities comprising 'X' varied slightly by a small fraction may nonetheless may also result in the unexpected and advantageous properties enabling the features of the invention to be retained. Thus the expression about 10% of 'X' includes 10% plus or minus a small fraction of 10%, for example, 9.5% to 10.5%.

Expressions which indicate an alloy consists of certain percentages of elements by weight may also refer to alloys which include the present of other trace elements as impurities even when no explicit reference is made to refer to such trace elements. In addition or in the alternative, an alloy which consists of certain percentages of elements by weight may also include trace elements which have no effect on the material properties of the alloy from a crimping perspective. Such trace elements will ideally be present as less than 0.1 %wt.

The crimp body is provided substantially in a cylindrical form consisting of a hollow elongated shape with at least one and preferably two open ends through which a pair of wires may pass. It
can be formed by suitably extruding a longer cylinder of material and segmenting this into a number of shorter sections. Alternatively individual crimps could be formed by moulding either individual crimps or a longer cylinder and segmenting this into sections. Alternatively, a sheet of material could be rolled or otherwise deformed into an appropriately cylindrical form, either to form an individual crimp or to create a longer cylindrical which can be segmented into a plurality of crimps using any suitable method.

A cylindrical form may have a circular or non-circular (e.g. triangular, square or other polygonal shape) in cross-section and the form need not be uniform along the length of the cylinder (although out of preference in practice the form is likely to be substantively the same along the length of the cylinder).

It is possible to also provide a crimp as a sheet material or as material provided in an unclosed cylindrical form which is then deformed in situ around wiring to form a cylindrical crimp joint wiring repair according to the invention.

In this way, however, a crimp may be manufactured and/or provided in situ which consists only of a cylindrical body surrounding the wiring to be crimped.

The invention as described herein includes references to features which may be modified in ways apparent to those of ordinary skill in the art and the scope of the invention as defined by the claims includes such apparent modifications and known functional equivalents to the features of the invention described herein unless explicit reference is made to the contrary.
CLAIMS

1. A crimp joint forming an electrical connection between two electrically conductive wires, the crimp joint comprising:
   a crimp comprising a cylindrical tube of material composed of an alloy comprising copper, iron, nickel and manganese, wherein, within the tubular portion of the crimp body, a length of the first end of one of said wires is adjacent to a length of the other wire to overlap with said other wire in a longitudinal direction within the cylindrical crimp body,
   wherein the crimp is comprises a substantially copper alloy including:
   nickel in quantities of about 9 to 11%wt,
   iron in quantities of about 1 to 2%wt, and
   manganese in quantities of about 0.3 to 1%wt.

2. A crimp joint as claimed in claim 1, wherein
   the iron is present in quantities of about 1 to 1.8%wt,
   the nickel is present in quantities of about 9 to 11%wt, and
   the manganese is present in quantities of about 0.5 to 1%wt.

3. A crimp joint as claimed in claim 1, further including lead present in qualities of up to about 0.1%wt.

4. A crimp joint as claimed in any previous claim, wherein the crimp is composed of an alloy conforming to the CN102 BS composition.

5. A crimp joint as claimed in any preceding claim, wherein each of said two electrically conductive wires remains fixedly attached at a far end when a near end of each said wire is inserted into said cylindrical crimp body, wherein either:
   the near end of each said wire is inserted into the same aperture of said crimp body; or
   the near end of each said wire is inserted into a different aperture of said crimp body and
   each said wire is pushed into said cylindrical crimp body sufficiently far to overlap with the other wire along the longitudinal axis of the crimp body.

6. A crimp joint as claimed in claim 5, wherein said electrically conductive wires lie substantially parallel to each other along the entire length of the crimp body.

7. A crimp joint as claimed in any previous claim, wherein crimp joint is used to repair a severed wire in a telecommunications exchange.
8. A crimp joint as claimed in any previous claim, wherein each wire end substantially comprises copper and has a diameter of at least 1mm²; and the external diameter of the crimp joint ranges between 1.35 and 1.39 mm, and the crimp joint retains each wire when each wire is subjected to a tensile force of at least 50N.

9. A crimp joint as claimed in claim 8, wherein each wire is subjected to a tensile force of at least 51N.

10. A crimp joint as claimed in claim 9, wherein each wire is subjected to a tensile force of at least 51.5N.

11. A crimp joint as claimed in any previous claim, forming a wiring repair in a telecommunications exchange, wherein each said wire is provided as a wire in a cable comprising a five pairs of said wires, and wherein each wire in the cable is able to resist a pull-out force of 51N applied in a longitudinal direction along the crimp joint, and wherein at least one said wire is connected at a distal end from the repair joint to a termination point main distribution frame in said telecommunications exchange.

12. A crimp for use in forming a crimp joint as claimed in any previous claim, the crimp comprising of a cylindrical tube of material composed of an alloy comprising copper, iron, nickel and manganese, wherein the alloy substantially comprises nickel present in quantities of about 9 to 11%wt, iron present in quantities of about 1 to 2%wt, and manganese present in quantities of about 0.3 to 1%wt.

13. A crimp as claimed in claim 12, wherein the nickel is present in quantities of about 10 to 11%wt, the iron is present in quantities of about 1 to 1.8%wt, and the manganese is present in quantities of about 0.5 to 1%wt.

14. A crimp as claimed in any one of claims 12 to 13, wherein the crimp has dimensions capable of receiving within the tubular portion of the crimp body at least two copper wires, the crimp dimensions comprising:

- an external diameter of about 1.45 to 1.49 mm;
- an internal diameter of about 1.0 to 1.1 mm; and a sheath thickness of about 0.35 to 0.49mm.
15. A crimp for use in forming a crimp joint as claimed in any one of claims 12 to 14, wherein the alloy has a composition conforming to the British Standard CN102.
INTERNATIONAL SEARCH REPORT

PCT/GB2010/000576

A. CLASSIFICATION OF SUBJECT MATTER

INV. H01R4/20 H01R13/03 H01R43/00 C22C9/06 H02G15/08

According to International Patent Classification (IPC) or to both national classification and IPC.

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
HOIR C22C H02

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched.

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal , WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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<td>US 4 020 546 A (MAY FRANCIS A) 3 May 1977 (1977-05-03) column 3, lines 35-53; figures 7,8 column 1, lines 15-22 column 8, lines 49-61 -------</td>
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<td>US 3 739 322 A (HAEGERT C) 12 June 1973 (1973-06-12) claim 10; figure 8 Table called COPPER BASED ALLOY column 4, lines 43-56 -------</td>
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D

Further documents are listed in the continuation of Box C

X

See patent family annex

' Special categories of cited documents

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on proactively claimed(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"I" later document published 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, the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance, the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents such combination being obvious to a person skilled in the art

"S" document member of the same patent family

Date of the actual completion of the international search
16 August 2010

Date of mailing of the international search report
20/08/2010

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NL - 2280 HV Rijswijk
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Fax (+31-70) 340-3016

Authorised officer

Hugueny, Bertrand
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