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DRAFT FOR PUBLIC CONSULTATION

Preface

This Code of Practice was prepared by the Inspection, Maintenance and Repair of Locomotive Boilers Development Group, overseen by the ARISO Rolling Stock Standing Committee.

Objective

The objective of this Code of Practice is to fill the gap left by the loss of experience as the use of steam locomotives continues into the 21st Century. This document provides a practical guide for rolling stock operators (RSOs) to assist them to meet their statutory responsibilities on steam locomotive boilers, which might be summarised as operating a boiler that is fit for service and presenting the minimum possible risk to any person with the minimum possible risk to the object so far as is reasonably practical (SFAIRP).

This is typically achieved by inspecting, repairing and maintaining boilers appropriately.

Commentary

Commentary *C Preface*

This Code of Practice includes a commentary on some of the clauses. The commentary directly follows the relevant clause, is designated by 'C' preceding the clause number and is printed in italics in a box. The commentary is for information and guidance.

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Section 1 Scope and general

1.1 Scope

During the 1990s, the federal and state governments transferred direct responsibility for boiler inspections by starting self-regulation through transferring responsibility to the rolling stock operator (RSO) through the *Rail Safety National Law and Regulations*.

This change required RSOs to implement comprehensive inspection, maintenance and repair programs to ensure ongoing fitness for service within their safety management systems (SMS). This has also typically resulted in the use of independent boiler inspectors.

Each state still requires boilers to be registered with the responsible authority. These authorities can audit RSOs that any time to determine that they are meeting their statutory responsibilities.

The Australian rail industry has recognised that steam locomotive boiler expertise is diminishing.

One of the sources of technical support services for the RSOs operating steam locomotives are independent boiler inspectors. There is also a range of familiarity and experience in the design and construction, and typical faults found in locomotive boilers used in railway service in the RSO organisations. In some cases, experienced practitioners can be sourced to provide technical advice, but they are rare.

With the advent of tourist and heritage railways, some of the larger organisations have established engineering workshops and begun reinvesting in and developing know how to help the construction, maintenance and inspection of the steam locomotive continue.

Importantly, each RSO is responsible for understanding their regulatory responsibilities set out by the laws and regulations that apply to them (i.e. *Rail Safety National Law and Regulations*, work, health, and safety legislation and regulations). This document does not intend to inform or instruct the RSO on the specifics of those responsibilities.

This document provides heritage RSOs with the necessary information to inspect, repair and maintain locomotive boilers.

The document aligns with the *ONRSR Rail Locomotive Boilers Guideline* and is intended to be read in conjunction with that guideline.

This document is intended to be used in its entirety. RSOs are encouraged to not pick and choose clauses to suit their requirements.

1.2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document:

- AS 1200:2015, *Pressure Equipment*
- AS 1210:2010, *Pressure Vessels*
- AS 1228:2016, *Pressure Equipment – Boilers*
- AS 1271:2003, *Safety valves, other valves, liquid level gauges and other fittings for boilers and unfired pressure vessels*
- AS 1349:1986, *Pressure and vacuum gauges*
- AS 1365:1996, *Tolerances for flat rolled steel products*
- AS 1565:1996, *Copper and copper alloys - Ingots and castings*
- AS 1732:1997, *Fusible Plugs for Boilers*
- AS 2593:2021, *Boilers – Safety management and supervision systems*

- AS 3678:2016, *Structural Steel Hot rolled plates, floorplates and slabs*
- AS 3679.1:2016, *Structural Steel Hot rolled bars*
- AS 3679.2:2016, *Structural Steel Welded*
- AS 3788:2024, *Pressure Equipment In-Service Inspection*
- AS 3873:2001, *Pressure equipment – Operation and maintenance*
- AS 3992:2020, *Pressure equipment – Welding and brazing qualification*
- AS 4037:2016, *Pressure equipment examination and testing*
- AS 4041:2006, *Pressure Piping*
- AS CB1.3-1957, *SAA Boiler Code, Part 3: Locomotive boilers for railway purposes*
- AS/NZS 4481:1997 Rec:2016, *Pressure equipment - Competencies of inspectors*
- BS 2874:1986, *Copper and copper alloy rods and sections (other than forging stock)*
- ASME SA-31:2025, *Standard Specification for Steel Rivets and Bars for Rivets, Pressure Vessels*
- ASME SA-675:2025, *Standard Specification for Steel Bars, Carbon, Hot-Wrought, Special Quality, Mechanical Properties*
- *ONRSR Rail Locomotive Boilers Guideline*

NOTE:

Documents for informative purposes are listed in a Bibliography at the back of the Standard.

1.3 Defined terms and abbreviations

For the purposes of this document, the following terms and definitions apply:

1.3.3 accumulation test

test which consists of shutting off all steam-discharge outlets not required for the test from the boiler and forcing the fire to the maximum

1.3.4 anneal

process of softening to remove internal stresses by heating and cooling

1.3.5 arch tubes

tubes located within the firebox to provide additional heating surface and to force water circulation around the firebox

1.3.6 banked boiler

boiler maintained at a low, standby heat level

Note 1 to entry: The boiler is not fully extinguished and uses minimal fuel, often by reducing air/fuel supply and closing dampers, to quickly bring it back to full operation when needed, conserving fuel while keeping the boiler warm

1.3.7 belly plate

type of access door typically fitted in the lowest part of the boiler barrel

1.3.8

blowdown valve (bottom)

valve fitted to the lowest part of the boiler to facilitate the removal of sediment and scale, reduce total dissolvable solids, and level and drain water from the boiler

1.3.9

boxing up

closing and sealing up of a vessel; refitting all mountings and plugs

1.3.10

brace

structural element fitted to support or strengthen

1.3.11

bridge

dog

fastening clamp used to draw the hand hole door onto its seat

1.3.12

bush (socket)

inserted fitting that may carry a plug, or be used to refurbish a worn or damaged threaded hole

1.3.13

bulge

deformation in a plate or tube

1.3.14

caulk/caulking

a process to seal a riveted joint or around a rivet head, effected by hammering with the blunt edge of a caulking tool

1.3.15

caustic embrittlement

metallurgical failure characterised by continuous, mostly intergranular cracks, that occurs under certain conditions, such as stressed metal, high pH, highly caustic water, traces of silica and a leakage path

1.3.16

chimney

funnel

hot gas exit from the boiler

1.3.17

cladding

cleading

external skin covering exposed boiler surfaces, typically made from sheet metal

1.3.18

competent person

person who has acquired through education, training, qualification or experience or a combination of these, the knowledge and skill enabling that person to perform the task required [Source AS 3788:2024]

Note 1 to entry: The term competent person is used in this document to address a variety of technical requirements.

Note 2 to entry: For some tasks the person could need to be assessed as competent to perform the task.

1.3.19

control of change

procedure whereby proposed variations to design are specified and reviewed by competent personnel before any modification is implemented

Note 1 to entry: The control of change also includes the assessment of risk, traceability and communication of the variation.

1.3.20

crack

linear defect in the homogenous structure of the material

1.3.21

cyclical stresses

internal distribution of forces that changes over time in a repetitive fashion

1.3.22

dezincification

corrosion of an alloy containing zinc (usually brass) involving loss of zinc

1.3.23

diaphragm

flexible material that allows for expansion and contraction

1.3.24

driven stay heads

act of forming by knocking down

1.3.25

fire crack

defect in material caused by heat

1.3.26

fire hole

opening in a boiler's furnace or firebox through which fuel is manually or automatically fed

1.3.27

flame impingement

direct contact of flame on surfaces, leading to degradation

1.3.28

flue tube

smoke tube

tube carrying gasses through the boiler

1.3.29

fullering

method of caulking where the width of the tool is equal to the width of the bevelled outer edge of the plate

1.3.30

funnel

see chimney

1.3.31

grooving

fatigue corrosion acting in certain areas where cyclic stresses are applied

1.3.32

gusset

bracing member or stay

1.3.33

hardening

metallurgical process used to change the molecular structure of the steel to increase its wearability or resistance to abrasion

1.3.34

history file

repository of all the relevant information and records of inspection, maintenance and repairs of the boiler

1.3.35

heat treatment

combination of heating and cooling operations applied to a metal or alloy to obtain desired metallurgical conditions or properties

1.3.36

inert gas

non-reactive gaseous element

1.3.37

jointing materials

jointing materials are used to provide a fluid tight seal between two stationary pressure parts (joints)

1.3.38

knocking down

driving heads

head formed by either mechanical or by hand methods, or located at the opposite end of the manufactured head on rivets and stays

1.3.39

knuckle(s)

compound radius corner where two plates join

Note 1 to entry: For example, a firebox tubeplate.

1.3.40

lagging

material with insulating properties applied to hot surfaces to retain heat

1.3.41

leak

escape of contents of the boiler to atmosphere

1.3.42

lime (hydrated)

substance used in the annealing process

Note 1 to entry: Refer to the SDS for this product.

1.3.43

lime (quick or slack)

substance used for long-term storage of boilers

1.3.44

safety data sheet (SDS)

form containing data regarding the properties of a substance

Note 1 to entry: The SDS is an important component of product stewardship and workplace safety. It is intended to provide workers and emergency personnel with procedures for handling or working with that substance in a safe manner, and information such as physical data (melting point, boiling point, flash point, etc.), toxicity, health effects, first aid, reactivity, storage, disposal, protective equipment and spill-handling procedures.

1.3.45

mode of failure

underlying causes of failure or which initiate a process that leads to a failure

1.3.46

monel metal

alloy based on nickel, copper, iron, manganese and other compounds

Note 1 to entry: The composition of monel metal is made up of 65% to 70% nickel, 20% to 29% copper and also contains 5% iron & manganese and other compounds.

1.3.47

non-destructive examination (NDE)

techniques used to test and inspect material properties without causing damage

1.3.48

normalise

heat-treatment process that has the object of relieving internal stresses and refining the grain structure

1.3.49

overhaul

perform the actions necessary to make the items fit for purpose

1.3.50

packing

packing materials are used to provide a fluid tight seal between a moving part (e.g., valve spindle or piston rod) and a stationary pressure part (i.e. the gland)

1.3.51

plate

sheet

flat metal

Note 1 to entry: The term sheet is commonly used in American practice.

1.3.52

pitting

localised corrosion that creates small, deep holes or cavities in metal, often leading to rapid, unexpected equipment failure

1.3.53

provenance

proven history

1.3.54

rail infrastructure manager (RIM)

As defined in Rail Safety National Law.

1.3.55

RSNL

Rail Safety National Law

1.3.56

rail transport operator (RTO)

As defined in Rail Safety National Law.

1.3.57

recondition

perform the actions necessary to make the items fit for purpose

1.3.58

red line

line on the pressure gauge that indicates the maximum allowable boiler operating pressure

1.3.59

rivet

fastener installed through multiple plates where the shank opposite the formed head is shaped into a head by hot or cold methods

1.3.60

rolling stock operator (RSO)

As defined in Rail Safety National Law.

1.3.61

safety critical

system or component whose malfunction or failure may result in injury or death

1.3.62

saturated steam

contains minute particle of water in suspension, also known as wet steam

1.3.63

scale

layer of foreign material adhered to a surface

Note to entry: Examples include corrosion scale or deposits of boiler water contaminants.

1.3.64

scarf

angle an item is cut to fit a mating piece

1.3.65

sealing

process of containing leaks

1.3.66

serviceable

item that is in a state in which it can perform its required function

1.3.67

sheet

see plate

1.3.68

shank

plain section of a rivet, stay or stud

1.3.69

sheathing plate

doubling plate fitted into the bottom of the barrel of some boilers

1.3.70

stay

mechanical device used to separate and support two plates

1.3.71

stay tube

tube designed to transfer heat and provide structural strength to the boiler

1.3.72

stud

threaded fastener

1.3.73

stud driver

device used when fitting studs

1.3.74

superheated steam

steam heated above the saturation temperature at that pressure

1.3.75

tempering

heat treatment process that is often used to improve hardness, strength, toughness, as well as decrease brittleness in fully hardened steel

1.3.76

tensile strength

a unit of measure describing the strength of a material

1.3.77

thermic syphon

tubes and a U shaped housing within the firebox, providing additional heating surface

1.3.78

TPI

threads per inch

1.3.79

wash out

process of cleaning scale, sludge and sediment from the water spaces of the boiler through the use of high pressure, high volume water flushing

1.3.80

water treatment

process used to make water more acceptable for use in a boiler

1.3.81

work harden

hardening of metal by plastic deformation

1.3.82

yield strength

stress at which the material becomes deformed plastically

General rail industry terms and definitions are maintained in the ARISO Glossary. Refer to:
<https://www.ariso.org.au/glossary/>

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Section 2 General responsibilities

2.1 Responsibilities of the RTO

2.1.1 Overview

The safe operation of boilers depends, in part, on the consistent application of good management and inspection practices that ensure the preparation (pre-operating), operation, inspection, testing, repair and maintenance of boilers is conducted to an adequate standard.

NOTE:

The competencies for inspections of boilers and those for assessment of repairs and alterations are different. See Clause 5.4 for repair and alteration competencies.

The RTO must define the responsibilities and competencies of the accountable person, responsible person and competent persons in accordance with the *Rail Safety National Law (RSNL)*. The appointments of both persons shall be recorded. See Figure 1.

In some organisations, an individual may fill more than one of these roles. It is important that in all cases the responsibilities and authority of each role is clear to all personnel involved in integrity management of the boiler.

The independent boiler inspector shall not be the accountable person or the responsible person.

The independent boiler inspector shall not be a competent person where that person performs any work on the boiler. They may be deemed a competent person for other purposes.

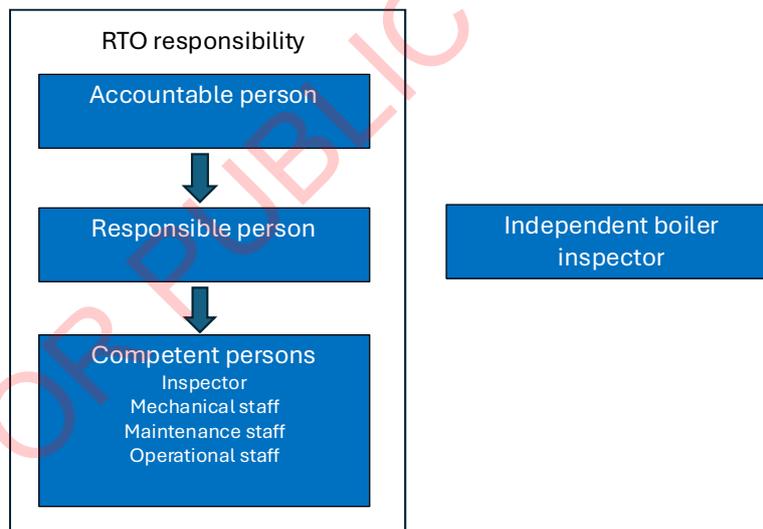


Figure 1 Responsibility hierarchy

2.1.2 Accountable person

An accountable person is considered responsible for the safety management system that the RTO operates under, approval of rail safety work, and ensure that safety related tasks have been completed correctly, in accordance with the RSNL. It is a fundamental requirement that the accountable personnel for each RTO (i.e. the owner/user operator) appoint a responsible person to manage and coordinate inspection, testing, repair and maintenance to ensure the safety of the boilers.

