



## GUIDANCE NOTE

# THERMIC SYPHONS AND ARCH TUBES

### 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**

- a) 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.
- b) 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 and insurers to discuss the issues, distil good practice and codify it into this series of Guidance Notes.
- c) 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.
- d) This guidance should also be useful to those in a supervisory or more general role. However, no work should be undertaken unless the persons concerned are deemed competent to do so.

**2. Recommendations**

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

**3. Dimensional Notation**

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

**4. Personal Protective Equipment**

- a) Before undertaking any work, a risk assessment must have been conducted.
- b) 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.
- c) The equipment must be:
  - i) Compliant with the latest Personal Protective Equipment Regulations;
  - ii) Properly assessed before use to ensure it is suitable;
  - iii) Maintained and stored properly;
  - iv) Provided with instructions on how to use it safely; and
  - v) Used correctly by those undertaking the work.

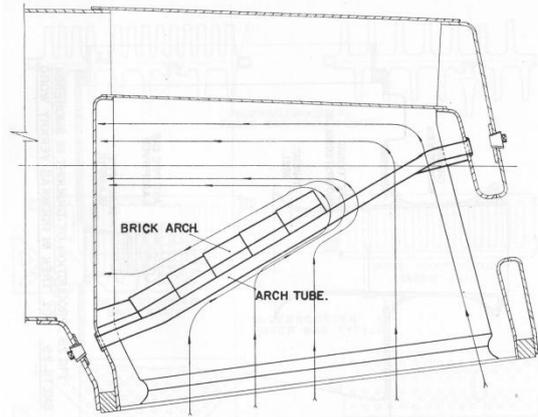
**5. Inspection**

In the event of finding that the syphons or arch tubes are suspect seek guidance from the boiler Competent Person before proceeding with any repair or replacement.

## 1. Introduction

- a) The circulation of the water in the boiler is very important, particularly when using a steel inner firebox, as the faster the water circulates the more readily is the heat of the fire absorbed by the water. As it is not possible to use pumps to give a rapid forced circulation of water in a locomotive boiler, reliance must be placed on natural circulation, and two devices are used to improve this natural circulation. They are Arch tubes and Thermic syphons.

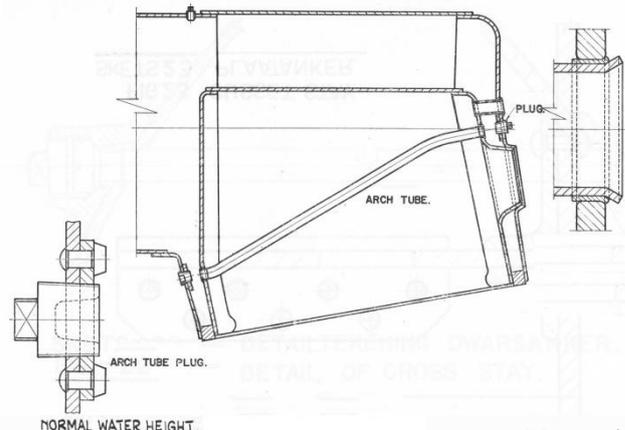
**Fig 1. Firebox with Arch Tubes showing the direction of draught and air currents.**



### Arch tubes

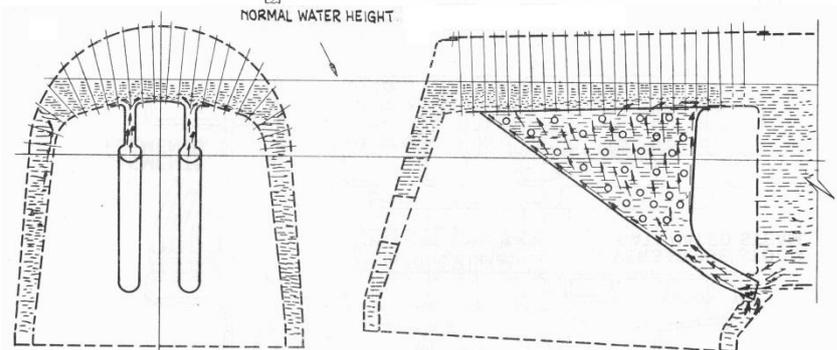
- b) These are connected to the lower portion of the tube plate in the throat area, and slope upwards from there to the inner back plate above the firehole. Increased firebox heating surface is thus provided and, further, the water in the front (throat) water space is caused to move rapidly through the arch tubes to the upper portion of the back water space. The arch tubes also serve to support the brick arch.

