

BOILER CODE OF  
PRACTICE (BCOP)



## GUIDANCE NOTE

# INNER FIREBOX REPAIR AND RENEWAL

### 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).

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## Table of Contents

<b><i>SECTION</i></b>	<b><i>Page Number</i></b>
1. Introduction .....	3
2. Units .....	3
3. Personal Protective Equipment .....	3
4. Inspection.....	3
5. Repair of Copper Inner Fireboxes .....	3
a) Welding of Copper Firebox Plates .....	3
b) Patching of Copper Firebox Plates.....	4
c) Reduced Lap Joints .....	6
d) Cracked Corner Radii .....	6
e) Reduced Plate Thickness .....	6
f) Quilted Plates .....	6
g) Bulged Plates.....	7
h) Corroded Lap Seam Rivets .....	7
i) Repair of stay holes .....	7
j) Repair of Fusible Plug Holes .....	7
k) Oversize tube holes or cracked tubeplate ligaments.....	8
6. Repair of Steel Inner Fireboxes .....	8
a) Welding of Steel Firebox Plates .....	8
b) Cracked Corner Radii .....	8
c) Reduced Plate Thickness .....	8
d) Bulged Plates.....	9
e) Corroded Lap Seam Rivets .....	9
f) Grooving .....	9
g) Repair of Stay holes .....	9
h) Repair of Fusible Plug Holes .....	9
i) Oversize Tube Holes or Cracked Tubeplate Ligaments.....	10
7. Replacement Inner Fireboxes.....	10
a) Design.....	10
b) Factors to be Considered when Converting Fireboxes from Copper to Steel.....	10
c) Factors to be Considered when Converting Fireboxes from Riveted to Welded Construction .....	11
8. Materials .....	11
9. References.....	11

## 1. Introduction

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 will also be useful to those in a supervisory or more general role, however no work should be undertaken unless the people concerned are deemed competent to do so.

Where managements 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 and a formal minute is recorded of both the reasons for and the decision reached.

## 2. Units

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 the original designs were documented have been used.

The term "psi" is used to indicate pressures in pounds per square inch.

## 3. 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

- In accordance 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.

## 4. Inspection

In the event of finding any problem with the firebox seek guidance from the boiler Competent Person before commencing any work.

## 5. Repair of Copper Inner Fireboxes

### a) Welding of Copper Firebox Plates

Copper plate that was deoxidised during the production process can be successfully welded by the Oxy Acetylene, MIG or TIG processes. This includes the grade C107 Phosphorous Deoxidised Arsenical Copper often used for locomotive fireboxes. However, it is not possible to produce welds of sufficient quality in non deoxidised or "Tough Pitch" copper, e.g., grade C105.

***It is essential therefore that the grade of copper is ascertained by chemical analysis before any welding repairs are attempted.***

*Welding repairs must only be undertaken by suitably qualified ("coded") personnel working to specified procedures that are acceptable to the boiler competent person.*

**b) Patching of Copper Firebox Plates**

If a welded repair is impractical then a patch repair to a copper plate may be possible subject to the approval of the boiler competent person.

The defective area of plate should be cut away and the patch ideally applied to the waterside of the hole, unless this would severely restrict the water space in which case it may be applied to the fireside. See Fig 1.

