

BOILER CODE OF  
PRACTICE (BCOP)



## GUIDANCE NOTE

## SUPERHEATERS

### 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**

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

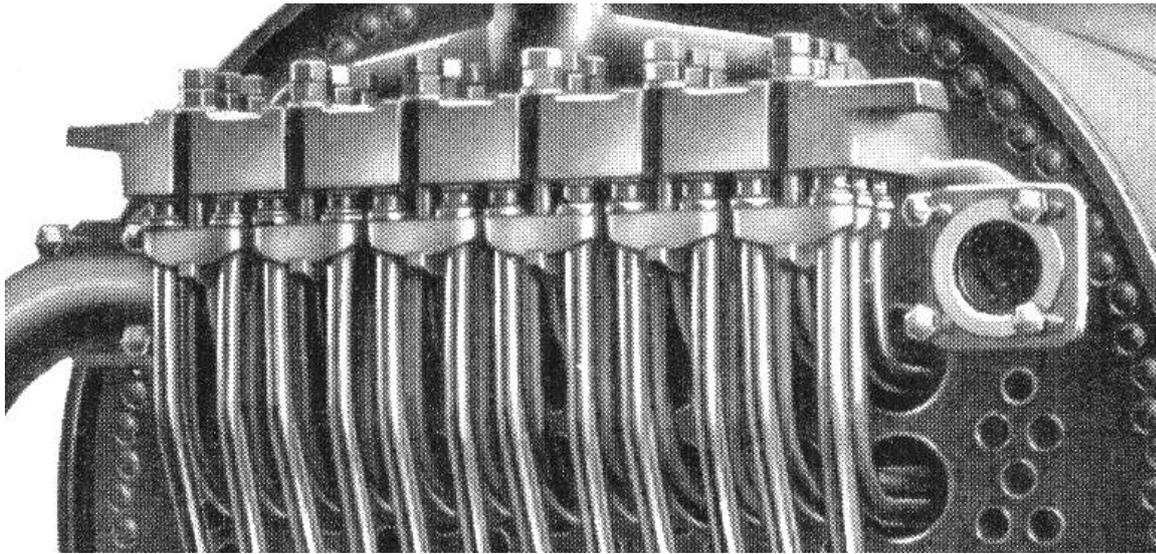
- In accordance with the latest Personal Protective Equipment regulations;
- Properly assessed before use to ensure it is suitable;
- Maintained and stored properly;
- Provided with instructions on how to use it safely; and
- Used correctly by those undertaking the work.

## **4. Inspection**

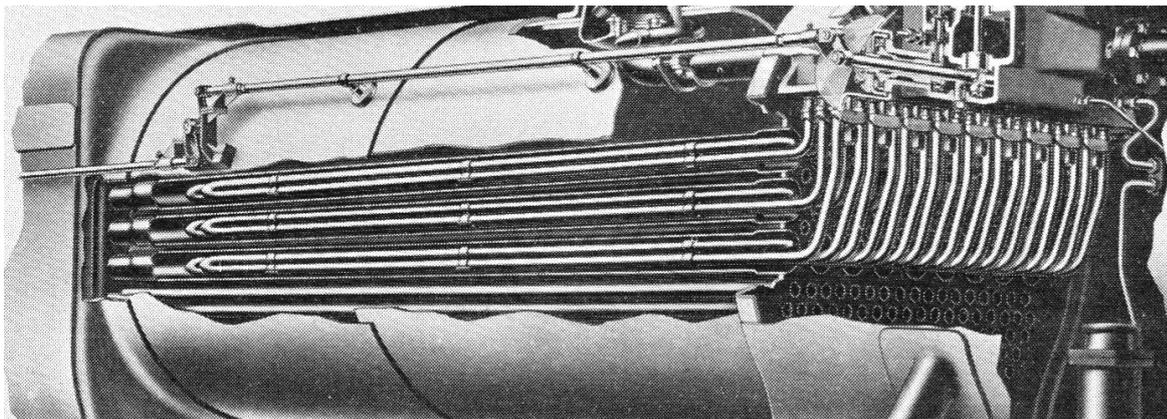
In the event of finding any superheater element to be defective or suspect seek guidance from the boiler Competent Person before proceeding with any repair.

