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Company Directive

STANDARD TECHNIQUE : TP21L/1

Fixed Earthing Systems - Construction Techniques - Jointing

Policy Summary

This document defines how jointing of earthing system conductors shall be performed when using bolting, brazing or exothermic welding techniques.

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Implementation Date: **April 2009**

Approved by PJ West

Policy Manager

Date: 24-4-09

IMPLEMENTATION PLAN

Introduction

The process for carrying out jointing using exothermic welding has been modified in line with the manufactures comments.

Main Changes

The amendments are minor and consist of checking the alignment of the mould prior to carrying out the procedure and that the igniter is functioning prior to connecting it (pages 12 & 13).

Reference to SHOPS have been replaced with E5.

The contact details on page 33 have been amended bringing it up to date in line to that held on E5.

Impact of Changes

There is no impact on company practice as the changes are minor in nature.

Implementation Actions

Team Managers shall advise their staff who are required to carry out jointing of an earthing system that this document has been amended.

Implementation Timetable

This Standard Technique can be implemented with immediate effect.

Document Revision & Review Table		
Date	**Comments**	**Author**
26/06/2014	The amendments are minor and consist of checking the alignment of the mould prior to carrying out the procedure and that the igniter is functioning prior to connecting it (pages 12 &13). Reference to SHOPS have been replaced with E5 The contact details on page 33 have been amended bringing it up to date in line to that held on E5	P. Hooper
23/07/2013	• Table D2 in Appendix D (page 33) has been extended to include 5 extra moulds to cover Cadwelding onto 12.5mm earth rods	Richard Summers

1.0 INTRODUCTION

1.1 This document defines how jointing of earthing system conductors shall be performed when using bolting, brazing or exothermic welding techniques.

2.0 SCOPE

2.1 This policy applies to all new or replacement substation earthing system joints when using bolting, brazing or exothermic welding techniques. Crimped (compression) joints are covered in ST:OH4F/3.

2.2 The general requirement for temporary adequately rated continuity bonding when making or breaking connections is covered in EE SPEC 89/1 clause 8.1. Selection of the appropriate jointing technique is also covered in EE SPEC 89/1 clause 8.3; note that this requires that bolted connections shall not be used below ground.

3.0 GENERAL REQUIREMENTS

3.1 This document shall be read in conjunction with Company Safety and Operational Policy, including:-

a) ST:HS20A Site Specific Safety Risk Assessment and Near Miss Reporting
b) POL:HS8/1 Personal Protective Equipment
c) ST:HF15D/1 The Safe Use Of Welding, Brazing and Flame Cutting Equipment.

3.2 Risk Assessment

3.2.1 In accordance with ST:HS20A, a risk assessment shall be performed before commencing work. Generic risk assessments are given in Appendices A and B.

3.3 Approved PPE

3.3.1 In accordance with POL:HS8/1, approved Personal Protective Equipment (PPE) shall be worn to control the hazards presented by jointing earthing system conductors. Approved PPE is given in Appendix E.

3.4 Training

3.4.1 All persons undertaking jointing shall be trained in effective and safe jointing techniques.

4.0 CONTROL OF HAZARDS

4.1 Control of Electric Shock Hazard

4.1.1 When undertaking jointing several hazards arise which could lead to electric shock if not adequately controlled. These hazards are briefly explained in Section 7.1.

4.1.2 Precautions shall be taken to prevent electric shock.

4.2 Control of Fume Hazard

4.2.1 Fumes are produced when making joints by brazing or exothermic welding techniques and also when tinning copper. This hazard is overcome in well ventilated areas when appropriate brazing/welding/tinning materials are used. Where ventilation is restricted, consideration shall be given to use of a suitable respiratory mask fitted with an appropriate cartridge filter system and/or forced ventilation/extraction.

4.3 Control of Hazard from Inadvertent Ignition of Exothermic Weld Reaction

4.3.1 There are two types of package used in exothermic welding - the original which employs a cartridge containing powdered weld material and compacted starting powder and the new type which has a sealed 'weld material cup' package and ignition strip (e.g. CADWELD PLUS). With the original 'cartridge and starting powder' type (e.g. standard CADWELD or FURSEWELD it was necessary to prevent unwanted ignition by suitable storage and removal of sources of ignition when preparing for jointing. The newer type with sealed package and ignition strip reduces this risk requiring electronic ignition using a dedicated control unit; it is also moisture resistant. Given the reduced risk, only the sealed package and ignition strip type is now approved for use (e.g. CADWELD PLUS). Weld material packages shall be stored and carried in a fire-proof and damp-proof container.

4.4 Control of Hazard from Molten Metal

4.4.1 Exothermic welding processes cause a rapid and substantial rise of temperature (i.e. $>1400^{o}C$) which melts conductors and weld material. If moisture is present molten metal can be ejected from the mould. Care is required to avoid this through removal of moisture from the mould. Further, under-sized conductor/very worn moulds must also be avoided to prevent ejection of molten metal. Precautions shall be taken to prevent injury and damage. These are detailed in the Jointing Methods below. The risk is further reduced by use of the newer sealed 'weld material cup' package and ignition strip (e.g. CADWELD PLUS) which incorporate a remote ignition control unit and long connecting lead. Risk is minimised by use of the longest lead available (e.g. 4.6m for CADWELD PLUS system). Given the reduced risk, only the sealed weld material package and ignition strip type with remote ignition control unit and lead not less than 4m is now approved for use (e.g. CADWELD PLUS).

4.5 Control of Hazard from Hot Equipment

4.5.1 Heat is involved with both the brazing and exothermic welding techniques. Care is required in handling hot equipment (e.g. hot torch, hot exothermic mould and hot newly made joint).

4.5.2 Precautions shall be taken to prevent burns and fire.

5.0 JOINTING METHOD

5.1 Approved methods shall be used for making joints using brazing and exothermic welding techniques. These approved methods are detailed below.

6.0 JOINT ACCEPTANCE

6.1 The resistance of joints shall be measured to verify low resistance. The required method and acceptance criteria are defined in ST:TP21O/2.

7.0 BACKGROUND

7.1 Electric Shock Hazards

7.1.1 The electric shock hazards include:-

a) Touch potential
b) Step potential
c) Potential difference across the joint.

7.2 Touch and Step Potential

7.2.1 Under earth fault conditions, current in the earthing system of a substation causes a voltage gradient across the site. Potential difference between accessible points may cause a hazard for personnel, for example between hand and feet, hand to hand, or foot to foot.

7.3 Potential Difference

7.3.1 A potential difference may exist or develop across conductors to be jointed. This hazard is controlled using temporary continuity bonds.

7.4 Exothermic Welding

7.4.1 The exothermic welding process is a method of making permanent electrical connection between metals. It is based on the reduction of copper oxide by aluminium. The process causes a flow of molten superheated metal, produced in a special mould, to be directed on to the conductors to be joined causing them to melt and weld together into a solid homogeneous mass. The reaction is rapid and the mould can be removed after ten seconds.

7.4.2 The welded connection formed has a current carrying capability equal to that of the conductors involved. Tests show that the conductors will melt before the joint. No loosening or corrosion can occur as no mechanical pressure or contact surfaces are involved.

7.5 **Brazing**

7.5.1 Brazing is a method of joining metals by 'hard soldering'. Brazing is particularly suited to copper-to-copper jointing. The brazing process uses capillary attraction to allow a molten filler metal to flow into a small gap between metals to be joined.

7.5.2 Two basic methods are possible:-

a) Hand feeding at brazing temperature
b) Brazing filler metal pre-placement.