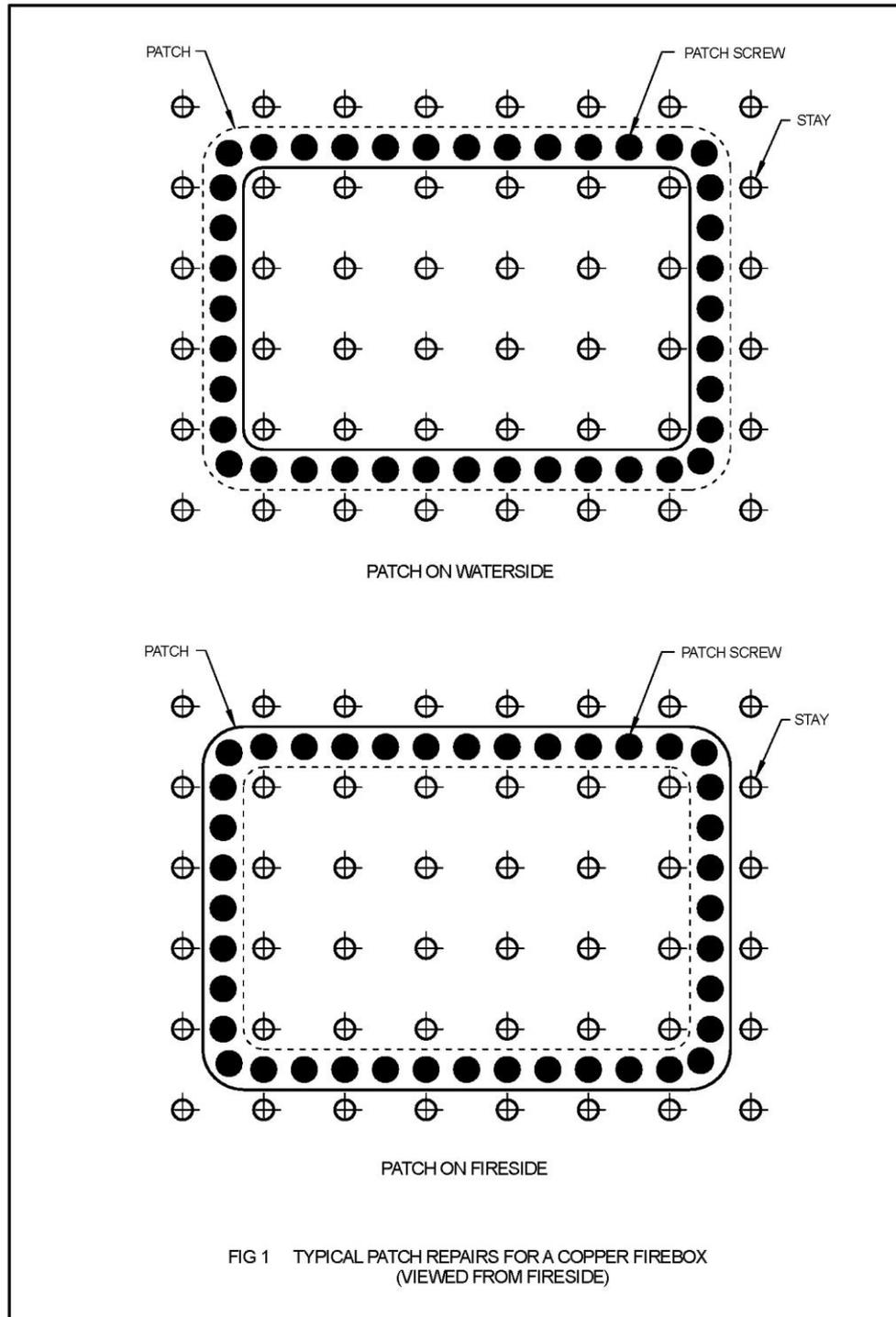
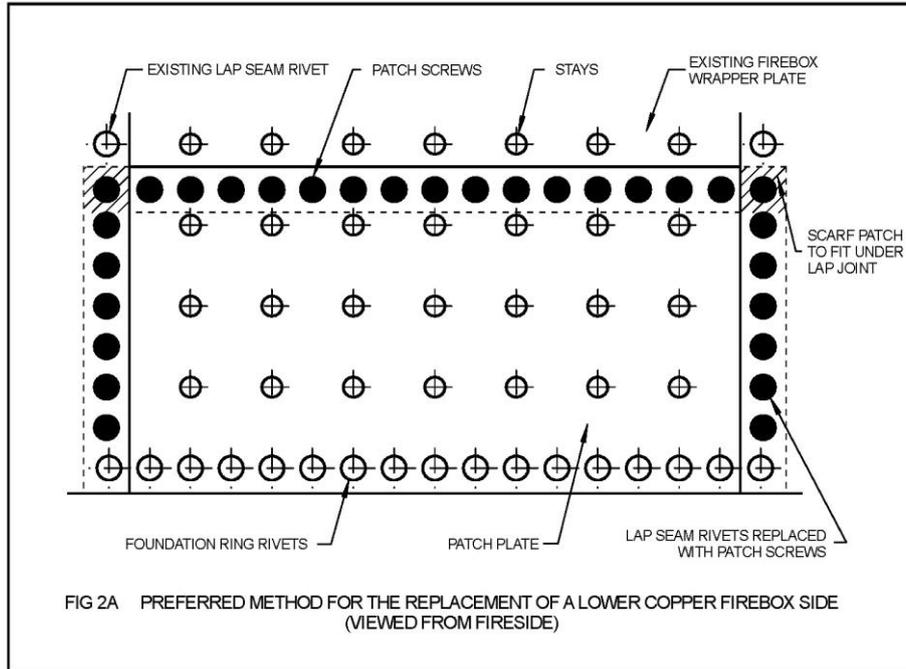
