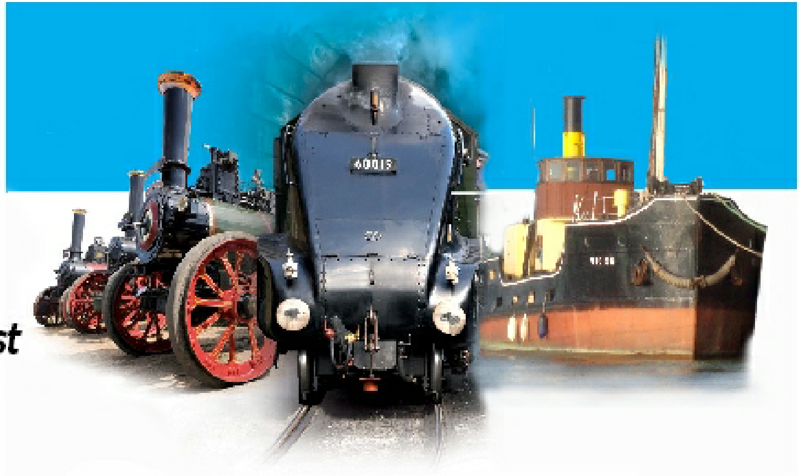
Bestt

Boiler & Engineering Skills Training Trust



Please note that this Content may change.
These boiler training modules, incorporating sections of the HRA/ORR boiler code of practice, were prepared in 2013 as part of the HLF funded BESTT training plan project and will be progressively reviewed and updated by the BESTT Technical Committee.

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Boiler & Engineering Skills Training Trust

Platework

Proposed Syllabus 2013

To be used in conjunction with:

HRA Guidance Note HGR-B9020- Is01

BESTT acknowledges the support of the HRA for allowing the use of the Guidance Notes

Proposed BESTT Syllabus Assessment Plan

Module: BESTT 9020

Platework
This module is to used in conjunction with HRA Guidance sheet BS9020–Is01

Aim
This unit will give the learners an understanding of platework applicable for use on steam boilers

Introduction
This unit will give practical knowledge of:
- Inspection
- Materials
- Building up
- Cracking
- Patches and Inserts
- Production of platework
- Production of flanged plates
- Heat Treatment
- Lapped Joints and seams
- Welded joints and fabrications
- Grades of Steel

Learning Outcomes
The numbers in parenthesis refers to the HRA Guidance note section.
Learning outcome 1 could be delivered in a classroom environment.
LO1
1. Identification of steam boiler components (5)
2. Identification of materials including grades of steel (6)
3. Grade of copper (6)
4. Traceability of material (6)
5. Lamination (6)
6. Checking for de-lamination (6)
7. Edge preparation (6)
8. Cleanliness (6)
9. Plate lamination (6)

LO2
1. Building up by welding (7)
2. Cracking of stay holes and seams (8)
3. Inspection aids (8)
4. Repairing cracks (8)
5. Cracks in plates with large radii (8)
6. Star cracking of stay holes (8)
7. Adjacent holes experiencing star cracking (8)

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LO3

1. Patches and Inserts (9)
2. Fixing a patch using patch screws (9)
3. Thickness variation (9)
4. Welded inserts (9)
5. Corner radii (9)
6. Good and bad patching (9)
7. Mismatched plates (9)
8. Barrel patches (9)
9. Weld peaking (9)

LO4

1. Forming of plates in copper (10)
2. Forming of plates in steel (10)
3. Temperature measurement (10)
4. Plate shaping using a press brake (10)
5. Stress caused by welding (10)
6. Overlap seams (10)
7. Tapered Barrel sections (10)

LO5

1. Flanging of boiler plates (i) (11)
2. Flanging of plates (ii) (11)
3. Fabrication of tube plates (11)
4. Alternate design for front tube plate (11)
5. Heat treatment (12)
6. Lapped joint and seams (13)
7. Building up of lap seams (13)
8. Fullering & Caulking (14)
9. Ferrous Metallurgy (17)

On completion of the module the trainee should be able to use correctly and safely the following equipment:

Ultrasonic probe
Heating equipment, Oxy-propane, oxy-acetylene
Heat protective PPE
Non-destructive testing equipment; on completion of the module the trainee should have a basic understanding of the different methods of non-destructive examination.

Assessment

Learners could demonstrate competence in this unit by:

- Documental evidence
- Photographic evidence
- Witness statements e.g. written or verbal statement from a competent person stating that they have completed tasks satisfactorily.
- Underpinning knowledge questions e.g. written questions, multi choice answer sheets, on-line tests, and assignments.
- Practical training tasks

BESTT acknowledges the support of the Heritage Railway Association in allowing us to use their Guidance Notes in this Syllabus.

Ref No: HGR-B9020

Issue No: 01

Issue Date: March 2012

HERITAGE RAILWAY ASSOCIATION

GUIDANCE NOTE

PLATEWORK

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

Endorsement

This document has been developed with and is fully endorsed by Her Majesty's Railway Inspectorate, a directorate of the Office of Rail Regulation (ORR).

Disclaimer

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Supply

This document is published by the Heritage Railway Association (HRA).

Copies are available electronically via our website www.heritagerailways.com

Users of this Guidance Note should check the HRA website to ensure that they have the latest version.

Table of Contents

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” 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 H.M.R.I. and H.R.A. 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.

3. Personal Protective Equipment

Before undertaking any works 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

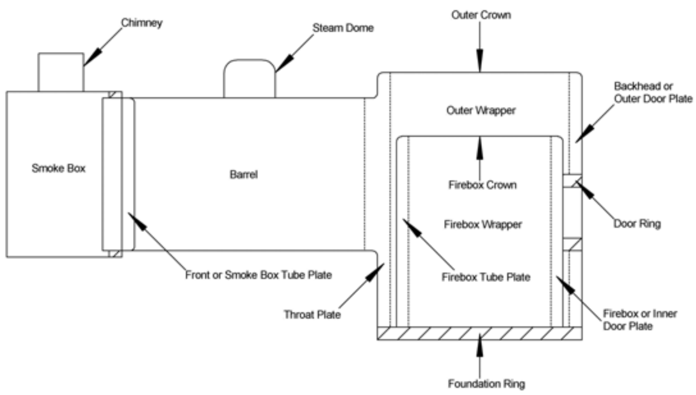
- In accordance with the latest Personal Protective Equipment regulations.
- Properly assessed before use to ensure it is suitable.
- Maintained and stored properly
- Provided with instructions on how to use it safely
- Used correctly by those undertaking the work.

4. Inspection

In the event of any doubt as to any process or the condition of any part; seek guidance from the boiler Competent Person before proceeding.

5. Conventions & Terminology

In this document the described parts of the boiler shall be as the simplified sketch to the right.



Proposed BESTT Syllabus Assessment Plan

Section Number	LO	Objectives	Assessment Criteria	Delivery	Date achieved and Supervisors signature
5	LO1 1	Identification of the principle components of a steam boiler	Draw an annotated diagram of a typical boiler	Classroom	

6. Materials

Existing Materials

Care must be taken to identify the parent materials when repairing boilers. It may be necessary to analyse existing boiler materials to ascertain the parentage. Older boilers may have been made with wrought iron plates or other materials which are prone to internal defects or that are not readily weldable. It may be necessary to take samples for chemical or mechanical analysis to be sure of the make up of the original material.

Copper

Copper plate for boiler work should be phosphorus deoxidised arsenical copper to BS C107 or equivalent.

ISO Designation	British Standard	ASTM Equivalent
Cu Asp	C107 (formerly BS2875)	C14200

This alloy contains between 0.30 and 0.50 percent of arsenic in solid solution and is supplied in the deoxidised condition.

The small addition of arsenic in C107 provides the alloy with enhanced strength properties that are retained at elevated temperatures. Apart from increasing the softening resistance, the arsenic addition also enhances corrosion resistance in specific environments.

Some fireboxes may be made from C105 or tough pitch copper, it may be necessary to analyse the parent material before carrying repairs to ensure the correct material is used. It is extremely difficult to achieve welds of a sufficient quality in tough pitch or C105 copper and other repair methods should be adopted where these materials are present.

Steel

Steel boiler plate should be carbon steel plate to grade BS1501 161 430A/B or equivalent.

British	Indian	German	American	Euro
BS:1501 161 430 A	IS:2041 IS:2100	DIN:17155 HII	ASTM A516 gr 60	EN 10028 P265GH

Traceability

Certificates of conformity for all materials used must be obtained and retained by the responsible person. Copies of all certificates should be sent to the competent person on completion of the repairs.

When receiving materials at the works, check the material for its identifying mark and relate it to any documentation accompanying the material.

All identifying markings must be transferred promptly and accurately when materials are cut. In certain applications the transfer of markings may need to be witnessed by the responsible person.

Marks should be made where they will be visible on an exterior surface of the plate after fitting to the boiler.

Wherever possible, marks should be made where they will cause least stress to the material after any manipulation has been carried out, i.e. away from curves, holes or laps. Soft stamps should be used to mark plate i.e. the letters are of a design, or font, where they do not have sharp edges or corners which can act as stress raisers.

If an identifying mark is altered through further work (drilling, welding etc.), the mark must be re made in a suitable location.

Proposed BESTT Syllabus Assessment Plan

Section Number	LO	Objectives	Assessment Criteria	Delivery	Date achieved and Supervisors signature
6	LO1 2	Older boilers were made from wrought iron, before commencing repair it is important to correctly identify the materials	Be able to take a sample of material for analysis	Workshop	
6	LO1 3	Copper used in boilers must be of the correct quality/grade Tough pitch copper	Identify the correct 'type' of copper, how could you confirm it is of the correct grade?	Classroom	
6	LO1 4	Traceability of materials, steel for use in boilers is BS:1501 161 430 A	Once the steel is marked out and cut how can you ensure traceability	Classroom	

Notes on plate defects

Though rare, it pays to be aware of defects which can occur in rolled plates. Below are some of the more common defects that may be encountered.

Laminations are usually caused by blow holes in the ingot when cast. If the plate is in great length in proportion to its width then the lamination will follow a similar path. Thus in plates, while laminations from blow holes rarely extend more than a few inches across, they may be several feet in length.

Another form of lamination may be caused by the rolls folding over the end of the bloom when rolling it into a plate. When finishing the plate this folded section is rolled tight together and sometimes not entirely sheared off. These laminations may be detected by a faint line along the edge of the plate. Laminations of this kind will generally run across the full length of the edge of the plate but not extend to a great depth.