7.5.3 For earthing system applications, brazing is used to join copper earth tapes together.

7.5.4 The hand feeding method involves:-

a) clamping the two tapes to be joined together with sufficient overlap
b) heating until a 'cherry red' appearance is seen
c) applying a suitable rod of filler metal on one side of the joint such that capillary attraction draws the molten filler metal through the joint.

7.5.5 The joint is complete when filler rod is seen to emerge from the opposite sides to which it was applied. The success of hand fed brazing is largely dependent upon skill.

7.5.6 With the pre-placement method, the filler metal is placed in the joint prior to heating. This simplifies the process as it ensures the correct amount of filler metal is available.

7.5.7 Advantages arise from using a silver-copper-phosphorus alloy brazing filler metal; namely, no flux is required and the toxic problems associated with filler metal containing cadmium and zinc are avoided.

JOINTING METHOD

TYPE: BRAZING (COPPER STRIP-COPPER STRIP)

BR1 EQUIPMENT

- Suitably rated approved continuity bond (3-way = SHOPS item 38986, 2-way = SHOPS item 40726)
- General engineering tools (hacksaw, files, hammer, scribing tool, set square, G-clamp and ruler)
- Wire brush, 'Scotchbrite' abrasive pad and approved degreasing agent
- Heat resistant packing (e.g. Thermalite block)
- Heat resistant material
- Oxy-acetylene welding equipment with selection of nozzles
- Filler rods or Silfos foil (W J Furse - Cat No FS005) suitable for copper-copper with melting point above 640^{o}C
- Flint gun
- Magnifying glass (x10)
- Bitumastic paint
- Micro-ohmmeter.

BR2 SAFETY PRECAUTIONS

The following precautions shall be taken:-

- Compliance with ST:HS15D/1
- Only trained operators shall use gas welding/cutting equipment – see ST:HS15D/1
- Operator to inspect all equipment before use - see ST:HS15D/1
- Wear appropriate PPE, including:
    - See ST:HS15D/1
    - Apply/remove earth continuity bond(s) across joint wearing Class 1 rubber gloves and safety footwear while standing on an insulated mat
- All work under immediate control of one person
- No work if lightning likely
- DO NOT COMPLETE THE POSSIBLE CIRCUIT BETWEEN CONDUCTORS WITHOUT AN EARTH CONTINUITY BOND APPLIED
- Remove all flammable materials from joint position
- Protect plant that cannot be removed (e.g. power cables) and equipment (e.g. gas bottles) from heat with heat resistant material
- Support conductors to be jointed on heat resistant packing (e.g. Thermalite blocks) - DO NOT APPLY HEAT TO CONCRETE
- Place a 2kg dry powder fire extinguisher and fire blanket at work location
- Warn other personnel of heat hazard
- Electrically test joint using ST:TP21O/2.

BR3 METHOD - BRAZING (COPPER STRIP-COPPER STRIP) - FILLER ROD

1	APPLY	Adequately rated continuity bond between conductors to be joined.
2	CUT	conductors to length; ensure ends are square.
3	PREPARE	conductors to ensure they are square, free from burrs and flat.
4	CLEAN	the conductors using wire brush (reserved for copper) and/or 'Scotchbrite' abrasive pad to achieve a bright-clean, slightly roughened finish. Degrease using an approved solvent and dry the conductors with a clean rag.
5	ASSEMBLE	conductors and clamp together using G-clamp or welding grips, ensuring correct contact area and close-fitting faces. Use heat resistant packing to support assembly. NOTE The area to be jointed shall overlap a distance at least equal to the width of the thinnest conductor (e.g. 25mm for a 50mm x 4mm to 25mm x 4mm joint).
6	SELECT	appropriate nozzle for size of copper to be joined.
7	LIGHT	oxy-acetylene torch and apply heat to joint until 'cherry red' appearance.
8	APPLY	appropriate filler metal rod to joint by running along one edge of the joint only. The molten filler should be seen to be 'sucked' into the joint by capillary action. By regulating the heat and adding more filler rod as required the filler will eventually appear on the opposite sides of the joint. The joint is then complete.
9	REMOVE	heat and allow to cool naturally. Do not disturb the joint in any way until it is cool. NOTE The copper will remain hot for some time.
10	WAIT	for the joint to cool.
11	CHECK	the joint visually. Are there any holes or cracks present (use x10 magnification)? Is full penetration of filler rod seen at edges?
12	REMOVE	continuity bond.
13	TEST	joint resistance in accordance with ST:TP21O/2.
14	APPLY	approved bitumastic paint to the completed joint.

BR4 METHOD - BRAZING (COPPER STRIP-COPPER STRIP) - SILFOS FOIL

1	APPLY	Adequately rated continuity bond between conductors to be joined.
2	CUT	conductors to length; ensure ends are square.
3	PREPARE	conductors to ensure they are square, free from burrs and flat.
4	CLEAN	the conductors using wire brush (reserved for copper) and/or 'Scotchbrite' abrasive pad to achieve a bright-clean, slightly roughened finish. Degrease using an approved solvent and dry the conductors with a clean rag.
5	ASSEMBLE	conductors and clamp together with a suitable length of the foil between the faces using G-clamp or welding grips, ensuring correct contact area and close-fitting faces. Use heat resistant packing to support assembly. The length of foil should equal the overlap of conductors. No flux is required. NOTE The area to be jointed shall overlap a distance at least equal to the width of the thinnest conductor (e.g. 25mm for a 50mm x 4mm to 25mm x 4mm joint).
6	SELECT	appropriate nozzle for size of copper to be joined.
7	LIGHT	oxy-acetylene torch and apply heat joint rapidly to 700^{o}C rapidly or until foil is seen to flow. NOTE Do not keep alloy molten longer than necessary.
8	REMOVE	heat and allow to cool naturally. Do not disturb the joint in any way until it is cool. NOTE The copper will remain hot for some time.
9	WAIT	for the joint to cool.
10	CHECK	the joint visually. Are there any holes or cracks present (use x10 magnification)? Has the filler metal flowed across the joint area? NOTE Unsatisfactory joints shall not be reheated. They shall be re-made - ensure continuity bond in place when breaking connection.
11	REMOVE	continuity bond.
12	TEST	joint resistance in accordance with ST:TP21O/2.
13	APPLY	approved bitumastic paint to the completed joint.

JOINTING METHOD

TYPE: EXOTHERMIC WELDING (CADWELD PLUS)

EX1 EQUIPMENT

- Suitably rated approved continuity bond (3-way = E5 item 38986, 2-way = E5 item 40726)
- General engineering tools (hacksaw, files, hammer, scribing tool, set square, callipers and ruler)
- Wire brush, 'Scotchbrite' abrasive pad and approved degreasing agent
- Heat resistant packing to support mould (e.g. Thermalite block)
- Heat resistant material
- Blow torch
- Graphite mould appropriate to conductors to be joined } – see Appendix D for supplier
- Sealed 'weld material cup' package }
- Ignition control unit with lead of length >4m }
- Mould cleaning tool and small brush
- Magnifying glass (x10)
- Micro-ohmmeter.