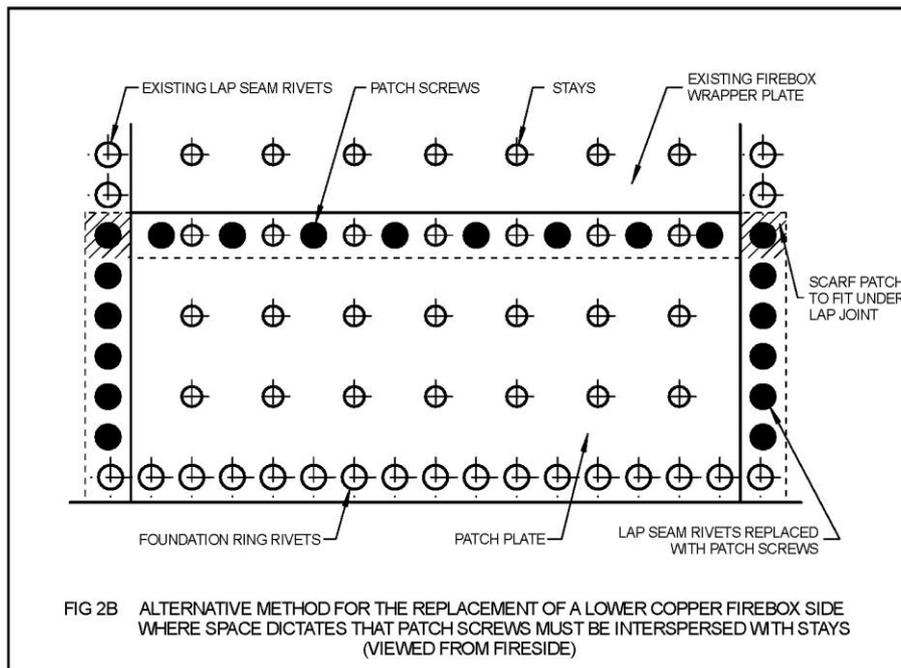