Lamination failure in modern copper boiler plate

Ultrasonic inspection can be used to diagnose or asses the extent of laminations in new or old boiler plates.

Another class of defect is caused by small cracks in the sides of the ingots when cast. These fractures are flattened down into the plate and are usually detected by a faint irregular line running across or along the plate. When chipped or ground out it is found to extend in a wedge shape to a slight depth into the plate and terminate.

Another defect results from oxide being rolled into the plate and causing pitting. These defects if not immediately apparent, generally show themselves by scale cracking off as the plates are formed. Foreign material is also sometimes rolled into the plate, causing deep sharp pitting and embedding grit into the plate.

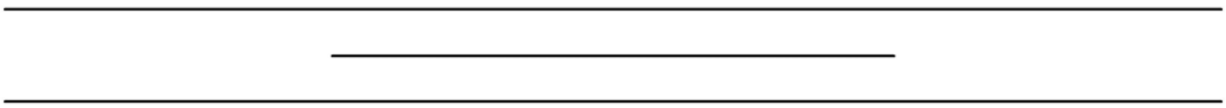
Care must be taken when selecting plate for pressure vessel applications to ensure it is of the highest quality and free of defects.

In wrought iron boiler plates, lamination can result from improper welding together of the layers of which the plate is formed.

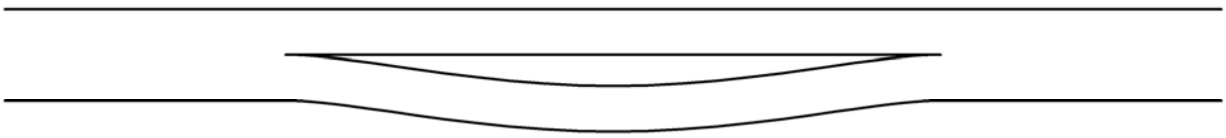
Lamination in existing shell plates

There are probably many boilers in service with undetected laminations however these can come to light during routine inspections particularly when carrying out a random ultrasonic thickness survey. Untreated laminations can blister or bulge particularly in furnace or firebox parts.

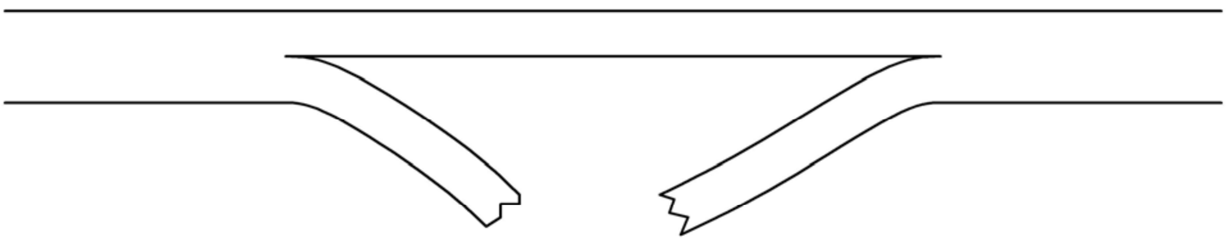
The separation at the defective part restricts the transmission of heat and so leads to overheating of the outer layer of plate, which first blisters or bulges and then splits off.



Lamination in firebox



Bulging of the plate due to overheating



Eventually the plate splits away entirely

Laminations must be reported to the competent person who will make a decision on the course of action. He must consider the location, size and expected stresses to which the area in question will be subjected.

If lamination is discovered on any inner firebox plate or smoke tube or flue tube or other area which is directly heated, the area in question must be replaced.

Mill Scale

Mill scale should be removed from plates prior to working and fitting to the boiler. If it is impractical to de-scale the whole plate, at the very least all mating surfaces must be free of scale.

Handling

Surface damage, such as gouges, in plates can be the starting points for cracks, pitting or grooving. Every effort must be made to avoid, gouging or denting plates. Avoid dragging plates when moving them, or dropping them.

Plate clamps can leave teeth marks in plates when lifting, avoid using such types of clamps where possible or leave excess plate for gripping which can be removed at a later date.

Proposed BESTT Syllabus Assessment Plan

Section Number	LO	Objectives	Assessment Criteria	Delivery	Date achieved and Supervisors signature
6	LO15	Understand lamination	Demonstrate with diagrams what lamination is and describe why it can occur	Classroom	
6	LO16	Understand how to check a barrel for delamination	Be able to use an ultrasonic probe.	Workshop	

Proposed BESTT Syllabus Assessment Plan

Section Number	LO	Objectives	Assessment Criteria	Delivery	Date achieved and Supervisors signature
6	LO1 7	Edge preparation	How are plate edges prepared? Why guillotined or flame cut edges are not acceptable	Classroom	
6	LO1 8	Cleanliness	Why it is important not to have oil or grease on the waterside of the plate	Classroom	
6	LO1 9	Plate lamination	It is suspected that delamination has occurred on some of the original firebox platework, How would you confirm that? How would it affect the performance of a boiler, What are the dangers of a fault going undetected?		

Plate Edges

All plates must have machined edges (i.e. milled or ground). Plates with flame cut or guillotined edges must not be fitted to boilers. Plate must be trimmed at least 10mm back from a guillotined edge. Flame cut edges should be dressed back to remove notches, slag and scale before welding.

Freedom from oil and grease

A layer of oil on the water side of a firebox plate can have a serious effect on the heat transfer in said area of plate. Every effort must be made to prevent oil contamination inside a boiler. Avoid excessive use of oil based cutting compounds or consider using water based cutting and tapping fluids. Any oil spills on boiler plate must be thoroughly removed before steaming.

7. Building Up

Small areas of thinning; pitting and grooving of boiler plates may be built up by welding to restore the area to its original thickness.

On barrel plates no one area of pitting of over 6 sq" (2" X 3" for example) should be repaired by welding nor should the total amount of welding in any one foot square of plate exceed 6 sq". The total area of welding in any one barrel plate should not exceed 24 sq".

Building up of steel plate in the outer shell should be restricted to pitting and grooving which is not deeper than half the original plate thickness.

Building up of copper plates is only permissible where the copper plate is not reduced below 5/16" in thickness.

Care should be taken to minimise the impact of heat during the welding process. Welded areas must be chipped or ground flat and flush after welding is completed.

Preheating the weld area before welding can be advantageous however extreme care will be required, especially in cylindrical plates, to avoid distorting the plate.

Building up by welding must be carried out by a competent welder who should be approved by the competent person. It is recommended built up areas are examined by NDT to ensure the weld metal is free of defects.

Records of areas built up by welding must be maintained and no areas already built up in the past should be built up again at a later date. Subsequent repairs must also comply with the total allowable areas of weld repair as shown above.

8. Cracking

Upon removal of stays, rivets and studs, all holes should be examined for signs of cracking. Plate edges that were not prepared properly before fitting are also prone to cracking and suspect areas should be examined carefully.

Cracks may only be welded by a coded welder. A record of the location of cracks and methods used should be retained by the responsible person. Crack repair should be approached in the same way as new welded joints with regards procedures and materials used.

The competent person must be informed as to the extent of cracking and the method of repair to be adopted.

Detection

While some cracking is visible to the naked eye this is usually only later on in the life of the crack. Most cracking originates on the water side of boilerplates.

Early detection and repair is of utmost importance. Mud holes and mirrors can give a limited view of the water space for examination. There are now mobile cameras available, which may be inserted into the boiler to make the task much easier.

Proposed BESTT Syllabus Assessment Plan

Section Number	LO	Objectives	Assessment Criteria	Delivery	Date achieved and Supervisors signature
6	LO17	Edge preparation	How are plate edges prepared? Why guillotined or flame cut edges are not acceptable	Classroom	
6	LO18	Cleanliness	Why it is important not to have oil or grease on the waterside of the plate	Classroom	
6	LO19	Plate lamination	It is suspected that delamination has occurred on some of the original firebox platework, How would you confirm that? How would it affect the performance of a boiler, What are the dangers of a fault going undetected?		

Modern portable digital camera with built in monitor

NDT will also facilitate crack detection; NDT should be carried out by a suitably skilled person with the agreement of the competent person. Both Dye Penetration and Magnetic Particle inspections are cost effective and simple methods of initial diagnosis.

Cracks in flat plates

A crack in a flat area of plate may be repaired be welding or patching. The crack must be fully ground out. NDT should be employed to confirm the crack is fully removed; MPI is the preferred method for crack detection. The crack may then be welded up by a coded welder in accordance with the approved procedure. The weld should be ground flush with the surface of the plate once welding is complete. The integrity of the weld should be confirmed by NDT once the repairs are complete.

Cracks in tube plates

Cracks in tube plate ligaments should be 'veed' out and welded appropriately. Each weld should be allowed to cool completely before starting another to minimise the stresses imposed on the tube plate. After welding the tube holes should be checked to ensure they have not been pulled out of round.

Cracks in flange radii

It is common for cracks to form in the radius of a flange these can be more extensive and numerous than maybe found in flat plates and therefore may not be suitable for repair by welding. Where cracks are simple and few, repairs may be carried out as for flat plates. The competent person should be informed and approval sought before carrying out repairs to flange radii.

Proposed BESTT Syllabus Assessment Plan

Section Number	LO	Objectives	Assessment Criteria	Delivery	Date achieved and Supervisors signature
7	LO2 1	Building up by welding	Why cannot large areas of thinned and corroded plate not just be built up by welding? What are the limits to the size of this type of repair?	Classroom	
8	LO2 2	Cracking of stay holes and lap seams	Explain how the cracking process is caused and how to check for lack of it in stay holes. Why does most cracking occur on waterside?	Classroom	

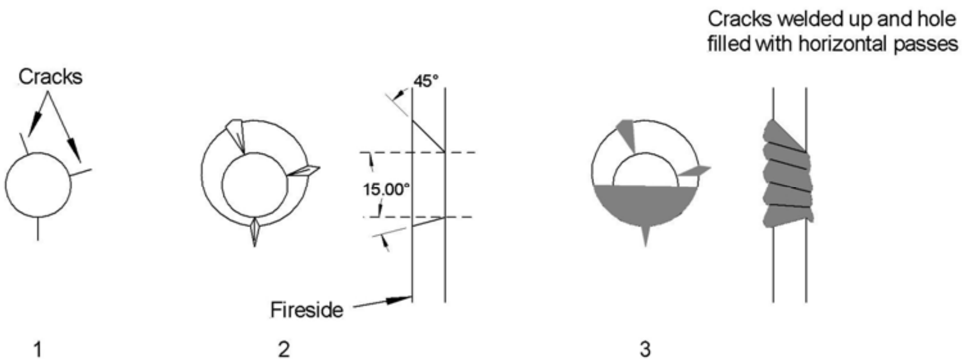
Cracks in a backhead radius, this type of cracking cannot be repaired by welding

The same radius pressed flat to show the severity of the cracking

Front tubeplate radius showing cracking caused by stress corrosion.