**Fig 2. Firebox with Arch Tubes**



### Thermic syphons

- c) These serve much the same purpose as arch tubes, but deliver water to the crown of the firebox, instead of to the back water space. They also provide a much larger heating surface than arch tubes. Some boilers are equipped with two thermic syphons to provide greater heating surface.



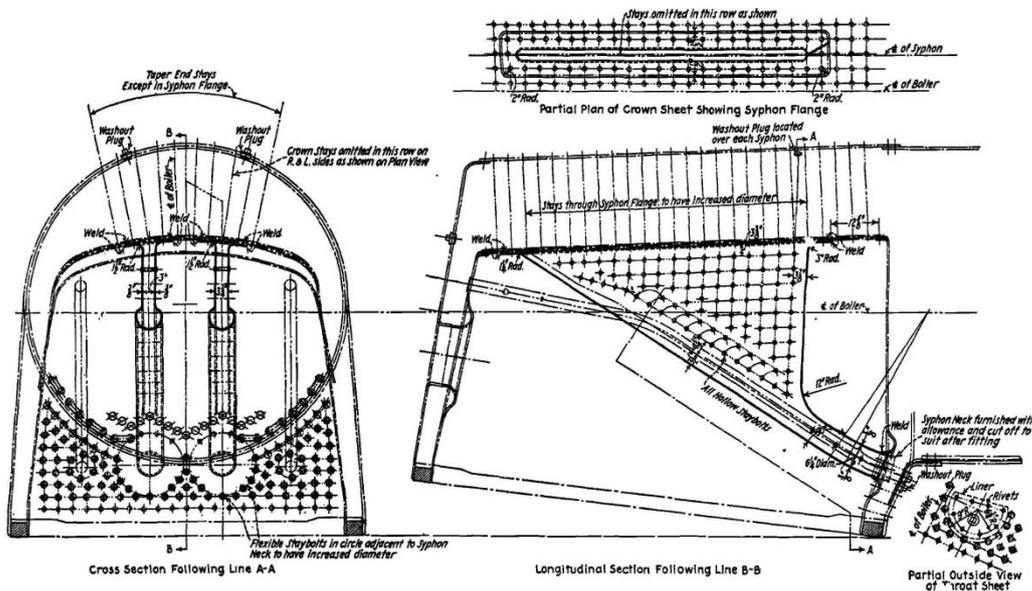
**Fig. 3 Firebox with Thermic Syphons**

## 2. Arch Tubes

- a) The arch tube is a thick-walled tube that is fitted to the lower part of the firebox inner tubeplate (or inner throatplate) and runs through the firebox on a rising gradient to the firebox inner doorplate allowing water to flow through it from the front to the back of the firebox.
- b) More than one tube is usually fitted, often three or four; they are thick walled, approximately 3/8" with a diameter varying between 2 3/4" to 3 1/2" and expanded into the firebox plates and bell mouthed or beaded inside the water spaces. They are so designed with some form of bend or curve in them to allow for expansion and movement, which is almost instant on lighting up relative to the rest of the firebox.
- c) Normally these are only fitted to steel inner fireboxes and therefore seal welding of the connections is necessary to maintain steam tightness.