Accountable personnel are also responsible for ensuring that the boiler integrity management system, with all its required elements, is an integral part of the safety management system required to achieve accreditation to operate.

2.1.3 Responsible person

The responsible person shall:

- (a) have a suitable set of skills and knowledge of locomotive boilers to fulfil the role set out in the position description, for example, the engineering manager or locomotive superintendent;
- (b) have a position description detailing the responsibilities and authority over operating boilers; and
- (c) be responsible for implementing the boiler integrity management system and its associated activities.

The responsible person shall not authorize themselves as the competent person.

2.1.4 Competent person

The competent person(s) shall be authorized by the responsible person to undertake any task or job of work on a boiler that may affect its integrity. This may include:

- (a) inspection;
- (b) condition assessment;
- (c) maintenance;
- (d) repairs;
- (e) modification;
- (f) supervision; and
- (g) instruction and training.

Refer to AS 3788:2024 and AS 4481:2016 for guidance on competent persons.

2.1.5 Independent boiler inspector

The independent boiler inspector shall be independent of any functions associated with the boiler operation and maintenance. Refer to the *ONRSR Rail Locomotive Boilers Guideline*.

The independent boiler inspector shall meet the requirements of the *ONRSR Rail Locomotive Boilers Guideline*.

The independent boiler inspector should be qualified in accordance with AS 4481:2016 and the requirements listed for in-service inspections as per AS 3788:2024, Clause 3.6.2

The independent boiler inspector should be familiar with this document and apply it as necessary.

It is important that the advice and direction provided by the independent boiler inspector is carefully considered and respected. Where a different opinion is requested and obtained, the RTO should document the variances and the reasoning behind the different opinions, and the reasoning supporting the final decision.

Commentary C2.1.5

Independent boiler inspectors can be certified by an appropriate certification board such as the Australian Institute for the Certification of Inspection Personnel. However, certification for boiler inspections does not necessarily mean that the certified boiler inspector is familiar or qualified to inspect steam locomotive boilers.

2.2 Planning the boiler inspection

Boiler inspections are a critical task required to ensure the safety of the boiler, the operators of the boiler and anyone within the vicinity of an operating boiler.

The RSO and independent boiler inspector shall meet and agree on the inspection plan.

The inspection program shall be carefully planned and prepared. This should include:

- (a) having or obtaining an understanding of the:
 - (i) regulatory responsibilities applicable to the boiler;
 - (ii) risks of inspecting and how to do it safely, for example, in confined spaces;
 - (iii) design and construction of the boiler; and
 - (iv) risk of failures of the boiler and its fittings and attachments to the operating crew, the public, and third parties affected by the failure.
- (b) having or obtaining sufficient knowledge of the:
 - (i) equipment degradation mechanisms (internal and external) applicable to a locomotive boiler and its fittings and attachments to be able to plan an inspection;
 - (ii) acceptability criteria for imperfections and defects;
 - (iii) inspection and test techniques and their effectiveness for a steam locomotive boiler, that is, visual, non-destructive (NDE), destructive, hammer, hydrostatic and operational; and
 - (iv) maintenance requirements to ensure critical boiler fittings and attachments are reliable, for example, safety valves, water gauge glasses, blowdown valves and fusible plugs.
- (c) keeping a current and detailed history file with:
 - (i) operational information;
 - (ii) repairs and maintenance information;
 - (iii) incident and accident data;
 - (iv) faults observed (such as, from operational surveillance reports); and
 - (v) boiler water condition management plan and outcomes.
- (d) gathering information on the previous history of the boiler, such as inspection reports, repairs, failures and incidents; and
- (e) having an inspection and maintenance plan for the operating cycle of the boiler.

2.3 Prepare the boiler for inspection

The boiler shall be prepared based on the inspection plan. Preparation for inspection should include:

- (a) checking that the boiler history file is up to date;
- (b) reviewing the boiler history file to ensure any work done has been recorded;
- (c) washing out the boiler;
- (d) drying out the boiler (as far as is practical);
- (e) preparing fittings and attachments for inspection and testing, removing lagging as needed;
- (f) attending to safety requirements; and
- (g) preparing facilities and equipment for the inspector.

In line with the plan the independent boiler inspector shall:

- (h) assess equipment integrity using experience and observation to broadly survey the boiler and important components;
- (i) follow the published standards and other relevant reference documents in the inspection, including (but not limited to) AS/NZS 3788:2024, Clause 9.6;
- (j) accurately record observations (including photographs) and collate other reports (such as NDE) to create a complete record of the inspection;
- (k) determine what defects and imperfections are evident;
- (l) decide on any further inspection and/or testing required to complete the inspection; and
- (m) report to the RSO the results of the inspection, such as defects, repairs, alterations and re-rating.

2.4 Reporting defects and imperfections

The independent boiler inspector shall advise the RSO of any defects or imperfections, and the acceptability (if any) of those defects or imperfections identified during the inspection.

The independent boiler inspector, where competent, should advise what repairs and testing are required. If not competent to do so, advise, where possible, what the RSO might need to do to return the boiler fit for service, depending on further assessment by suitably competent personnel, for example, a welder certified to AS 3992

If required, and where the independent boiler inspector is competent, advise that the boiler may be operated at a specified reduced pressure.

The independent boiler inspector is to inspect after repairs in line with design or fabrication standards.

2.5 Completion certificates

The RSO and the independent boiler inspector are to review the inspection report, revise the inspection plan and set the next inspection date. See Clause 3.2 for further information.

Completed inspection reports shall include RSO and all third-party information (such as NDE reports), assessments of fitness for service, detailed information on defects and imperfections and any post repair inspections and testing done.

Any changes to the management and operation of the boiler recommended by the report to ensure fitness for service up to the next inspection, are to be discussed.

On an acceptable completion of an inspection the independent boiler inspector shall issue a certificate of inspection stating that the:

- (a) pressure equipment has been maintained in a safe condition; and
- (b) the boiler is safe to operate under the applicable regulations, reference standards and the *ONRSR Rail Locomotive Boilers Guideline*.

2.6 Commissioning

The RSO shall reassemble the boiler and test for commissioning as required in the inspection and maintenance plan, such as hydrostatic leak testing, setting safety valves in steam, leak inspection in steam and other operational checks.

The independent boiler inspector may attend the tests. The inspection plan or inspection report shall specify if this is required.

The RSO shall operate the boiler in line with instructions and conduct and record operational surveillance specified in the inspection and maintenance plan.

Section 3 Inspections

3.1 Overview

This section contains detailed inspection requirements for locomotive boilers. Inspection of items described in this section may include application of this document's appendices.

While this section provides a comprehensive list of required inspections, it is not necessarily a complete list as an individual boiler may have specific design features or historical degradations inherent in their manufacture and operation. The RSO shall review the inspections listed in this document, and, where necessary, implement additional inspection regimes to cover any areas specific to their boiler.

Information provided in this section makes up essential requirements to conduct a comprehensive inspection of a locomotive boiler as laid out in this document. It is strongly recommended that the RSO consult with the independent boiler inspector before any inspection is conducted to ensure that all necessary items are included in the independent boiler inspector's examination and report.

3.2 Assessment of faults

Faults shall be assessed in accordance with AS 3788:2024

The RSO shall assess the cumulative effect of faults to determine whether the boiler is safe to operate. For example, a boiler could have several faults which, individually, are not considered as significant. However, cumulatively, the sum of all faults could make the boiler unsafe to operate.

3.3 Periodic inspections

3.3.1 General

Inspections can be broadly grouped into the following areas:

- (a) Operational inspections – Conducted before, during and after a boiler is operated.
- (b) Interim inspections – Conducted after a washout or once repairs have been completed.
- (c) Annual inspections – Visual inspection of critical areas.
- (d) Major inspections – Generally involving a full internal inspection.

A detailed risk assessment shall be conducted to determine:

- (e) areas of the boiler that require inspection;
- (f) inspections are to take place; and
- (g) level of experience and knowledge required to conduct the inspection.

A failure mode, effects, and criticality analysis may also assist RSOs in determining the above.

All faults found during inspections shall be recorded in the boiler history file.

3.3.2 Inspection and test plan

Inspections shall be detailed in an inspection and test plan (ITP). The ITP shall include:

- (a) what inspection tasks are to be carried out; and
- (b) who is responsible for carrying out each inspection task.

A responsible, accountable, consulted and informed (RACI) chart can be used to assist in developing the ITP.

The ITP should be developed based on this document and the risks being mitigated by the inspection task.

Individual ITPs may be developed for the different roles detailed in Clause 2.1

Further information on each type of inspection and the associated task is provided in the Clause 3.5 and Clause 3.6

3.3.3 Operational inspection

Inspections shall be completed by operational personnel when lighting up, during operation and stabling the locomotive. This is referred to as operating surveillance and monitoring in AS 3788

The RSO shall establish and implement procedures and practices for operations personnel regarding operational inspections during their duties in accordance with the *ONRSR Rail Locomotive Boilers Guideline*. These should include the specific inspection requirements, equipment condition standards to be met, and any record keeping requirements. This requirement shall be included in the safety management system within the equipment operational procedures.

When developing operational inspection procedures, the following should be considered as a minimum prior to and during lighting up the boiler (pre-start):

- (a) All valves, including safety valves, are operating as designed.
- (b) Tubes blanked or blocked.
- (c) Expansion brackets/plates (Can the boiler expand freely?)

Commentary C3.3.3

Loud bangs as the boiler warms can indicate issues with the expansion plates.

- (d) Water or steam leaks.
- (e) Condition of the brick arch.
- (f) Condition of burners (oil-fired boilers only)
- (g) Lubrication of expansion brackets.

During operation of the boiler the following shall be checked and monitored:

- (h) Condition of water (e.g., level of treatment, foaming, colour):
- (i) Is the boiler steaming well? If not, it can indicate issues.
- (j) Components becoming faulty.

Following operation, the following should be monitored:

- (k) Signs of steam or water leaks (Do leaks form as the boiler relaxes?)
- (l) Signs of water discolouration.

3.3.4 Interim inspection

Boilers shall be inspected by competent persons under the inspection plan at any washouts between the annual inspection. An independent boiler inspector may check that the boiler is safe to operate after a washout if it is deemed necessary by the responsible person.

After an incident that requires the boiler to be taken out of service or placed in a workshop for boiler repairs, an independent boiler inspection should inspect the boiler. The inspection shall assess if there is

any visible degradation or further damage requiring attention, or whether the repairs have been completed to the required standards.

3.3.5 Annual inspection

NOTE:

An annual inspection is the same as an in-service inspection as described in AS 3788

Annual inspections shall be scheduled every 12 months unless otherwise agreed with the independent boiler inspector and in accordance with AS 3788:2024. When deciding whether a boiler inspection period can extend beyond 12 months, the independent boiler inspector shall assess, as a minimum, the:

- (a) operating hours of the boiler;
- (b) boiler history file;
- (c) expected workload of the boiler;
- (d) operating pressure (compared to the maximum working or design pressure); and
- (e) overall condition of the boiler.

Any conditions placed on the boiler to enable a greater than 12-month inspection schedule shall be recorded on the completion certificate. The RSO shall comply with the conditions stated. Where the conditions are not complied with, the boiler shall be inspected within 12 months of the previous inspection unless otherwise agreed with the independent boiler inspector.

The annual inspection, using the available inspection openings, shall include a close visual examination of the areas that can be seen. To ensure that no cracking, grooving or general wastage has occurred, this typically includes:

- (f) the internal steam/waterside surfaces of the boiler barrel and shell end plates;
- (g) firebox;
- (h) foundation ring;
- (i) all tubes, stay bars plus the fireside surfaces of the firebox; and
- (j) tube plates and tubes.

The visual inspection shall be done with all surfaces dry. The independent boiler inspector may request the removal of cladding and lagging in the way of known problem areas.

Boilers shall be inspected under steam by the competent person after each annual inspection. The inspection shall include testing the safety valve, and the examination and safe operation of all fittings, valves and injectors. The inspection zones in Figure 2 may assist in identifying areas for inspection.

The steaming after inspection may be attended by the independent boiler inspector where required by the independent boiler inspector.

3.3.6 Major inspection

The interval for, or the necessity of, the major inspection shall be determined by the independent boiler inspector in accordance with AS 3788:2024, Clause 9.6.5.3

Locomotive boilers shall have an inspection of all waterside, fireside and external surfaces of the boiler including its shell, tube plates, firebox, foundation ring, stay bars, stay tubes and other stays every ten (10) years or as deemed required by the independent boiler inspector. The requirements set out in Appendix D shall also apply. Methods for conducting the inspection are provided in Clause 3.4

Where a major inspection period is extended beyond ten (10) years, this decision should be supported by a detailed risk assessment, a failure mode, effects and criticality analysis, or similar assessment.

The annual inspection conducted through the available openings does not provide sufficient access to many internal surfaces, stays, etc. to accurately assess the long-term integrity of the boiler. Typically, sufficient tubes need to be removed to allow access for the preparing of surfaces and inspection.

The requirement for a full internal visual (intrusive) inspection may be waived if an appropriate technical assessment by the independent boiler inspector determines that the long-term integrity of the boiler can be assured by means other than a full internal visual inspection. The independent boiler inspector shall specify the inspection plan and techniques that will provide an outcome of equal quality to a full internal inspection. This assessment should consider:

- (a) the state of knowledge of the effectiveness of the boiler water treatment;
- (b) the history of inspection and repairs, operating hours and storage method when not in use; and
- (c) common failure modes and operational regime (e.g., loads hauled, cyclic service impact, operating conditions).

Non-intrusive inspections shall be carried out in accordance with AS 3788:2024, Clause 4.3.3.1 and Clause 4.3.4

The interval between inspections may need to be shortened if the operational and maintenance history shows active degradation mechanisms, or operational circumstances that may result in accelerated deterioration or as otherwise required by the independent boiler inspector.

In circumstances where it is not possible to determine when the boiler had the last full internal inspection, then, in consultation with the independent boiler inspector, a full internal inspection should be considered for the next annual inspection.

