

BOILER CODE OF
PRACTICE (BCOP)



GUIDANCE NOTE

WELDING PROCEDURES & PROCESSES

Applicable to Locomotive Steam Boilers

Purpose

This document describes good practice in relation to its subject to be followed by Heritage Railways, Tramways and similar bodies to whom this document applies.

Development

This document has been developed by boiler experts in consultation with His Majesty's Railway Inspectorate (HMRI) a directorate of the Office of Rail and Road (ORR). The document HGR B9000 sets out the background to setting up the Boiler Code of Practice Committee (BCOP).

Disclaimer

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1. Introduction

This Guidance Note is one of a series dealing with Locomotive Boilers that were produced by the “Steam Locomotive Boiler Codes of Practice” (BCOP) practitioners’ meetings.

Railway locomotive boilers are designed to create, store and distribute steam at high pressure. The working life of such a boiler can be considerably shortened if due care is not taken at all stages of inspection, repair, running maintenance and day-to-day running.

In the past, there have been a series of accidents and explosions due to work being undertaken without having due regard to the inherent risks involved. It is with that in mind that HMRI and HRA set up the series of meetings of boiler practitioners to discuss the issues; distil good practice and codify it into this series of Guidance Notes.

This guidance is written for the assistance of people competent to perform these tasks. In places the terminology used may be specific to such practitioners.

This guidance should also be useful to those in a supervisory or more general role. However, no work should be undertaken unless the persons concerned are deemed competent to do so.

2. Recommendations

This guidance note is issued as recommendations to duty holders.

Where duty holders decide to take actions that are not in agreement with these recommendations following appropriate risk assessments or for other reasons, it is recommended that those decisions are reviewed by the senior management body of the organisation concerned and a formal minute is recorded of both the decision reached and the reasons for reaching it.

3. Dimensional Notation

The dimensions in this document are variously described in a mixture of imperial and metric units. Where practical equivalent dimensions have been shown but in some cases the dimensions do not easily equate and so the units in force at the time that the original designs were documented have been used.

4. Personal Protective Equipment

Before undertaking any work, a risk assessment must be conducted.

Protective equipment is to be supplied and used at work wherever there are risks to health and safety that cannot be adequately controlled in other ways.

The equipment must be:

- Compliant with the latest Personal Protective Equipment regulations;
- Properly assessed before use to ensure it is suitable;
- Maintained and stored properly;
- Provided with instructions on how to use it safely; and
- Used correctly by those undertaking the work.

5. General points concerning Welding

The welding activity must be carried out in an environment that is not detrimental to the finished weld.

Method statements should take account of the specific risks associated with the welding procedure being used.

Before commencement of any welding process, agreement must be obtained from the Competent Person. The Competent Person may require to witness the plate preparation, root run, the finished weld and its testing.

All welding must be carried out under an approved procedure which will take into account material specification, location and orientation of weld, weld process and welder qualification. It may not be possible to introduce a localised welded repair due to the poor condition of the components. If this is the case a new boiler or platework should be considered.

The planned repair work must be agreed by the Competent person and/or the intended inspection body.

6. Competent Person

The person responsible for the pressure vessel on the railway or whoever owns the vehicle should seek the agreement of the boiler Competent Person before proceeding with any repairs involving welding. Conversations between the welder, inspecting body and any other experts must ascertain that the intended welding procedure fits the work and materials to be used and any requirements of the Pressure Vessel Regulations. **The Competent Person should be a member of a Type A notified body, fully independent with no conflicts of interest.**

7. Welder qualification

All welding on pressure vessels must be carried out by an approved welder to a certified welding procedure, i.e. the ISO 17024 scheme. The welder's qualification to the ISO standards must be verified by the Competent Person to ensure that it is appropriate for the weld being undertaken.

8. Weld Procedure

A Welding Procedure Specification (WPS) is a formal written document describing the welding process, which provides direction to the welder or welding operators for making metallurgically sound welds. The purpose of the document is to guide welders to the accepted procedures so that suitable and repeatable welding techniques are used. A WPS must be developed for each material alloy and for each welding type used. A WPS must be developed by a competent person such as a welding engineer. A WPS must be supported by a Procedure Qualification Record (PQR or WPQR).