FIG 1 TYPICAL PATCH REPAIRS FOR A COPPER FIREBOX (VIEWED FROM FIRESIDE)

Alternatively, the patch can extend down to the foundation ring as shown in Fig 2A.



If space is restricted then lap seams may encompass both patch screws and stays as shown in Fig 2B.



In all cases, the overlap of the patch should be kept to a minimum to reduce the risk of the caulked edge becoming overheated. The patch should be carefully bedded to the firebox plate and the patch screws should normally be at between 1 7/8 and 2 1/8" pitch. (For further details of patch screws see separate Guidance Note B9025).

Note that if a patch is inserted in the firebox crown, the low water level and/or fusible plug position may require alteration to suit the slightly different level of the patch relative to the original plate.

### c) Reduced Lap Joints

The rivet centre line to lap edge distance can become reduced due to wastage or repeated caulking of the joint. In this case the lap may be built up with weld or it may be cut back and a new lap butt welded in place. Note that in both cases this is subject to the material being suitable for welding (see above) and that the firebox is at least partially dismantled in order to give complete access to the edge of the plate that is to be repaired. The area of plate around the lap seam rivet holes should be checked for cracks using a suitable NDT method, e.g. dye penetrant, before refitting any rivets or patch screws.

### d) Cracked Corner Radii

Cracks in tubeplate, throatplate and doorplate corner radii may be welded provided that they do not completely penetrate the plate and the material is suitable for welding, (see above).

The crack should be fully removed by chipping or grinding and its removal verified by dye penetrant testing. The ground area should then be filled with weld and ground flush.

If there are multiple cracks or the crack has penetrated through to the other side of the plate then it is recommended that area be replaced with a set in patch or the entire plate replaced.

### e) Reduced Plate Thickness

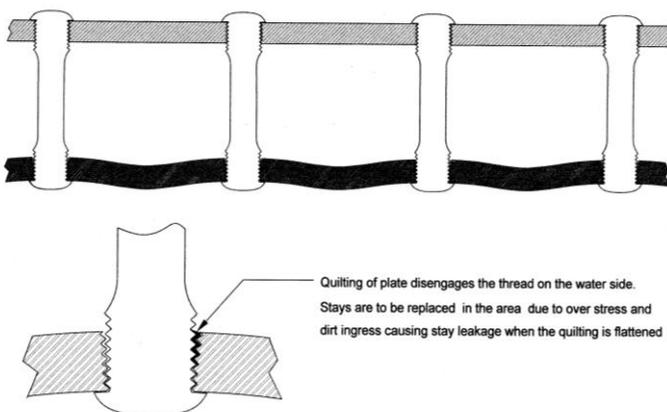
The allowable degree of wastage depends upon several factors, e.g. the pitch of the stays, the flatness of the plates, the working pressure and condition of the material in the affected area.

If it is determined that the plate has excessively thinned then, as a general guide, a plate may be built up with weld provided that the material is suitable for welding, it has not thinned to below 70% of its original thickness, and that the wasted area extends no further than that supported by any four stays.

Plates thinned to less than 3/8" should only be welded using MIG or TIG processes as Oxy Acetylene welding of thin sections can cause cracking of the plate. Plates thinned below 5/16" should not be welded by any process for the same reason.

In all other circumstances the affected area of plate should ideally be cut out and either a new piece welded in place or a patch applied. Welded in plates should have rounded corners to avoid stress concentrations and be attached using full penetration butt welds. Single sided welds are permitted where unavoidable but in all cases the weld should be verified by suitable NDT methods. Welded joints should wherever possible go midway between the stay holes and not through them.

### f) Quilted Plates



If the boiler pressure has pushed the firebox plate towards the fireside in an area between some stays, the plate is normally referred to as being "quilted".

Quilting of the plate is caused by a loss of strength due to overheating as a result of a shortage of water, or the build up of scale or oil on the waterside. It could also be due to a lamination within the plate.

In all cases the cause should first be identified and corrected. In addition, the thickness of the plate should be checked by ultrasonic testing or by drilling a small hole which is subsequently plugged. This will permit the identification of thinned or laminated plates.

**Fig 3 Quilting of plates**

If the quilting is not severe, and the plate still has sufficient thickness, then repair may not be essential but the condition should be monitored in service. Alternatively, the plate can either be pushed back with a jack,

or a rivet gun and a flat snap. However, in more extreme cases the section of plate should be replaced. Note that any pushing back of the plate should be performed cold as localised heating can result in cracking.