A hydrostatic test in accordance with AS 3788:2024, Appendix A.8 shall be done at the end of the work before the boiler is steamed.

3.3.7 Specific state legislation requirements

Legislative requirements for locomotive boilers and pressure vessels can vary between states and territories across Australia. Such requirements must be considered as well as those in this document.

3.3.8 Pre-inspection preparation of locomotive boilers

A competent person should inspect the boiler when it arrives in the workshops in as in-service condition. The positioning of ash and indicators of leaks or other boiler defects may be seen and noted before cleaning in preparation for the formal internal inspection.

Before the internal inspection, the boiler shall be cleaned by removing all products of combustion (i.e. ash, cinders and the like), water side deposits and corrosion products. Tell-tale holes in stays should be proven clear.

A complete washout shall be completed in line with Appendix D prior to internal inspection of the boiler.

All surfaces to be inspected shall be dry.

When cladding and lagging is removed for inspection of external surfaces, all foreign material that will limit the effectiveness of the inspection shall be removed.

3.4 Inspection methods

3.4.1 Methods

In accordance with AS 3788:2024, inspections shall include a visual examination supplemented, where necessary, by other methods. These supplementary methods may include:

- (a) magnetic particle examination;
- (b) penetrant examination;
- (c) radiographic examination;
- (d) ultrasonic thickness measurements and flaw detection;
- (e) eddy current testing;
- (f) hardness testing;
- (g) acoustic emission techniques;
- (h) leak testing;
- (i) monitoring operations; and
- (j) other applicable methods.

Inspection design and planning should recognise that inspection techniques could not detect all defects. The reliability and sensitivity of the inspection techniques should be considered in consultation with persons experienced with non-destructive examination.

3.4.2 Non-destructive examination

Non-destructive examination (NDE) provides a method of carrying out detailed examinations of some parts of a boiler that otherwise can be difficult to assess without major work, for example, removal of smoke tubes.

When choosing a suitable NDE method the competent person and independent boiler inspector should assess:

- (a) What defects are being looked for?
- (b) What is the geometry of the area to be inspected?
- (c) What material is being inspected?
- (d) Is the NDE tester experienced in inspections of boilers?

In some cases where access is limited NDE could be unsuitable. The type and thickness of the material, or locations where materials are joined, could also be a limiting factor.

The competent person and independent boiler inspector shall determine which, if any, NDE method is suitable and the parameters of that testing.

3.4.3 Plate thickness

Plate thickness and depth of corrosion may be determined by using the ultrasonic thickness testing process or other approved methods.

Where access is possible, the depth of pitting may be found by using a depth micrometer or a pit gauge.

On boilers of an unknown provenance or where there is a lack of knowledge or experience of the usual wastage and damage zones, it is recommended that plate thickness readings are taken across the entire boiler.

On stayed sections, the plate thickness readings should be taken on a grid not exceeding the maximum stay pitch at the centre of each section of four (4) stays. Additional readings shall be taken close to each stay to determine whether wastage or thinning has occurred close to the stay. This can be done using a small diameter probe.

Attention should be given to the joint between the stay and the plate and to any areas known for wastage.

On unstayed sections, the plate thickness readings should be taken on a grid not exceeding 305 mm (12") centres. Locations that are prone to corrosion and/or erosion should have the grid area reduced. This could include the:

- (a) bottom of the barrel where deposits can accumulate causing corrosion;
- (b) typical waterline/s (water/steam interface) when the boiler is being operated; and
- (c) location where the feedwater treatment enters the boiler.

When developing a scanning grid, a strip at least 100 mm above and below the typical waterline should be used.

Where grid scanning indicates generalised or localised corrosion, grid spacings should be closer to accurately map and ascertain the extent and severity of corrosion losses

Alternatively, a pattern of profile scans may be appropriate, or other NDE processes can be considered.

If thinning of the plate is detected, a further ultrasonic B scan should be carried out over the affected area. For further information on thinning of plates, refer to AS 3788:2024, Appendix B.2

3.4.4 Plate cracking

Plate cracking may be detected by visual inspection or by the use of appropriate NDE techniques (e.g., dye penetrant testing, magnetic particle, ultrasonic flaw detection or ultrasonic phased array, etc).

Consideration should be given to the type of ultrasonic tested deploy (i.e. angle probe, phased array etc.) to appropriately determine the extent and nature of any cracking identified.

3.4.5 Separation of plate

Separation of plates at riveted seams may be detected by use of a feeler gauge and magnifying glass or other applicable method.

3.4.6 Broken or cracked stays

Stays shall be inspected for cracking or breakage. Where a broken or cracked stay is identified, the boiler should not be operated until the stay is repaired (see Clause 5.9).

Broken or cracked stays can be detected by:

- (a) leakage through clean, clear tell-tale holes when the boiler is under steam, hydrostatic test, or in wet storage;
- (b) hammer test (refer to AS 3788:2024, Appendix A.6.2);
- (c) ultrasonic flaw testing; and
- (d) ultrasonic crack testing.

Welded stays shall have the welds inspected for cracking.

The type of test used will depend on the manufacture, length and type of stay.

3.4.7 Light source

Varying the intensity of inspection lights could assist discovery of defects. Placement of the light to shine parallel to the surface is one method of detecting pits and surface irregularities.

When inspecting internal stayed surfaces, placement of a light source within the stayed zone can aid the inspection.

3.4.8 Optical device

Using optical devices (i.e. borescope, mirrors, AUV/ROV, PTZ cameras, etc.) for viewing beyond that observable from the inspection openings should be considered.

3.5 Inspection zones

3.5.1 Specific zones

This section outlines guidance for inspection to each specific sub assembly (inspection zones). Notes are also provided that may assist if further evaluation is required.

3.5.2 Rivet seams and rivet heads

Riveted seams and rivet heads shall be inspected for:

- (a) grooving;
- (b) corrosion cracks pitting leakage;
- (c) separation of the plates;
- (d) excessive or deep caulking of the plate edges and rivet head condition of seal-welded plate edges;
- (e) defective components of the seam; and
- (f) cracking in the ligament between stays or running away from a stay.

Rivet heads that have been built up by, covered over completely by, or sealed by weld repair rivets that have been replaced by patch bolts shall be inspected for cracking or damage.

Commentary C3.5.2

Broken rivet heads or cracked plates can result from sodium hydroxide cracking (caustic embrittlement).

Lap seams should be tested using the ultrasonic flaw detection. Any cracking detected shall be assessed by means of the ultrasonic phased array technique. The image of the defect shall be recorded for future reference.

The independent boiler inspector shall examine any test grooves (if cut) for damage or modification (refer to AS 3788:2024, Clause 9.6). If test grooves are not cut the lap seams should be tested using the ultrasonic flaw detection method.

When determining the extent of corrosion to rivet heads, it is important to know the rivet size and the type of rivet head used for the original construction. Corrosion can alter the appearance of these items and disguise the full extent of the damage.

Rivet heads may be hammer tested in the shear direction to check for any breaks or movement in the hole. Rivets should be lightly tapped so not to damage good rivets.

3.5.3 Welding and riveted repairs

Welded and riveted repairs shall be inspected for:

- (a) correct application of welded patches or weld application correct application of riveting;
- (b) cracks;
- (c) separation of the plates;
- (d) dents or other mechanical damage leakage; and
- (e) previous repairs shall be closely inspected to prove their ongoing integrity.

3.5.4 Boiler shell

The boiler shell inspection shall include examination for:

- (a) grooving or cuts;
- (b) corrosion cracks pitting;
- (c) separation of the plates;
- (d) decolourization of the sheet (overheating);
- (e) bowing of boiler structure/sheets;
- (f) deflection of boiler structure;
- (g) bulging;
- (h) dents or other mechanical damage leakage; and
- (i) sheathing plates, if fitted, shall be thoroughly inspected, particularly for separation and/or bulging from the barrel due to corrosion products.

Whenever a sufficient number of tubes are removed from a locomotive boiler during repairs, the independent boiler inspector shall inspect the interior of the barrel (and sheathing plates, if fitted), and write a report on the condition of the barrel.

NOTE 1:

An accurate inspection often cannot be done until all or some of the tubes have been removed and the interior has been cleaned, since mud and scale make it difficult to detect defects.

NOTE 2:

Inspection of the interior of the boiler is undertaken whenever the majority of the tubes are removed.

3.5.5 Dome and dome lid/cover/flanges

The dome and dome lid shall be inspected for:

- (a) grooving;
- (b) corrosion, especially at the interior section attached to the boiler course cracks;
- (c) pitting;
- (d) separation of plates;
- (e) dents or other mechanical damage leakage;
- (f) stretched, bent or corroded dome studs; and
- (g) damage to the steam dome cover sealing surfaces.

The dome lid locating flange on the dome, where fitted with doubler plates, shall be checked to confirm that its thickness complies with the minimum required.

Close inspection should be made to the interior section at the joint attached to the boiler course.

If the dome studs are bent, a careful evaluation should be made of the lid for leakage and mechanical damage.

3.5.6 Foundation ring or mud ring

The foundation ring and rivets shall be inspected for:

- (a) mud and scale on the waterside;
- (b) debris on the waterside corrosion;
- (c) grooving cracks (in particular, in corners or where stiffness changes);

- (d) rivet head wastage;
- (e) separation of the firebox plates from the mud ring dents or other mechanical damage;
- (f) leakage; and
- (g) smooth wastage on the outside surface caused by leaking foundation rivets.

3.5.7 Tube plates.

Tube plates shall be inspected for:

- (a) grooving around tube holes, rivet seams and braces cracking of the ligaments between tube holes;
- (b) with the tubes removed, condition and dimensions of holes (including out of roundness) pitting;
- (c) cracks radiating from holes through the tube ligaments;

Commentary C3.5.7

Cracking, such as ligament cracking or thermal cracking, or longitudinal cracking along the tubes, can be found using magnetic particle testing or dye penetrant detection examinations.

- (d) fireside and waterside corrosion thermal cracking;
- (e) bulges;
- (f) signs of leakage;
- (g) condition of the holes in the tube plates (radii/chamfer is to standard or design, burrs are cleaned up); and
- (h) excessive or deep caulking of the plate edges flame impingement (firebox tube plate).

Boilers with bulging plates shall not be operated.

Corrosion is common at the bottom of the smokebox tube plate and smokebox tube plate. For example, this could be fireside corrosion due to smokebox deposits or waterside corrosion due to crevice corrosion. The joint between smokebox tube plate and shell shall be closely inspected.

3.5.8 Flange plates

The flanged section of all flanged plates shall be inspected for:

- (a) pitting;
- (b) corrosion, cracks and grooving;
- (c) scale and mud deposits; and
- (d) correct fit up and alignment of the flanged plate to the adjacent plates.

Cracking is common around washout plug holes in the flange radii that are not fitted with a supporting doubling plate.

The flanges should have a smooth, uniform curvature and make a smooth transition to the flat sheets.

Grooving and cracking in the radius of the flanged section will occur over time. This is an essential item for close examination.

3.5.9 Stayed plates

Stayed plate shall be examined for:

- (a) scale and mud deposits;
- (b) loss of plate thickness around wall stay holes;
- (c) deterioration of the joint between the stay;
- (d) sheet grooving on the waterside section;
- (e) pitting;
- (f) fireside and waterside corrosion overheating;
- (g) fire cracks at riveted lap seams;
- (h) bulges; and
- (i) erosion.

Boilers with bulging plates shall not be operated.

Close inspection of plates behind refractory or grate bars should be done for fireside corrosion. Corrosion of firebox plates and rivets inside the firebox can also occur through contact of wet ashes when allowed to remain between the grate and firebox plates, and by leakage of water from under rivet heads.

Locomotive firebox plates conduct a high heat flux and are subjected to high cyclic stresses, particularly around the back corners. A close and detailed inspection of these plates shall occur to ensure that these conditions are monitored.

The competent person shall examine this part of each firebox frequently to observe if leakage or other conditions exist that would corrode the plate.

Close inspection should be made for grooving on waterside surfaces of the stayed sheets just above the foundation ring. Presence of any welding in locomotive corner may indicate internal grooving.

3.5.10 Wall stays

Wall stays shall be inspected for:

- (a) cracks in or breakage of the body;
- (b) wastage or necking of the stay, particularly in the middle of its span;
- (c) wastage of the stay head;
- (d) wall stay head flush with or below the surface of the sheet;
- (e) waterside corrosion;
- (f) tell tale holes, where applicable, are clear and not blocked/welded, brazed over or plugged; and
- (g) wall stay heads that have been built up, repaired, sealed or covered over by welding correct application of seal welding to wall stays.

NOTE:

An indicator of waterside corrosion on threaded stays is the lack of threads on the section of the stays body just above the sheet.

Broken or cracked stays can be found through the methods listed in Clause 3.4.6

When a broken stay is found, the stays next to it should be examined closely as these could have become overstressed by adding the load from the broken stay.

Plugging of stays with tell-tale holes is not permitted.

The boiler shall be hydrostatically leak tested to determine the condition of the wall stays.

One indication that a threaded wall stay is leaking during service could be due to the head being re-driven repeatedly.

Wall stays that have been repeatedly repaired typically indicate a degradation of the wall plate and/or wall stay. Refer to the boiler history file (see Appendix B) for details of when and why these repairs were done.

3.5.11 Flexible wall stays and sleeves

Flexible wall stay sleeves and caps shall be inspected for:

- (a) corrosion (including the electrolytic corrosion between the cap gasket and cup, and around the exterior of the stay cups);
- (b) cracks;
- (c) dents or other mechanical damage leakage;
- (d) damaged threads or welds;
- (e) flexible stay cup seal and/or gaskets in good condition;
- (f) scale and mud accumulations inside the sleeve that could restrict bolt movement correct application of welding to welded sleeves and welded caps; and
- (g) seal welding of threaded sleeves or threaded caps.

NOTE:

An indicator of waterside corrosion on threaded stays is the lack of threads on the section of the stay body just above the sheet.

Broken or cracked stays can be found through the methods listed in Clause 3.4.6

Another method can be twisting the ball head using a long-handled wrench. Access to the ball head is by removing the cap from the sleeve, depending upon the design of the stay.

When a broken stay is found, the stays next to it should be examined closely because these may have become overstressed by adding the load from the broken stay.

Plugging of stays with tell-tale holes is not permitted.

The boiler shall be hydrostatically tested to show the condition of the wall stays.

Wall stays that have been repeatedly repaired typically indicate a degradation of the wall plate and/or wall stay. Refer to the boiler history file for details to identify when and why these repairs were completed.

3.5.12 Girder stay and crown bars

Girder stays are designed to transfer the load and, as such, shall be inspected to ensure that the load bearing is in accordance with the original design.