A Weld Procedure Qualification Record (WPQR) is a record of a test weld performed and assessed by a combination of non-destructive and metallurgical testing to demonstrate that the welding procedure will produce a satisfactory weld. A single WPQR can, in some cases, cover a number of related weld procedure specifications. Weld procedure qualification tests are normally witnessed and certified by an independent inspection body.

A Welder Qualification is a qualification test by which individual welders are certified to carry out welding to a defined WPQR. A Welder Qualification Test Record (WQTR) demonstrates that the welder has the understanding and demonstrated ability to work within the specified WPS. Welder qualification tests are normally witnessed and certified by an independent inspection body. WQTR need to be periodically reviewed to demonstrate that welders are maintaining their competency.

All written documents should be retained with the boiler's records and copies made available to the Competent Person and inspecting authority.

Further reference: Procedures EN ISO 15609 -1:2004 Formerly BS 288 part 2

9. Material

Existing boilers are not all made of the same material i.e. mild steel boiler plate. The main materials currently in widespread use are mild steel boiler plate, 2% nickel steel plate, carbon manganese steel plate and copper.

If any doubt exists, the material should be analysed to establish its composition, specification and suitability for weld repair.

The specifications of materials used in boiler construction include:

- Mild steel boiler plate BS EN 10029-1991, BS1501 161-430B and BS EN 10028 -1-2-3 :1993
- Carbon Manganese steel plate BS 1501 – 224 – 490B – LT50
- 2% Nickel steel plate, originally B.R SPEC III. There is no equivalent modern specification but the chemical analysis comprises: C 0.2-0.25%, Si 0.1-0.15% Mn 0.5-0.7% Ni 1.75-2.0%, S< 0.04% P< 0.04%
- Copper plate BS 2875 Grade C107 (phosphorous deoxidise arsenical), now BS EN 1652:1998 and BS EN 1653:1998.

Other copper plate grades such as BS 2875 Grade C105 and C101 are not recommended for welding.

It is important that the Competent Person vetts the suppliers of all materials that may be used in the welding processes.

10. Welding consumables

It is important to select the correct grade of welding electrode or filler suited to the parent plates being joined and ensure these are stored and prepared for use in accordance with the manufacturer's instructions. **The selection of the filler material to be used should be stated in the approved process.**

If Manual Metal Arc (MMA) is selected for the process E7018 or E7016 low hydrogen electrodes should be used when joining boiler plates made to BS EN 10029-1991 and BS EN 10028 -1-2-3 :1993.

Welding Process Steel plates

Manual metal arc is the preferred and proven process by which best results will be achieved on plate work especially for repair work. On new builds, it may be possible to use the Metal Active Gas (MAG) process. Other welding processes can be applied provided they have been included in the method statement as producing satisfactory results.

Further reference: Fusion welding of steel - BS EN ISO 15607: 2003

11. Weld Location and Preparation in Steel Plate

Once the material specification has been verified attention needs to focus on the positioning and configuration of the weld itself. Any weld needs to avoid, where possible, high stress areas or areas prone to cracking to minimise the possibility of repeat failure. If the proposed insert is bordered by a riveted joint, the rivets should be removed and the insert made to include the joint. It is poor practice to weld alongside the existing seam. Wherever possible a weld should be placed between stay rows and away from radii etc. The problem with inserts in radii is trying to achieve correct profiles. As most welds involving the replacement of plate work are only accessible from one side, all weld preps will be of a single vee type. If access is available from both sides a double vee enables a full penetration weld to be effected, with a smaller cap. J-type or fillet preparation may be required for items such as welded firebox stays, washout plug bosses and mounting pads. The plate preparation details should be included in the welding procedure. Typical examples of weld preparations and details are covered in BS2790: 1992, BS EN 12953:2002 and Weld joints & preparations BS 499-1 2009.