Star cracking of stay holes

Star cracking is a common problem in boiler stay holes. Isolated cases may be repaired by welding.



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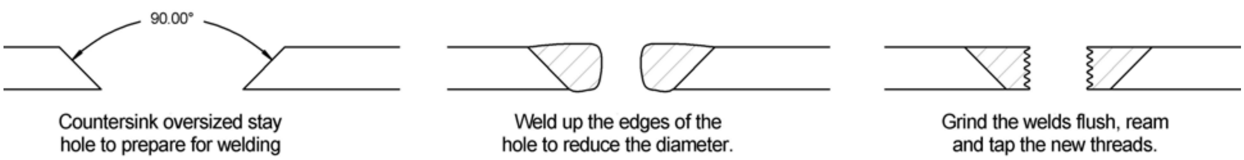
8	LO2 2	Cracking of stay holes and lap seams	Explain how the cracking process is caused and how to check for lack of it in stay holes. Why does most cracking occur on waterside?	Classroom	

- Take out the stay and chip out a V on the crack (1 & 2)
- Weld up the cracks and plug the hole with horizontal passes (3)
- Chip off or grind flush the welded deposit
- Drill and tap the hole
- Replace the stay

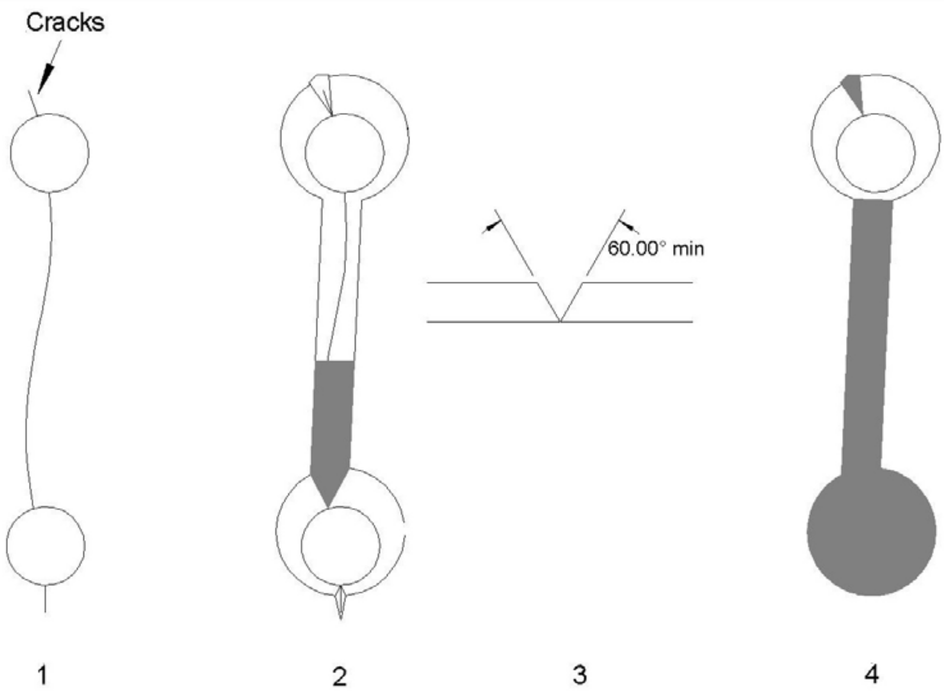
Cracks emanating only a short distance from the hole may also be repaired by the following method which may also be used to restore oversized stay holes to a smaller size. Be sure all cracks have been removed by reaming and countersinking before welding.



Alternative method for repairing cracked or oversize stay holes

A crack connecting two stay holes

Where cracks have connected two stay holes the following procedure should be adopted.



- Take out the stays in the crack line also those in the vicinity so as to give some liberty for the plate to accommodate in view of the welding stresses.
- Bevel out the holes and make a V on the cracks (2 & 3)
- Weld first the principle crack (2), then weld the smaller cracks, finish by plugging the holes with horizontal passes (4) as for star cracking.
- Drill tap and fit the stays.

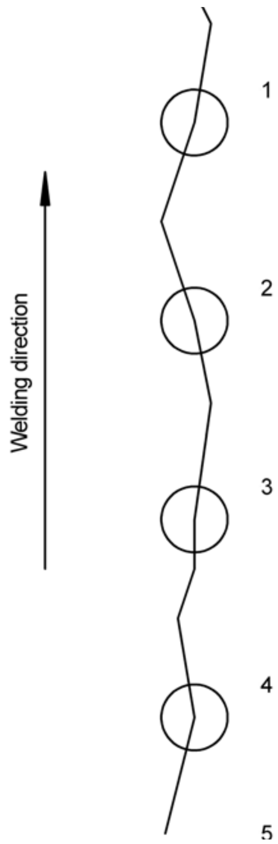
Proposed BESTT Syllabus Assessment Plan

Section Number	LO	Objectives	Assessment Criteria	Delivery	Date achieved and Supervisors signature
8	LO2 7	Adjacent holes experiencing star cracking	How does the method of repair change when two stay holes, one above the other exhibit star cracking	Classroom	

Crack propagating along several holes

Carry out the repair in upward passes as shown, in 'steps' namely 2 to 1, followed by 3 to 2 etc.

- Take out the stay and 'V' out the crack completely
- Weld up the principle crack, then any smaller cracks and plug the hole with horizontal passes (as for star cracking)
- Chip off or grind flush the welded deposit
- Drill and tap the hole
- Replace the stay



9. Patches & Inserts

The responsible person should submit a proposal for fitting any patches or inserts to the competent person. The competent person should give his written consent to any patching or to the fitting of inserts and should confirm approval regarding the use of materials and the method of work.

Patches may be joined to the parent metal by means of rivets or welding to the appropriate standards or in limited cases, patch screws. Lapped joints rely not only on the shear strength of rivets for joint integrity but also the high level of friction produced between the plates as the rivets cool and shrink pulling the joint tightly together. Wherever practical replace rivets with rivets.

Firebox patches may be any shape providing they are adequately supported by stays, rivets, tubes or other supporting structures.

Patches in stayed plates should be arranged so the weld passes equidistant between stay rows wherever possible. If it is not possible to avoid stay holes then the weld should bisect the hole rather than passing very close to it.

Patches should be made from material equal in thickness to the original plate, it may be necessary to taper the plate edges to avoid misalignment at the welded joint.

All rectangular or angled welded patches must have adequate radii at the corners; the minimum radius should not be less than three times the plate thickness.

It may be helpful when fitting large plate patches to be welded from one side to give the plate a slightly spherical form before fitting to the boiler. The contraction of the weld will pull the plate flat once the welding is complete.

Proposed BESTT Syllabus Assessment Plan

Section Number	LO	Objectives	Assessment Criteria	Delivery	Date achieved and Supervisors signature
9	LO3 1	Patches and inserts	Explain the difference between a patch and an insert and draw where they might be fitted in the boiler	Classroom	
9	LO3 2	Fixing a patch using patch screws	When would a patch be attached using patch screws instead of rivets?	Classroom	
9	LO3 3	Thickness variation	What thickness variation is allowed when using patches and inserts	Classroom	
9	LO3 4	Welded inserts	Where should the welds on an insert pass in relation to the stay pattern? Draw a typical firebox outer replacement lower side insert	Classroom	
9	LO3 5	Corner radii	Why must there be a radii at the corners of patches and inserts? What is the rule of thumb for radii	Classroom	

Care must be taken when choosing a patch design. The following photo shows a patch fitted to a throatplate. The choice of patch design is poor and likely to lead to a reduced lifespan; the welded seam runs along the top of the foundation ring. This is a stressed area due to the rigidity of the foundation ring and prone to grooving, a far better solution here would be to remove the foundation ring rivets and extend the patch to the bottom of the foundation ring.

Photo of poorly designed patch repair

Mismatching

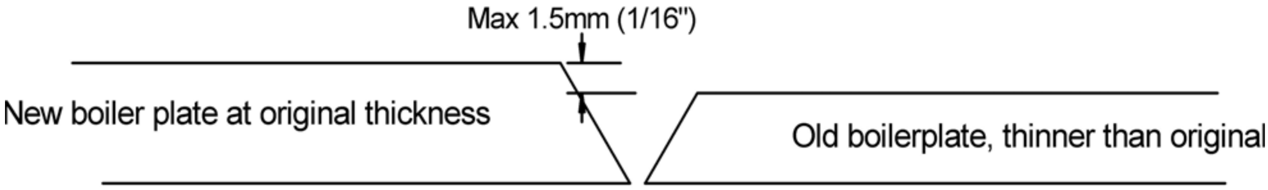
Sometimes, when fitting patches to a boiler, there will be an inevitable element of mismatch in thickness between the plates. The new patch must be made of material the same thickness as that originally fitted to the boiler; however the parent material to which the patch will be fixed may be thinner.

The maximum allowable offset between the two plate edges shall be 1.5mm (1/16”). If the mismatch is more than this the plate edge must be tapered away from the joint to create a gradual transition of thickness.

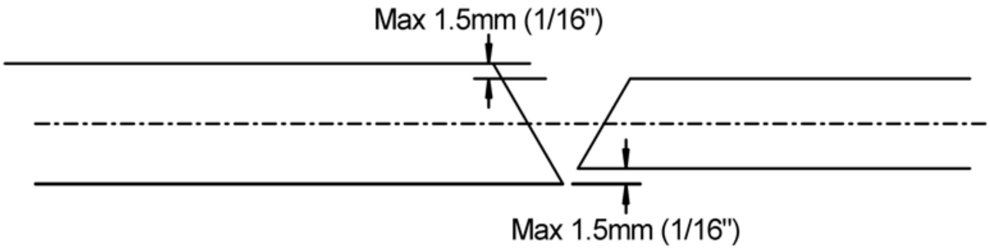
Wherever possible the plate faces should be set flush on the waterside, especially so on plates exposed directly to the fire.