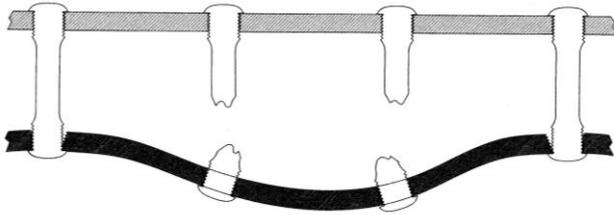
In all cases the stays in the quilted area must be renewed.

### g) Bulged Plates

If the boiler pressure has pushed the firebox plate towards the fireside in an area that extends beyond some stays, the plate is normally referred to as being "bulged".

Bulging of the plate is caused by one or more broken stays.

If the bulging is not severe, and the plate still has sufficient thickness, it can either be pushed back with a jack, or a rivet gun and a flat snap. However, in more extreme cases the section of plate should be replaced. Note that any pushing back of the plate should be performed cold as localised heating can result in cracking.



Any stays in the vicinity of those that have broken will have been subjected to additional loading and may have been weakened. These stays should therefore be renewed along with the broken ones.

**Fig 4: Bulged Plates**

### h) Corroded Lap Seam Rivets

Lap seam rivets with excessively corroded heads should be replaced with new rivets where ever possible. If the fitting of rivets is not practical then copper or steel patch screws may be used.

As the old rivets are removed, they should be replaced with bolts such that there are never more than two adjacent empty rivet holes. This will help prevent the plates from springing apart. If the plates are not a close fit, for instance if a new flange has been attached, then every hole should be bolted.

To further ensure that the plates are a close fit, a flat bob tool in a small pneumatic hammer should be used to hammer the plate around the bolts. The bolts should then be re-tightened before riveting commences.

For further details of patch screws and their applications see separate Guidance Note.

### i) Repair of stay holes

Stay holes with worn or damaged threads should be re threaded to take the next size of stay. If the holes are already at maximum size, it is sometimes possible to partially fill the hole with weld and re thread. Otherwise, the firebox plate should be replaced, or a patch repair considered.

Damage to the plate in the vicinity of the hole as a result of excessive caulking of the stay may be built up with weld subject to the material being suitable for welding (see above).

### j) Repair of Fusible Plug Holes

Fusible plug holes with worn or damaged threads should be re threaded to take the next size plug and where required spot faced square with thread. If the hole is already at maximum size, it should be plugged and a new hole cut.

The material for the new bush should be Copper Plate (BS2875 - C107) or Copper Bar (BS2874 - C107).

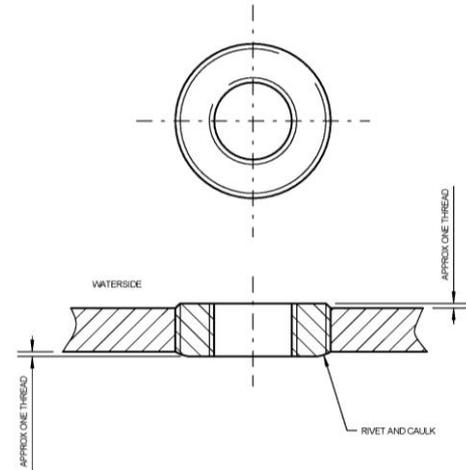
The location of the new hole should be as follows:

- Where one or more plugs were fitted on the centre line of the crown plate the new hole(s) should be as close as possible to the old but equidistant from four adjacent stays.
- Where two plugs were fitted at diagonal corners the new plugs should be in corresponding positions on the opposite diagonal.

Care should be taken not to position a new hole directly below an obstruction such as a longitudinal or transverse stay.

If there are no alternative hole positions available then, subject to there being sufficient plate thickness, a damaged hole may be opened out and threaded to take a bush. The bush should be riveted and caulked on the fireside to prevent it coming loose. See Fig 5.