New plate of the original design thickness should always be used or a metric equivalent thicker than original plate may be considered provided that it is not more than 20% greater than the plate it is being welded to. Care should be taken to maintain alignment and keep distortion to a minimum.

12. Welding of Steel Boilers – Significant change in design

Traditionally only the inner steel firebox, where fitted, was welded; all outer construction being of the riveted design. All significant design changes, such as replacement of a riveted design by welding or changes of material used will require a formal design assessment by the Competent Person.

13. Common Defects and Permissible Repairs to Inner Steel Fireboxes

A full NDT survey must be carried out by a suitably approved qualified specialist to the requirement of the Competent Person before any repairs are carried out repairing to identify the full extent of any defects. **Ideally the NDT company employed should be ISO 17020 or 17025 accredited and can provide evidence that their accreditations are up to date.**

1 - Fractured sealing welds on tubes, where possible, may be machined out and re-welded using the MMA process.

2 - Cracking from stay holes in the throat plate adjacent to siphon necks, breaking zones and stays in fire area where possible, can be ground out and re-welded using MMA process.

3 - Plate thinning in firebox areas - these can be cut out and replaced with the correct specification material and welded with a single vee weld. The weld preparation dimensions should be left to the repairer based on their own weld procedure qualification. All welding should be carried out from the fireside.

4 - Waterside grooving adjacent to foundation ring may be repaired by machining or grinding out and re-welding on removal of the foundation ring.

5 - Ex Merchant Navy & West Country Classes - a feature of this type of steel fireboxes is the fitting of thermic syphons welded between the crown sheet and throat plate. Cracking occurs at the connection between syphon and syphon neck. This can be repaired by grinding out and re-welding or by complete removal of weld to stress relieve the component and then re-weld.

14. Weld Repairs to Riveted Outer Fireboxes and Barrel

Listed below are common defects and permissible repairs in steel fireboxes. A full NDT survey by an accredited body (see 13) must be carried out by the competent person or approved qualified specialist before repairing to identify the full extent of any defects.

1 - Waterside stress cracking in the door plate shoulders between washout plug holes and cracking between stay holes in end vertical rows at the breaking zones to the door plate, throat plate and to a lesser degree both side plates. All may be welded if access is available from the waterside. A fully satisfactory repair using MMA process is achievable by grinding to remove the crack and then welding. If this is not the case it will require a welded insert or a patch laid over. If the cracking is too extensive either in width or length a new section should be fitted. If a patch is to be laid over, design approval will be required from the Competent Person. In the case of a welded insert, the joint should be placed between stay rows or as a minimum on a flat area and not on a bend due to possible variation in profile. As previously stated, where an insert meets a riveted joint, the joint should be separated and the new insert attached via the rivets.

2 - Waterside stress cracking in the top corners of throat plate, i.e. knuckle areas - repair by grinding out the cracking and welding, which should be done from the waterside.

3 - Waterside grooving on outer firebox plates adjacent to foundation ring as well as wastage and corner cracking on the foundation ring. If the foundation ring is removed it should be possible to effect a repair by grinding and welding any grooving/cracking to the platework and ring.

4 - Waterside stress cracking on radius of front steel tube plate. The steel tube plate should be removed for this repair.

5 - Where electrolytic corrosion around copper stay heads, pitting on barrel inside & outside, plate thinning around firebox or localised wastage in various areas and components occurs, small areas of localised pitting / thinning may be repaired by building up with weld. Any one area of pitting of over 6 sq inches (2" x 3" for example) should not be repaired by welding nor should the total amount of welding in any one foot square of plate exceed 6 sq inches. The total area of welding in any plate should not exceed 24 sq inches.

6 - Barrel extension to smokebox wasted. Corrosion of barrel extensions occurs ahead of steel tube plate and therefore ahead of the pressure joint; effect a repair using materials and procedures as for any weld on the boiler.

15. Non-Destructive Testing and Weld Inspection (Steel)

On completion of welding all welds to be tested to specifications approved by the Competent Person.