## **5. General**

Most modern locomotive boilers with the exception of small and industrial locomotive boilers are fitted with superheaters for the purpose of raising the temperature of the boiler steam above saturation temperature. Almost without exception the superheaters fitted are of the smoke tube type. Diagram 1 shows the header for distributing the steam to the superheater elements. Diagram 2 shows the arrangement of the superheater elements within the flue tubes.



*Diagram 1. Superheater header, MeLeSco type.*



*Diagram 2. Arrangement of typical superheater elements and header.*

## 6. Competency

The inspection, fitting and repair of superheaters are safety critical tasks. Only those trained, deemed competent and authorised should be responsible for the fitting and inspection of superheaters. Records should be kept of the action taken at each inspection, or repair, and by whom.

## 7. Maintenance plan

The boiler maintenance documentation should reference the identification, origin, materials, test certification and age of any superheaters fitted to a boiler.

## **8. Materials**

### **Headers:**

Material for superheater headers varied with design, Some were of cast iron and some cast steel. It is important that the correct grade of material is adopted for the particular design.

Cast Steel – BR spec 118 A. BS3100 A1

Cast Iron – LMS cylinder quality 14 tons min. BS EN 1561 grade 250

### **Elements:**

BS EN 10216-1:2002 (Seamless steel tubes for pressure purposes)

BS EN 10217-1:2002 (welded steel tubes for pressure purposes)

### **Return bends:**

Cast Steel – BS EN 10293

### **Clamp bolts or studs:**

High tensile steel – EN 16 condition T. BS 970, 605M36 condition T.

Nuts – EN8. BS 970, 080M40 condition P.

### **Clamp:**

Forged steel – BS 970 070M20

Cast Steel – BS3100 A1

### **Header block:**

Steel- BS 970 070M20

## **9. Headers**

Superheater headers are of two basic types with sub-categories. The two basic types are those which incorporate the regulator within the main casting and those that are separate to the regulator.

Superheater headers which incorporate the regulator are bolted directly to the boiler and they form part of the pressure vessel, as such they should be inspected as part of the pressure vessel and subject to a hydraulic and steam test in conjunction with the boiler.

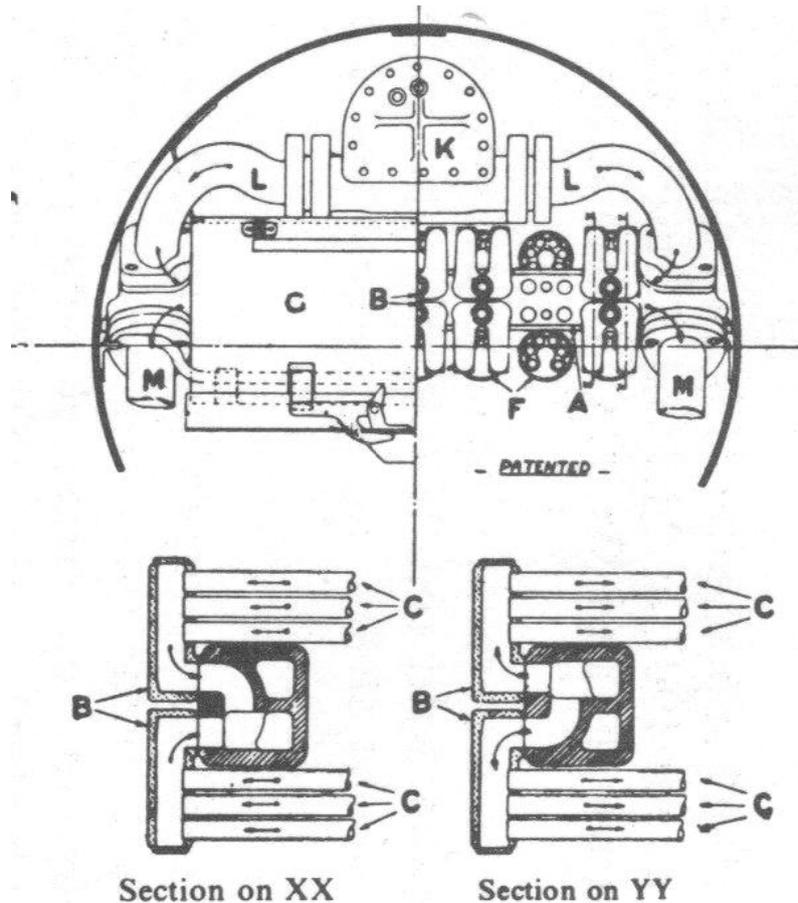
Superheater headers which do not incorporate the regulator are either separate from the boiler and joined via one or two pipes, or bolted to the boiler. In both cases where the superheater header does not incorporate the regulator and does not form part of the pressure vessel it need not be tested in conjunction with the boiler, but should be tested separately, being part of a pressure system.