EX2 SAFETY PRECAUTIONS

The following precautions shall be taken:-

- Read the manufacturer's instructions
- Only trained operators shall use exothermic welding equipment
- Operator to inspect all equipment before use; do not use worn or broken equipment which could cause molten metal leakage
- Wear appropriate PPE, including:
    - Eye protection, Hand protection & foot protection
    - When preparing copper or cleaning the graphite mould, wear a suitable mask to avoid dust inhalation or ventilate as necessary and wear cotton overalls with hide gloves
    - Wear face visor, hide gloves and safety footwear when handling welding material package and when jointing including when attaching the control unit termination clip to the ignition strip
    - Apply/remove earth continuity bond(s) across joint wearing Class 1 rubber gloves and safety footwear while standing on an insulated mat
- All work under immediate control of one person
- DO NOT COMPLETE THE POSSIBLE CIRCUIT BETWEEN CONDUCTORS WITHOUT AN EARTH CONTINUITY BOND APPLIED
- Remove all flammable materials from joint position
- Protect plant that cannot be removed (e.g. power cables) and equipment (e.g. propane bottles) from heat with heat resistant material
- Support conductors/mould on heat resistant packing (e.g. Thermalite blocks)
- Ensure a 2kg dry powder fire extinguisher is available at work location
- Warn nearby personnel of heat and molten metal hazard
- Provide adequate ventilation to the work area.
- Avoid contact with hot materials
- Do not use welding material package if damaged or not fully intact.
- Ignite from a position >2m from the mould and not horizontally below it.
- Avoid direct eye contact with 'flash' of light from ignition
- Electrically test joint using ST:TP21O/2.

EX3 METHOD - EXOTHERMIC WELDING (CADWELD PLUS)

1	APPLY	Adequately rated continuity bond between conductors to be joined.
2	SELECT	appropriate mould and handle for given conductors and application.
3	INSPECT	mould and handle for damage, wear and cleanliness.
4	CHECK	mould entries match conductors and application. NOTE Use of the incorrect mould may cause molten metal to be ejected on ignition.
5	FIT	mould handle clamp to mould.
6	CLOSE	the handle checking that the mould closes fully but not exerting too much pressure. NOTE The clamping pressure exerted by the handles can be adjusted by an adjustment screw on the handle
7	SELECT	appropriate 'weld material cup' package for given mould. NOTE There are different sizes of package and incorrect choice can lead to inadequate joints. The required package is stamped on the mould label. If two packages are required, this is explicitly stated.
8	CUT	conductors to length.
9	PREPARE	conductors to ensure they are free from burrs and flat/round where they would enter mould.
10	CHECK	that the conductors do not hold the mould faces open when the clamp is closed. NOTE A small gap may be enough to cause molten metal to be ejected on ignition and can lead to inadequate joints.
11	DRY	The conductor by wiping with a clean rag
12	DRY	the mould and dry the conductors thoroughly using a blow torch until all moisture is removed. Heat the mould from the outside. Do not heat the inside of the mould directly. NOTE If moisture is present this may cause the mould to crack and/or eject molten metal and or create a porous , inadequate joint.
13	CLEAN	the conductors using wire brush (reserved for the purpose) and 'Scotchbrite' abrasive pad to achieve a bright-clean finish free of oxides. Degrease using an approved solvent and dry the conductors with clean rag. NOTE It may be necessary to use an approved solvent to remove grease etc. If so, the conductor must be dried.
14	INSERT	the conductors in the mould and position appropriately. The required gap is marked on the mould label and the gap must be centred under the tap hole. Mark the conductors where they enter the mould.
15	LOCK	the two sections of the mould together using the mould handle clamp. Ensure the mould faces meet fully. NOTE Molten metal may be ejected if the mould faces do not meet.
16	INSERT	the sealed 'weld material cup' package (e.g. CADWELD PLUS package) into the mould.

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17	CHECK	ignition control unit is not damaged and functioning correctly
18	ATTACH	the ignition control unit termination clip to the ignition strip of the sealed 'weld material cup' package.
19	CLOSE	the mould-top cover.
20	MOVE	to a location >2m from the mould.
21	PRESS	and hold the control unit switch and wait for the ignition.
22	WAIT	15-20 seconds.
23	OPEN	and remove the mould carefully so as to prevent chipping. Remove the expended steel cup. Any excess tap metal/slag can be removed while the weld is hot. NOTE The mould (and conductors) remain hot for some time.
24	WAIT	for the joint to cool.
25	CHECK	the joint visually. Are there any holes or cracks present (use x10 magnification)? Refer to manufacturer's guide extract to visually check a joint is good, acceptable or must be rejected – Appendix C.
26	REMOVE	continuity bond.
27	TEST	the joint resistance in accordance with ST:TP21O/2.
28	CLEAN	the slag from the mould using the appropriate tool. Do not use a wire brush as this will wear the carbon mould significantly. Lightly brush away the remaining residue.
29	STORE	the mould when cool.

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JOINTING METHOD

TYPE: BOLTING - COPPER-COPPER (ABOVE GROUND)

BCC1 EQUIPMENT

- Suitably rated approved continuity bond (3-way = E5 item 38986, 2-way = E5 item 40726)
- General engineering tools (hacksaw, files, drill, hammer, scribing tool, set square, callipers, ruler and spanners)
- Wire brush, 'Scotchbrite' abrasive pad and approved degreasing agent
- Blow torch
- Flint gun
- Tinmans Solder rod (E5 item 31327) and flux paste or tinning paint (E5 item 32497) and no flux
- Bolts, nuts and washers shall be of steel, spun galvanised to BSEN1461 or stainless steel. Bolts and nuts to ISO metric strength grade designation 8.8 of BS4190, threads conforming to BS3643 Part 2 (coarse).
- Neutral compound grease (Castrol Rustillo 431 or Shell Ensis CD)
- Bitumastic paint
- Micro-ohmmeter.

BCC2 SAFETY PRECAUTIONS

The following precautions shall be taken:-

- Wear appropriate PPE, including:
    - When preparing copper, wear a suitable mask to avoid dust inhalation or ventilate as necessary and wear cotton overalls with hide gloves
    - Wear eye protection, hide gloves and safety footwear when tinning
    - Apply/remove earth continuity bond(s) across joint wearing Class 1 rubber gloves and safety footwear while standing on an insulated mat
- All work under immediate control of one person
- DO NOT COMPLETE THE POSSIBLE CIRCUIT BETWEEN CONDUCTORS WITHOUT AN EARTH CONTINUITY BOND APPLIED
- Remove all flammable materials from tinning position
- Protect plant that cannot be removed (e.g. power cables) and equipment (e.g. propane bottles) from heat with heat resistant material
- Support conductors on heat resistant packing (e.g. Thermalite blocks) - DO NOT APPLY HEAT TO CONCRETE
- Place a 2kg dry powder fire extinguisher and fire blanket at work location
- Warn other personnel of heat hazard
- Electrically test joint using ST:TP21O/2.

BCC3 METHOD - BOLTING (COPPER-COPPER)

1	APPLY	Adequately rated continuity bond between conductors to be joined.
2	CUT	conductors to length; ensure ends are square. NOTE See table BCC1 for overlap requirement. For tee-off points, a tag can be brazed on to allow this requirement to be met if bolting is required.
3	PREPARE	conductors to ensure they are square, free from burrs and flat.
4	DRILL	holes for bolts (minimum of 2). NOTE See table BCC1 for hole diameter requirement.
5	CLEAN	the conductors using wire brush (reserved for copper) and/or 'Scotchbrite' abrasive pad to achieve a bright-clean, smooth finish. Degrease using an approved solvent and dry the conductors.
6	TIN	the copper across the area of overlap. Tinmans Solder rod method: Apply flux paste to cleaned conductor and clean rag. Heat conductor and apply solder rod to form pool of solder on conductor and wipe around to cover required area, removing excess. Tinning paint method: Paint cleaned conductor with tinning paint to cover required area. Heat painted area and wipe off excess with clean rag.
7	APPLY	neutral compound grease to joint faces.
8	BOLT	conductors together. NOTE See Table 1 for bolt diameter and torque.
9	REMOVE	continuity bond.
10	TEST	joint resistance in accordance with ST:TP21O/2.
11	APPLY	neutral compound grease to the completed joint. Wipe off excess.
12	APPLY	bitumastic paint.