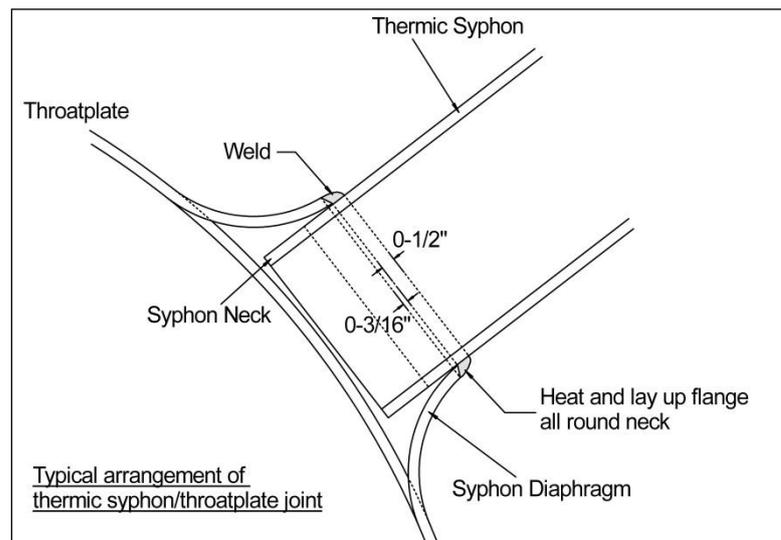
- d) To allow periodic inspection and cleaning on the inside, large type washout plugs are fitted to the throatplate and doorplate in line with the tubes. These are usually supported on thick compensating rings riveted or welded to the plating to take the extra threads.
- e) Because of their position in the firebox, the refractory brick arch is usually built on top of these tubes. They are exposed to the direct radiant heat from the fire and generate a great deal of steam.
- f) Being simple tubes at full boiler pressure, they are often the most delicate parts of the boiler. Care must be taken to avoid damage from fire irons etc.
- g) Being full of water these are the first parts to generate steam on lighting up the boiler and so start a rapid circulation of the water round the firebox and speeding up the temperature distribution around the boiler.
- h) In addition to the advantages mentioned, they have distinct disadvantages. Being exposed to the direct combustion of the fuel they suffer from great mechanical straining and are vulnerable to cracking at tube and door plate welded joints as they try to expand and break their connections to the tube and door plates.
- i) External erosion can occur as char and cinders are scoured over them. Steam ebullition (common on water tube boilers) occurs where steam is generated so fast on the inside of the tubes that it reduces the capacity of the water to remove the heat transferred to the tube from the radiant heat from the fire. This causes the tube to burn externally; this is made much worse by any accumulation of hard scale on the inside of the tube.
- j) It is essential to keep these tubes free from any form of sludge and scale build up.
- k) Special mechanical tube scalers are available to put through the tubes and remove hard scale deposits that have formed and should be available for use at depots during boiler washout.
- l) It is essential not to allow the scale to form in the first instance by adopting a quality boiler water treatment programme.

**3. Thermic Syphons**



**Fig. 4 Details of Firebox with Thermic Syphons**

- a) The thermic syphon is an extension of the process of drawing cooler water in from the lower firebox throatplate and spreading the water up onto and over the firebox crown plate. This distributes and diffuses the water to the hotter regions of the firebox so setting up a rapid circulation throughout the boiler in a forced stirring action.
- b) Thermic Syphons are normally only fitted to steel inner fireboxes of the wide firebox type where circulation problems are most acute.
- c) It is similar to a typical funnel with the wide top having been flattened into a narrow water wall supported by short fixed steel stays, the top being flanged outwards and securely attached to the crown plate. The lower end of the funnel is bent round to form the connection on to the firebox inner throatplate about 12" above the firebar level. This is attached to the throatplate by a special flexible steel diaphragm plate, which allows the syphon to move and expand relative to the rest of the firebox. This is also assisted by the throatplate having a ring of steel flexible stays around the diaphragm plate.
- d) The syphon neck is of large diameter approximately 6.1/2" bore and a pressing, welded to the side pressings and the top inlet pressing. There are three pressings that make up the complete syphon. The diaphragm plate is also a pressing and welded to the throatplate. The neck of the syphon slips inside this diaphragm and projects through into the water space. This sliding joint is finally closed off by a wide fillet weld after all other welding and staying of the syphon has been carried out, allowing the neck to adopt a stress-free configuration after all the mechanical straining has settled out.



**Fig. 5 Details of thermic syphon / throatplate joint**

- e) Usually, two syphons are fitted in the firebox and as with the arch tubes these assist the formation of the refractory brick arch.
- f) To allow periodic inspection and cleaning on the inside, large type washout plugs are fitted to the throatplate in line with the neck. These are usually supported on thick compensating rings riveted or welded to the plating to take the extra threads. On the top of the outer firebox, standard washout plugs are fitted over the top of the syphon water walls.
- g) The advantages of the thermic syphon are claimed to give improved rapid circulation within the boiler and some short-term protection of the crown plate in the event of low water situations, by pumping the water over the exposed crown.
- h) They speed up the increase in water temperature in the otherwise dead spots of the boiler reducing mechanical straining especially when lighting up from cold.
- i) Their disadvantages are varied, as the firebox construction is more complex. Increased periodic maintenance may be necessary with the importance of keeping the water passageways clear of mud and scale. They are prone to cracking in certain highly stressed areas. This is linked to stress corrosion cracking due to poor quality boiler water and lack of boiler water treatment.

**4. Materials of Construction**

Arch tubes; Boiler and Superheater tube to 101216-1-2002 and 10217-1-2002 or  
 10216-2-2002 and BS EN 10217-2-2002  
 DIN 17175-79 grade St35.8 1/2  
 ASTM 192-02 (2012).

Supplied as Hot Finished Seamless or Cold Finished Seamless and in the Normalised condition.  
 Electric Resistance Welded tubes should not be used.