Headers should be manufactured in accordance with original drawings and specifications. Changes of design or material need to be subject to formal approval by the Competent Person. When new, all superheater headers should be hydraulically tested to 360psi for 30 minutes. A separate hydraulic test should be independently undertaken to both the saturated and superheated compartments. A new header should be subjected to NDT such as radiography to confirm that it is free from surface breaking and volumetric defects.

Elements can be attached to the header by a variety of methods:

- Clamped by means of a through bolt and clamp (MeLeSco pattern). Diagram 3.
- Clamped by means of a stud and clamp (Midland Rly and GWR new pattern). Diagram 4 and 5.
- Directly bolted by means of a stud (GWR old pattern). Diagram 6.
- Expanded (Robinson type).





**Diagram 6 GWR old pattern flat ended element block.**

## 10. Elements

Elements can be of varying patterns but all will have an out (or saturated) tube from the header and a return (or superheated) tube going back to the header. One or more return bends are incorporated to increase the length of tube in each element. In some patterns, the tubes are bifurcated to produce two tubes with parallel flows.

Except where expanded directly into the header, the element tubes are welded or brazed to a fitting which is clamped to the header. Return bends and bifurcation castings are welded to the tube.

After manufacture or repair, elements should be subjected to light hammer blows to remove scale and debris before being filled with water and tested under hydraulic pressure to 1,000 psi.

## 11. Element tube

Material for element tube should be to one of the specifications above. OD and ID of tube vary with design but most are 1.25"od, other sizes being 1.5" or 1". In all cases the gauge of the tube is 9 or 10 swg except for GWR old pattern 6 tube elements which were 1"od by 14 swg.

Element tubes must be supplied with material certificates to ensure traceability.

## 12. Return Bends, header blocks and bifurcation Castings.

Return bends, header blocks and bifurcation castings should be of cast or forged steel free from defects. The castings must be supplied with material certificates and preferably X-ray results to indicate that the casting is not porous which would fail later on hydraulic test.

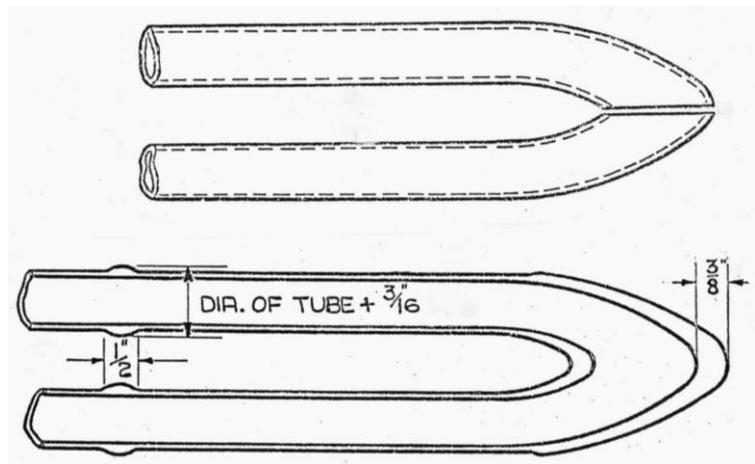
**13. Built up return bends**

Return bends can be manufactured by:

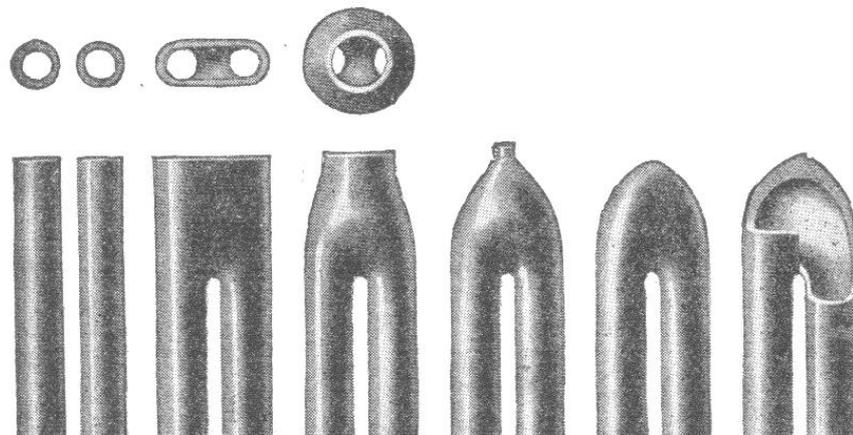
- Tightly bending the tube back on itself, it is important that the metal is thickened by the process and not thinned, especially on the outside of the bend.
- Welding together the curved ends of two tubes to form a spear end, Diagram 7.
- Welding a cast return bend onto the end of two tubes.
- Manipulating and forging together the ends of two tubes to form a forged return bend, a process used by MeLeSco, Diagrams 8 and 9.

If necessary, the end face of the bend may be further protected by the addition of metal plates or layered up weld material.

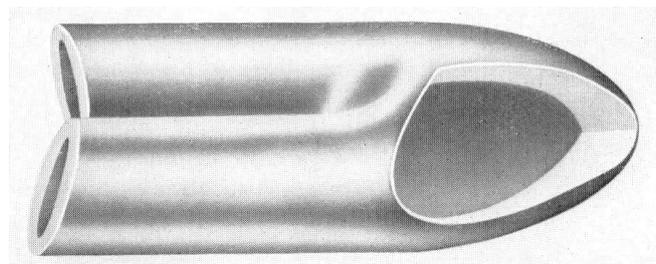
*Diagram 7. Spear end formed by welding shaped tube together and building up with weld material*



*Diagram 8. Progressive stages in the manufacture of MeLeSco solid machine forged return bends.*



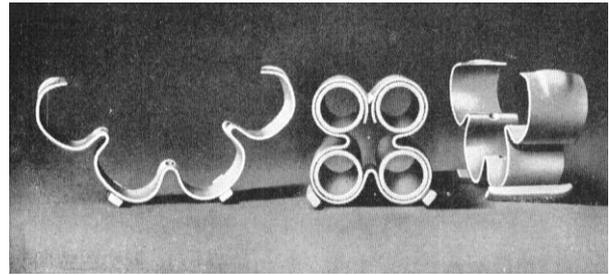
*Diagram 9. A MeLeSco forged return bend indicating thickening of material on the bend.*



#### 14. Bands and feet

Strip steel bands are shaped and used to space the element tubes apart at intervals down the length of the element, this spacing is typically every 4 feet. The band nearest the return bend end of the element will have two small feet to support the free end of the element and centralise it within the flue tube.

*Diagram 10. Element bands and feet.*



#### 15. Element to header seals

To seal the individual elements to the header, face to face joints are commonly used. Occasionally on old headers an asbestos impregnated copper ring will be found that should be disposed of in compliance with appropriate Regulations. In every case a graphite grease sealing compound should be applied to the surfaces before assembly and an anti-seize compound to the bolt or stud threads.

#### 16. Welding of elements

All welding of element tubes and fittings should be undertaken by a coded welder. Welding and welder qualifications should conform to BS EN 9606. Current standards should be checked with the competent person. Welds should be tested for cracking using processes to establish surface breaking and volumetric defects.

#### 17. Brazing of elements to header block, GWR pattern

If brazing is adopted to join tubes to the sockets in the header block, this should be carried out by a competent person to BS EN 14324:2004. Braze material should be to BS EN ISO 17672, 2024. Current standards should be checked with the competent person. Upon completion, the braze must appear to have flowed freely and formed a fillet around all element tubes. It is important that all four element tubes are to the same length and engage fully into the header block before assembly. All tubes should be raised in temperature uniformly during brazing to avoid any differential expansion which will alter the engagement of other tubes. New assemblies which have not previously been brazed may be welded. Welding and welder qualifications should conform to BS EN 9606. Welds should be tested for cracking using processes to establish surface breaking and volumetric defects.