Tape Width (mm)	Length of Overlap (mm)	Minimum Dimensions A (mm)	Minimum Dimensions B (mm)	Bolt	Bolt Hole Diameter (mm)	Torque (Nm)	Maximum Spanner Length (mm)
25mm	75	20	12.5	M10	12	35	150
50mm	100	25	25	M12	14	50	200

Table BCC1 - Bolting Schedule

Refer to Figure 1.

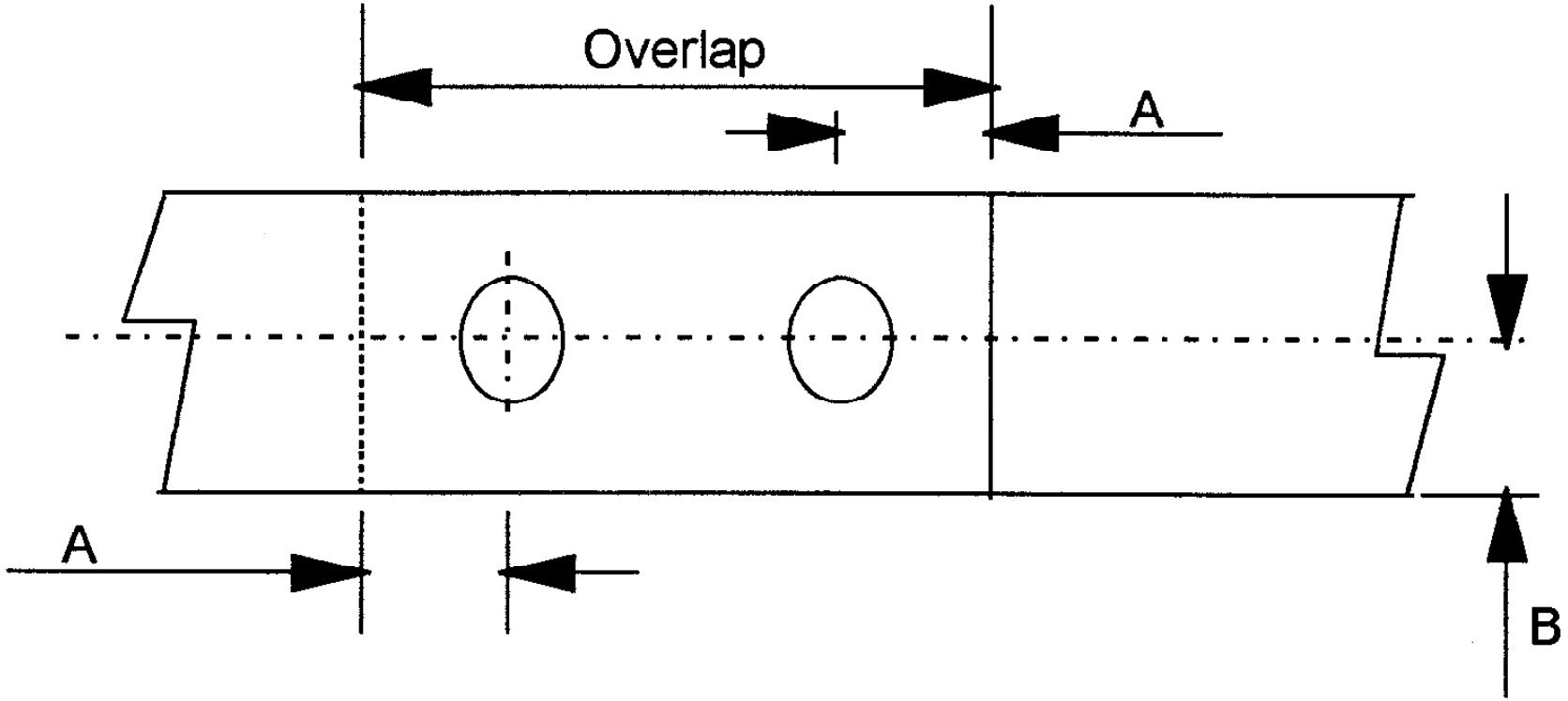


Figure 1 - Bolting Arrangement

JOINTING METHOD

TYPE: BOLTING - COPPER-EQUIPMENT EARTH TERMINAL (ABOVE GROUND)

BCC1 EQUIPMENT

- Suitably rated approved continuity bond (3-way = E5 item 38986, 2-way = E5 item 40726)
- General engineering tools (hacksaw, files, drill, hammer, scribing tool, set square, callipers, ruler and spanners)
- Wire brush, 'Scotchbrite' abrasive pad and approved degreasing agent
- Blow torch
- Flint gun
- Tinmans Solder rod (E5 item 31327) and flux paste or tinning paint (E5 item 32497) and no flux
- Bolts, nuts and washers shall be of steel, spun galvanised to BSEN1461 or stainless steel. Bolts and nuts to ISO metric strength grade designation 8.8 of BS4190, threads conforming to BS3643 Part 2 (coarse).
- Neutral compound grease (Castrol Rustillo 431 or Shell Ensis CD)
- Micro-ohmmeter.

BCC2 SAFETY PRECAUTIONS

The following precautions shall be taken:-

- Wear appropriate PPE, including:
    - When preparing copper, wear a suitable mask to avoid dust inhalation or ventilate as necessary and wear cotton overalls with hide gloves
    - Wear eye protection, hide gloves and safety footwear when tinning
    - Apply/remove earth continuity bond(s) across joint wearing Class 1 rubber gloves and safety footwear while standing on an insulated mat
- All work under immediate control of one person
- DO NOT COMPLETE THE POSSIBLE CIRCUIT BETWEEN CONDUCTORS WITHOUT AN EARTH CONTINUITY BOND APPLIED
- Remove all flammable materials from tinning position
- Protect plant that cannot be removed (e.g. power cables) and equipment (e.g. propane bottles) from heat with heat resistant material
- Support conductors on heat resistant packing (e.g. Thermalite blocks) - DO NOT APPLY HEAT TO CONCRETE
- Place a 2kg dry powder fire extinguisher and fire blanket at work location
- Warn other personnel of heat hazard
- Electrically test joint using ST:TP21O/2.

BCE3 METHOD - BOLTING (COPPER-EQUIPMENT EARTH TERMINAL)

1	APPLY	Adequately rated continuity bond between conductors to be joined.
2	CUT	conductors to length; ensure ends are square.
3	PREPARE	conductors to ensure they are square, free from burrs and flat.
4	DRILL	hole(s) for bolt(s) to match equipment earth terminal.
5	CLEAN	the copper conductor using wire brush (reserved for copper) and/or 'Scotchbrite' abrasive pad to achieve a bright-clean, smooth finish. Degrease using an approved solvent and dry the conductors.
6	TIN	the copper across the area of overlap. Tinmans Solder rod method: Apply flux paste to cleaned conductor and clean rag. Heat conductor and apply solder rod to form pool of solder on conductor and wipe around to cover required area, removing excess. Tinning paint method: Paint cleaned conductor with tinning paint to cover required area. Heat painted area and wipe off excess with clean rag.
7	CLEAN	the equipment earth terminal to a bright clean, smooth finish. Degrease using an approved solvent and dry the conductors.
8	APPLY	neutral compound grease to joint faces.
9	BOLT	conductors together.
10	REMOVE	continuity bond.
11	TEST	joint resistance in accordance with ST:TP21O/2.
12	APPLY	neutral compound grease to the completed joint.

