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GUIDANCE NOTE

PREPARATION, OPERATION and DISPOSAL of Steam Locomotive Boilers

Purpose

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

Development

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

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1. Introduction

- a) 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.
- b) 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.
- c) 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.
- d) 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.
- e) 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. Scope of this Guidance

- a) This guidance is ONLY concerned with those actions that could adversely affect the life and / or the safe operation of the boiler. Duty holders should consider all aspects of each of the sections covered before determining their procedures.

4. Dimensional Notation

- a) 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.

5. 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.

6. Principles

- a) The purpose of this guidance note is to ensure the safe operation of the boiler by the footplate crew and to maximise the operating life of the boiler before repairs become necessary, by presenting best practice for the footplate crew to follow.
- b) To avoid damage to any boiler, two principles are essential:
 - i) If possible, the temperature of all parts of the boiler should remain constant; if this is not possible, the rate of change of temperature should be as slow as possible throughout the operating cycle.
- c) In practice, these principles are difficult to achieve for locomotive boilers, but every effort must be made not to stray too far from the ideal. This can be achieved by:
 - i) When raising boiler pressure from cold taking as long as possible;
 - ii) Whilst operating, keeping the boiler pressure nearly constant without rapid fluctuations;
 - iii) At the end of the day, letting the boiler pressure fall gradually;
 - iv) Avoiding rapid changes in fire temperatures, firing little and often, and avoiding excess cold air;
 - v) Adding feed water as steam is used; avoiding allowing the water level to fall at times of high steam demand and then adding feed by using both injectors; and
 - vi) Maintaining a level of water in the glass to avoid excessive use of the injectors at the end of the day which will cool the boiler down too rapidly.
- d) Adhering to these principals will maximise boiler life and effect an economy in coal consumption.

7. Preparation

- a) In accordance with local instructions:
 - i) Check locomotive repair documents for previously booked faults, either rectified or otherwise, and check for any new notices concerning particular locomotives.
 - ii) Walk around locomotive to ascertain if any persons are working on the locomotive and check for the presence of "Not to be moved" board or red flags.
- b) Commence preparation of the locomotive:
 - i) Check that the locomotive is secure. Is hand brake fully applied? Is the loco in mid-gear? Are the drain cocks open? Is the regulator shut?
 - ii) Ensure that the locomotive is complete and in order, with all valves and fittings turned off.
 - iii) Check the correct operation of water gauge(s) and boiler water level.
 - iv) Check the operation of water level trial taps if fitted.
 - v) Looking through the firehole door, examine the interior of firebox (as far as possible) for leakage or distortion. Particularly: stays, stay nuts, lap seams, tubes, fusible plugs, grate, brick arch, thermic syphon.
 - vi) Examine accessible areas of boiler for leaks including mud hole doors, washout plugs, manifold and fittings.
 - vii) Check the water level of the tank or tender.
 - viii) Open the smokebox and examine for leaks and loose components. Particularly: is the spark arrestor clean and secure? Are all fittings secured? Is the blast-pipe jumper free? Are there any signs of leaks from pipes, superheaters, tubes, washout plugs, blastpipe base, blower, flanges, boiler joints and rivets? Is the ash disturbed in the bottom of the smokebox, if not already cleaned out? Check that the door seal is in good condition, check that the crossbar is secure, close the door and secure tightly.
 - ix) Remove the chimney lid if fitted.

- x) Check the condition of the ashpan including the fit of damper doors and hopper doors.
- xi) Report and record any defects in accordance with local instructions.
- c) Disposal, if not already done:
 - i) Empty the smokebox. Ensure that ash is cleared away from all vulnerable parts (steam pipes, tube plate flanges etc.) to minimise corrosion.
 - ii) Clean the spark arrester and close the smokebox door.
 - iii) Remove the remains of the fire either by “paddling” out with a clinker shovel or by use of the rocking grate. If rocking grates are used, ensure all clinker is broken up and the fire is drawn off the rocking section before it is operated. Avoid the excessive use of the blower. Having any dampers shut will help reduce dust blowing into the cab.
 - iv) Empty ashpan. If possible, soak ashes first to avoid contamination of the motion with fine dust. Ensure all ashes are removed from the ashpan.