Thermic syphons; Steel plate for pressure purposes to BS.1501;PT1 161. 430 A/B  
 BS EN 10029-1991 and 10028-1-2-3-1991

Diaphragm plates: .. .. . As above.

Stays: .. .. . BS.970. EN3B. C/EN32 , ASTM A31 -04 -(2009)  
 (BS EN 10083 070M20). 080A15

For repairs to syphon neck: Steel tube for pressure proposes;  
 DIN 17175-79.  
 . ASTM. A192 or A106

For all other repairs, modern equivalents to the original must be used, or in consultation with the competent person and inspecting authority.

**5. Common Defects Associated with Arch Tubes**

- a) Leakages at expanded connections of throatplate and doorplate due to rapid expansion of the tube during lighting up periods.
- b) Overheating of the tube leading to burning, bulging, cracking or complete failure due to build-up of hard scale on the waterside.
- c) Distortion of the tubes due to a combination of the above.
- d) Erosion and stress corrosion on the waterside due to water and steam ebolution.
- e) Corrosion of the tube wall on the inside due to poor water quality.
- f) Erosion of the tube on the fireside due to scouring action of the char from the fuel.
- g) Corrosion of the tubes where refractory is in contact
- h) Where the connections are welded to the tubeplate/doorplate, cracking of the plate due to working of the tube on lighting up.
- i) Cracks in welds.

**6. Common Defects Associated with Thermic Syphons.**

- a) Cracking of fillet welds on syphon neck to diaphragm due to mechanical straining and/or overheating due to scale formed between inside of the diaphragm plate and the neck of the syphon protrusion into the water space.
- b) This also can cause the lower section of the diaphragm plate adjacent to the weld to bulge for the same reason.
- c) Multiple small cracks in both diaphragm plate and on weld and neck for the same reason.
- d) Waterside grooving on back heel and flange back radius caused by scouring action of the water and steam bubbles.

- e) Transverse cracking across the back welded seams.
- f) Cracking alongside weld of the top rear flange of syphon on the crown plate.
- g) Corrosion on the waterside at top of the syphon flange, where it is welded to the crown plate. This is nearly always at the rear.
- h) Corrosion and deep pitting of the syphon neck on the waterside due to scaling causing localised overheating.
- i) Abrasive wear of the syphon where the refractory is in contact.
- j) Broken flexible stays around the diaphragm plates due to these becoming seized up, through scale formation on the ball end not allowing any bending movement.
- k) Star cracking from the stay holes of the inner throatplate between the diaphragm plates.

### **7. Inspection Methods and Procedures**

- a) The inner firebox fireside visual examination, with the boiler either full of water or drained, will provide the first clues of any obvious leakages at the welded seams or connections to the throatplate or doorplate.
- b) The welded seams should be carefully examined all along their length for surface cracking.
- c) If the refractory brick arch is removed at any time, an inspection should be made of the arch tubes and thermic syphons. If there is suspicion of the condition of any tube or syphon neck obscured by the brick arch then this must be removed to allow a more detailed examination.
- d) The refractory brick arch should be removed irrespective of the above at periods not exceeding two years.
- e) General plate thickness and depth of corrosion may be determined by use of ultrasonic thickness measurements.
- f) Where access is possible, the depth of pitting may be determined by use of depth micrometer or pit gauge.
- g) Broken stays may be detected by light hammer testing, or by using two hammers either side of the syphon water wall. If the stay is sound the opposite hammer should bounce off.
- h) Any suspect areas may be further investigated using appropriate NDT methods - liquid penetrant, magnetic particle, ultrasonics, or radiography.
- i) With all inspection plugs removed and the boiler washed out a thorough examination of the inside of the tube or syphon can be carried out. Any hard to see areas must be investigated with a suitable endoscope or mirrors inserted into the inspection holes.

### **Arch tubes.**

- a) Arch tubes should be inspected for:
  - i) Erosion;
  - ii) Corrosion;
  - iii) Fire side Cracking;
  - iv) Cracking of tube ends;
  - v) Overheating and Blistering;
  - vi) Bulges and distortion;
  - vii) Mud and Scale build up;
  - viii) Weld repairs;
  - ix) Correct fitting to the tubeplate / throatplate and doorplate; and
  - x) Evidence of refractory brick damage to tubes when the refractory is removed.

- b) Any replacement tubes should be to the original specification.