JOINTING METHOD

TYPE: BOLTING - COPPER-ALUMINIUM (≥150mm ABOVE GROUND LEVEL)

BCA1 EQUIPMENT

- Suitably rated approved continuity bond (3-way = E5 item 38986, 2-way = E5 item 40726)
- General engineering tools (hacksaw, files, drill, hammer, scribing tool, set square, callipers, ruler and spanners)
- Wire brush, 'Scotchbrite' abrasive pad and approved degreasing agent
- Blow torch
- Flint gun
- Tinmans Solder rod (E5 item 31327) and flux paste or tinning paint (E5 item 32497) and no flux
- Bolts, nuts and washers shall be of steel, spun galvanised to BSEN1461 or stainless steel. Bolts and nuts to ISO metric strength grade designation 8.8 of BS4190, threads conforming to BS3643 Part 2 (coarse).
- Neutral compound grease (Castrol Rustillo 431 or Shell Ensis CD)
- Bitumastic paint
- Micro-ohmmeter.

BCA2 SAFETY PRECAUTIONS

The following precautions shall be taken:-

- Wear appropriate PPE, including:
  - When preparing copper, wear a suitable mask to avoid dust inhalation or ventilate as necessary and wear cotton overalls with hide gloves
  - Wear eye protection, hide gloves and safety footwear when tinning
  - Apply/remove earth continuity bond(s) across joint wearing Class 1 rubber gloves and safety footwear while standing on an insulated mat
- All work under immediate control of one person
- DO NOT COMPLETE THE POSSIBLE CIRCUIT BETWEEN CONDUCTORS WITHOUT AN EARTH CONTINUITY BOND APPLIED
- Remove all flammable materials from tinning position
- Protect plant that cannot be removed (e.g. power cables) and equipment (e.g. propane bottles) from heat with heat resistant material
- Support conductors on heat resistant packing (e.g. Thermalite blocks) - DO NOT APPLY HEAT TO CONCRETE
- Place a 2kg dry powder fire extinguisher and fire blanket at work location
- Warn other personnel of heat hazard
- Electrically test joint using ST:TP21O/2.

BCA3 METHOD - BOLTING (COPPER-ALUMINIUM)

1	APPLY	Adequately rated continuity bond between conductors to be joined.
2	CUT	conductors to length; ensure ends are square. NOTE See Table BCC1 for overlap requirement. The joint shall be in the vertical plane and the bottom of the overlap shall be a minimum of 150mm above ground level.
3	PREPARE	conductors to ensure they are square, free from burrs and flat.
4	DRILL	holes for bolts (minimum of 2). NOTE See Table BCC1 for hole diameter requirement.
5	CLEAN	the conductors using wire brush (one reserved for copper and one for aluminium) and/or 'Scotchbrite' abrasive pad (reserved for copper and aluminium respectively) to achieve a bright-clean, smooth finish. Degrease using an approved solvent and dry the conductors.
6	TIN	the copper across the area of overlap. Tinmans Solder rod method: Apply flux paste to cleaned conductor and clean rag. Heat conductor and apply solder rod to form pool of solder on conductor and wipe around to cover required area, removing excess. Tinning paint method: Paint cleaned conductor with tinning paint to cover required area. Heat painted area and wipe off excess with clean rag.
7	APPLY	neutral compound grease to joint faces.
8	BOLT	conductors together. NOTE See Table BCC1 for bolt diameter and torque.
9	REMOVE	continuity bond.
10	TEST	joint resistance in accordance with ST:TP21O/2.
11	APPLY	neutral compound grease to the completed joint. Wipe off excess.
12	APPLY	bitumastic paint to the completed joint.

APPENDIX A

RISK ASSESSMENT - BRAZING

Nature of Hazard	Control Measures
Dust	Suitable respiratory mask fitted with appropriate cartridge as necessary Clear goggles.
Fumes	Adequate ventilation/forced extraction Suitable respiratory mask fitted with appropriate cartridge (i.e. P3) as necessary.
Arc eye	Welding goggles/face visor.
Inflammable Gas	Training.
Hot/molten metal	Welding goggles/face visor Leather safety boots. Cotton overalls, leather apron and cap. Hide gloves/leather gauntlets and leather spats. Remove flammable materials from joint position. Protect plant with heat resistant material. 2kg dry powder fire extinguisher and fire blanket.
Touch potential Step potential	No work if lightning likely. No work if fault switching. HV electrical gloves where possible. Footwear with substantial sole. Insulated mat at joint position.
Potential difference	Adequately rated continuity bond between conductors to be joined.

NB See ST:HS15D/1 for further details.

APPENDIX B

RISK ASSESSMENT - EXOTHERMIC WELDING (CADWELD PLUS)

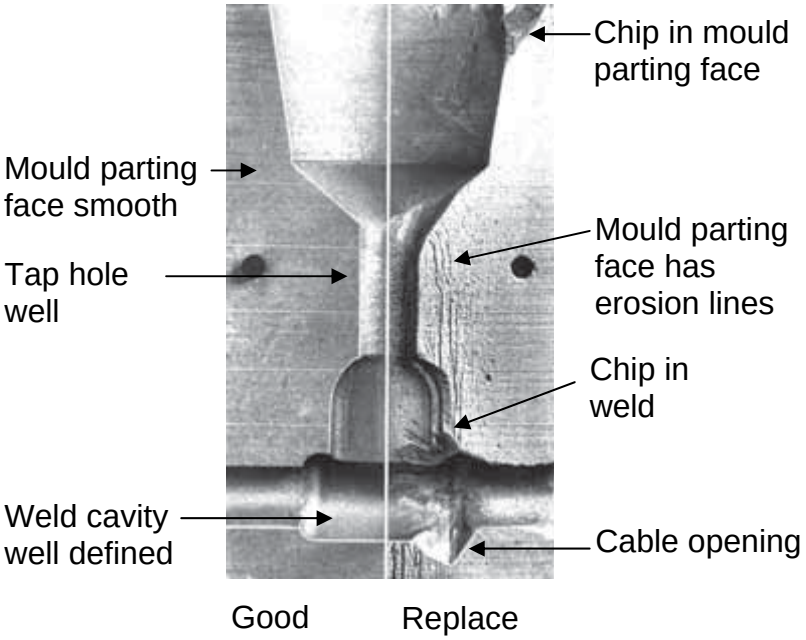
Nature of Hazard	Control Measures
Dust	Suitable respiratory mask fitted with appropriate cartridge as necessary Clear goggles.
Fumes	Adequate ventilation Suitable respiratory mask fitted with appropriate cartridge (i.e. P3) as necessary.
Hot/molten metal	Face visor Cotton overalls Hide gloves/leather gauntlets Safety footwear Remove flammable materials from joint position Protect plant with heat resistant material 2kg dry powder fire extinguisher Use correct mould Check mould faces meet when conductor fitted Pre-heat mould Remote ignition control unit operated from >2m If sealant is used to prevent leakage only the specific sealant recommended by the mould manufacturer shall be used.
Hot mould	Hide gloves/leather gauntlets.
Touch potential Step potential	No work if lightning likely No work if fault switching HV electrical gloves Footwear with substantial sole Insulated mat at joint position.
Potential difference	Adequately rated continuity bond between conductors to be joined.

APPENDIX C

CADWELD PHOTOGRAPHIC GUIDE & PROBLEM SOLVER

(Extract from ERICO Publication 'A-7D Installer's and Inspectors Guide for CADWELD Electrical Connections').