Proposed BESTT Syllabus Assessment Plan

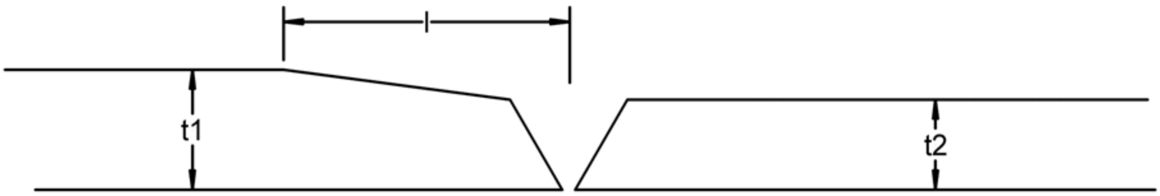
Section Number	LO	Objectives	Assessment Criteria	Delivery	Date achieved and Supervisors signature
9	LO3 6	Good and Bad patching	A patch needs to be put on to repair an inner firebox tubeplate below the tubes and above the foundation ring. Draw a design and submit to your mentor for approval. Draw an example of good and bad practice in a patch/insert repair.	Classroom	



Maximum mismatch in plate thickness allowed



Equal mismatch on both faces,
maximum mismatch 1/16" per side.



Where the mismatch is greater than 1/16" the new plate
is tapered gradually away from the original material.
l = 4(t1-t2) but not less than 1 1/2"

Welding of mismatched plates should be carried out in accordance with BS 2790:1992. Welding must be carried out by a coded welder to approved procedures.

Barrel Patches

Where the boiler barrel is too heavily pitted or cracked to allow a repair by building up with weld, replacement of barrel sections may be advised.

The best method of repair is to cut longitudinally along the barrel above the level of the affected area of plate for the full length of the barrel segment. A rolled barrel plate can then be let in and welded. The rivets at the front and back of the barrel section can be replaced.

Consider splitting the barrel along the longitudinal riveted seam on one side and cutting on the other, this means only one welded joint in the barrel and less resultant distortion.

If replacement of the full length of the barrel segment is not possible you may consider fitting a 'D' patch to the affected area of the barrel (often the area near to the front tube plate). Care needs to be taken choosing the shape of the patch and weld procedure to minimise stresses placed on the joint. 'D' patches have a tendency to shrink when welded and care must be taken to maintain a true radius in keeping with the rest of the barrel once the weld is complete.

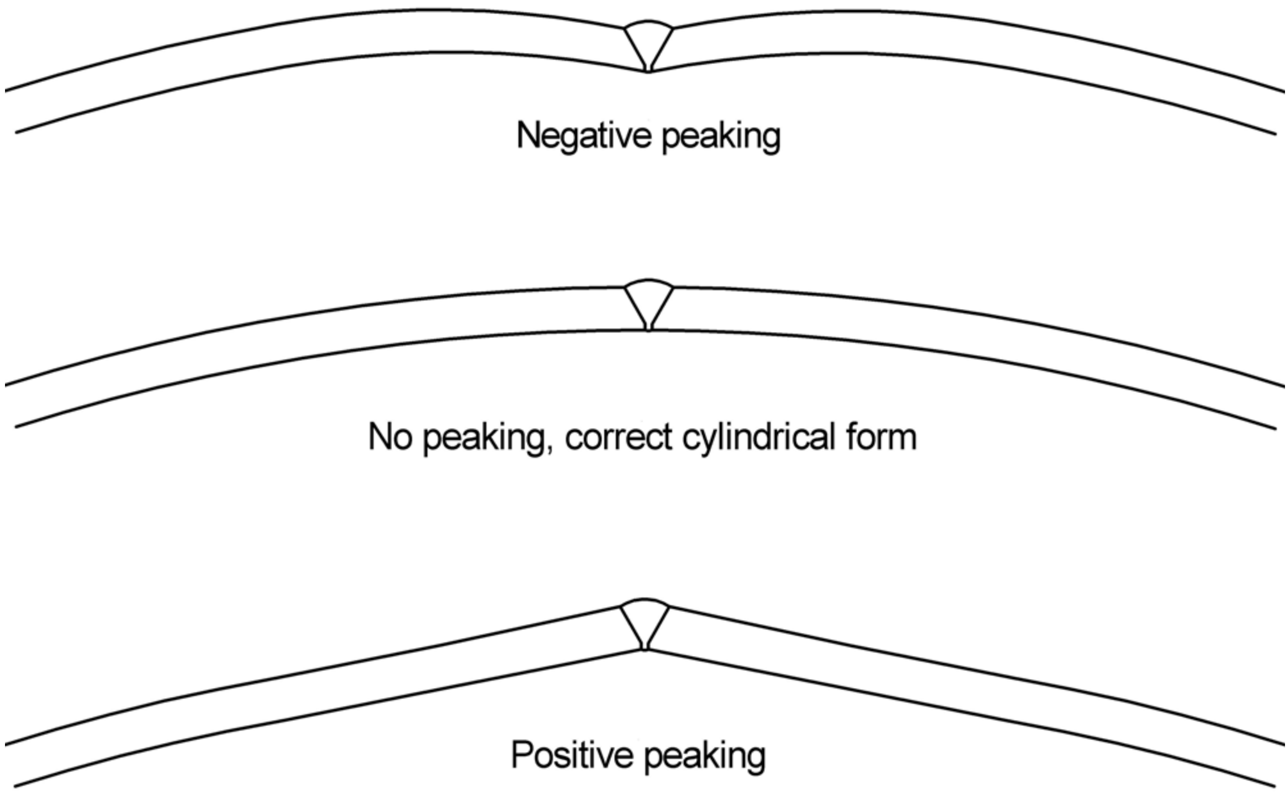
It is also possible to fit a riveted reinforcing patch over the affected area of the barrel. Riveted patches must be fitted to the outside of the original plate. The plate patch must fully encompass the defective area of plate and the rivets must be fitted through sound plate.

Proposed BESTT Syllabus Assessment Plan

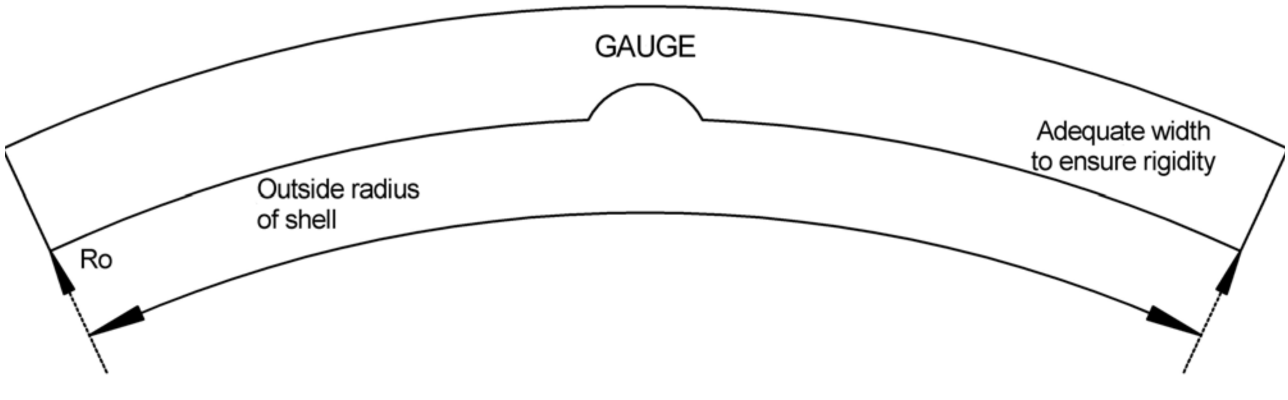
Section Number	LO	Objectives	Assessment Criteria	Delivery	Date achieved and Supervisors signature
11	LO5 2	Flanging of plates	What are the issues to be aware of when producing new flanged plates in a) Steel b) Copper What must happen at the end of the procedure? What hammers will you use and why	Classroom	
11	LO5 3	Flanging versus fabrication of circular tube plates	Explain why you would not fabricate from flat plate and rim using welding.	Classroom	

Weld Peaking

A common problem encountered when fitting welded patches to cylinders, especially D patches, is that of weld peaking, or flat spots adjacent to the weld cased by the shrinkage of the weld. This shrinkage can also result in ovality of the barrel or even a reduction in final diameter of the cylinder.



Extent of peaking is calculated as the angle resulting from the intersection of tangents taken from the surface of the two components being welded. The depth of peaking is measured from the true circumference of the barrel to the highest point of the peak ignoring the depth of weld reinforcing.



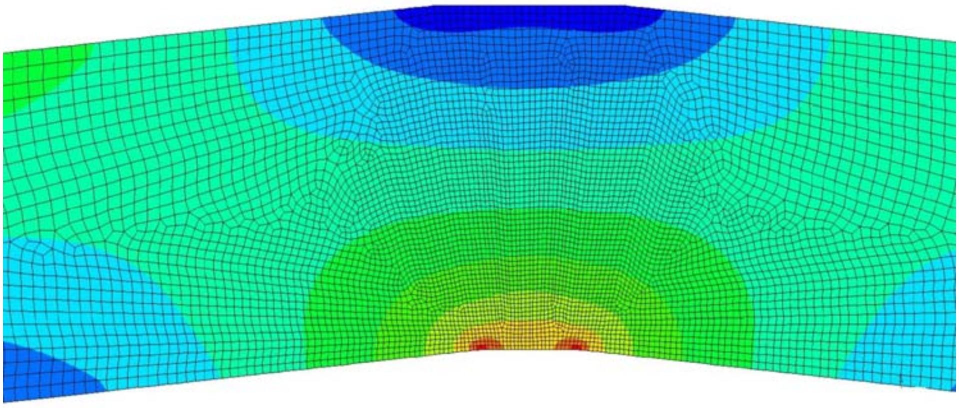
To enable peaking to be measured externally a profile gauge should be made for each size of boiler to be examined. (Details of the gauge are shown above). The minimum arc length should be 0.175 Do (20° of arc), where Do is the external diameter of the boiler. This diameter should be checked by measurement of the actual boiler shell.