8. Blowing Down

- a) Boilers subject to poor water should be blown down at intervals to reduce the levels of dissolved solids in the boiler. Blowing down is achieved by opening the blow down valve, preferably when the boiler is in low steam, but at a pressure that the injectors will work reliably.
- b) The blowdown valve is opened and the water level is allowed to fall towards the lowest safe working level in the glass, at which point the blowdown valve is closed and the boiler refilled to the top of the glass by means of one injector only. During this procedure, the fire must be bright enough to maintain a steady boiler pressure; this will prevent excessive cooling of the boiler. This is repeated 2 or 3 times on a daily basis, at a time of day to suit operational requirements.
- c) Blowdown valves should be either locked shut to prevent misuse or located in such a position to prevent accidental opening. Blowing down should be restricted to those authorised to perform the operation and its operation performed in a location that will prevent risk to staff and public.

9. Steam Raising

- a) Raise steam slowly without excessive smoke, taking care to avoid excessive stresses on the boiler by:
 - i) Commencing with a light fire;
 - ii) Lighting the fire at the lowest part of the grate to promote water circulation within the boiler;
 - iii) Not using the blower, even if steam is available, until the fire has spread across the entire grate and has become established;
 - iv) Keeping dampers shut. This will assist in reducing the amount of smoke that may come out through the fire hole door;
 - v) Building the fire gradually and avoiding large quantities of fast burning material such as wood;
 - vi) Not using accelerators such as bottles full of combustible liquid to liven the fire;
 - vii) Avoiding timber contaminated with paints, metal fittings, plasterboard etc; plastic materials or other combustible items which may produce toxic fumes and tarry deposits on plates and in tubes; and
 - viii) As soon as possible confirming the satisfactory operation of any injector or pump. The boiler must have two independent means of feeding water, and both must be operational.
- b) Once steam is raised to working pressure:
 - i) Re-check the operation of injectors or pumps;
 - ii) Re-check the condition of firebox as far as possible; listen for sounds of leaks;
 - iii) Re-check externally for leaks;
 - iv) Re-check smokebox for leaks;

- v) Test the safety valves; note the pressure registering on the gauge compared to the maximum operating pressure (the red line);
- vi) Test water gauge frames by momentarily opening drain cocks to observe the fall and rise of water level. Test again with top cock closed, and again with bottom cock closed. Do both gauges agree? Operate water test cocks if fitted;
- vii) Report and record any defects in accordance with local instructions;
- viii) Administer any water treatment chemicals in accordance with local instructions; and
- ix) Blow down the boiler in accordance with local instructions.