CADWELD MOULD INSPECTION



A CADWELD® mould is designed to last for an average of 50 connections. This will vary according to the care given to the mould during use.

Inspect the mould regularly. Check the following items to determine if a mould should be replaced:

Cable Opening

- The conductor should fit snugly. A loose fit will cause leakage.
- The opening should not be chipped or worn.

Weld Cavity

- The cavity should be well defined.
- There should be no chips or gouges.

Tap Hole

- The tap hole should be well defined.

Mould Parting Face

- The parting face should not be chipped.
- The parting face should always be cleaned properly. Use a clean shop towel or newspaper and wipe clean. Using a wire brush to clean the mould will cause erosion and quickly destroy the mould.

INSPECTION OF CADWELD CONNECTIONS - GENERAL INDICATIONS

Proper inspection of a CADWELD® connection relies on the judgment of the field personnel. Look closely at the size, colour, surface finish, and porosity of the connection. Following the guidelines below will assist in making meaningful inspections. Photographs of good, acceptable, and reject connections appear below.

Size

1. No portion of the conductor within the confines of the weld should be exposed.

2. Maximum depression under the riser on horizontal connections (after the slag has been removed) should be no lower than the top of the conductor.

A low fill indicates:
(a) Not enough weld material was used.
(b) Excessive leakage of molten metal.
(c) Improper positioning of the conductor inside the mould.
(d) Movement of conductor.

3. Excessively high fill (tall riser) indicates:
(a) Too large weld material size was used (connection is still acceptable).
(b) Apparent volume increase due to contaminants in conductor or mould (see "Porosity" below).

Colour

The colour of a CADWELD® connection is best seen after a light wire brushing of the connection. It should normally be gold to bronze in colour. Occasionally, it may be silvery at the top. This silver colour indicates "tin sweat" of the surface, a normal condition. A CADWELD connection to cast iron or galvanized surfaces is often silvery due to alloying with the metals.

Surface Finish

The surface of a CADWELD connection should be reasonably smooth and free of major slag deposits. If slag deposits cover more than 20% of the connection surface, or if any cable strands are exposed after slag has been removed, the connection must be rejected.

Porosity

The connection should be essentially free from porosity. Excessive porosity is normally the result of contaminants (water, oil, dirt, etc.) in the conductor and/or mould. A few small pinholes may be present on the surface of the riser. The depth of a pinhole must never extend beyond the centre of the conductor. To check the depth, probe the pinhole with a 1/32-in.-diameter wire (paper clip). Reject the connection if the depth of the pinhole extends beyond the centre of the conductor.

INSPECTION OF CADWELD CONNECTIONS - VISUAL INSPECTION

Photographic Guides

Like all electrical connections, a visual inspection is no guarantee of performance. Crimped or bolted connections cannot be inspected visually, but CADWELD® connections can be visually inspected and provide an indication of the quality of the weld. Visual inspection is recommended as a practical minimum. Use the photographs on the following pages as a guide to visual inspection. CADWELD connections are normally rated as good, acceptable or reject.

A **good** connection is a normal weld with only minor surface imperfections. An **acceptable** connection is a less than normal weld, but a good performing weld.

Imperfections indicate that:-

1) A new mould is required

2) A change in procedure is necessary

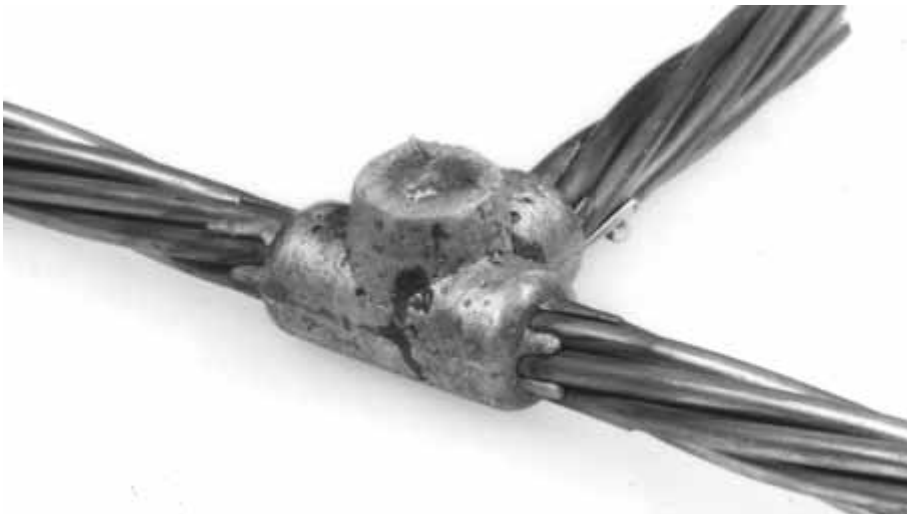
3) The proper mould conductor and/or weld metal should be used.

A **reject** connection shows inadequate fill or an extra high riser due to:-

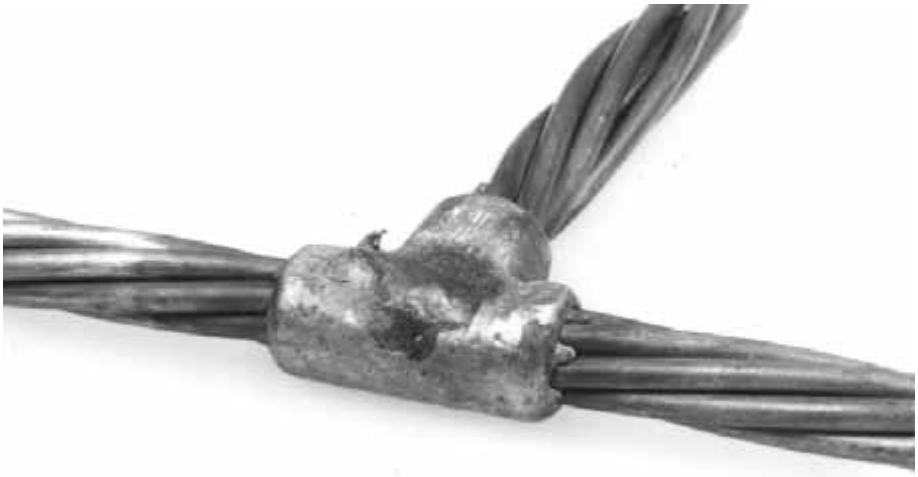
1) Use of incorrect procedure

2) Use of incorrect equipment and/or equipment worn beyond its useful life

3) Use of incorrect material.



Good.
A solid weld with only minor surface imperfections.

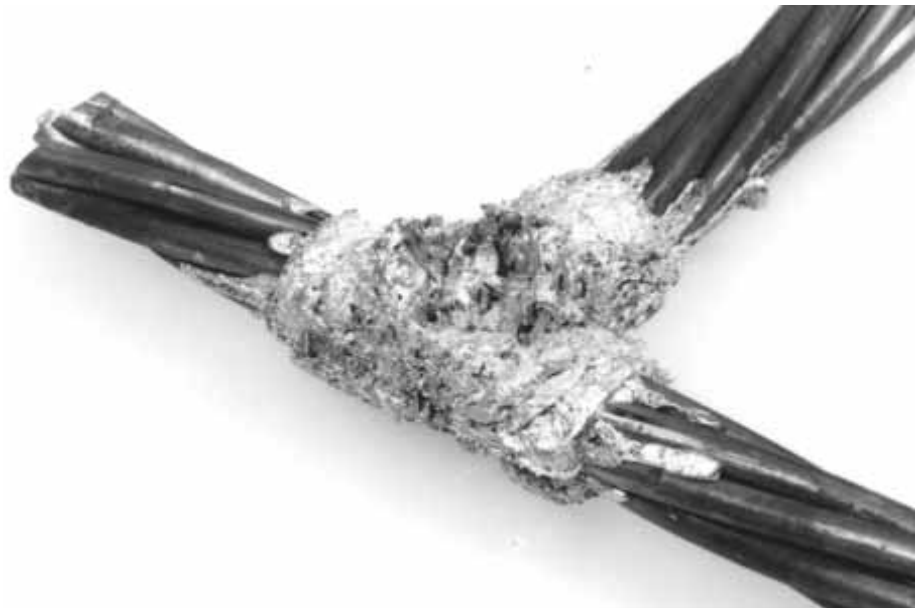


Acceptable.
Fill is lower than normal, but still sufficient.