SAFed document SBG2, chapter 4 gives comprehensive advice on assessing the extent of peaking in longitudinal welded seams. BS2790, 1992, section 4.4.2.2 gives information on what extent of peaking is allowable before action is necessary.

Proposed BESTT Syllabus Assessment Plan

Section Number	LO	Objectives	Assessment Criteria	Delivery	Date achieved and Supervisors signature
9	LO3 9	Weld Peaking	Describe with diagrams what weld peaking is and what the dangers are and how they can be avoided in correct preparation of material.	Classroom	
10	LO4 1	Forming of Plates in copper	Experience working copper to a shape on a scrap piece to achieve a work hardened sample. Understand the annealing process. How many anneals was needed to achieve a 90º bend	Workshop	
10	LO4 2	Forming of Plates in steel	Form a piece of steel, same initial thickness, to the same shape. Anneal at end to reduce stress and note that steel can only be worked hot.	Workshop	

The image below shows the stresses exerted on a positively peaked weld in service. Under pressure the cylinder tries to revert to a true circular shape, this places stress on the root of the weld as shown by the red shading. These areas will be extremely liable to cracking or grooving under continued service. Negatively peaked joints act in a similar way to an arch against the pressure and do not exhibit the same problematic symptoms as a positive peak.



Stress analysis of positively peaked longitudinal weld in pressure vessel cylinder

Any patch joint which shows deflection from the true circumference exceeding the levels set in BS2790, 1992, section 4.4.2.2, must be rejected and rectified before the vessel is put into service. Any patch showing positive peaking must be recorded by the responsible person and should be subjected to regular NDT examination at no more than 5 yearly intervals.

Distortion may be reduced by selecting a welding sequence which will suitably distribute the stresses so that they tend to cancel each other out. Choice of a suitable welding sequence is probably the most effective method of overcoming distortion, although an unsuitable sequence could exaggerate it. Simultaneous welding on both sides of the joint by two welders is often successful in eliminating distortion.

10. Production of Formed Plates

Hot or Cold Working Copper

Copper plate may be worked hot or cold. When working hot the plate should be worked while at a temperature of around 850ºc.

It is necessary to observe the copper carefully, so that when it has reached the right temperature it may be withdrawn from the heat. This is important, for if the copper is heated too high, or is left in the heat at the ordinary temperature of annealing too long, it is burnt. Copper that has been burnt is yellow, coarsely granular, and exceedingly brittle; even more brittle at a red heat than when cold.

Copper may be worked cold but will rapidly work harden and require annealing before each subsequent stage of working. Copper can be annealed by heating to a temperature of around 500ºc and then cooling in air or by quenching in water.

Hot or Cold Working Steel

Due to its properties steel boiler plate may be worked hot or cold. Simple bending operations can be carried out cold and do not necessarily require post operation heat treatment. Document EN 13445-4 (2002), clause 9 gives information on the extent of deformation allowed when cold working plates before heat treatment must be applied after forming is complete.

Working or forming of steel plate must not be carried out between the temperatures of 90ºc and 550ºc (Dark to Blood Red), in this range the steel will be in a brittle state, working plate in this temperature range may result in internal stresses and fractures forming.

Steel boiler plate should not be heated, for the purposes of flanging or forging, above 950ºc (orange).

Modern remote infra red thermometers make temperature monitoring much easier

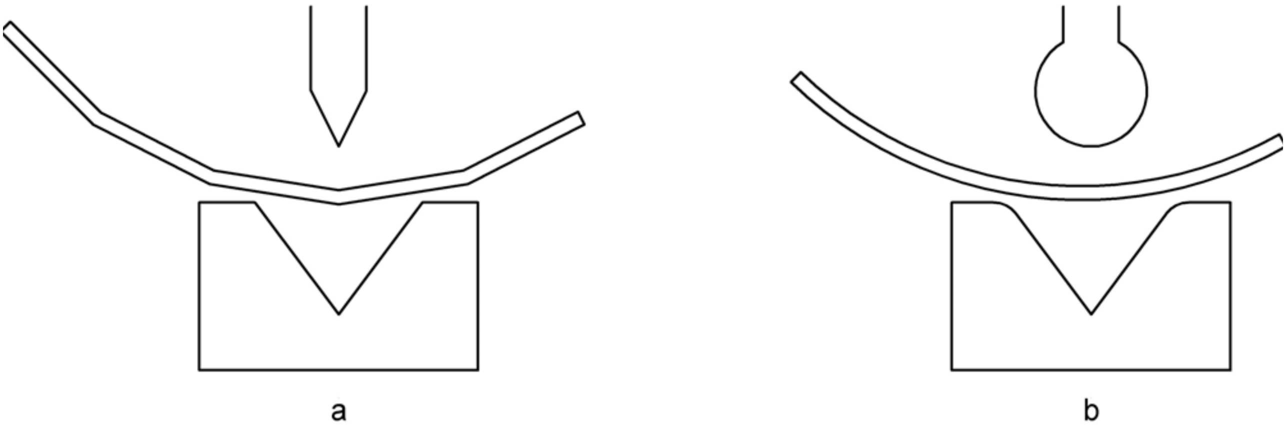
See appendix 1 for more information of temperatures and comparative colours of steel materials.

Plate Rolling

Curved plates such as side plates and wrapper plates are best formed by rolling. This will ensure smooth curves and transitions.

Press Braking

Where rolling of plates is not possible press brake development may be required. Wherever possible try to use full form tools for the bending of plate. Press braking with a narrow tool leads to a faceted curve (a) and stresses along each bend line. If it is not possible to avoid press braking then use large radius tools (b) to eliminate point loading of the plate during forming. Increase the number of press increments and reduce the depth of each press stroke to keep the curve smooth.



Incorrect (a) and suitable method (b) for press braking of boiler plates

If press braking is to be used for the forming of boiler plates the competent person should approve the process of manufacture and intended application of the plates.

Cylinders and cylindrical sections

Cylinders and cylinder sections will usually be found as boiler barrels or barrel repair patches on locomotives or as shell plates or flues in other types of boiler.

Each entire cylinder should be constructed of one plate. Joints should wherever possible be arranged to fall within the steam space. Some older boilers were constructed with the seam below the water line, if it is possible consider moving the seam above the water line when replacing entire barrel sections.

Cylindrical plates should be shaped to a true cylindrical form by rolls or similar suitable machine. BS2790, 1992, 4.4.2.2 give the acceptable limits for deviation from circularity when rolling boiler shells.

Proposed BESTT Syllabus Assessment Plan

Section Number	LO	Objectives	Assessment Criteria	Delivery	Date achieved and Supervisors signature
10	LO4 3	Temperature measurement, using colour chart for steel, or Infra-red thermometer	What temperature or colour would you use to anneal copper? And normalise steel?	Classroom	
10	LO4 4	Plate shaping using a press brake	Using 2D and 3D diagrams explain how to produce a curved patch or insert.	Classroom	
10	LO4 5	Stress caused by Welding	Explain where a weld should be positioned in a newly rolled barrel section	Classroom	
10	LO4 6	Overlap seams in older boilers	Explain why this is not good practice, what problems it leads to and how it can be overcome in a modern riveted design	Classroom	
10	LO4 7	Tapered barrel section	Why do some boilers have a tapered boiler section and what purpose does it serve? Draw a section through a GWR or similar tapered boiler barrel.	Classroom	

When thicker plates are rolled to smaller diameters, say 1" thick plate bent to a diameter of 4ft of less it is recommended the plates are normalised after forming. Plates rolled to a larger diameter should not usually need heat treatment after forming.

The best cylinder design will be rolled with a welded longitudinal seam. In a riveted lap joint at a longitudinal seam the transmission of stress is not direct along the plate and there is a tendency grooving and stress cracking at the edge of the lap of the seam.

If a riveted seam is desired then a cylinder should be rolled with a butt joint with doubling plates inside and out will provide a better solution than a rolled and lapped design. Butt joints with single doubling plates should be avoided.

Doubling plates should be made from the same thickness material as the cylinder and made from rolled plates with diameters corresponding to their placement on the cylinder. The thinning of butt straps for fitting under other plates at the ends is best performed by machining rather than heating and hammering.

Where two cylinders are joined care must be taken to ensure a snug fit of the larger cylinder over the smaller. There should be no clearance at the lap of the ring seam before riveting is commenced.

Cylinder sections, such as for repairing barrels should be rolled, be aware some roll configurations require a sacrificial area at each end of the radius which will remain flat, allow extra material so this may be removed once the rolling is complete.

Tapered Barrel Sections

Many boilers have one or more tapered or conical barrel sections, these may take the form of a true cone, an oblique cone where say the bottom of the barrel is flat and the top of the barrel tapers or an irregular cone where the top and bottom both taper but at different rates.

The ideal method of producing cones or conical sections is with the use of a vertical hydraulic plate bending machine or horizontal rolls. If neither option is feasible then it is possible to press brake the sections however the same precautions must be observed as in the earlier section on press braking.

11. Production of Flanged Plates

The process of flanging usually involves stretching the plate. Unless carried out carefully and the proper thickness of plate allowed local or general thinning of the plate may result. Where the flanging has been carried out at an improper temperature or has been roughly done or flanged around too tight a corner fractures may result on the inside or outside of the radius.