Girder stays, crown bars and their fasteners including stays, rivets, pins, washers, nuts, thimbles, spacers and the adjacent sections of the firebox plates, shall be inspected for:

- (a) correct fit and alignment of the girder stay or crown bar to the firebox plate surface, including flanged sections;
- (b) cracks;
- (c) mud and scale corrosion;
- (d) corrosion of fitting;

- (e) correct fit and alignment of the thimbles, spacers and pins to the girder stay or crown bar and the firebox plates;
- (f) dents or other mechanical damage;
- (g) stays or rivets built up by or covered over completely by welding leakage from the stay heads;
- (h) seal welding of rivet heads;
- (i) correct application of retainers to all nuts and fasteners;
- (j) condition of gaskets (if used) with crown stay nuts;
- (k) degradation of fasteners (threads, nuts, etc.); and
- (l) missing fasteners, including nuts, bolts, cotters, split pins or other retainers.

NOTE:

An accurate inspection often cannot be done until the girder stay, or crown bar has been cleaned, since mud and scale will make it difficult to detect defects.

When a broken stay is found, the stays next to it should be examined closely because these may have become overstressed by adding the load from the broken stay.

3.5.13 Sling or link stays

Sling or link stays and their associated fasteners including the pins, retainers, washers, nuts and their associated attachment at eyes, girder stays, or crown stays, shall be inspected for:

- (a) corrosion cracks;
- (b) dents, wear or other mechanical damage mud and scale;
- (c) wear to the pin hole or expansion slot of the sling stay and mating component correct application of retainers to the pins; and
- (d) missing fasteners, including nuts, bolts, cotters, split pins or other retainers any of the above that would restrict the sling stays moving.

NOTE:

An accurate inspection often cannot be done until the sling stay has been cleaned since mud and scale will make it difficult to detect defects.

When a broken or loose stay is found, the stays next to it should be examined closely because these may have become overstressed by adding the load from the defective stay.

Special attention should be given to the row of sling stays next to the flue sheet to ensure that these stays are not loose.

3.5.14 Crown stays (bolts) – Flexible and fixed

All crown stays shall be inspected for:

- (a) cracks in, or breakage of, the body;
- (b) crown stay nuts for wastage;
- (c) condition and form of gaskets (if used);
- (d) dents, wear, or other mechanical damage wastage of the head;
- (e) plugging of tell-tale holes (where fitted in crown stays) waterside corrosion;
- (f) stay heads that have been covered over by welding;

- (g) correct application of seal welding to stay heads, where applicable correct application of retainers to the pins, where applicable;
- (h) missing fasteners, including nuts, bolts, cotters, split pins or other retainers correct fit and alignment of the stay assembly; and
- (i) corrosion in the cups/caps of flexible stays.

NOTE:

An indicator of waterside corrosion on threaded stays is the lack of threads on the section of the stay body just above the sheet.

Broken stays can be detected by leakage through telltale holes (if these are drilled). Any bulging in the crown sheet is an indication that the crown sheet has overheated, the plate has thinned, or there could be broken crown stays. Boilers with bulging plates shall not be operated. The reason for bulging in a crown sheet shall be absolutely known and corrected before the boiler is steamed.

For asset reliability, cracked stays (not through to tell tale) may be detected by means of ultrasonic crack detection scanning along the stay.

Stays without tell tale holes shall be tested by means of ultrasonic crack detection scanning along the stay.

Broken or cracked stays can be found through the methods listed in Clause 3.4.6

When a broken stay is found, the stays next to it should be examined closely, because these could have become overstressed by adding the load from the broken stay.

Plugging of stays with tell-tale holes is not permitted.

Plugging the fire-side of continuously drilled stays (i.e. those that extend through from the fireside to the outside) is permitted using refractory. The refractory shall not pass beyond the thickness of the plate.

Crown stays that have been repeatedly repaired typically show a degradation of the crown sheet and/or crown stay. Refer to the boiler history file for details to identify when and why these repairs were done.

Specifically examine the row of stays next to the tube sheet to ensure that these stays are not lose or otherwise defective.

Also see Section 11.

3.5.15 Diagonal and gusset stays

Diagonal and gusset stays, and their attachments, shall be inspected for:

- (a) looseness;
- (b) corrosion cracks;
- (c) stress corrosion at reinforcing pads, where plate stiffness (geometry) changes size;
- (d) welded repairs;
- (e) missing pins or pin retainers;
- (f) defective rivets; and
- (g) scale and mud deposits.

Diagonal and gusset braces should be under tension.

The brace pins should fit the brace clevis and eye securely and be retained from coming out by a type of fixed or keyed retainer.

Diagonal braces having loop-type ends should be closely inspected for cracks and corrosion. The loop-type end is formed by the brace body being split, looped around, and forged to the body. Some versions have a low margin of material to give the required strength.

An accurate inspection often cannot be completed until all or some of the tubes have been removed and interior has been cleaned.

3.5.16 Longitudinal and transverse stays

Longitudinal and transverse stays and their attachments shall be inspected for:

- (a) looseness;
- (b) corrosion cracks;
- (c) welded repairs;
- (d) exposure of copper ferrule underneath tube;
- (e) missing pins or pin retainers;
- (f) defective rivets; and
- (g) scale and mud deposits.

Where the stay is of a known length, the stay shall be tested by means of ultrasonic crack detection scanning along the stay.

Longitudinal and transverse stays should be under tension.

The brace pins should fit the brace clevis and eye securely and be retained from coming out by some type of fixed or keyed retainer.

An accurate inspection often cannot be completed until all or some of the tubes have been removed and interior has been cleaned.

3.5.17 Superheater flue tubes and smoke tubes

All superheater flue tubes and smoke tubes shall be inspected for:

- (a) fire cracks (in the area of the tube that projects into the firebox through the tube plate) pitting;
- (b) corrosion (of both the tube and the ends in the smoke box) erosion;
- (c) obstructions in the tube interior;
- (d) mud or scale build up on the waterside;
- (e) erosion or cracking of the tube ends, flue beads and/or seal welds leakage;
- (f) welded joints in the tubes, as far as practical, should be checked; and
- (g) correct application, including expanding/rolling and belling, beading, or seal welding of the tube end.

NOTE:

Erosion (cinder cutting) generally occurs to the firebox end of the flue.

Grooving or cracking can be caused by over-expanding the tubes in the tube plates, or through the tube holes not being deburred.

Galvanic corrosion of the tube in the tube sheets can occur if tubes are installed with copper ferrules and of the firebox plates, if installed with copper firebox and stay.

Specialist NDE techniques, such as long range ultrasonic testing, may be used to inspect the length of the tubes to find if there are unseen defects.

3.5.18 Superheater elements and header

Superheater elements and the superheater header should be inspected for:

- (a) pitting;
- (b) cracks;
- (c) erosion (particularly in the return bends at the firebox end) corrosion;
- (d) bulges;
- (e) leakage;
- (f) missing shields;
- (g) missing or broken bands or supports on the superheater units; and
- (h) missing, damaged, or welded attachment bolts, nuts, clamps, studs and washers; and
- (i) adequate structural bracing and support of the superheater header.

3.5.19 Arch tubes

Arch tubes shall be inspected for:

- (a) erosion;
- (b) corrosion fire cracks pitting;
- (c) cracking of tube ends overheating and blistering bulges;
- (d) mud and scale build up in the waterside repairs; and
- (e) correct application, including expanding/rolling and beading, or seal welding of the tube end.

Each time bricks are removed, and before a new arch is fitted, the arch tubes shall be examined for evidence of brick wear.

An example of the location of arch tubes is provided in Figure 2.

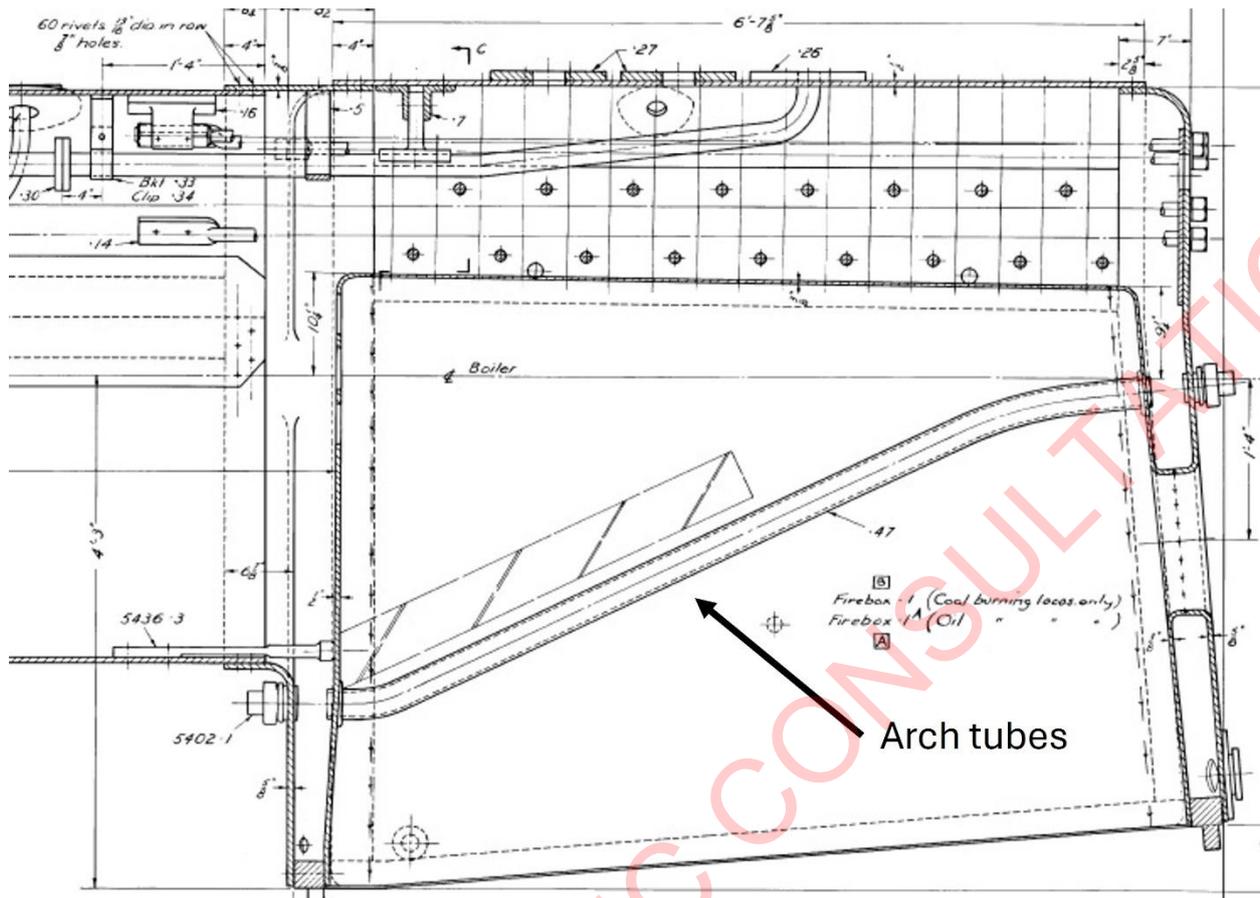


Figure 2 Arch tubes in a Victorian Railways J class

3.5.20 Thermic siphons

Thermic siphons shall be inspected for:

- (a) erosion;
- (b) corrosion;
- (c) cracking;
- (d) pitting;
- (e) cracking of the siphon neck;
- (f) overheating and blistering bulges;
- (g) mud and scale blockage in the waterside; and
- (h) broken or damaged stays.

Further information on examination of thermic siphons is provided in Clause 9.7

Refer to inspection zones (i.e. stays, stayed plates and flanged plates) for extra inspection items.

An example of the location of thermic siphons is provided in Figure 3.

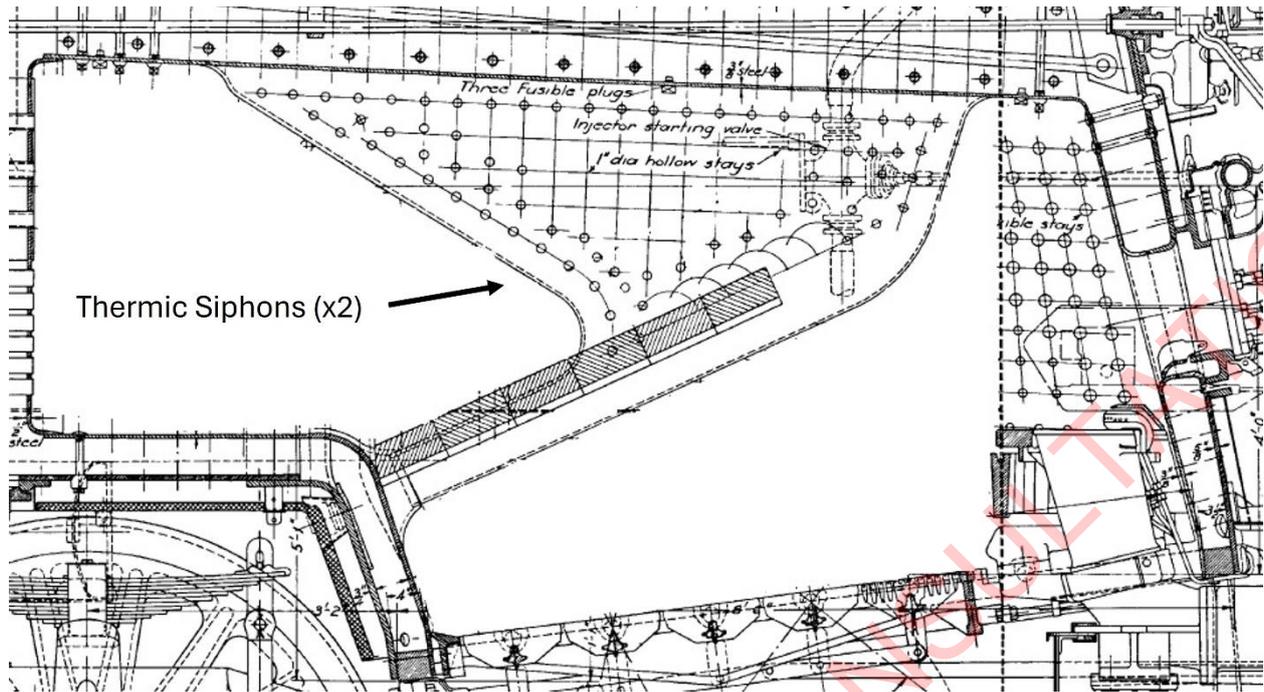


Figure 3 Thermic siphons in a Victorian Railways R Class (drawing modified for clarity)

3.5.21 Firebox refractory

Firebox refractory should be inspected to ensure it is properly applied and maintained to stop flame affecting the firebox sheets.