Acceptable.
A worn or incorrect mould was used, allowing leakage around conductor. The fill in this connection is sufficient to allow it as acceptable. Attention to mould is required prior to making next connection.

Acceptable.
The presence of water/moisture in conductor strands or mould indicates that one or both were not properly dried. Although the riser is porous, the weld is solid. The degree of porosity is not sufficient to reject this connection.

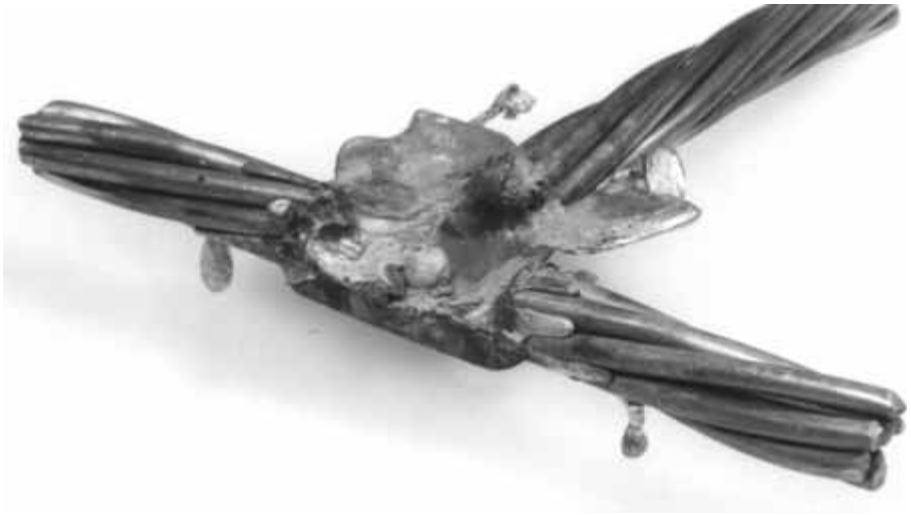
Reject.
Extreme amounts of slag on surface are caused by weld material leaking past disk or complete lack of disk. Inspect the condition of mould disk seat and check disk positioning prior to making the next connection. This is not a problem associated with CADWELD PLUS as the system does not employ a separate disk and is therefore shown for information only.



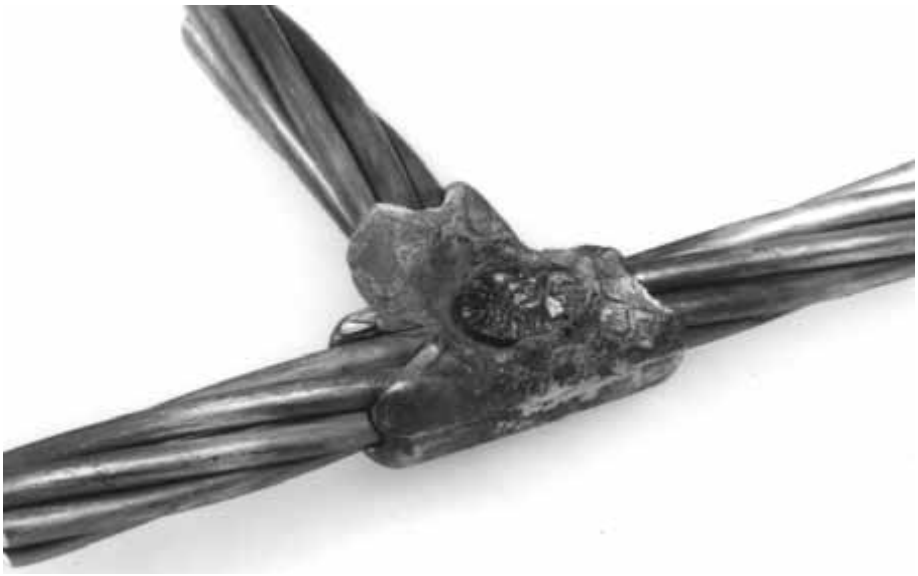
Reject.
Excessive water in cable strands and/or mould. Cable and mould must be dried by heating.

Reject.
Light carbon traces on cable and connection are evidence of oil on cable strands. Oily cables must be cleaned with safety solvent, before brushing and drying

Reject.
Heavy carbon coating on cable and connection is evidence of large amounts of oil or grease on cable. Cable must be cleaned with safety solvent, before brushing and drying



Reject.
Fill too low. Weld cavity was not filled over cable strands. “Fins” indicate that the mould was not closed tightly due to incorrect mould, incorrectly adjusted handle clamp, or presence of foreign material in mould parting line. Before making the next connection, check the mould for each of the above.



Reject.
Fill too low. Weld cavity was not filled over cable strands. Absence of leakage indicates that weld material size was incorrect (too small) or through conductor moved.

Problem A
THE MOULD DOESN'T CLOSE TIGHTLY
Check for:
1. Adjustment of handle clamps.
2. Cables out of round or bent.
3. Dirt or slag in mould parting line.
4. Correct cable size.
NOTE: Use "C" clamp if necessary.

Problem B
THE CONNECTION IS COVERED WITH EXCESSIVE SLAG (Not a phenomenon associated with Cadweld Plus)
Check for:
1. Weld material leaking past the disk, caused by:
(a) Chipped graphite at tap hole.
(b) Disk moved when weld material was dumped.
(c) Disk not properly seated.
(d) Disk was not installed.
NOTE: A small amount of slag on the surface is not abnormal.

Problem C
MOLTEN METAL "SPITS" OUT OF THE CRUCIBLE WHEN MAKING A CONNECTION
Remedy:
1. See Problem D

Problem D
THE CONNECTION IS POROUS
Check for:
1. Presence of moisture either in conductor or mould.

Remedy:
(a) Dry the conductor by wiping and heating.
(b) Heat mould with torch (to above 120°C (212°F))until a discernable colour change (light grey)

2. Other contaminants (oil, insulation, etc.) present in conductors.

Remedy:
(a) Use a safety solvent to wash the conductor, and then dry it.
(b) If insulation is present between strands, remove it.

Check for:
3. Mould packing material in weld cavity of mould.

Remedy:
(a) Always apply mould packing material to conductor after mould is closed.

Problem E
THE CONDUCTORS DO NOT WELD
Check for:
1. Conductors were not properly cleaned and dried.

Remedy:
(a) Remove oxides with a wire brush. If heavily oxidized, have fresh-cut conductor end and use CADWELD® Heavy Duty moulds.
(b) Dry conductors with a torch.

Check for:
2. Conductors not properly positioned in the mould.