The major methods of testing and inspection available are;

BS EN ISO 17637:2011 Visual testing of fusion-welded joints

ISO 3452 : 2008 parts 1 to 6 Penetrant testing

BS EN ISO 17638 : 2009 Magnetic particle inspection

BS EN ISO 17640 : 2010 Ultrasonics

BS EN ISO 17636 : 2013 Radiography

BS EN ISO 5173 : 2010 plus A1 2011 Destructive tests on welds in metallic materials – bend tests

BS EN 9712: 2012 NDT and certification/qualification of NDT personnel

Welding Of Copper Fireboxes ##**16. Characteristics of copper**

Copper is tough, ductile and malleable. On the application of cold work, the metal hardens and loses some of its ductility, but the ductility can be restored by annealing. The metal melts at about 1083 degrees C and when molten is very fluid. The thermal conductivity of copper is extremely high, equal to about eight times that of steel. As the material becomes hot, copper rapidly loses its mechanical properties, particularly from 300 degrees C upwards. At 500 degrees C, the tensile strength is only 40% of that at normal temperature, and will collapse near the melting point unless care is taken. Some grades of copper alloy contain a percentage of Arsenic which helps the material properties at elevated temperatures.

When the metal is in the molten or in the plastic state, it absorbs oxygen, hydrogen, carbon dioxide and the majority of the commonly occurring gases. In the annealed condition, copper is not very strong, and has tensile strength of about 14 tons per square inch, but after work hardening, the tensile strength may be up to 25 tons.

There are two main types of copper used in firebox construction - C107 phosphorus deoxidised arsenical copper to BS2875 1980, now BS EN 1652:1998 and BS EN 1653:1998, and C105 Tough pitch arsenical copper plate for riveted and studded construction only, both consisting of about 99.2% of copper with 0.3 /0.5% arsenic.

Tough pitch copper, C105, does not weld satisfactorily due to the fact that copper containing even a small amount of oxygen is quite unsuitable for welding. The metallurgical explanation is that oxygen unites with the copper to form a compound, cuprous oxide. As small a quantity as one part of cuprous oxide in a thousand parts of copper is sufficient to cause a great modification of the mechanical properties of the copper. Cuprous oxide is soluble in liquid copper, but only slightly soluble in the solid metal. The cuprous oxide, therefore, which is dissolved in copper when the metal is liquid, separates out as the molten metal cools down and solidifies.

The oxide forms a network around the crystals of pure copper and renders the material brittle. On applying any hot work or cold work to the solid metal a series of inter-crystalline cracks is formed and the material is useless for locomotive firebox purposes.

Consequently, it is necessary to use de-oxidized copper for welding, grades C106 and C107. De-oxidized copper is copper which has been manufactured in the usual way, but to which has been added about 0.015 to 0.080% of phosphorus as a de-oxidizing agent which will combine with the oxygen in the copper and so prevent formation of cuprous oxide.

Further reference: Fusion welding of copper – BS EN 9606-3-1999

17. Tacking Joints

Tacking to preserve alignment is not advised owing to the weakness of copper on account of the metal being “short” and possessing no tenacity at red heat. When welding long seams, tapered spacing clamps or jigs should be used to ensure correct spacing of the joint, care being taken that these do not put sufficient pressure on the edges to indent them when hot.

18. Preparation for copper welding

As is the case with any welding operations carried out on pressure vessels, any proposed repairs by Copper welding must be discussed and agreed with the Competent Person prior to commencing work, and the welding carried out by a qualified operator under an approved procedure.

The welder should bear in mind that merely heating the copper to red heat in the atmosphere and allowing it to cool down is sufficient for oxygen to be absorbed and give rise to toxic cuprous oxide which also weakens the metal.

It will be appreciated that not only must the material being welded be de-oxidized copper, but the welding rod used must be similarly a special rod and not just a rod of pure copper. There are several proprietary brands of welding rod available, each containing a sufficient quantity of a suitable de-oxidizing agent.