**Fig 5: Typical method for fitting a Fusible Plug bush to Copper Fireboxes**



### k) Oversize tube holes or cracked tubeplate ligaments.

Please refer to the relevant sections of the Guidance Notes on the fitment of boiler tubes.

## 6. Repair of Steel Inner Fireboxes

### a) Welding of Steel Firebox Plates

Welding repairs to steel fireboxes should not cause any difficulty except that some early boilers (pre c.1890) were made of wrought iron or "Lowmoor" iron and no attempt should be made to weld these materials.

***It is essential therefore that the nature of the steel is ascertained and recorded before any welding repairs are attempted.***

***Welding repairs must only be undertaken by suitably qualified ("coded") personnel working to specified procedures that are acceptable to the boiler competent person.***

### b) Cracked Corner Radii

Cracks in tubeplate, throatplate and doorplate corner radii should be fully removed by chipping or grinding and their removal verified, ideally by magnetic particle inspection, ultrasonic or by dye penetrant testing. The ground area should then be filled with weld and ground flush.

If there are multiple cracks or the crack has penetrated through to the other side of the plate then it is recommended that area be replaced with a set in patch or the entire plate replaced.

Welded in plates should have rounded corners to avoid stress concentrations and be attached using full penetration butt welds. Single sided welds are permitted where unavoidable but in all cases the weld should be verified by suitable NDT methods eg dye penetrant or magnetic particle inspection.

### c) Reduced Plate Thickness

The allowable degree of wastage depends upon several factors, e.g. the pitch of the stays, the flatness of the plates, the working pressure and condition of the material in the affected area.

If it is determined that the plate has excessively thinned then, as a general guide, a plate may be built up with weld provided that the material is suitable for welding, it has not thinned to below 70% of its original thickness and that the wasted area extends no further than that supported by any four stays.

In all other circumstances the affected area of plate should ideally be cut out and a new piece welded in place. Welded in plates should have rounded corners to avoid stress concentrations and be attached using full penetration butt welds. Single sided welds are permitted where unavoidable but in all cases the weld should be verified by suitable NDT methods. Welded joints should wherever possible go around, not through, the stay holes.

### d) Bulged Plates

If the boiler pressure has pushed firebox plate towards the fireside in an area that extends beyond some stays, the plate is normally referred to as being “bulged”.

Bulging of the plate is caused by one or more broken stays.

If the bulging is not severe, and the plate still has sufficient thickness, it may be possible to heat the plate and push it back with a jack. However, in more extreme cases, the section of plate should be replaced.

Any stays in the vicinity of those that have broken will have been subjected to additional loading and may have been weakened. These stays should therefore be renewed along with the broken ones.

### e) Corroded Lap Seam Rivets

Lap seam rivets with excessively corroded heads should be replaced with new rivets where ever possible. If the fitting of rivets is not practical then steel patch screws may be used.

As the old rivets are removed, they should be replaced with bolts such that there are never more than two adjacent empty rivet holes. This will help prevent the plates from springing apart. If the plates are not a close fit, for instance if a new flange has been attached, then every hole should be bolted.

To further ensure that the plates are a close fit, a flat bob tool in a small pneumatic hammer should be used to hammer the plate around the bolts. The bolts should then be re-tightened before riveting commences.

(For further details of patch screws and their applications see separate Guidance Note).

### f) Grooving

Grooving is caused by stress corrosion as a result of the continual thermal and pressure cycling to which a locomotive boiler is subjected. It is most common adjacent to a fixed point like the foundation ring but can occur at any lap seam. In minor or isolated cases, it may be possible to build the area up with weld. However, the welding of an already highly stressed area is often not desirable and consequently a better solution is to replace the area of plate.

### g) Repair of Stay holes

Stay holes with worn or damaged threads should be re threaded to take the next size of stay. If the holes are already at maximum size, the firebox plate should be replaced or a patch inserted. Alternatively, in isolated cases, the holes may be filled with weld and then re-drilled and threaded.