3.5.22 Fire hole compensation ring

The fire door opening compensation ring, if fitted and dependent on the material, should have magnetic particle or dye penetrant crack detection examination.

3.5.23 Internal main steam pipes

The internal main steam pipe of boilers with dome mounted (internal) regulator shall be inspected for:

- (a) erosion;
- (b) corrosion cracks;
- (c) adequate structural bracing, support, and attachment to the boiler and dome; and
- (d) loose, bent or damaged rivets, nuts, bolts and studs.

NOTE:

A steam leak into the steam pipe of a dome-mounted (internal) throttle valve will send an unregulated flow of steam to the cylinders.

Inspections can be limited with the pipe in place. It may be necessary to remove parts of the assembly for a better inspection. A full inspection shall be done at any time that the smoke tubes are removed.

3.5.24 Regulator valve

The regulator handle and its mechanism shall be inspected for:

- (a) proper operation (which includes ensuring that the regulator shuts off correctly before the handle hits the stop in the cab);

- (b) lost motion or looseness;
- (c) adequate structural bracing, support and attachment to the boiler, dome or firebox loose, bent or damaged nuts, bolts and studs; and
- (d) the integrity of the support bushing for the regulator spindle/shaft fitted in the internal steam piping the integrity of fastenings such as tie-wire, split pins and cotter pins.

There shall be a method of preventing steam entering the cylinders for maintenance or operational reasons. This could include mechanical locking out of the regulator. Where such locking is in place, this shall be examined for correct operation.

3.5.25 Screw-type washout plugs, holes and caps

Screw-type washout plugs, holes and sleeves shall be inspected for:

- (a) damaged or cracked threads on the plug, hole or caps corrosion;
- (b) cracks distortion looseness leakage; and
- (c) steam cuts to threads and sealing surfaces twisting of the plug head or body. See Section 12.

3.5.26 Hand-hole/mud-hole washout doors

Hand-hole or mud-hole washout doors and their mating surfaces shall be inspected for:

- (a) damaged or cracked threads on the door studs;
- (b) corrosion of door sealing surfaces and stud's cracks;
- (c) stretching or bending of the door stud or hand-hole door looseness;
- (d) leakage and steam cuts;
- (e) damage to the dog (or bridge);
- (f) seating surface on the sheet;
- (g) confirm the hand-hole door is a proper fit to ensure the radial gap between the hole and the boss on the door is not excessive, otherwise the gasket may extrude and blow out under pressure;
- (h) material of the hand-hole door gaskets should be reviewed to confirm that it meets the pressure and temperature conditions of the boiler, and is of the correct size; and
- (i) correct repairs.

Doors shall fit closely and properly to the internal surfaces. When the spigot or recess is in a central position, it shall at no point have a clearance greater than 1.5 mm (refer AS 1228:2016).

See Section 20.

3.5.27 Attachment stud and bosses

Threaded and welded attachments shall be inspected for:

- (a) corrosion, especially at the sheet;
- (b) cracks;
- (c) damaged threads stretching or bending looseness; and
- (d) leakage.

3.5.28 Fusible plugs and mounting boss

Fusible plugs and mounting bosses shall be inspected for:

- (a) corrosion;
- (b) scale build up on the waterside damage;
- (c) correct fit;
- (d) modification or alteration that could affect the performance of the plug;
- (e) correct distance from the crown sheet;
- (f) evidence of thread damage to the plug and boss;
- (g) signs of boiler treatment stalactite (indicating plug failure);
- (h) failure of welded boss or sleeve threads and welds;
- (i) adequate threads in firebox sheet and thickness of firebox sheet;
- (j) leakage from the threads;
- (k) leakage from the lead core;
- (l) height of the plug above waterside of crown sheet evidence of melting or overheating; and
- (m) proper marking and correct installation.

See also Section 6.

3.5.29 Water glass, water column and gauge cocks

The water glass, water column and gauge cock boiler connections and piping shall be inspected for:

- (a) blockages of passageways (including squashed rubbers, incorrect glass length or distorted packing);
- (b) kinks, or sharp or flattened bends, or other restrictions in the piping or any blockage in the drain piping;
- (c) sags in the piping horizontal runs;
- (d) condition of tubular or reflex water glass;
- (e) correct type and material of piping and fittings;
- (f) correct location, size and installation of the connections to the sheets correct installation of the safety shield (if used);
- (g) correct installation of the viewing light (if used);
- (h) correct installation and operation of the valves;
- (i) proper bracing to prevent vibration;
- (j) loose, bent or damaged nuts, bolts and studs;
- (k) damage to any part of the assembly;
- (l) protective safety shields are fitted;
- (m) safety shutoff balls are installed within the waterway and steamway cocks;
- (n) erosion of ports and component sealing surfaces; and
- (o) parallax striped lines are set behind the mounts.

3.5.30 Steam pressure gauge

The steam pressure gauge, gauge cock (where fitted) boiler connections and piping shall be inspected for:

- (a) kinks or sharp, restricted or flattened bends in the piping;
- (b) correct installation of the shutoff valve and siphon proper size, type, and material of piping and fittings proper installation;
- (c) proper lighting for viewing;
- (d) readability in all operating conditions (operators view is unrestricted);
- (e) proper bracing to prevent vibration and heat; and
- (f) calibration that is traceable to a NATA-approved organisation or equivalent.

Syphon pipes should be annealed if the steam pressure gauge is removed if not already done, to reduce the risk of pipe fracture where the piping is subject to movement between the boiler and the frame. Where the steam pressure gauge is mounted to the boiler i.e. the pipe is not subject to regular movement, annealing is not necessary.

An independent tapping point to the boiler gauge should be provided for the fitting of a test gauge for use when steam testing and setting of safety valves. The tapping point shall be fitted with an isolation valve and be plugged off when not in use.

3.5.31 Boiler fittings and piping

The boiler fittings and piping shall be inspected for:

- (a) cracks;
- (b) corrosion;
- (c) pitting;
- (d) leakage;
- (e) looseness;
- (f) fretting corrosion for piping (i.e. vibration induced rubbing, particularly at mounts etc.);
- (g) loose, bent or damaged nuts, bolts and studs; and
- (h) adequate structural bracing, support, attachment and provision for expansion proper size, type and material.

At the discretion of the independent boiler inspector, non-destructive or hydrostatic testing may be required on boiler fittings to confirm their structural integrity as fittings may deteriorate under certain conditions.

3.5.32 External steam pipes

External steam pipes (i.e. pipes external to the boiler shell) shall be inspected. The inspection shall be based on an assessment of the risk posed by failure of the external steam pipes.

3.5.33 Boiler expansion brackets

Seized or jammed expansion brackets can place significant stresses on the boiler plates and stays leading to failure. If any of the following defects are found, they could be a result of seized or jammed expansion brackets:

- (a) Working of the joints between plates or plates and the foundation ring.
- (b) Increased grooving of the plates above the foundation ring (corrosion fatigue).

- (c) Radial cracking on the water side of the stay holes, particularly above the expansion brackets.
- (d) Twisting of the boiler if only one side is seized.
- (e) Broken stays on the firebox sides of narrow firebox boilers.

The boiler expansion brackets, components and fasteners used to secure the boiler to the frame shall be inspected for:

- (f) correct installation and effective lubrication (not applicable for diaphragm plates);
- (g) damaged or missing components;
- (h) structural integrity of the joint;
- (i) looseness;
- (j) leakage;
- (k) loose, bent or damaged rivets, nuts, bolts and studs;
- (l) defective rivets; and
- (m) freedom to expand and flex corrosion and build up.

Where expansion brackets are not easily inspected due to their location, the RSO should have a process or technique for identifying seized brackets. For example, expansion mounts could have indicator markings to enable verification of expansion to the required parameter.

See Section 8.

3.5.34 External surfaces

Visible external surfaces of the boiler and the cladding over the boiler sheets shall be inspected at each annual inspection for:

- (a) corrosion;
- (b) leaks or the signs of leaks;
- (c) build-up of surface deposits likely to create a corrosive environment; and
- (d) cladding condition likely to allow water into the insulation.

NOTE:

Section 7 specifies the requirements for removing lagging and the boiler from the frame to inspect for external corrosion.

3.6 Inspection undertaken by the competent person

3.6.1 Inspections

All items in this section shall be inspected by the RSO's competent person. See Clause 2.2.4

3.6.2 Fire door

The fire door, the locking mechanism (where fitted) and the operating mechanism shall be inspected for:

- (a) safe and suitable operation, including proper fitment when closed;
- (b) cracked, damaged or burned parts; and
- (c) loose, damaged or bent rivets, nuts, bolts and studs.

Where fitted to outward opening fire doors, the locking mechanism shall be inspected for correct operation to confirm it will not allow the door to open if the firebox becomes pressurised due to a failed tube.

3.6.3 Firebox

The firebox shall be inspected to check the condition of:

- (a) the arch (brick, steel or cast);
- (b) the firebox refractory (oil burners); and
- (c) oil burner alignment.

3.6.4 Grates, fire pans and grate operating mechanism

The grates and fire pans (oil burners) shall be inspected for cracked, damaged, burned or missing segments.

The grate operating mechanism of rocking grates shall be checked for:

- (a) uniform operation of all segments;
- (b) corrosion;
- (c) worn or cracked linkage;
- (d) correct fit of the shaker bar on the linkage;
- (e) missing pins or pin retainers; and
- (f) loose, bent or damaged nuts, bolts and studs.

3.6.5 Smokebox

The smokebox shall be inspected for:

- (a) erosion;
- (b) corrosion;
- (c) leakage;
- (d) signs of overheating;
- (e) condition of smokebox seal;
- (f) alignment of the funnel to the blast nozzle/pipe and blower;
- (g) holes;
- (h) looseness;
- (i) loose, bent or damaged nuts, bolts and studs;
- (j) condition of the refractory floor (where fitted); and
- (k) condition of the spark arrestors (where fitted).

3.6.6 Smokebox steam pipes

The smokebox steam pipes shall be inspected for:

- (a) erosion;
- (b) corrosion;
- (c) pitting;
- (d) leakage;

- (e) looseness; and
- (f) loose, bent or damaged nuts, bolts and studs.

NOTE:

Pitting from the casting process may be evident on cast thick wall steam pipes but may not be a defect.

3.6.7 Ash pan or fire pan

The ash pan or fire pan shall be inspected for:

- (a) corrosion;
- (b) holes;
- (c) looseness;
- (d) loose or damaged rivets, nuts, bolts and studs;
- (e) secure attachment to the frame or firebox;
- (f) proper operation of the slides, clean out doors, dumping mechanism, ash arrestors/deflectors and dampers; and
- (g) proper sealing of the slides, clean out doors, ash arrestors and dampers.

The flushing mechanism (where fitted) should be inspected for its integrity and security.

NOTE:

Proper sealing of the slides, clean out doors, ash arrestors, and dampers prevents hot ash or embers to falling onto the track, which can cause lineside fires.

Section 4 Steam locomotive boiler anatomy

4.1 General

This section provides basic information about the major components, construction and some of the fittings of a locomotive boiler (see Figure 4). It is not intended to facilitate design. This section does not seek to demonstrate all combinations and possibilities but merely discusses a few of the most common features. The RSO is responsible for understanding the details and requirements of the boiler that they are operating. Terms are often derived from both British and American practice, and many terms differ across different jurisdictions.

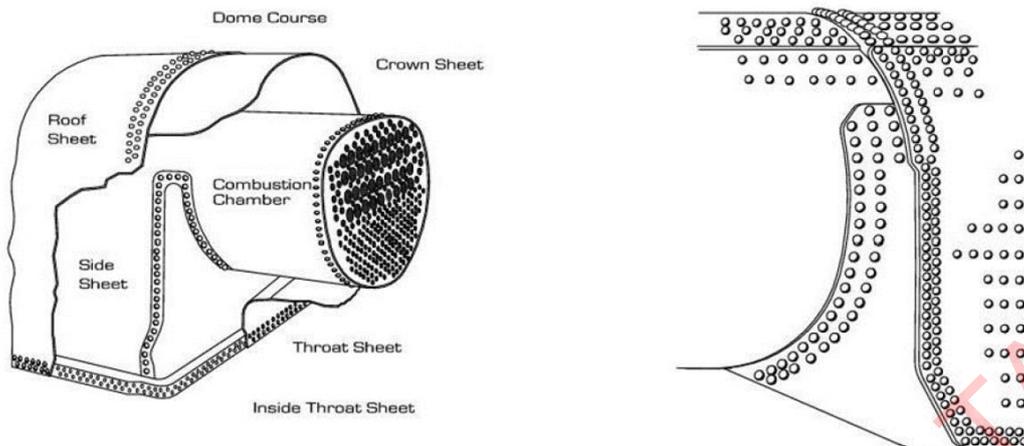


Figure 5 Boiler details

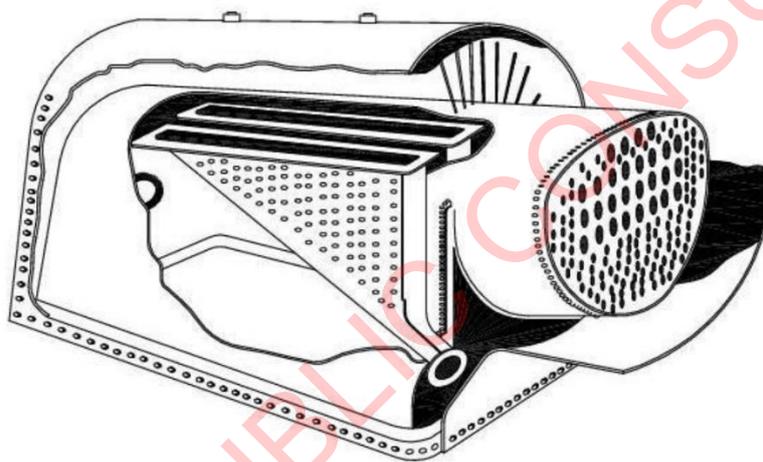


Figure 6 Firebox section

4.3 Locomotive boiler joint method

There are three types of joint methods:

- (a) Riveted Boilers – A riveted boiler is one in which all joints are held together by riveting.
- (b) Welded Boilers – A welded boiler is one in which all joints are welded.
- (c) Composite Boilers – A composite boiler is one in which some joints are welded, and some joints are riveted.