#### 18. Element removal

Elements are removed by undoing the clamp nut. In practice, this is often rusted to the stud in which case the nut can be heated to expand it and break the joint. Care should be taken when heating as any significant rise in temperature will affect the heat-treated condition of the alloy steel stud. If damaged, the stud and nut should be replaced. Old elements can be difficult to remove from flue tubes as they often distort and jamb, it may be necessary to attach a "pull lift" to the element to extract it from the flue.

#### 19. Element repairs

Over time, elements will be eroded by the effects of ash passing over with the products of combustion and corrosion to both the external and internal surfaces.

Repair by oxy acetylene welding, MIG or TIG is possible but may not be economic in the long term. All welding repairs should be carried out by a coded welder. Care must be taken to ensure complete fusion without leaving rough metal fouling the interior or exterior of the tubes. All welds must be slightly reinforced by means of additional filler rod material built up around the periphery of any holes.

Ball-ended elements can have the spherical surface of the joint cleaned up by means of a cup shaped grinding wheel held in a portable air or electric drill. The cup must be to the correct profile and dressed when worn.

Header blocks will corrode and thin over time; minimum material thickness for GWR steel header blocks is typically 5/16" when new. Thinning below 1/4" should be brought to the attention of the Competent Person and tested ultrasonically to confirm the actual thickness.

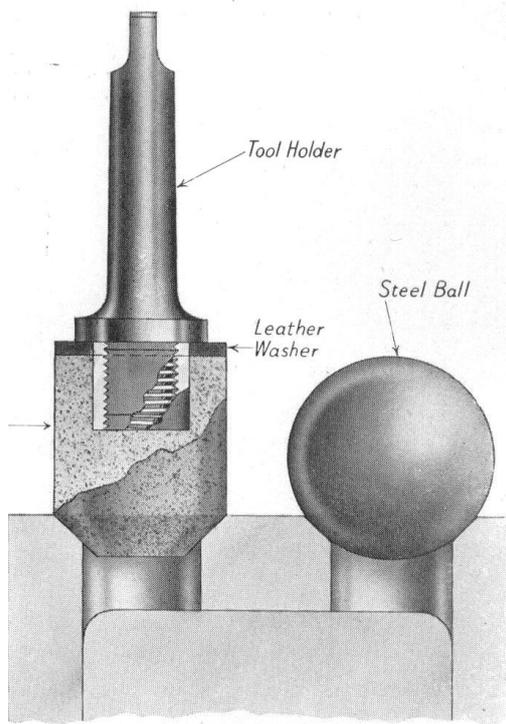
**Header repairs**

Both cast iron and steel headers will corrode and loose thickness over time. In addition, cracking of cast iron may occur. The assembly should be inspected annually by the competent person and stripped at intervals defined in the Written Scheme of Examination for the competent person to inspect. At each interval, the condition of the header should be confirmed and its suitability to continue in service established. In addition, the Competent Person should have the opportunity to thoroughly inspect the header on the bench after it has been cleaned and hydraulically tested to 150% of the boiler's safe operating limit. Defects such as cracking will indicate that the header has reached the end of its service life and a replacement should be manufactured. Cast iron welding or stitching is not recommended.

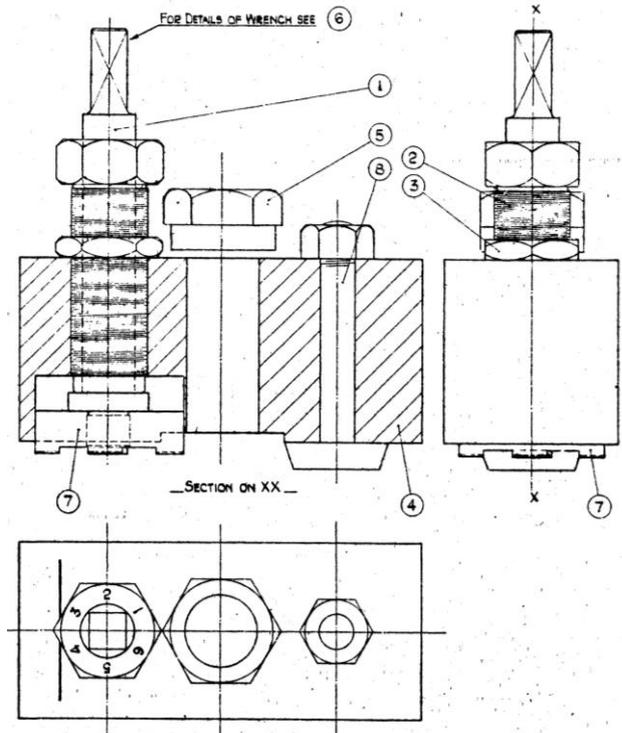
Damaged element seats can be either refaced by machine whilst the header is removed from the locomotive. This is the preferred option, or this can be carried out by means of a specially shaped grinding wheel held in a portable air or electric drill.