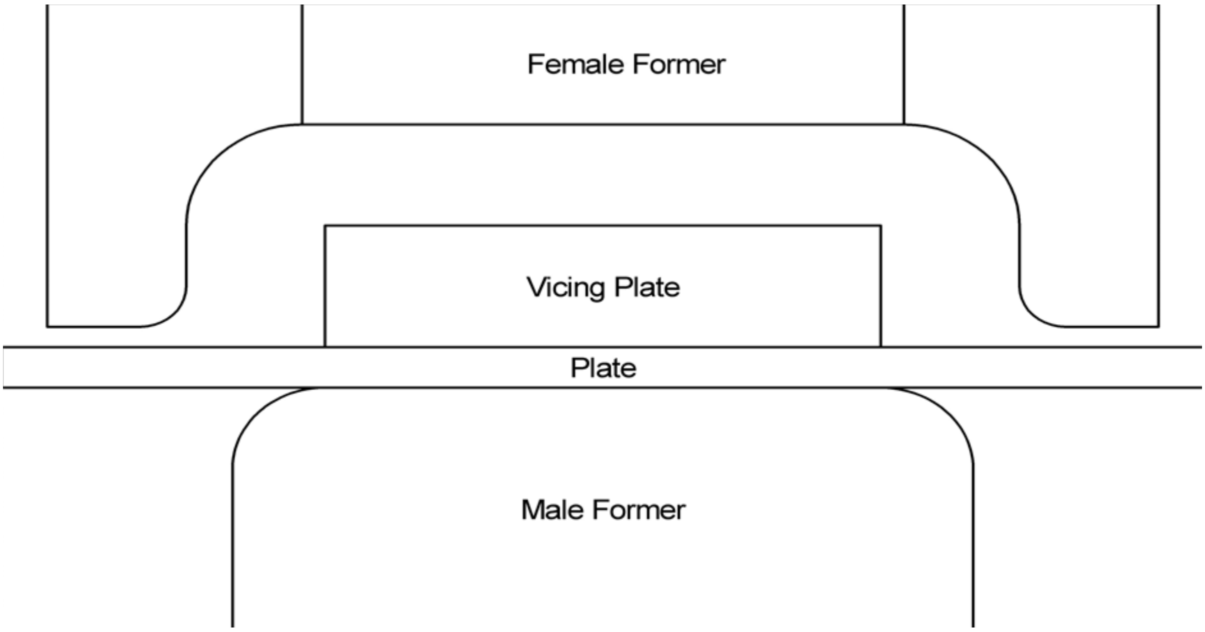
Care is necessary to ensure the full thickness of the plate is heated through before the forming process commences. The plate needs sufficient soaking time in the furnace or fire to allow the heat to penetrate the full thickness of the material.

Flanged plates should have as large a radius as circumstances will allow. Flanges with sharp bends or a small radius are much more liable to give problems due to grooving. Wherever possible the radius should be at least four times the thickness of the plate.

The preferred method of producing flanges is to hot press the plates in one operation. A male and female former should be produced to match the dimensions of the plates required. The plate should be heated to a uniform temperature and sufficient pressing force applied to effect the forming. Heat maybe applied to the edges of the plate being formed if the capacity to heat the whole plate is not available.

Proposed BESTT Syllabus Assessment Plan

Section Number	LO	Objectives	Assessment Criteria	Delivery	Date achieved and Supervisors signature
11	LO5 1	Flanging of boiler plates	Witness flanging being carried out by a) Hand b) Mechanically assisted pressing c) Press brake	Workshop observation	



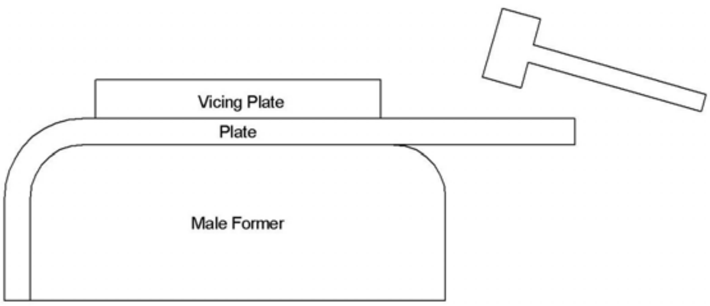
Simplified sketch of pressing arrangement

Copper may be machine flanged hot or cold. If the work is carried out cold it should be carried out in multiple steps. As the copper is pressed it will work harden and become brittle or tear. The copper must be annealed at appropriate stages during the flanging process.

With care quite acceptable flanges can be achieved by hand flanging. A male former should be produced to match the dimensions of the plates required. The plate is placed onto the former and localised heating applied. The flanges are then formed by hammering the plate over the former.

Care must be exercised to control the heat applied to the plate to avoid overheating or burning of the plate. The total number of heatings should be kept to a minimum. The plate must only be worked while it is at a suitable temperature. Careful use of the hammer must be exercised to avoid thinning the plate or damaging the surface of the plate.

Choosing an appropriate material for your hammer will help to achieve the best possible finish when hand flanging. Consider using hammers made from wood, aluminium, nylon, copper or lead to protect the plate surface.



Simplified sketch of hand flanging arrangement

Copper plate can be hand flanged while cold. As the plate is formed it will work harden and will need to be annealed at appropriate intervals. The plate should not be worked in the while in the hard state.

Proposed BESTT Syllabus Assessment Plan

Section Number	LO	Objectives	Assessment Criteria	Delivery	Date achieved and Supervisors signature
11	LO5 2	Flanging of plates	What are the issues to be aware of when producing new flanged plates in a) Steel b) Copper What must happen at the end of the procedure? What hammers will you use and why	Classroom	
11	LO5 3	Flanging versus fabrication of circular tube plates	Explain why you would not fabricate from flat plate and rim using welding.	Classroom	

When cutting the plate before fitting to the male former care must be take to allow enough material to properly effect the draw of the plate with out excess material being present which may lead to crumpling of the plate especially around tight corners.

Circular Flanged Plates (Tubeplates)

Circular flanged plates may be pressed or hand flanged. Though not the preferred method in certain situations it may be possible to fabricate a tubeplate by welding a rolled flange to a circular profile. The competent person must approve the design and construction process.

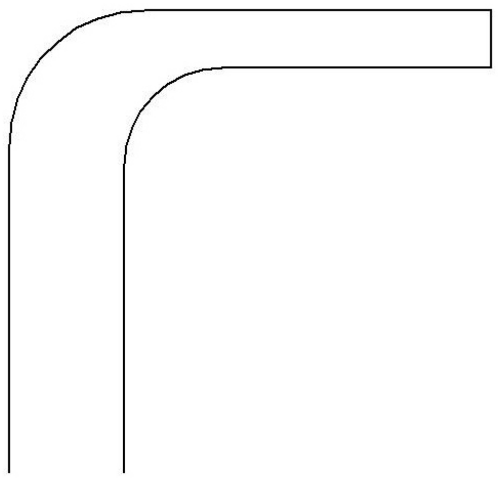
Locomotives with angle ring mounted tube plates may have a flange welded to a flat plate. This flange is external to the pressure vessel and used to support the smoke box. The welding must still be carried out by a competent person as this flange still may form an integral part of the overall structure or support the boiler itself.

Improvement to Copper Tube Plate Flanges

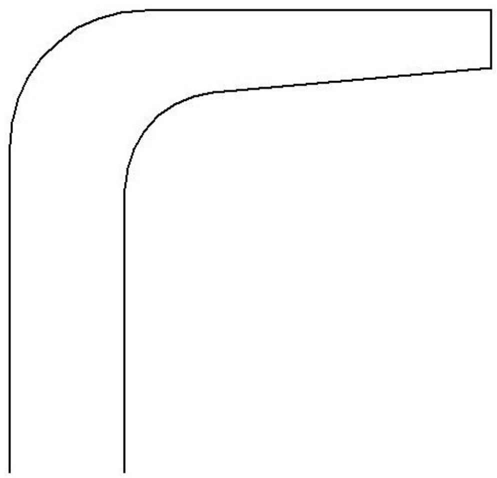
Common locomotive tube plate designs include a thick tube nest area, say 1 1/4", with a throat plate and flange thickness of say 5/8". Originally this thinning was achieved by forging the blank plate in the relevant areas prior to forming. Modern machining techniques have superseded this process and plates can be milled to the correct form with relative ease.

Flange cracking has always been a common problem. By ensuring the thinned part of the flange does not coincide with the most severely stressed areas significant improvements in tube plate life can be achieved.

Fig. a below represents the section through an existing copper tube plate flange, fig.b shows a suggested modification to the thickness.



a) Common tubeplate flange design



b) Suggested improvement to flange design

Post Flanging Processes

The work of flanging usually warps a plate more or less, though the work of straightening can frequently be done before the plate goes for heat treatment.

After flanging the plates can be reheated and set to template gauges or where these facilities are not available it may be necessary to make final adjustments to the fit of the plate in situ using localised heating. Originally flanged plates were placed in a large furnace, heated red, and drawn out on a level floor of cast-iron slabs to be straightened by mauls and flatters.

12. Heat Treatment

Heat Treatment of Boiler Plates Post Forming

It is noteworthy that while the term heat treatment applies only to processes where the heating and cooling are done for the specific purpose of altering properties intentionally, heating and cooling often occur incidentally during other manufacturing processes such as hot forming or welding.

Steel Boiler Plate

Definitions:

- **Full annealing**: Average boiler plate is heated to approximately 900 °C for around half an hour; this assures all the ferrite transforms into austenite (although cementite might still exist if the carbon content is greater than the eutectoid). The steel must then be cooled slowly, in the realm of 38 °C per hour. Usually it is just furnace cooled, where the furnace is turned off with the steel still inside. This results in a coarse pearlitic structure, which means the "bands" of pearlite are thick. Fully-annealed steel is soft and ductile, with no internal stresses, which is often necessary for cost-effective forming.
- **Normalizing**: Average boiler plate is heated to approximately 915 °C for around half an hour; this assures the steel completely transforms to austenite. The steel is then air-cooled, which is a cooling rate of approximately 38 °C (100 °F) per minute. This results in a fine pearlitic structure, and a more-uniform structure. Normalized steel has a higher strength than annealed steel; it has a relatively high strength and ductility.

Exact times and temperatures will vary depending on the exact composition of the material and dimensions of the piece being treated. As a rule the higher the carbon content, the lower the treatment temperature required.

The process chosen will depend on the nature of work carried out on the plate in question and the intended final use of the plate.

Plates which have been formed through a process involving multiple heatings (i.e. hand flanging) should be normalized after production to ensure a uniformity throughout the material.

If localised heating was used during a single heat forming process, plates should be normalized after forming as there will be differentials in the material qualities, especially in the heat transition zones.

Colour	Temperature	
	ºF	ºC
Faint red visible in dark	750	399
Faint red	900	482
Blood red	1050	565
Dark Cherry	1075	579
Medium Cherry	1250	677
Cherry of full red	1375	746
Bright red	1550	843
Salmon	1650	899
Orange	1725	940
Lemon	1825	996
Light yellow	1975	1079
White	2200	1204
Dazzling white	2350	1288

Proposed BESTT Syllabus Assessment Plan

Section Number	LO	Objectives	Assessment Criteria	Delivery	Date achieved and Supervisors signature
11	LO5 2	Flanging of plates	What are the issues to be aware of when producing new flanged plates in a) Steel b) Copper What must happen at the end of the procedure? What hammers will you use and why	Classroom	
11	LO5 3	Flanging versus fabrication of circular tube plates	Explain why you would not fabricate from flat plate and rim using welding.	Classroom	

Thickness of Metal (inches)	Time of heating to required temperature (hr)	Soaking time (hr)
Up to 1	3/4	1/2
1 to 2	1 1/4	1/2
2 to 3	1 3/4	3/4
3 to 4	2 1/4	1
4 to 5	2 3/4	1
5 to 8	3 1/2	1 1/2

Copper Boiler Plate

Copper plates are commonly worked cold. It is important that once the final forming operation has been completed the affected areas are annealed, ideally in a furnace.