4.4 Boiler types

4.4.1 General

Boilers can be divided into two types, those with round-top fireboxes and those with Belpaire fireboxes. Both may also be classified as those with narrow or wide fireboxes. Narrow fireboxes are generally fitted between the frames, whilst wide fireboxes are carried over the frame.

4.4.2 Belpaire boiler

The Belpaire boiler (see Figure 7) is fitted with a type of firebox invented by Belgian, Alfred Belpaire. This has flat firebox plates that are at right angles to each other, which simplifies staying and offers increased steam space and water surface. The advantages of a Belpaire firebox are:

- (a) Constant water area above the crown sheet, where the evaporation is greatest and most efficient, irrespective of level of water in the boiler.
- (b) Full threads in both inner and outer plates for stays, which are in all cases at or near right angles to the plates.
- (c) Increased steam and water spaces. The effects of expansion on the crown sheet are less marked.
- (d) The construction is altogether more flexible; there is therefore less stay breakage and a diminution of roof stay trouble in-service. With a round topped box, the variations in the lengths of the direct stays may lead to distortion of the crown.
- (e) Base of seatings for stay heads are flat and not rounded, facilitating and simplifying the fitting of stays.

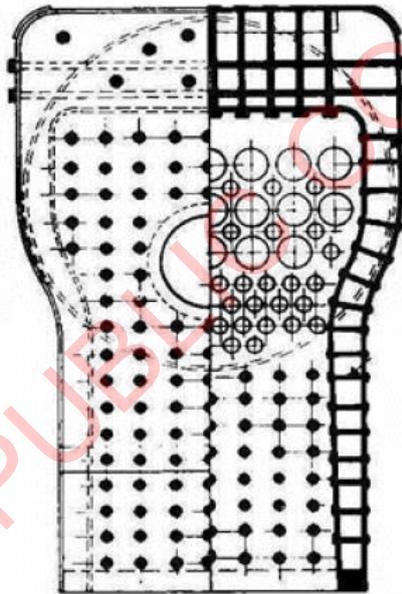


Figure 7 Belpaire narrow firebox boiler

4.4.3 Round-top boiler

A boiler whose firebox outer wrapper top is a continuation of the boiler barrel shape (see Figure 8).

Stays in round-top boilers are in many cases not at or near right angles to the plate, which reduces the number of full threads. Girder stays, or roof bars, are generally not used, owing to the virtual impossibility of keeping the firebox crown free of scale in bad water areas. Their advantages are:

- (a) they are relatively simple to manufacture;
- (b) they are lighter than the Belpaire boiler both in itself and in the amount of water they contain; and
- (c) decreased chances of grooving due to water circulation.

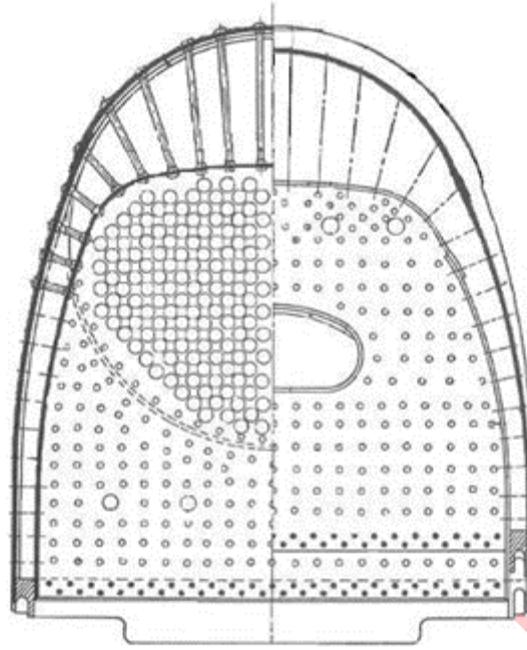


Figure 8 Generic wide round top boiler

4.5 Principal constructional features of a locomotive type boiler

4.5.1 Principal components

A locomotive type boiler is divided in three principal components:

- (a) The firebox, which contains the grate, brick arch, and, in some cases, arch tubes and thermic siphons. In the case of oil-burning locomotives, fireboxes also contain refractory bricks lining the walls and floor, and a burner.
- (b) The outer firebox wrapper.
- (c) The barrel, which contains the flues, tubes and steam dome.

4.5.2 The firebox

The firebox is made from either copper or steel and is the location of the fire. Around its sides, at the back and the front (except for the fire door) is a narrow water space. Across this space the sides of the firebox are tied to the sides of the outer wrapper by numerous steel, copper or monel stays, depending on the firebox construction material. Stays are drilled with tell-tale holes (see Section 11).

The firebox crown and outer wrapper plate are tied together with crown stays (see Section 11). Alternatively, girder stays may be used on smaller boilers. The bottom of the firebox plates is secured to a foundation ring.

To alert the operator to an extreme low water condition, the crown sheet of the firebox is fitted with one or more fusible plugs (see Section 6).

Arch tubes and thermic siphons are provided in some fireboxes to improve water circulation through the hottest part of the boiler and to take full advantage of the radiant heat available in the firebox (see Section 9 and Section 16).

Some boilers are provided with a combustion chamber to increase the volume of the firebox, increase the length of the gas path (thus improving combustion), increase heating surface, and reduce tube length.

The term gas path relates to areas through ashpan dampers, air space through grate, free area through tubes and flues, etc.

4.5.3 Fire grate and bars

On coal or wood fired locomotives the fire grate is composed of segments, generally manufactured from cast iron, shaped to allow the ashes to fall freely through to the ashpan and to admit primary air necessary for proper combustion of fuel.

Fire bars take many forms, for example, Waugh or Hulson type, full width grates, full-length straight bars. Made of cast iron, fire bars in plain view are generally parallel and are made up of small castings mounted on carrier bars which in turn are mounted on bearer bars.

Grates in modern locomotives can be rocked and/or shaken by the means of levers to clear the fire bed of ash, clinker and dump the fire. Grates in some older locomotives do not rock and are manually cleaned.

4.5.4 Fire pan

On oil-fired locomotives, the fire grate is replaced by a fire pan that consists of a solid floor and all sides lined with refractory bricks. The bricks act to protect the lower sections of the firebox from the flame from the oil burner and provides thermal inertia for the fire similar to what the ash bed does in a coal fired locomotive.

4.5.5 Brick arch

The purpose of the brick arch is to increase the length of the path taken by the combustion gases on their way from the fire bed to the tubes, thus providing for the mixing of secondary air, which is essential for complete combustion. The arch helps to maintain a higher firebox temperature and also prevents cold air entering from the fire hole passing directly to the tubes.

The brick arch, which is constructed of firebricks or refractory cement, is positioned beneath the lower row of tubes and inclined to be level with the top of the fire hole door. The number of courses of fire brick may depend on the design of the inner firebox and the steaming characteristics of the boiler.

The arch may be supported by fittings attached to the inner firebox, arch tubes or thermic siphons in fireboxes so fitted.

The advantages of a brick arch are as follows:

- (a) The finer particles of the fuel are prevented from being drawn through the tubes before they are properly burnt.
- (b) The arch becomes intensely hot (up to 1,371°C, 2,500°F) and acts as a reservoir of heat that assists in maintaining an even firebox temperature.
- (c) Reduces chilling by preventing cold air being drawn directly to the firebox tube plate when the fire door is opened.
- (d) Provides combustion gases with a circuitous path thus giving more time for complete combustion.
- (e) Reduces smoke emissions.
- (f) When the fire is dropped, the heat retained in the arch assists the boiler to cool gradually, thus reducing stress effects that are brought about by too rapid cooling.

4.5.6 Firebox crown

The crown is the roof of the firebox. It suffers from rapid expansion and contraction stresses, high temperatures and cooling from opening the firebox door. The crown is supported by crown stays.

4.5.7 Firebox side sheet

These include all the inner firebox plates (such as the side plates and back plate). These are typically flat and are stayed surfaces.

4.5.8 Firebox door sheet

The door sheet is the rear plate of the inner firebox. It includes the fire hole door opening and is separated from the back head by the back water space.

4.5.9 Combustion chamber

Combustion chambers increase the firebox heating surface, efficiency and volume and improves the completeness of combustion.

Combustion chambers reduce direct flame impingement on tube ends and shorten tube lengths.

4.5.10 Firebox tube plate

The firebox tubeplate is the plate into which the tubes are inserted, to allow the firebox gases to flow to the smokebox.

4.5.11 Stays

Stays are made from steel, copper or monel and used to maintain shape and prevent bulging. There are many different types of stays found in a locomotive boiler, fitted in various locations. See Section 11 for more information.

4.5.12 Ash pan

The ash pan is positioned below the fire grate to receive ashes and clinkers from a coal-fire boiler as they fall from the fire bed. Oil-fired boilers have a brick pan that contains the fire within the firebox.

Some ash and brick pans regulate, via the dampers, the amount of primary air entering the grate. The shape of the pan varies with the width of the grate and the position of the axles and the design of the locomotive. It may be formed in the shape of a hopper to facilitate emptying.

4.5.13 Fire hole ring

An interfacing ring between the holes in the inner and outer firebox plates that may be riveted or welded.

Flanged plates that butt together shall be welded.

Plates may lap each other and be riveted. Plates may be dished and riveted or welded.

4.5.14 Fire hole

The fire hole's function is to provide fuel access to the firebox. In many boilers its other function is to admit secondary air to complete combustion and it may provide access to facilitate inspection and repair of the inner firebox.

4.5.15 Fire bar carriers

Fire bar carriers support the fire bars and generally carry out the rocking, shaking movement

4.5.16 Bearer bars

In most locomotives bearer bars are attached to the foundation ring by bolts or brackets and hold the carrier bars in pockets to allow the grate carriers to pivot.

4.5.17 Foundation ring

The foundation ring, also known as the mud ring, unites the lower edges of the inner and outer firebox plates (sheets). It can be forged, cast, welded or a pressed U-section.

Because of the tight radius of corners in riveted foundation rings, the plates are held in place with boilermaker's (or patch) screws (see Figure 9).

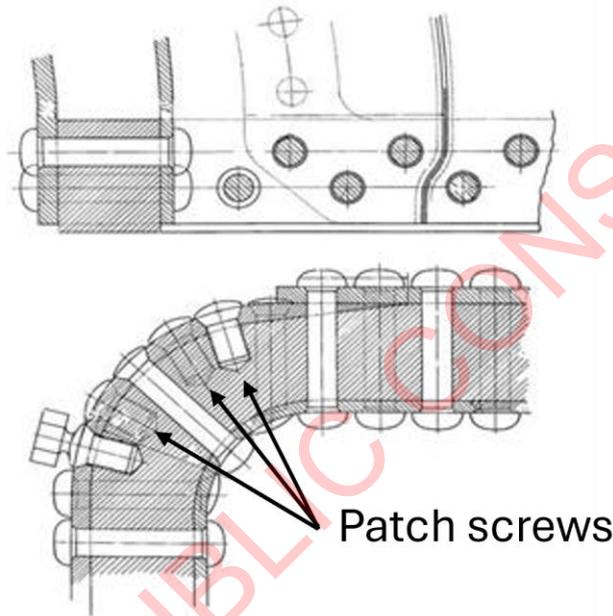


Figure 9 Foundation ring corner

4.5.18 Fusible plugs

To alert the operator to an extreme low water condition, the crown sheet of the firebox is fitted with one or more fusible plugs (see Section 6).

4.5.19 Dampers

Dampers regulate the admission of air to the fire bed and can improve combustion and boiler operation and efficiency.

4.5.20 Arch tubes

Arch tubes (see Figure 10) are steel tubes two or more in number fitted in the firebox and connected into the lower portion of the firebox tube plate and the upper end into the back plate above the fire hole.

In addition to increasing the heating surface and enhancing the circulation, the tubes also support the brick arch.

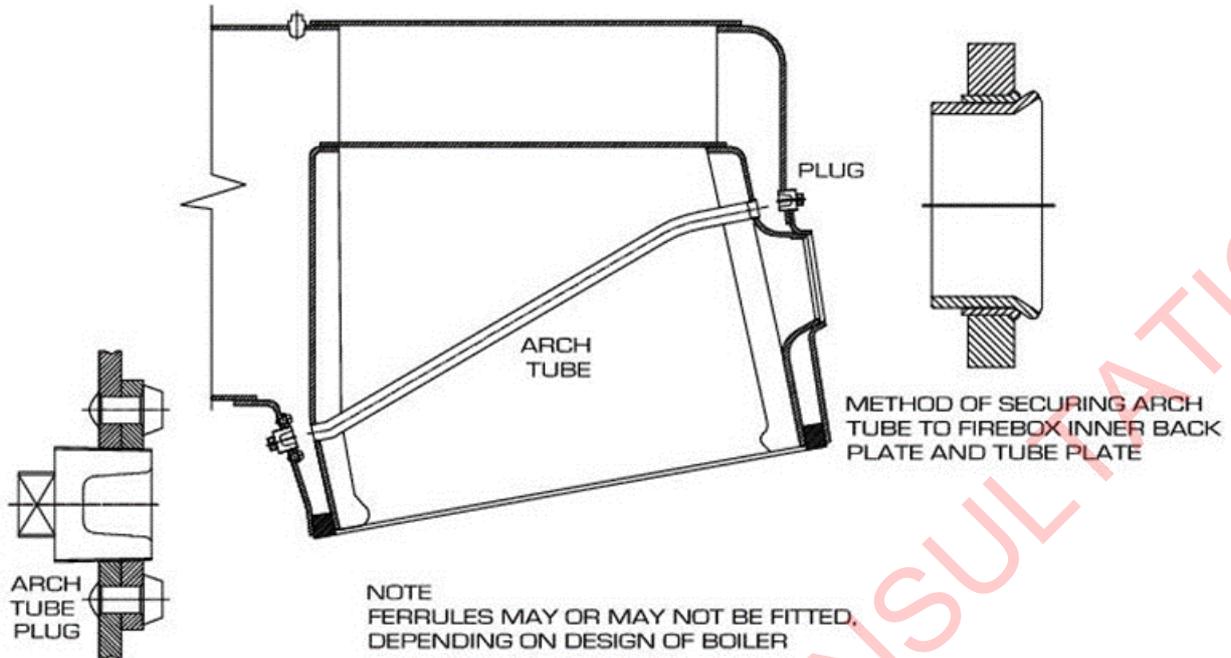


Figure 10 Arch tube

4.5.21 Arch tube plugs

Arch tube plugs (see Figure 11) are threaded plugs that fit into holes provided in the throat plate and back plate to provide for cleaning and inspection of the arch tubes.