10. Driving & Firing

- a) Constant boiler temperature is the ultimate intention, as boiler water temperature is directly related to boiler steam pressure. The desired pressure is just below the point at which the safety valves will begin to lift.
- b) Injectors are used to maintain the correct water level within the boiler; the purpose of the injector is not to control boiler pressure. Boiler pressure is maintained by the appropriate application of coal as required and the use of dampers to restrict (but not stop) air flow to the fire.
- c) Good firing practice is to maintain a constant level of bright fire over the grate all of the time that the locomotive is working and the blast pipe is creating a vacuum in the smokebox. The well accepted phrase of "little and often" is good advice for firing technique.
- d) Do not:
 - i) Fire when starting away from rest; the open fire hole door will allow cold air into the fire box and the fresh coal will be too cold to produce any heat.
 - ii) Fill up the fire box with coal just prior to starting away, as the fresh coal will absorb the heat from the established fire.
 - iii) Allow holes to develop in the fire bed, particularly around the sides, front or back as the cold air drawn in will cool the boiler plates in the firebox.
 - iv) Allow excessive amounts of secondary air in through the firehole when the locomotive is working hard; secondary air should only be applied when the fire bed is incandescent and able to heat the incoming air rapidly.
 - v) Use the boiler without a deflector or smoke plate in the fire hole to deflect the secondary air.
- e) Do:
 - i) Maintain a constant high boiler pressure as this will allow the locomotive to operate more efficiently.
 - ii) Fire little and often.
 - iii) Maintain a consistent water level, normally 2/3 full in the gauge glass but this may vary with duty, locomotive design and railway operation.
 - iv) Listen for defects from within the firebox such as the onset of a hissing sound indicating a leak.
 - v) Reduce the depth of the fire towards the end of the run/day to anticipate arrival time at the destination.
 - vi) Use the blower only for reasons of safety to ensure the products of combustion do not enter the cab. The blower should not normally be needed to increase boiler pressure.
 - vii) Open the blower on the approach to tunnels and low bridges; at higher speeds more blower will be required.
 - viii) Anticipate changes in gradient and the effect on water level due to grade and rail cant.
 - ix) Avoid very heavy braking, particularly on falling gradients, due to the short-term effects on water level over the firebox.

- x) Aim to arrive on shed with a high water level, steam pressure falling and a burnt through fire that is still alight right across the grate without any holes.
- xi) Report and record any defects in accordance with local instructions.

11. Disposal

- a) Now is the time when the boiler is often subjected to damaging stresses by crew mishandling. It is important to avoid rapid filling of the boiler with cold water as this produces a quick drop in temperature and uneven contraction that will lead to boiler damage.
- b) Blow down and slowly refill boiler in accordance with local instructions. It is important that the fire is still bright whilst this process takes place, so that the fresh feed water may be raised to the temperature of the rest of the boiler and not form a cold layer above the foundation ring. (see Section 7).
- c) Depending upon how often the boiler is steamed, it is best to leave disposal of ashes in the smokebox and remnants of the fire in the fire box until the following day. Doing this allows the boiler to cool down slowly overnight and the residue of the fire assists in sealing the grate from circulating cold air. An additional benefit is that crews do not have to handle hot coals or be subjected to hot char blowing around from the open smokebox.
- d) For this to work satisfactorily, the crew must stay with the boiler for sufficient time to confirm that the fire is dying and that the boiler pressure is falling. It is not sufficient to reduce boiler pressure artificially by use of the injector and assume that pressure will remain low.
- e) Follow local instructions to ensure that the locomotive is secure.
 - i) Is the hand brake fully applied?
 - ii) Is the loco in mid gear?
 - iii) Are the drain cocks open?
 - iv) Is the regulator shut?
- f) If local instructions are to dispose the fire, it must be done with the minimum use of the blower and circulation of cold air. Once disposed, all dampers and the firehole door should be closed.
- g) The boiler should be filled to a level that allows for a good water level to show in the glass the following day, once the water has cooled and contracted. Normally having a water level at the top of the glass is sufficient. Shut off the water gauge frame, drain the water but do not leave the drain open. This will protect the water in the boiler in the event of a broken glass or leaking rubbers.
- h) Checks:
 - i) Examine the firebox interior (where possible) for leakage or distortion including stays, stay nuts, lap seams, tubes, fusible plugs, grate, brick arch, thermic siphon.
 - ii) Examine accessible areas of boiler for leaks including mudhole doors, washout plugs, manifold and fittings.
 - iii) Open the smokebox and examine for leaks and loose components, including:
 - (1) Is the spark arrestor clean and secure?
 - (2) Are all fittings secured?
 - (3) Is the blast-pipe jumper free?
 - (4) Are there any signs of leaks from pipes, superheaters, tubes, washout plugs, blast pipe base, blower, flanges and joints?
 - (5) Is the ash disturbed in the bottom of the smokebox, if not already cleaned out?
 - (6) Check that the door seal is in good condition, check crossbar is secure, close door and secure tightly.
 - iv) Report and record any defects in accordance with local instructions.