Copper becomes hard and brittle when mechanically worked; however, it can be made soft again by annealing. The annealing temperature for copper boiler plate is between 370ºc and 480ºc. Copper may be cooled rapidly or slowly since the cooling rate has little effect on the heat treatment. The one drawback experienced in annealing copper is the phenomenon called "hot shortness". At about 480°c, copper loses its tensile strength, and if not properly supported, it could fracture.

Heat Treatment of Boiler Plates Post Welding

Areas of welded repairs and welded seams inevitably hold stresses and may shrink contorting the parent materials. It is advisable that these plates are stress relieved once the welding processes are complete. It may be necessary to brace the plates in the correct position before heat treating so that the desired form is maintained once the process is complete.

Where it is deemed necessary to carry out heat treatment of boiler components after welding it should be carried out in accordance with the standards set in BS2790 (1992) chapter 5.5.2.

It is not necessary that the work piece be taken to the heat source for treatment; there are companies who specialise in mobile heat treatment using induction heating or other processes.

13. Lapped Joints and Seams

Riveted Seams

The design of riveted joints should be such that it does not subject any part to unduly high stress and must be arranged to ensure a tight joint and permit satisfactory work while riveting.

Too wide a pitch of rivets will allow the plate to spring up between the rivets preventing proper fullering or caulking.

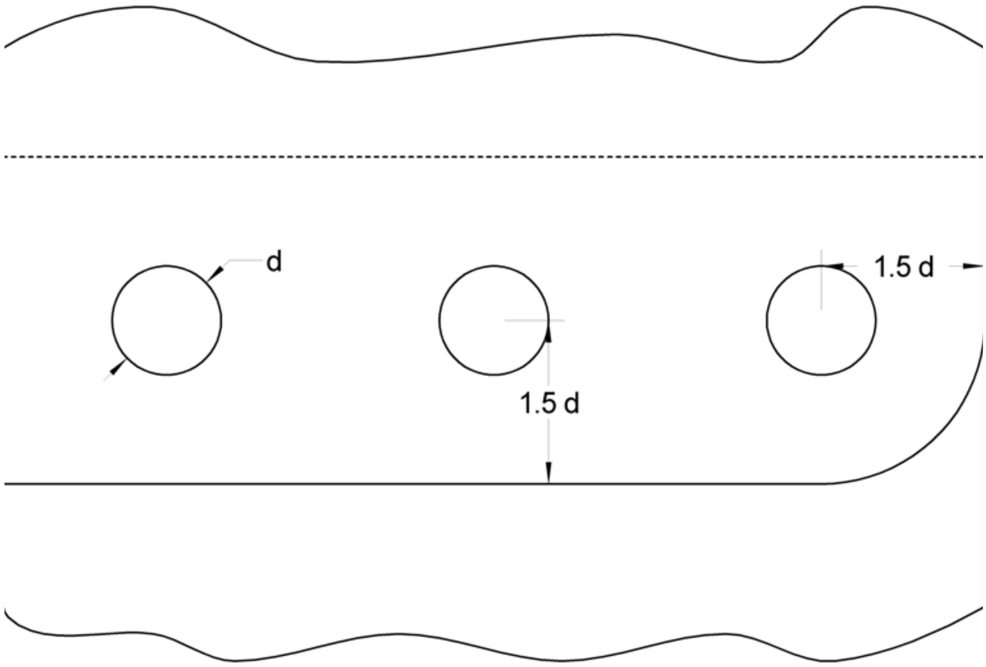
Rivets which are placed too closely together will reduce the plate section at the joint and result in a weaker joint. Larger rivets pitched closely together can result in the plate overheating during the riveting process leading to loose or leaky joints. The recommended minimum rivet pitches are given overleaf.

Proposed BESTT Syllabus Assessment Plan

Section Number	LO	Objectives	Assessment Criteria	Delivery	Date achieved and Supervisors signature
13	LO5 6	Lapped joint and seams	Explain how the correct spacing of rivets is arrived at. What happens if rivets are a) too close together b) too far apart c) too far from front edge of lap	Classroom	

RIVETING	MINIMUM PITCH	
Size of rivet hole	Single riveting	Double riveting
3/4"	1 3/4"	2"
13/16"	2"	2 1/4"
7/8"	2 1/8"	2 1/2"
15/16"	2 1/4"	2 3/4"

The lap of the plate, that is the distance from the centre of the rivet hole to the nearest edge of the plate, should be one and a half times the diameter of the rivet hole.



Sketch showing correct spacing of rivet holes from lap edges

All holes in the pressure vessel plates must be made by drilling. Punching is not acceptable in boiler construction. The holes should be made after the plates are formed and are fixed together in the position they will occupy when finally riveted up.

Care must be taken when trimming flanged plates to length such that there must be sufficient overlap of the plates to allow for proper pitching of the rivet holes. Similarly flanges which are too long will be impossible to caulk and could impinge on other features such as stay holes.

After the holes have been drilled the plate work should be taken apart and the rough, sharp, edges, formed in drilling the holes, should be taken off or de-burred, so that no burr remains such as might lie between the plates and prevent a tight joint being made. Riveted joints must be clean and free from scale paint or other contaminants.

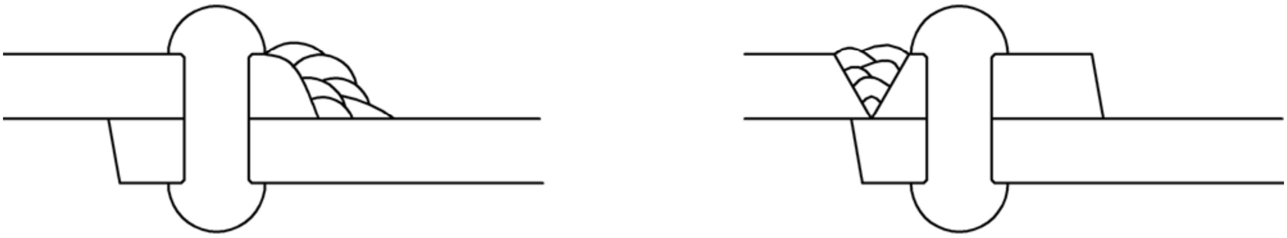
Proposed BESTT Syllabus Assessment Plan

Section Number	LO	Objectives	Assessment Criteria	Delivery	Date achieved and Supervisors signature
13	LO5 7	Building up of lap seams	Understand building up lap seams by copper welding after part of the lap has been eroded. Replacing a section of the lap using patch screws if rivets cannot be used	Classroom	

Building up of lap edges

Where the edges of the lap have been burnt away, reducing the distance between the rivet hole and the lap edge, it may be possible to repair the lap edge by welding. Once the welding is complete the edge can be ground to the correct profile.

The best method of repair, for more severely wasted edges, is to weld a strip of similar to renew the affected area of lap. Once the weld is complete the excess material can be carefully removed until the correct profile is achieved. Welding must be carried out by a competent welder with the approval of the competent person.



Lap edge repair by building up and repair showing edging strip welded to reduced edge

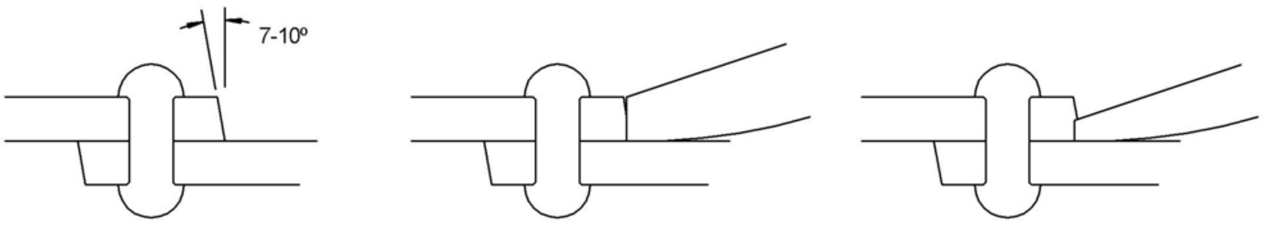
If the weld has bonded to the opposite plate to that being welded, the seam must not be caulked or fullered once complete.

Heat from welding may loosen the rivets, the rivets should be removed from the joint prior to welding and replaced once the welding process is complete.

14. Fullering / Caulking

Riveted plate seams are made pressure tight through the process of fullering or caulking; that is hammering the bevelled edge of the plate into the seam. Fullering is the process of sealing the plate seam with a wide faced tool acting across the full plate thickness, Caulking is the process of sealing with a narrow faced tool. Both methods of sealing are most effective when carried out with a pneumatic hammer.

The plate edge should be prepared with an edge tapered at around 7-10º. The joints must be clean and free of scale, paint or other contaminants. The plate edges should be tight together prior to riveting. These joints rely on the correct rivet pitch and spacing being adhered to.



Great care must be taken when caulking to avoid injuring the edge of the plate. Excessive caulking will result in opening of the joint between the extreme edge and point where it is held by the rivet, for this reason fullering is the preferred method.

Ingress or seepage of boiler water into the lapped seam can lead to deterioration of the plates. Seams should be sealed on the waterside as well as the air side, particularly below the water line.

Proposed BESTT Syllabus Assessment Plan

Section Number	LO	Objectives	Assessment Criteria	Delivery	Date achieved and Supervisors signature
14	LO5 8	Fullering/caulking of riveted plates	Describe the fullering/caulking process. Angle of approach in fullering a longitudinal barrel seam	Masterclass	

When the longitudinal seams of cylinders are caulked on the inside, particularly in smaller diameter cylinders, care must be taken to avoid indentation of the plate alongside the seam. The sweep of the plate prevents the tool being held in a tangential position (a). To avoid indentation or nicking the plate the tools used should be of a bent form with rounded corners (b). The use of improper tools and the resultant grooving is likely to result in cracks forming in the damaged plate.

a

b

15. Welded Joints and Fabrications

Welded Joints

The preferred method of welded construction is flanged and welded. The weld should be placed to be sufficiently far enough away from the flange radius and the stresses in that area. When fitting patches to boiler plates the patch should be located a suitable distance from the radius edge.