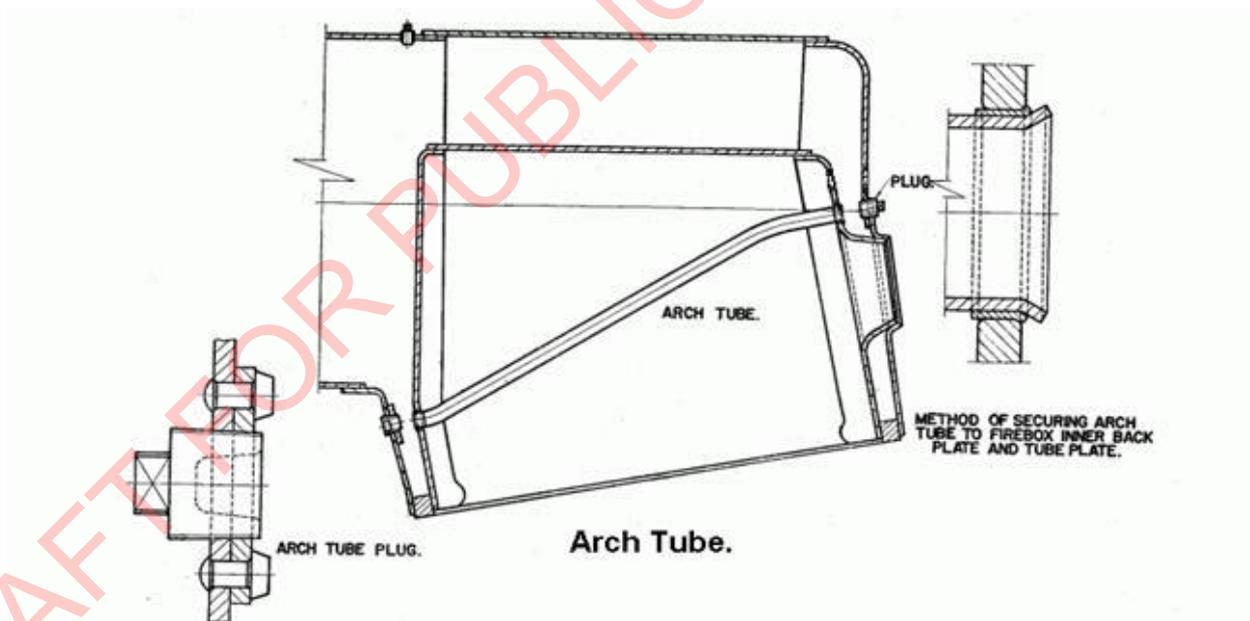


Figure 11 Arch tube

4.5.22 Thermic siphons

The Nicholson thermic siphon (see Figure 12) resembles a flattened funnel with the upper edge attached to the firebox crown and the neck attached at the lower combustion chamber throat plate. Thermic siphons increase the firebox heating surface, aid circulation and heat transfer (which increases boiler

efficiency) and help support the brick arch (see Section 9). Other thermic syphons are shown in Figure 13 and Figure 14.

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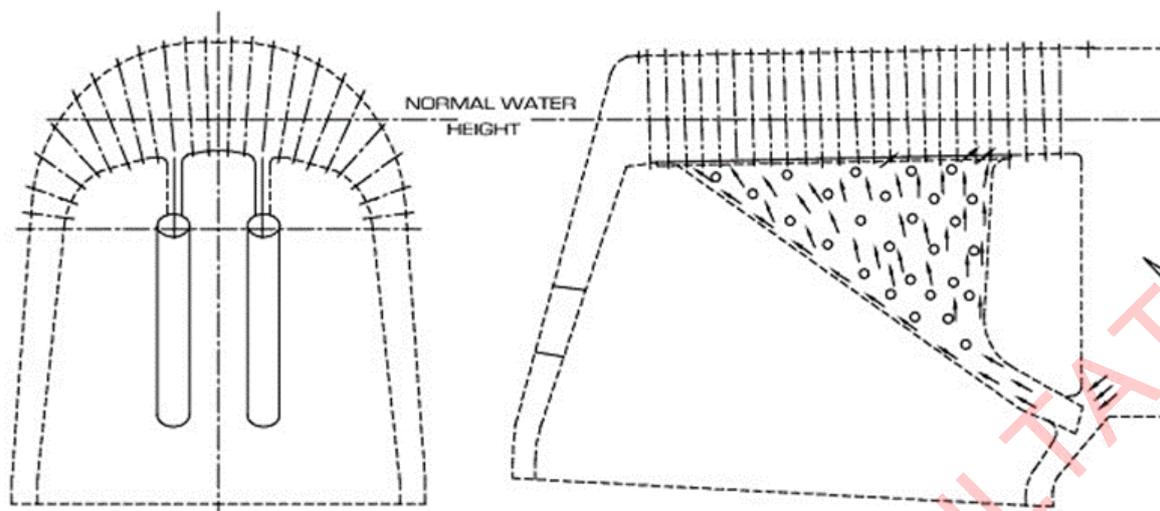


Figure 12 Thermic siphon

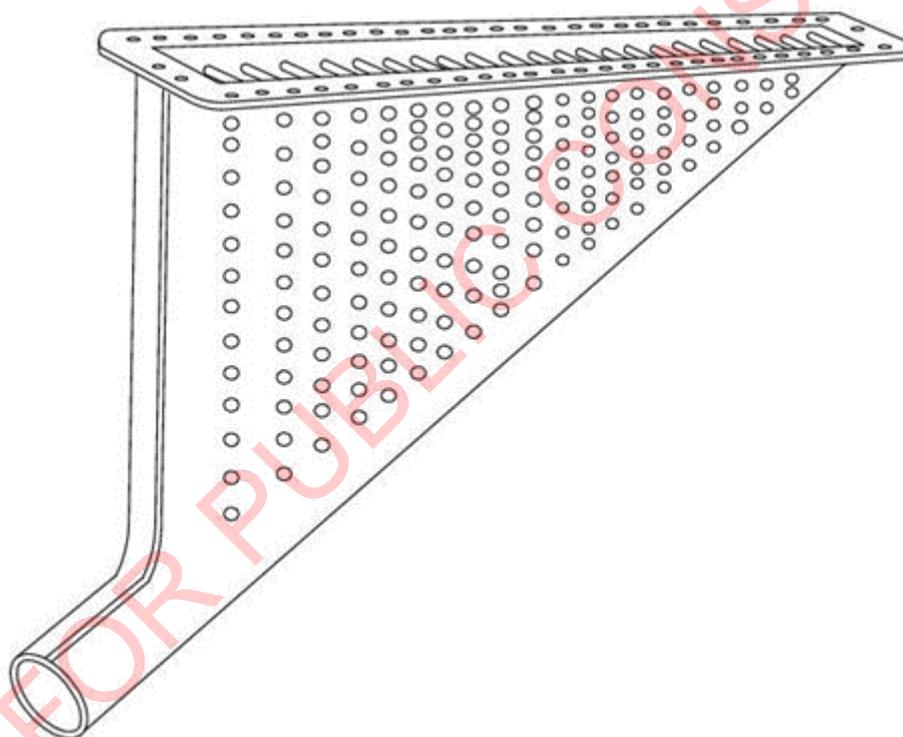


Figure 13 Thermic siphon

Diaphragm

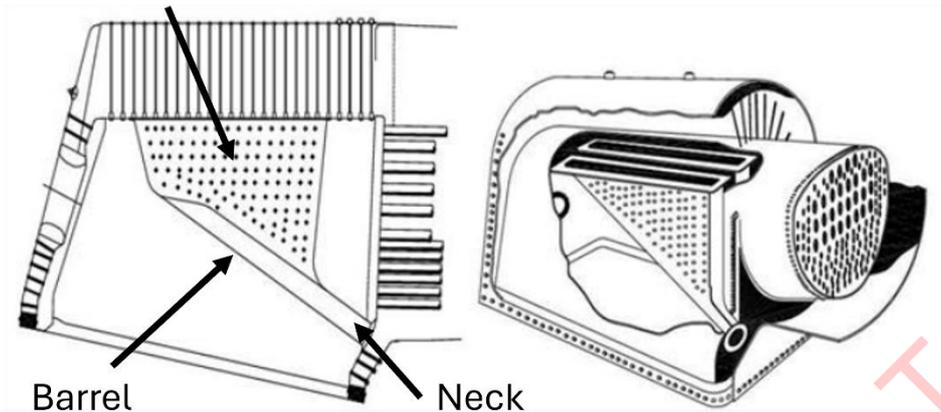


Figure 14 Thermic siphon within the firebox section

4.5.23 Barrel

The barrel is manufactured from steel plate and is joined to the firebox at the throat plate. A tube plate is fitted at the smoke-box end of the barrel.

The barrel contains several different types of stays, for example, longitudinal, palm and gusset (see Section 10). Boiler barrels may be tapered or parallel or a combination of the two.

4.5.24 Dome

The dome is an extension, usually but not always cylindrical, positioned on top of the boiler barrel and designed to provide a steam space as high as possible above the water level. It is the location of steam outlets.

The placement of the dome ensures that the steam will be as dry as possible and minimizes the chances of water carry over that may cause possible damage to the cylinders and the washing away of lubrication in the valves and pistons.

4.5.25 Boiler shell or barrel sections

Boiler barrels are made from steel plate rolled into segments of the required diameter. The segments are joined together at the circumferential seam by riveting or welding, while the longitudinal seams on the individual segments are usually butted together and either welded or riveted using butt straps (see Figure 15).

Some older barrels on low-pressure boilers were fitted with simple riveted lap seams. Where this occurs examination grooves to show up cracks shall be cut into the plate in accordance with AS 3788:2024

AS 3788:2024, Section 9.6.3 provides information on type faults for lap joints.

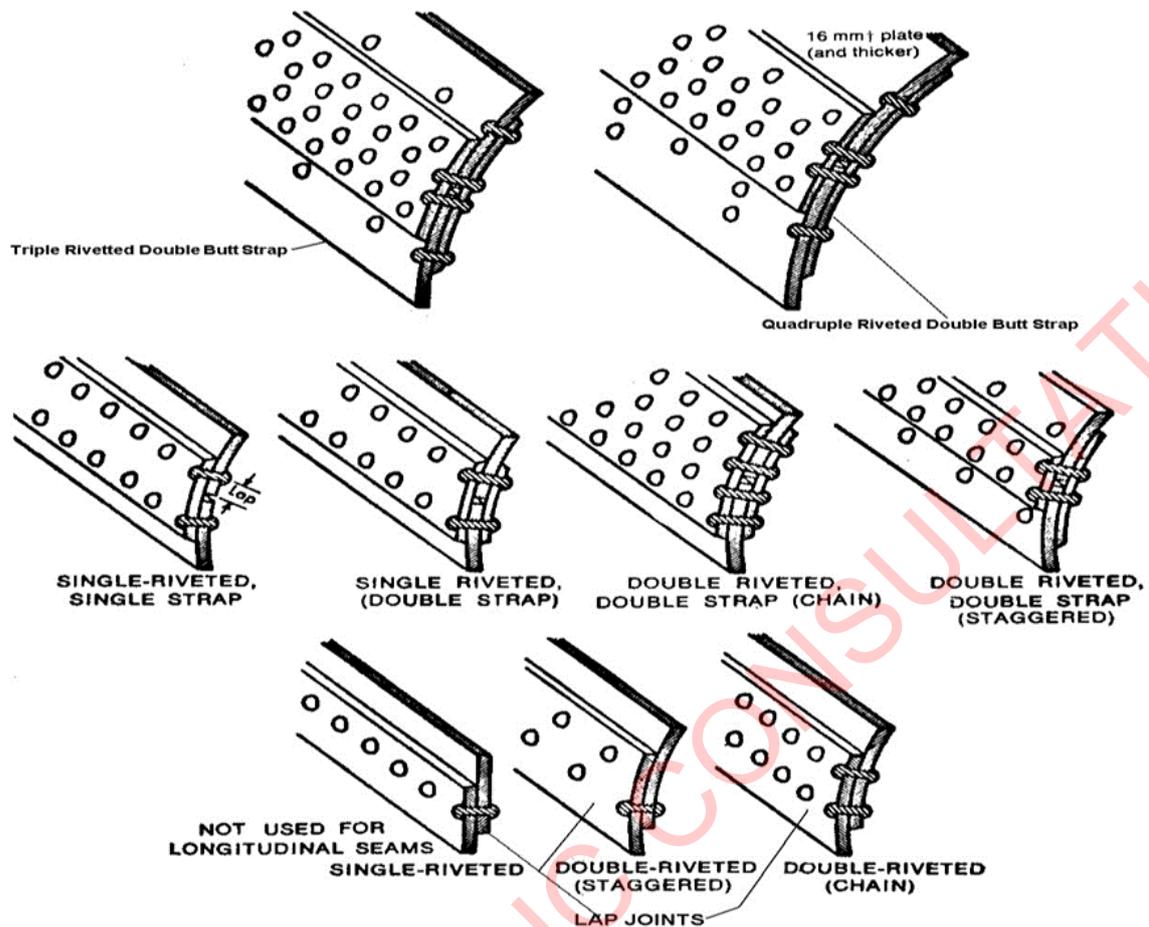


Figure 15 Boiler shell/barrel section lap joints

4.5.26 Compensation rings

Compensation rings are reinforcement plates for openings in boilers where the opening size exceeds the plate thickness by $4\frac{1}{2}$ times.

4.5.27 Smokebox tube plate

The smokebox tube plate is made of steel and attached to the boiler barrel. It has holes bored to receive tubes, the main steam pipe, inspection plugs and longitudinal stays, etc.

4.5.28 Flue/smoke tubes

Flue tubes are large-diameter tubes designed specifically to house superheater elements and connect the firebox to the smoke box. These tubes are surrounded by water and the products of combustion pass through from the firebox to the smoke box, giving up heat to the water.

Smoke tubes are smaller diameter tubes that connect the firebox to the smoke box. The products of combustion pass through from the firebox to the smoke box giving up heat to the water.

4.5.29 Outer wrapper or outside firebox plates

The outer wrapper includes all the outer firebox plates (such as the side plates, back head, throat plate and roof sheet). These are stayed surfaces.

4.5.30 Firebox back head

The firebox back head is the outer rear plate of the firebox. It contains the fire hole and some boiler mountings.

4.5.31 Throat plate

The throat plate is the front lower outer firebox below the barrel that joins the firebox to the barrel.

4.6 Other common items

4.6.1 Mounting studs

Mounting studs are used to attach boiler fittings to the boiler (see Section 13).

4.6.2 Regulator valve/throttle

The regulator valve can be located in the steam dome or the smoke box and is used to control steam flow from the boiler via the main steam pipe to the valves and cylinders.

The regulator valve is controlled by the regulator rod and handle located within the locomotive cab.