As most welds involving the replacement of plate work are only accessible from one side, all weld preps will be of a single vee or J type. If access can be gained to both sides, this route should be taken.

A double-sided weld requires a much smaller prep, reducing the amount of filler required and hence reducing distortion. Weld preparations and details are covered in several British standards; Welding procedures should be approved to BS EN ISO 15614-6 and welders should be approved to BS EN ISO 9606-3.

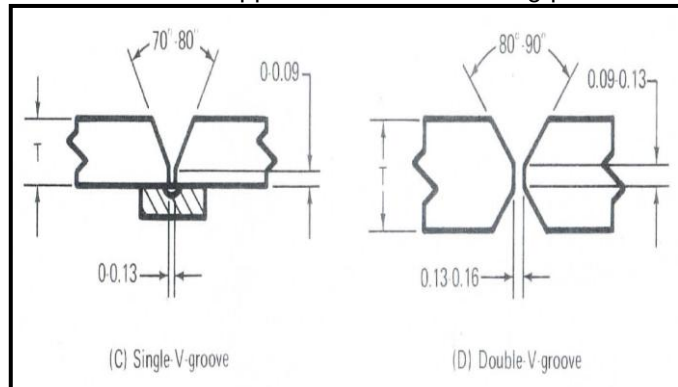
The surfaces are thoroughly cleaned and the edges are prepared by grinding and chipping. Copper has a high coefficient of expansion, and it is necessary therefore to set the plates diverging at the rate of 3/16" per ft. run, because they come together so much on being welded.

Since copper is weak at high temperatures, the weld should be well supported – a steel backing plate under the weld prep will hold the plates in alignment, allow for back purging on a double-sided weld, and prevent 'burn through' on a single sided weld. Care should be taken to avoid fusing the support to the weld.

A single sided weld may be backed with a thin copper strip to assist root fusion while protecting the support.

Typical weld preparations for copper are shown in the diagram opposite:

(Diagram dimensions are in inches)



Copper Welding rod Filler Materials

Covered and bare welding consumables are available for welding copper. When selecting the size of filling rod this should be larger than for welding steel of a similar thickness. Copper electrodes and rods are generally produced with a minimum copper content of 98% for gas metal arc welding of deoxidized copper. Covered /cored electrodes are generally manufactured with deoxidized copper core wire; for TIG and MAG use BS2901 Part 3 C1, C7 or C21 and for oxy-acetylene use BS EN 12536:2000.

Preheating

The relatively high thermal conductivities of copper result in the rapid conduction of heat from the weld joint to the surrounding base metal. Heat loss from the weld zone can be reduced by preheating the base metal to decrease the temperature differential.

The optimum preheat temperature depends on the welding process and the metal thickness or mass. Thin sections or high energy welding processes, such as gas metal arc, generally require less preheat than do thick sections or low energy welding processes, such as gas tungsten arc and oxy-acetylene welding.

When preheat is used, the base metal adjacent to the joint must be heated uniformly to temperature. The temperature should be maintained until the joint is completed.

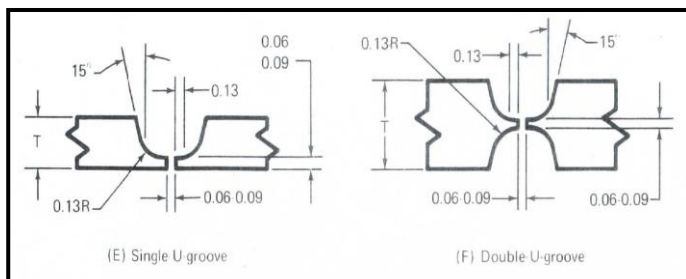
Heat loss should be minimized, where appropriate, by insulating the parts with appropriate materials.

19. Arc Welding De-oxidized Copper

Welding of copper was carried out almost entirely by the oxy-acetylene process. Modern welding methods such as the gas tungsten arc (TIG) and Metallic Inert Gas (MIG) arc processes are now used.