Welded fabrications

Where it is not possible to flange plates there may be no option but to produce fabricated plates, these may be fabricated from multiple flats or multiple pre formed plates or a combination. Care must be taken over the design of fabricated plates such that welds are not placed in areas of elevated stress such as close to radii or stiffening plates. The design of fabricated plates must be approved by the competent person.

NDT

Wherever possible welds should be 100% examined by a suitable NDT method when complete. Records of procedure and NDT should be retained by the responsible person with copies sent to the competent person.

Further information

Further information on the correct welding procedures and design can be found in the Heritage Railway Association Guidance Note 'Welding' and 'BS 2790:1992; Specification for design and manufacture of shell boilers of welded construction'.

16. References

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17. Colour of Steel Materials in relation to Temperature

The chart shown overleaf gives an indication of the colour of steel materials in relation to temperature. However due to variation in monitor or printer settings it should only be used as an approximate guide, it should not replace proper temperature measurement by appropriate means. A more accurate printed version of this document may be purchased from Tempil.

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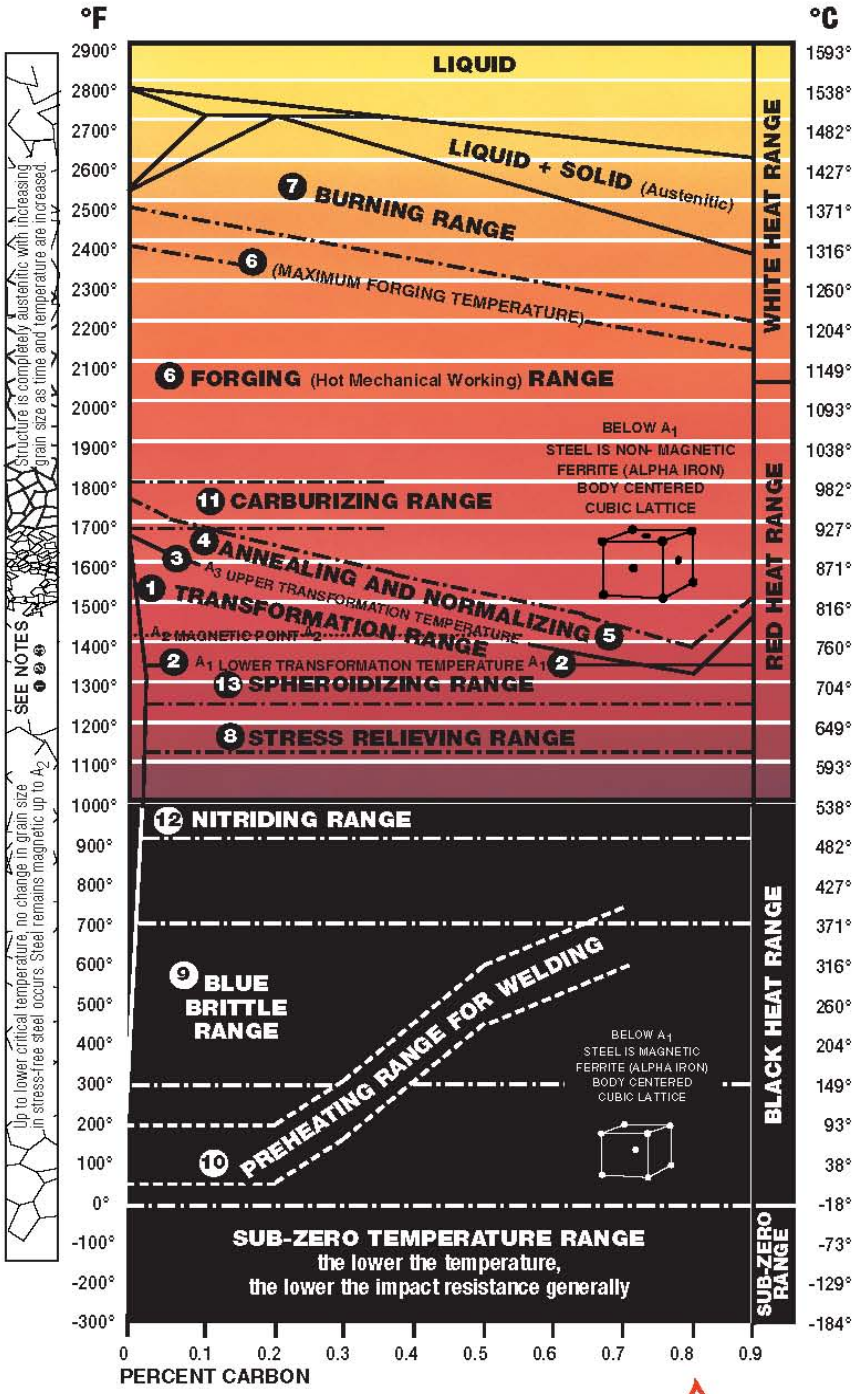
Basic Guide to Ferrous Metallurgy



1. **TRANSFORMATION RANGE**- In this range steels undergo internal atomic changes which radically affect the properties of the material.
2. **LOWER TRANSFORMATION TEMPERATURE (A_1).** Termed Ac_1 on heating, Ar_1 on cooling. Below Ac_1 structure ordinarily consists of FERRITE and PEARLITE (see below). On heating through Ac_1 these constituents begin to dissolve in each other to form AUSTENITE (see below) which is non-magnetic. This dissolving action continues on heating through the TRANSFORMATION RANGE until the solid solution is complete at the upper transformation temperature.
3. **UPPER TRANSFORMATION TEMPERATURE (A_3).** Termed Ac_3 on heating, Ar_3 on cooling. Above this temperature the structure consists wholly of AUSTENITE which coarsens with increasing time and temperature. Upper transformation temperature is lowered as carbon increases to 0.85% (eutectoid point).

- **FERRITE** is practically pure iron (in plain carbon steels) existing below the lower transformation temperature. It is magnetic and has very slight solid solubility for carbon.
- **PEARLITE** is a mechanical mixture of FERRITE and CEMENTITE.
- **CEMENTITE** or IRON CARBIDE is a compound of iron and carbide, Fe_3C.
- **AUSTENITE** is the non-magnetic form of iron and has the power to dissolve carbon and alloying elements.

4. **ANNEALING,** frequently referred to as FULL ANNEALING, consists of heating steels to slightly above Ac_3, holding for AUSTENITE to form, then slowly cooling in order to produce small grain size, softness, good ductility and other desirable properties. On cooling slowly the AUSTENITE transforms to FERRITE and PEARLITE.
5. **NORMALIZING** consists of heating steels to slightly above Ac_3, holding for AUSTENITE to form, then followed by cooling (in still air). On cooling, AUSTENITE transforms giving somewhat higher strength and hardness and slightly less ductility than in annealing.
6. **FORGING RANGE** extends to several hundred degrees above the UPPER TRANSFORMATION TEMPERATURE.
7. **BURNING RANGE** is above the FORGING RANGE. Burned steel is ruined and *cannot be cured* except by remelting.
8. **STRESS RELIEVING** consists of heating to a point below the LOWER TRANSFORMATION TEMPERATURE, A_1, holding for a sufficiently long period to relieve locked-up stresses, then slowly cooling. This process is sometimes called PROCESS ANNEALING.
9. **BLUE BRITTLE RANGE** occurs approximately from 300° to 700°F. Peening or working of steels should not be done between these temperatures, since they are more brittle in this range than above or below it.
10. **PREHEATING FOR WELDING** is carried out to prevent crack formation. See TEMPIL° PREHEATING CHART for recommended temperature for various steels and non-ferrous metals.
11. **CARBURIZING** consists of dissolving carbon into surface of steel by heating to above transformation range in presence of carburizing compounds.
12. **NITRIDING** consists of heating certain *special steels* to about 1000°F for long periods in the presence of ammonia gas. Nitrogen is absorbed into the surface to produce extremely hard "skins".
13. **SPHEROIDIZING** consists of heating to just below the lower transformation temperature, A_1, for a sufficient length of time to put the CEMENTITE constituent of PEARLITE into popular form. This produces softness and in many cases good machinability.

- **MARTENSITE** is the hardest of the transformation products of AUSTENITE and is formed only on cooling below a certain temperature known as the M_s temperature (about 400° to 600°F for carbon steels). Cooling to this temperature must be sufficiently rapid to prevent AUSTENITE from transforming to softer constituents at higher temperatures.
- **EUTECTOID STEEL** contains approximately 0.85% carbon.
- **FLAKING** occurs in many alloy steels and is a defect characterized by localized micro-cracking and "flake-like" fracturing. It is usually attributed to hydrogen bursts. Cure consists of cooling to at least 600°F before air-cooling.
- **OPEN OR RIMMING STEEL** has not been completely deoxidized and the ingot solidifies with a sound surface ("rim") and a core portion containing blowholes which are welded in subsequent hot rolling.
- **KILLED STEEL** has been deoxidized at least sufficiently to solidify without appreciable gas evolution.
- **SEMI-KILLED STEEL** has been partially deoxidized to reduce solidification shrinkage in the ingot.
- **A SIMPLE RULE:** Brinell Hardness divided by two, times 1000, equals approximate Tensile Strength in pounds per square inch. (200 Brinell ÷ 2 x 1000 = approx. 100,000 Tensile Strength, p.s.i.).

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Proposed BESTT Syllabus Assessment Plan

Section Number	LO	Objectives	Assessment Criteria	Delivery	Date achieved and Supervisors signature
17	LO5 9	Ferrous Metallurgy	Identify and understand the milestones on a TEMPIL colour chart	Classroom	

BESTT
Platework - Module 9020 Is03

Assessment Record for: **Training Centre:** **Year: August 14 – July 15**

LO1	**1**	**2**	**3**	**4**	**5**	**6**	**7**	8	9
Supervisor Initials and date when completed									
LO2	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Supervisor Initials and date when completed									
LO3	**1**	**2**	**3**	**4**	**5**	6	7	8	9
Supervisor Initials and date when completed									
LO4	1	2	3	4	5	6	7	8	9
Supervisor Initials and date when completed									
LO5	1	2	3	4	5	6	7	8	9
Supervisor Initials and date when completed									