Remedy:
(a) Check for proper gap or butting as required (see the mould tag and read the instructions packaged with mould).
(b) Check to be sure gap is centred under tap hole.
NOTE: In some cases, the run (through) conductor must be cut and gapped. Follow instructions for same or use CADWELD Heavy Duty moulds.

Problem F
THE WELD MATERIAL LEAKS AROUND THE CONDUCTOR

Remedy:
1. Use packing material around the conductor after the mould is closed.
2. Use moulds with wear plates (which also act as chill plates).
3. Check for the proper mould. Mould must be sized for the cable being welded.
4. If the mould is excessively worn, replace with a new mould.

Problem G
THE CONNECTION HAS "FINS"– METAL IS LOST
Check for:
1. Mould not completely closed.
2. Mould worn beyond useful life and needs replacement.

Problem H
THE CABLES PULL OUT OF THE MOULD DURING WELDING
Remedy:
1. Use a clamp (CADWELD® B-265) or other means to prevent movement of conductors when welding.

Problem I
INSUFFICIENT FILL MATERIAL TO COVER CONDUCTORS
Check for:
1. Use of proper weld material size (see mould tag).
2. Too large a gap between conductors (see positioning instructions).
3. Mould leakage.
Remedy:
(a) See Problem F.
(b) See Problem G.
(c) See Problem H.

4. Conductor movement.

Problem J
THE RISER IS TOO HIGH
Check for:
1. Use of proper weld material size (see mould tag).
2. Moisture in mould or conductor.
Remedy:
(a) See Problem D.

Problem K
THE MOULD WEARS OUT QUICKLY
(Moulds should produce an average of 50 connections.)
Remedy:
1. Use CADWELD® B-265 cable clamp for hard-drawn copper or DSA Copperweld®.
2. Clean the mould with a soft brush, clean cloth, or newspaper. DO NOT USE A WIRE BRUSH.
3. Use care in removing the mould from a finished connection to prevent chipping of mould.

Problem L
WHEN WELDING TO STEEL, THE WELD DOES NOT "STICK" TO THE STEEL
Remedy:
1. Clean the steel with a rasp or grinder to bright metal. When grinding, use an ERICO® approved grinding wheel only. All mill scale, paint, and/or other coating must be removed. Wire brushing will NOT suffice. Grease must be removed with safety solvent before cleaning.
2. Clean galvanized surfaces with a wire brush or emery cloth. However, extra heavy galvanized steel must be cleaned with a rasp.
3. If the steel is moist, heat with a torch (from the back side if possible). Any carbon deposit from the flame must be removed.
4. If conductors are not in proper position, check the instruction sheet.

Problem M
WHEN WELDING TO DUCTILE IRON OR CAST IRON, THE WELD DOES NOT "STICK" TO THE SURFACE
Remedy:
1. Remove all coatings before cleaning.
2. Clean the surface with a rasp or grinder to bright metal. When grinding, use an ERICO-approved wheel only.
3. Clean the surface with a safety solvent after grinding or rasping.
4. Use CADWELD® XF-19 alloy weld material (orange cap).

APPENDIX D

CADWELD PLUS SUPPLIER INFORMATION

Company	ETS Cable Components (Vendor No 101762)
Contact	Ben Hancock Tel No 020 8405 6789 Mobile No 078 17580341 E-Mail www.etcc.co.uk

Table D1 – Supplier Information – CADWELD Plus

Page revised 26 June 2014

Table D2- Common Cadweld Joints and Associated Mould, Weldmetal and Mould Clamps

Function			Mould	Cadweld Plus Weldmetal	Mould Clamps
Conductor A	**Conductor B**	**Joint**			
70mm^2 stranded copper [Y4] (E5 Item 30006)	70mm^2 stranded copper [Y4] (E5 Item 30006)	Straight	SSC-Y4	65 PLUS F20 Dark Green	L-160
70mm^2 stranded copper [Y4] (E5 Item 30006)	12.5mm dia. copper-clad steel rod (E5 Item 30554)	Through conductor to rod side	GYE-P128-Y4	115 PLUS F20 Orange	L-160 + M32
70mm^2 stranded copper [Y4] (E5 Item 30006)	7 No.8 stranded copper-clad steel	Straight	GFC-P100-Y4	65 PLUS F20 Dark Green	L-160
50mm x 4mm copper tape (E5 Item 30606)	50mm x 4mm copper tape (E5 Item 30606)	Cross	EBC-EAM	200 PLUS F20 Yellow	L-160
50mm x 4mm copper tape (E5 Item 30606)	50mm x 3mm copper tape (E5 Item 41285)	Tee to 50mm x 3mm through conductor	BMD-CAM-EAM	200 PLUS F20 Yellow	L-159
50mm x 4mm copper tape (E5 Item 30606)	70mm^2 stranded copper [Y4] (E5 Item 30006)	Tee to 50mm x 4mm through conductor	LJC-Y4-EAM	90 PLUS F20 Grey	L-160
50mm x 3mm copper tape (E5 Item 41285)	70mm^2 stranded copper [Y4] (E5 Item 30006)	Tee to 50mm x 3mm through conductor	LJC-Y4-CAM	65 PLUS F20 Dark Green	L-160
50mm x 4mm copper tape (E5 Item 30606)	12.5mm dia. copper-clad steel rod (E5 Item 30554)	Elbow joint	CNC-P128-EAM	115 PLUS F20 Orange	L-160
50mm x 3mm copper tape (E5 Item 41285)	12.5mm dia. copper-clad steel rod (E5 Item 30554)	Elbow joint	CNC-P128-CAM	90 PLUS F20 Grey	L-160
7 No.8 stranded copper-clad steel	Lug	Lug joint	SSC-Y4-W8	65 PLUS F20 Dark Green	L-160
5mm earth electrode solid (SHOPS item 39101)	12.5mmEarth Rod CC (E5 item 30554)	"h"	GYE14W3M	90PLUSF20	L-160
16mm^2 stranded copper (SHOPS item 30039)	12.5mmEarth Rod CC (E5 item 30554)	"h"	GYE14W3	90PLUSF20	L-160
35mm^2 stranded copper (SHOPS 36969)	12.5mmEarth Rod CC (E5 item 30554)	"h"	GYE14Y2	90PLUSF20	L-160
70mm^2 stranded copper (SHOPS Item 30006)	12.5mmEarth Rod CC (E5item 30554)	"h"	GYE14Y4	115PLUSF20	L-160
120mm^2 stranded copper (E5Item 50036)	12.5mmEarth Rod CC (E5 item 30554)	"h"	GYE14Y6	115PLUSF20	L-160

Page revised 23 July 2013

APPENDIX E

APPROVED PERSONAL PROTECTIVE EQUIPMENT

The PPE referred to under Safety Precautions is approved.

APPENDIX F

SUPERSEDED DOCUMENTATION

This document supersedes ST:TP21L dated May 1999 which should now be withdrawn.

APPENDIX G

ASSOCIATED DOCUMENTATION

ST:OH4F/3	Construction Techniques for Wood Pole Lines
ST:HS20A	Site Specific Safety Risk Assessment and Near Miss Reporting
POL:HS8/1	Personal Protective Equipment
EE SPEC 89/1	Fixed Earthing Systems for Major Substations
ST:TP21O/2	Measurements Associated With Earthing Systems
ST:HS15D/1	Relating To The Safe Use Of Welding, Brazing and Flame Cutting Equipment

APPENDIX H

KEY WORDS

Brazing, Bonding Conductor, Cadweld, Continuity Bond, Earth Electrode, Earthing, Earthing Conductor, Earthing System, Exothermic Weld, Jointing, Step Potential, Testing, Touch Potential.