A material of low conductivity, such as steel, can be arc welded satisfactorily at a comparatively high speed and usually less skill is required than for gas welding. Owing to the high thermal conductivity of copper, however, a larger heat input is required which necessitates some pre-heating and higher currents. An additional disadvantage is the ease with which gases are absorbed by the metal at the high temperature of the arc, resulting in porous welds.

20. Gas tungsten arc (TIG)welding



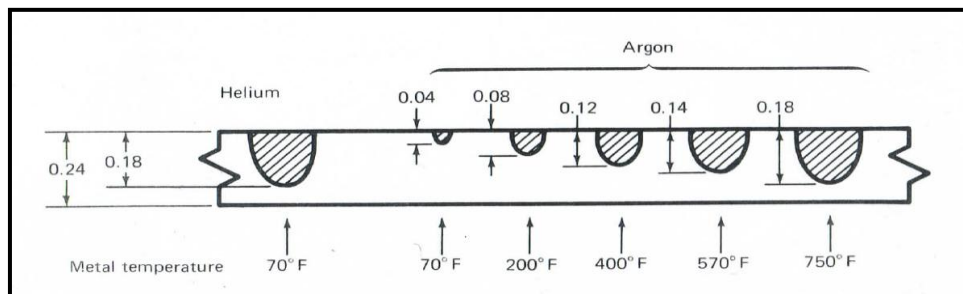
Gas tungsten arc welding (TIG) is best suited for all sections. It can be used advantageously for thicker sections when welding in a position other than flat. Typical joint designs for gas tungsten arc welding of copper are shown in the figure to the left.

A grooved copper backing strip may be used to aid in the control of root surface contour.

(Diagram dimensions are in inches)

Shielding Gases for Gas Tungsten Arc and MIG

Argon shielding is preferred only for welding thin sections. With thicker sections, low travel speeds and high preheat are required with argon shielding. Helium is preferred for welding thicker sections as it has a higher ionisation voltage so increases the heat input for a given current setting. The weld pool is more fluid and cleaner, and the risk of oxide entrapment is considerably reduced. Compared to argon, it permits deeper penetration or higher travel speeds at the same welding current. The diagram to the right illustrates the differences in penetration in copper with argon and helium as well as the effect of pre heat temperature with argon.



Effect of shielding gas and preheat temperature on weld bead penetration in copper when tungsten arc welding with 300 A dc at a travel speed of 8 in /min. Dimensions are in inches.

Mixtures of these gases result in intermediate welding characteristics. For welding positions other than flat, a mixture of 65 to 75% helium- argon produces a good balance between the penetrating quality with pure helium and the ease of control with argon.

Welding Technique

Either forehand or backhand welding may be used. Forehand welding is preferred for all welding positions. It can provide a more uniform, smaller bead than with backhand welding. However, a larger number of beads may be required to fill the joint. The joint should be filled with one or more stringer beads or narrow weave beads. Wide oscillation of the arc should be avoided because it intermittently exposes each edge of the bead to the atmosphere and consequent oxidation. The first bead should penetrate to the root of the joint and be fairly thick to provide time for de-oxidization of the weld metal and to avoid cracking of the bead.

Typical pre-heating temperatures and welding conditions for gas tungsten arc welding of copper are shown below. The conditions should only be used as guides for establishing welding procedures for a particular application. The high thermal conductivity of copper and the rapid conduction of heat from the joint area into the components and the fixturing make it difficult to give welding conditions suitable for all applications. High welding current should not be used to compensate for lack of preheat.