**Thermic Syphons.**

- a) Thermic syphons should be inspected for:
  - i) Erosion;
  - ii) Corrosion;
  - iii) Fire side cracking;
  - iv) Corrosion and Pitting in the water spaces;
  - v) Cracking of the syphon neck, any cracking or bulging, particularly at the joint between the Neck and Diaphragm plate on the fire side;
  - vi) Overheating and Blistering;
  - vii) Mud and Scale build up or blockage on the waterside;
  - viii) Broken or damaged stays and flexible stays;
  - ix) Weld repairs; and
  - x) Evidence of refractory brick damage to neck when the refractory is removed.

**8. Acceptable repair methods.****Arch tubes:**

- a) Arch tubes that are damaged or reduced to less than the minimum required tube wall thickness shall be replaced in their entirety by a new one-piece tube, with complete traceability and certification to the specified standard.
- b) Welded repairs or partial replacement are not permitted.
- c) When arch tubes are installed by rolling, the tube end shall project through the firebox plate into the boiler not less than 1/4" (6.0mm), and not more than 3/4" (19.0mm) before flaring or beading.
- d) The flaring of the tube ends should be at least 1/8" (3.0mm) bigger than the nominal diameter of the tube hole.
- e) The new tube should be formed so that it sits perfectly squarely into the firebox plate before welding or expanding. Adjustments should be made to the tube to achieve this.
- f) The boiler should be hydraulic tested on completion of arch tube renewal.

**Thermic Syphons:**

- a) Where cracks in the diaphragm plate pressing occur on a regular basis, consideration should be given to relieving the syphon at the point where it connects to the diaphragm plate. The fillet weld round the neck is ground off and the syphon released. The diaphragm is opened out at this point creating a gap around the neck. If the syphon is under strain from any region this will allow it to relieve that strain and attain its new position. The diaphragm is then dressed back to the neck and re-welded.
- b) If there have been recurrent repair welds to the diaphragm, a judgement needs to be made as to whether to continue with any more welds or to cut it out from the throatplate and renewed. The flexible stays round the outer region will require replacing at this time.
- c) The boiler should be hydraulic tested on completion of thermic syphon repair.
- d) Where waterside corrosion is bad, cutting out and renewal of sections of the crown plate is the only solution.

**9. Cracking in the firebox crown plate adjacent to the syphon flaring or flange.**

- a) This is usually attributed to problems of stress corrosion cracking on the waterside but can also be due to prolonged mechanical straining within the firebox itself.
- b) Depending on their location, cracks can be ground out and re-welded from the fireside without disturbing any crown stays, provided the material is sound and not suffering from extensive corrosion from the waterside.
- c) Patches to the syphon water wall and top flange can be made up and welded into the affected areas. This is a more permanent solution. However, extensive patching should not be considered and complete syphon replacement is the best option.
- d) Consideration should be given to relieving the neck of the syphon at the diaphragm plate by suitable methods and re-welding the closing fillet weld.

**10. Cracks in the lower areas of the syphon neck or deep pitting on the waterside.**

- a) Consideration should be given to the replacement of the lower section, by cutting along each side of the neck up to the change in section at the back and welding in a half-section patch derived from a piece of seamless tube. All completed butt welds should be subject to ultrasonic inspection before the fillet weld is carried out on to the diaphragm plate.
- b) Crack or fractures in the syphon neck or the back heel of the syphon water wall, although not as common, can be ground out and re-welded provided there is only one crack and this is no closer than 1" (25mm) to any existing or previous repair.
- c) Cracking between stays on the syphon water wall may be repaired by welding after the stays are removed and Magnetic Particle Inspection of the areas carried out. The cap of the weld should remain and not be flushed off. This will allow a witness of the repair for future reference and consideration of suitable future repair in that particular area and new stays fitted on completion.
- d) Small transverse cracks in the back heel of the syphon water wall, across the welded seam, should be ground out and welded provided they are not nearer than 1"(25mm) from a previous repair or another crack.
- e) Erosion or stress corrosion cracking on the waterside of the back heel of the water wall should be cut out and a patch welded in position. This could extend from the start of the top flared section down to the point where the heel meets the neck. Consideration should be given to the extent of the corrosion.

**11. References.**

- a) Institute of Mechanical Engineers Journal Vol.154 1946 – "Some notes on the Merchant Navy Class Locomotives of the Southern Railway-" Bullied OVS
- b) Institute of Locomotive Engineers Vol.48 paper 584 – "Experiences with the Steel Fireboxes of the Southern Region Pacific Locomotives" –Burrows & Wallace
- c) American National Board Inspection Code. Appendix 3. – "Steam locomotive firetube boiler inspection, repair and storage."
- d) Australian Rail industry safety standards board (RISSB) – "Boilers for Rail, Code of Practice."

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