If using the grinding method, it is important that the grinding wheel is regularly dressed to a true profile and, when in use, it is held perpendicular to the face of the header. Progress can be monitored by the use of an appropriate diameter ball and high spot blue. See diagram 11.

On flat faced headers, a seat cutting tool may be adopted which is clamped to the header via the stud and is located by a pin into the adjacent hole. See diagram 12.



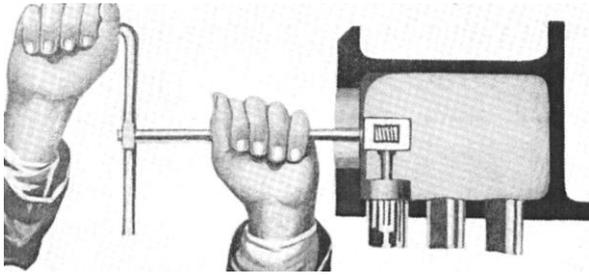
**Diagram 11. Grindstone for cleaning up the coned seat of a header joint.**



**Diagram 12. GWR tool for facing up the element joint face, flat joint type, using cutter item 7**

## 20. Robinson type

The Robinson type superheater is similar to all others with the exception of the means of fixing the elements into the header. In Robinson type superheaters, the tubes are expanded into the header using special worm drive expanders. Once expanded, the element and header are as one piece similar to smoke tubes in a boiler - see Diagram 13. The special expander must be of the parallel pattern to avoid the tube coming loose in the header and blowing out. The access hole for the expander is covered by a bolted plate when not required. Ends of tubes and tube holes in the header should be clean and free from oil before expanding.



**Diagram 13. Expanding Robinson superheater tubes into the header with special expander**

To remove Robinson type superheater tubes, it is normal firstly to cut off the element below the header and slit the tube. Using drifts, the remains of the tube can be forced out of the header.

## 21. Testing elements in service

Superheaters and headers should be subjected to regular inspection and testing in service. Inspection should be via both the smokebox and firebox during washouts, Signs of leaking elements or joints are indicated by the presence of water or staining from boiler salts. When in steam, the following process should be adopted to test for leaks. One person must stay in the cab at all times for safety:

- Secure the locomotive by applying the power brake and place scotches under the wheels;
- Ensure reverser is in mid gear with drain cocks shut;
- Close fire hole doors and dampers, shut off blower and open smoke box door;
- Open regulator to pressurise steam chest and superheater assemblies;
- Apply a lighted taper on the end of a long wire to each of the joints between element and header; and
- Apply the taper to the end of each of the flue tubes.

The presence of a blowing joint or element will be indicated by the deflection of the flame from the taper. Depending upon the location and severity of the blow, the taper may be either blown out or flattened by the jet of steam. Alternatively, if it is sucked down a flue then it is an indication that the blow is towards the fire box end of the element.

During this process it is easiest if the fire in the fire box is out or almost out, otherwise the absence of oxygen close to the tube ends makes the taper difficult to keep lit.

## 22. References

- Red Book section B13 superheater elements.
- Red Book section J6 and J7 manufacture of new superheater elements by welding.
- GWR drawing 108602A, lengths of standard superheater elements.
- GWR drawing 118297, superheater with combined regulator.
- GWR drawing 125892, standard junction header spherical type.
- GWR drawing 134481, 4 tube superheater.
- The superheater company booklet "Installation, maintenance and operation of MeLeSco locomotive superheaters"