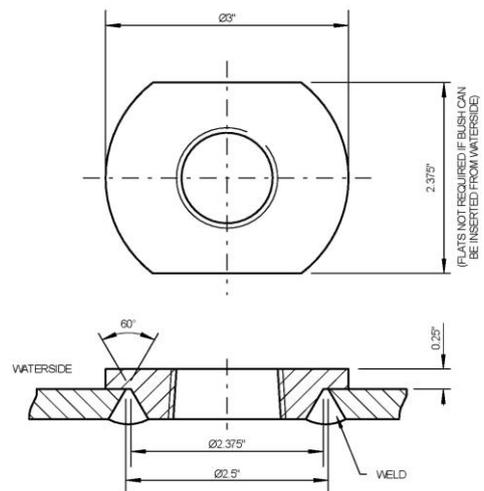
### h) Repair of Fusible Plug Holes

Fusible plug holes with worn or damaged threads should be re threaded to take the next size plug. If the hole is already at maximum size then, subject to there being sufficient plate thickness, it should be fitted with a bush threaded to take the standard (smallest) size of plug.

The material for the new bush should be Boiler Plate (BS EN10028-2 P265GH) or Mild Steel Bar (BS970:070M20 or BS970:080M15).

The bush should ideally be of “top hat” section and be fitted from the waterside. Alternatively, it can be of “top hat” section but with a pair of “flats” to allow it to pass through the hole from the fireside. See Fig 6.

If neither option is practical then a plain bush may be fitted. In all cases the weld should be of full penetration and from the fireside.



**Fig 6: Typical method for fitting a Fusible Plug bush to Steel Fireboxes**

**i) Oversize Tube Holes or Cracked Tubeplate Ligaments.**

Please refer to the relevant sections of the Guidance Notes on the fitment of boiler tubes.

**7. Replacement Inner Fireboxes****a) Design**

It was common within the British Isles for locomotive fireboxes to be of riveted copper construction. Such fireboxes are expensive, although relatively long lasting, compared to the welded steel fireboxes favoured elsewhere within Europe and in America.

It is permitted to change the firebox design and/or material during renewal provided this offers no increased risk to the operation of the boiler. Hence any design change should be reviewed and documented by the Competent Person before work commences.

**b) Factors to be Considered when Converting Fireboxes from Copper to Steel**

The properties of copper compared to steel can be summarised as:

- better conductor of heat (7 times as great);
- much greater corrosion resistance; and
- greater ductility

but:

- lower strength, particularly at elevated temperature;
- higher coefficient of expansion (1.5 times as great);
- higher cost; and
- difficult to obtain in the arsenical form best suited to high temperature use.

Hence if changing from copper to steel the following factors should be considered:

- Steel is stronger than copper so the plate thickness can be reduced.
- Reducing the plate thickness will help with the heat transfer but note that this is still likely to be only about 30% of that for copper. Burning of the plate due to hot spots may therefore occur.
- Steel corrodes much faster than copper so the plate thickness chosen needs to include a corrosion allowance. Even then the life of the firebox may only be one half to one third of that for copper. It is strongly recommended therefore that boiler water treatment should be used. (see Boiler Water Treatment guidance notes B9118).
- The greater expansion of copper firebox tubeplates compared to steel boiler tubes helps to maintain a watertight seal. Steel tubeplates containing steel tubes are however more susceptible to leakage and it may be necessary to do more than just expand the tubes into the tubeplate. Seal welding is common practice but other methods include copper liners between the tube and tubeplate or internal tube ferrules. The choice of a suitable method should be discussed and agreed by the boiler competent person.
- The lower ductility of steel (together with lower corrosion resistance) can result in cracks forming in the firebox corner radii. The use of flexible stays adjacent to the firebox corners should be considered.