Typical conditions for manual gas tungsten arc welding of copper							
Metal thickness In	Joint Design	Shielding Gas	Tungsten Electrode diam, in	Welding Rod diam, in	Preheat Temp °F	Welding current A	No. of passes
0.5	E	He	0.125, 0156	0.125	650	350-420	4-6

0.62 and above	F	He	0.188	0.125	750 min.	400-475	As required
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21. Gas Metal Arc Welding

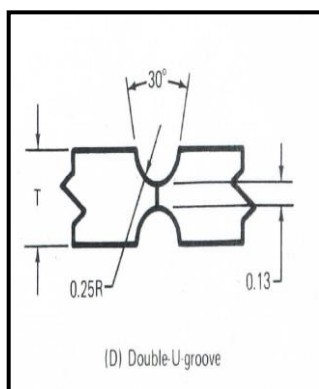
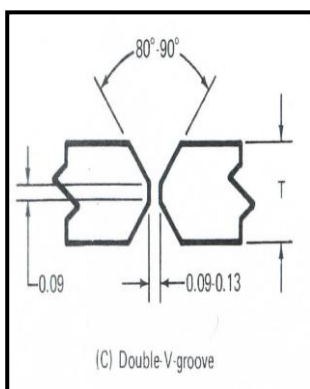
Shielding Gases

A mixture of 75% helium/ 25% argon is recommended for gas metal arc welding of copper. The helium-argon mixture is recommended for welding of thicker sections because the preheat requirements are lower, joint penetration is better, and filler metal deposition rates are higher.

Welding Technique

Type ERCu copper wire is recommended for welding copper. The proper wire size will depend on the base metal thickness and the joint design. The filler metal should be deposited in stringer beads or narrow weave beads. Wide weaving of the electrode may result in oxidation at the edges of the bead. Approximate minimum conditions for spray transfer with copper electrodes and argon/helium shielding are given below.

Typical conditions for gas metal arc welding of copper								
Electrode								
Metal thickness In	Joint Design	Shielding Gas	Diam In.	Feed In/min	Preheat Temp °F	Welding Current A	Travel speed In/min	No. of passes
0.50	C	75% He 25% Ar	0.062	210-270	600	330-400	8-14	2-4
0.63 and above	D	75% He 25% Ar	0.062 0.094	210-270 150-190	800 800	330-400 500-600	6-12 8-14	As req As req



Suggested joint designs for gas metal arc welding of copper are shown to the left. Typical preheat temperatures and welding conditions are given above. These should only be used as a guide in establishing suitable welding conditions that are substantiated by appropriate tests.

The forehand welding technique should be used in the flat position. In the vertical position, the progression of welding should be up. Gas metal arc welding of copper is not recommended for the overhead position because the bead shape will be poor. Gas tungsten arc welding is the preferred method for this position.

(Diagram dimensions are in inches)

22. Firebox Welding Repairs

Items that may require welding include: - Replacing half sides, flange inserts in doorplate or tube plate, firehole inserts, firehole bulbs, welding cracks between stay holes, building up flanges, building up tube plate between tube holes, filling in flange rivet holes, filling in caulking holes, welding cracks from rivet holes, welding fractured tube plate bridges and welding fractures in flange radii in tube plate and door plate.

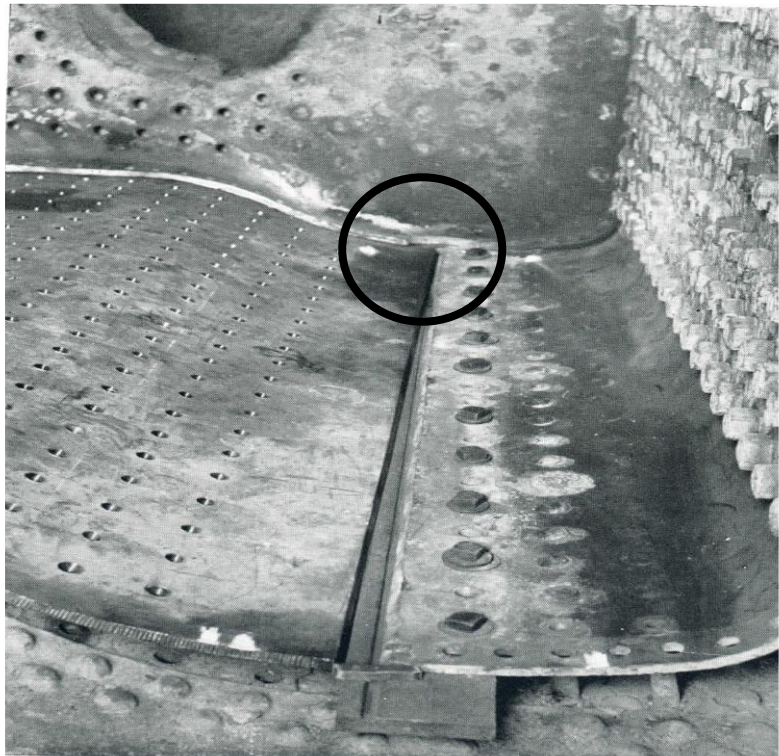
Standards and parameters for repair welding are the same as for new construction apart from techniques applicable to each type of repair. See Platework guidance note HGR-B9020 for the minimum plate thickness permissible.