- v) Record use of boiler/locomotive during the day in accordance with local instructions.
- vi) Carry out frost precautions if appropriate in accordance with local instructions.

12. Safe Working

- a) Report defects or problems.
- b) Minimise lone-working.
- c) Don't remove a gauge glass protector unless the gauge frame is shut off and the drain is open.
- d) Don't tamper with safety valves.
- e) Don't tamper with washout plugs or mudhole doors, unless authorised to do so.
- f) Don't tamper with fittings which have a steam leak, unless authorised to do so.
- g) Don't open firehole doors without using sufficient blower to ensure protection against blowback.

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Appendix A: Coal

Coal which is of vegetable origin, varies considerably in composition due to its degree of coalification or age, and to the extent to which it has been subjected to pressure and heat during its formation. It is not even uniform in any one seam throughout its thickness.

With the massive reduction in the use of coal for industrial purposes, there are now no coal mines operational in the UK with one of the last at Fros-y-Fam closing in November 2023 despite representations by the Heritage Railway Association to have an indigenous source of coal survive the cull. The last coal fired power station at Ratcliffe in Nottinghamshire closed in October 2024. The coal that was imported for this power station was pulverised so was totally unsuitable for steam locomotives which require lumped coal either of the “cobbles” or “trebles” sizes. There are some small mines in the Forest of Dean but the production from these mines is insufficient to cover the needs of all heritage railways and thus there is now an almost total reliance on imported coal at hugely increased cost for the industry.

The HRA has been a leading light in working with interested parties and various heritage railways in testing alternatives to imported coal and these investigations continue and are reported upon on in the HRA *Insights* magazine to member railways.

Constituents

Coal is mainly composed of “fixed carbons” and “volatile matter”. The percentage of volatile matter is the prime method of grading the coal.

The bulk of the coal will be the fixed Carbon; this may vary from less than 50% for low grade coals to over 90% for quality anthracites.

The volatile matter consists of various hydrocarbon compounds within the coal that are driven off in gaseous form as the coal heats up. These may vary from a few % up to 50% of the different types of coal available.

Ash represents a number of incombustible compounds and is usually around 5-10%. Ash when heated to a high enough temperature will melt and combine with other impurities to form clinker.

Sulphur is a significant element in coal and is undesirable because of its acrid smell and corrosive nature when combined with water to form Sulphuric acid. Sulphur is normally less than 3%.

Chlorine is also a significant undesirable element because of its corrosive nature when combined with water to form Hydrochloric acid. Chlorine is normally less than 0.5%.

Friability is a measure of how robust the coal is to resist physical damage before it crumbles to dust. Friable coals must be handled carefully to avoid degradation.

Swell factor is how much the coal physically grows when heated; for most coal now mined this is low.

Selecting a suitable coal

Coal, with volatile levels:

Less than 12% are generally not suited to locomotive use due to the slow rate of burning unless of very small size.

Between 13% and 25% will burn with little or no smoke but require a degree of anticipation on the part of the fireman due to the time taken for the coal to start burning fully.

Between 26% and 40% will burn rapidly due to the volatiles being driven off the fixed carbon quickly when heated. Unless sufficient air (oxygen) is introduced to the fire most of the combustible volatiles will remain unburnt and appear at the chimney as black smoke and wasted fuel.

Ash, low if possible but the “ash fusion temperature” should be as high as possible, or above 1400 C. Ash fusion temperature is more important than the ash percentage, however even ash fusion temperature is not a good indicator of the quantity of clinker formed. Trial is the only satisfactory method to establish suitability for any particular grate/firebox/blast and fire thickness combination.

Sulphur. As low as possible, avoid coals over 1.5%.

Chlorine. As low as possible, avoid coals over 0.3%.

Calorific value, this is of little consequence in use, but will affect cost. A coal with lower calorific value will require a greater quantity to do the same work. A low-priced coal, if indeed it can now even be sourced is not necessarily the cheapest per unit of work done.

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