The type of weld preparation process and procedure adopted will depend on the individual circumstance and conditions. Generally speaking, it will not be possible to let in an insert into centre of the plate due to expansion and contraction problems, resulting in weld cracking.

Where weld repairs are to take place, any stays, rivets or flange studs in that area should be removed prior to welding and replaced upon completion of repairs. Fire erosion is to be weld repaired after removal of copper or steel stays. Large areas would require plate renewal.

When a three-quarter side weld is made with the fire-door plate or tube plate in position, access to the ends of the seam is provided by cutting out a half-moon piece from the fire-door or tube plate flange, a new piece of plate being subsequently welded into the flange (see circle on diagram).

When welding the longitudinal seam of three-quarter sides, a steel backing bar is used to support the joint and guide the new side. With the seam horizontal, the plate is clamped in such a way that a tapering gap allows for expansion and the new plate can move to close the gap as welding progresses.



23. After treatment

Assuming that the copper welds are sound, the deposited metal is obviously in the cast condition and in order to improve the strength it is necessary to work-harden by light hammering the welded seam, where practicable. It is best applied to the weld and to the metal adjacent to the weld at low heat, as this serves to remove contractional stresses and to consolidate the surface of the weld.

Non-Destructive Testing and Weld Inspection of Copper

On completion of welding all welds should be tested to specification approved by the Competent Person.

The major methods of testing and inspection available are:

BS EN ISO 17637:2011 Visual testing of fusion-welded joints.

ISO 3452: 2008 parts 1 to 6 Penetrant testing.

BS EN ISO 17640: 2010 Ultrasonics.

BS EN ISO 17636: 2013 Radiography.

BS EN ISO 5173: 2010 plus A1 2011 Destructive tests on welds in metallic materials – bend tests.

BS EN 9712: 2012 NDT and certification/qualification of NDT personnel.

24. Acceptance of Weld Quality

Assessment of weld quality is laid down in appropriate standards:

Steel: refer to BS2790 Design and Manufacture of Shell Boilers of Welded Construction, also BS EN 12953:2002.

Copper: refer to BS EN 12953 -Shell Boilers Part 4.

See also:

ASME Boiler and Pressure Vessel Code V Non-destructive Examination.

ASME Boiler and Pressure Vessel Code 1X Welding and Brazing Qualifications.

BS EN ISO 5817:2007 Arc welded joints in steel, guidance on quality levels for imperfections.

BS EN ISO 3834-1-2005 Quality requirements for welding.

BS EN 13585:2012 Brazing and Brazer Appraisal.

BS EN 13134:2000 Brazing Procedure Appraisal.

25. References

BS2790:1992 Specification for design and manufacture of shell boilers of welded construction, also BS EN 12953:2002

The Science and Practice of Welding 1993 - A C Davies - C.U.P. (2 volumes).

The Welding, Brazing and Soldering of Copper and its Alloys Copper Development Association.

The Application of Welding to Locomotive Firebox Construction – Paper no 511 Institution of Locomotive Engineers.

Copper and Copper Alloys for Locomotive Firebox Construction Paper no 393 Institution of Locomotive Engineers.