4.6.3 Internal regulator stuffing box (gland)

The stuffing box holds rings of packing to form a water-and steam-tight seal. Packing is compressed around the shaft by tightening the gland follower.

4.6.4 Safety valves

Safety valves are a critical and essential safety device, the purpose of which is to relieve a boiler of pressure in excess of its registered maximum allowable working pressure (see Section 19).

4.6.5 Superheater header

A superheater header (see Figure 16) is a chambered header fitted to the smokebox tube plate in which saturated steam is collected from the main steam pipe and distributed through superheater elements to reheat steam, before distributing it to the valves of superheated engines.

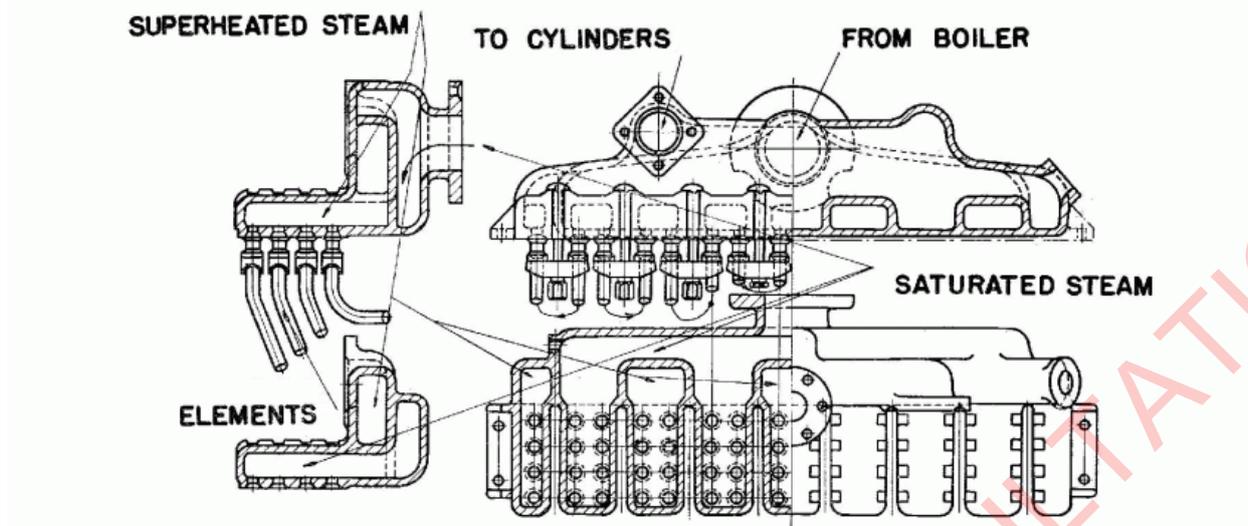


Figure 16 Superheater header

4.6.6 Superheater elements

Superheater elements (see Figure 17) are manufactured from steel tube and typically comprise multiple lengths of tubing joined by return bends. The inlet and outlet ends are joined to either the saturated steam chamber or the superheated steam chamber of the superheater header.

NOTE:

Superheated steam is an invisible high temperature gas. Extreme care needs to be taken whenever looking for superheated steam leaks due to the danger of high temperature scalding/death.

To diagnose if a superheater element is leaking, it is safer to pressurize the boiler with air (up to boiler working pressure is not required), then open the regulators slightly. The leaking element can then be heard inside the respective flue tube and/or the air detected escaping from that flue tube.

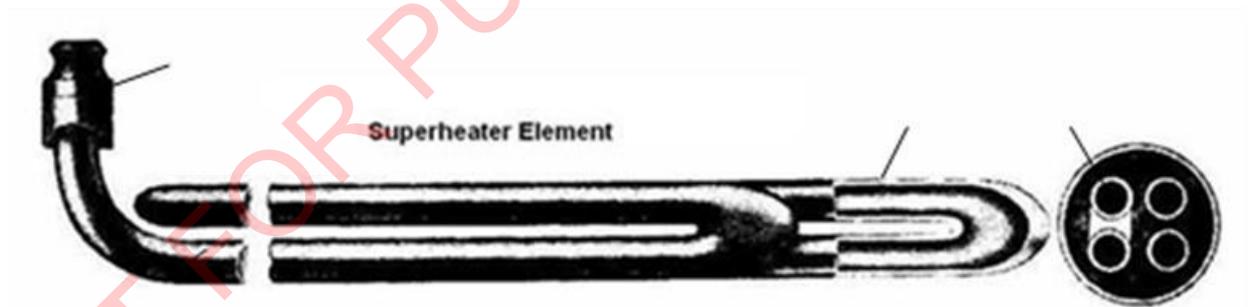


Figure 17 Superheater element

4.6.7 Washout and inspection openings

Plug and hand holes for cleaning and inspecting internal surfaces of a locomotive boiler are positioned to allow the boiler to be washed out and the internal surfaces inspected (see Section 12 and Section 21).

Section 5 Maintenance, repairs and alterations

5.1 Introduction

This section sets out the general requirements that apply to performing maintenance, repairs and alterations to locomotive boilers.

Work on boilers may arise from planned maintenance activities, repairs required between annual inspections, or from defects found during the annual inspections.

In all cases, it is essential to control the work to ensure that the integrity of the boiler is maintained. The SMS of the RSO shall establish the principles and procedural controls necessary to achieve this.

Where new practices or designs are introduced into the maintenance and repair of boilers this shall be done in accordance with the RSNL and the RSO's SMS. Also refer to AS 3920

The practices and procedures in this section have been sourced from recognised and generally accepted good engineering practice used by railway engineering workshops, such as state government rail authorities, when maintaining locomotive boilers during their service life. In all cases, where repairs are required, and no past proven railway practice exists, the RSO shall develop a repair proposal supported by the necessary technical expertise and technical review.

Historically, there are variations between state jurisdictions in the constructional detail used in locomotive boilers, therefore before any work is done the original design drawings, specifications and procedures shall be reviewed as far as practicable. This is also an essential part of setting out the inspection and test plan.

The RSO and the independent boiler inspector should have or obtain an understanding of the design and construction of the boiler. See Section 3 for further guidance.

5.2 Construction standards

In all cases, the original design and construction standards should be referenced to confirm design criteria so that any proposed repairs and alterations do not compromise the integrity of the design. Where there is no documented information available (e.g., drawings or specifications), the RSO and inspector should, together with other competent, experienced and specially trained personnel, develop a work scope based on good engineering principles and current standards to establish document detailing the existing design. A degree of interpretation and comparison between the actual construction and the current standards could be required. This requires the involvement of competent personnel who have an appropriate blend of current and historical engineering knowledge.

The requirements of AS 1228:2016 and AS 3788:2024 shall be followed so far as is reasonably practical (recognising the original engineering criteria) to ensure that the current standards are complied with if any repairs or alterations are to take place.

A boiler constructed to a standard other than the Australian Standards shall be maintained and/or altered according to the standard to which it was built. Inspection and fitness-for-service assessments shall be conducted in accordance with the original design standards.

Where the information on the design standard of the boiler is not practically available, the boiler shall be maintained or modified to the current Australian Standards.

5.3 Materials of construction

The materials of construction of locomotive boilers manufactured before 1980 are likely to be quite different in composition and mechanical properties to modern materials.

Locomotive boilers shall be inspected for any stampings or references to standards, as this could provide guidance as to the material composition of older boilers.

Because of this, it is essential that, as far as practicable, the material properties of the boiler are determined before any repairs are considered. Failure to take sufficient care in determining the properties, or tests to establish essential parameters, could lead to unsuccessful and possibly dangerous repairs. This is especially the case when, for example, welding of old materials is being considered as a repair technique, because of the propensity to have laminations in the plates.

If there is insufficient information available to make a satisfactory determination of the materials properties, then samples should be taken for analysis of composition, hardness and grain structure as necessary. If welding is being considered, it is strongly advised to carry out qualification welds with material removed from the boiler to prove mechanical suitability of material and welds.

The advice of welding or metallurgy experts should be sought for more guidance.

5.4 Repair and alteration competencies

All repairs and alterations that vary from the original construction (e.g., welded repair in place of riveted joint) shall only be carried out in consultation with the independent boiler inspector and any specialist inspector or technical expert required to properly scope the work, inspection and test plan (ITP).

NOTE:

Significantly changing the design and construction philosophy of a boiler through major repairs could affect exemptions for design registration for heritage boilers.

When engaging an independent boiler inspector for assessment of repairs and alterations, they shall have suitable competencies to assess the work done, in accordance with AS 4481. Where the independent boiler inspector does not have the required competencies a specialist inspector competent to assess the repair or alteration shall be engaged to assist the independent boiler.

For example:

- (a) weld repairs may require a fabrication or welding specialist to accurately determine whether the welding repair is suitable for a pressure vessel; and
- (b) alterations from the original construction may require assessment by a fabrication specialist, qualified in assessment of pressure vessels.

Where welding is conducted in areas subject to steam pressure, the welder should be deemed competent in accordance with AS 3992. Welds should be assessed in accordance with AS 4037

Refer to the *ONRSR Rail Locomotive Boilers Guideline* for further guidance.

At the completion of each inspection, the independent boiler inspector shall complete a written report, as per Appendix B. The report shall include any recommended maintenance, repairs or alterations that may be required. The report may include recommendations for the ITP or a maintenance strategy.

The independent boiler inspector, in conjunction with any engaged specialist inspector, may choose to advise on how this work may be completed, but the RSO has the ultimate responsibility to ensure that integrity of the boiler is maintained. Work should be done co-operatively with the independent boiler inspector and with any engaged specialist inspector

The independent boiler inspector, in conjunction with any engaged specialist inspector, shall detail all hold points for tests or inspection during the work in the repair/alteration scope and test plan. This shall include all plate preparations and weld procedures before welding begins.

The authority and powers of the independent boiler inspector can vary between jurisdictions and it is important for both parties to understand the specific requirements in each case.

5.5 Repair techniques

As with materials of construction, the maintenance, repair or alteration work technique should be in accordance with the original construction and repair practices and procedures, unless an appropriate assessment of any alternative technique(s) finds that it can produce a result that maintains the integrity of the boiler.

There are many opportunities to use modern techniques such as welding to complete work on boilers. It is imperative that an appropriate amount of research is done on the construction, materials and design principles of the original boiler to prove the alternative technique will produce an outcome of equal or better quality.

The independent boiler inspector may choose to advise on using this alternative technique, but the RSO has the ultimate responsibility to ensure that integrity of the boiler is maintained. This should be done co-operatively with the independent boiler inspector who, if familiar with locomotive boilers and competent to give advice on the work, is a valuable resource. If the independent boiler inspector does not have the competencies to provide guidance on completing the work, then the RSO is responsible for finding competent engineering resources to complete the work.

5.6 Repair management

Before performing any repairs or alterations to boilers, a competent person shall prepare a detailed scope of work and an ITP. This should be reviewed by a competent person before implementing.

Where welding is required, the documentation shall include all weld procedures, welder qualification reports and traceability of all work by each welder as per AS 3992. This shall include any specific requirements on welder qualifications required by each state authority.

5.7 Records

All reports and any other correspondence relevant to the work shall be included in the boiler history file. A full traceable history of all documentation, tests, reports and correspondence on the work shall be maintained.

Refer to AS 3873:2001 and the *ONRSR Rail Locomotive Boilers Guideline* for further guidance on record keeping.

5.8 General requirements

5.8.1 Welding activities

Before performing any welding activities, the weldability of locomotive boiler materials shall be assessed. This should include a determination of any laminations or other inclusions that will prevent a satisfactory weld. These plate defects may be detected using NDE.

A portion of the material cut out for the repair shall be used as a test plate to weld old to new, to prove the developed weld procedure and the compatibility of the plates. Mechanical testing shall also be carried out. The certificates developed from these shall be added to the boiler history files.

Approval from the independent boiler inspector, suitably advised by a welding specialist, may be required before starting welding on locomotive boilers.

5.8.2 Materials

The older steels used in riveted construction were frequently high in carbon, sulphur, phosphorus and hydrogen. The older steels were not melted to a fine grain practice and will typically have poor toughness properties.

If welding is to be used to repair a pressure-retaining item that was manufactured using riveted construction, the repair organisation should do a chemical composition analysis on the steel plate base metal and rivet material to determine weldability. Specific quantities of carbon, manganese, sulphur, phosphorus and aluminium shall be identified and included in the analysis.

The result of the analysis shall be acceptable to all parties before work starts.

Copper piping used in boiler construction shall meet the requirements of AS 1228:2016

Plumbing copper that meets the requirements of AS 4041 may be used for auxiliary piping.

Cold rolled steel shall not be used in boiler fabrications and repairs. Cold working increases the mechanical properties, tensile strength, yield strength and decrease ductility.

5.8.3 Material list for steam locomotive boilers

A material list is intended as a basic guideline only and covers basic carbon steel and some alloy steel material specifications. Other alloy materials may be available for these applications if necessary.

AS 1548 PT-460 steel is recommended for firebox and other boiler repairs. It is a fine grain steel that accepts flanging and bending with less tendency to crack than coarse grain steels. Coarse grain steels have, on occasion, been found to crack or split after complicated flanging, bending and forming.

Where copper is used for the firebox or stays the copper should be phosphorus deoxidised arsenical copper to C107 (also known as C10700) grade as per BS 2874. Due to the specialist nature of copper welding, any welding involving copper shall be conducted by personal experienced in copper welding.

Structural steel shall comply to AS/NZ 3678:2016 or 3679.2:2016

When rivets are made from ASME SA-675:2025, the finished rivets shall meet the physical requirements of the original rivet specification or ASME SA-31:2025, Grade A or Grade B.

5.8.4 Formulae and calculations for steam boilers

Most steam locomotive boilers were manufactured in the first half of the 20th century or before. The calculations, formula, and shop practices used are now distant history and quite difficult to obtain. The rules for riveted construction were last published by Australian Standards in CB1, 1957 Edition.

This document is based in part on the AS CB1-1957, which was the last published edition of the standard.

For formulae and calculations for welded boilers, refer to AS 1228

5.9 Repairs

5.9.1 Repair of stay holes

Stay holes may be repaired by welding, reaming, bushed or re-tapping to a larger size or by installing a flush patch. The minimum increments of diameter shall be used to form a new thread where the thread needs reworking.

If the stay hole was threaded and is to be repaired by welding, the threads shall be removed before welding.

Stay holes in the outer wrapper plate exceeding limits may be bushed. Where there are multiple stay holes exceeding limits in close proximity the plate section should be replaced.

Stay holes in the inner wrapper plate shall not be bushed. The plate section shall be replaced.

See Figure 18 for stay hole repair.

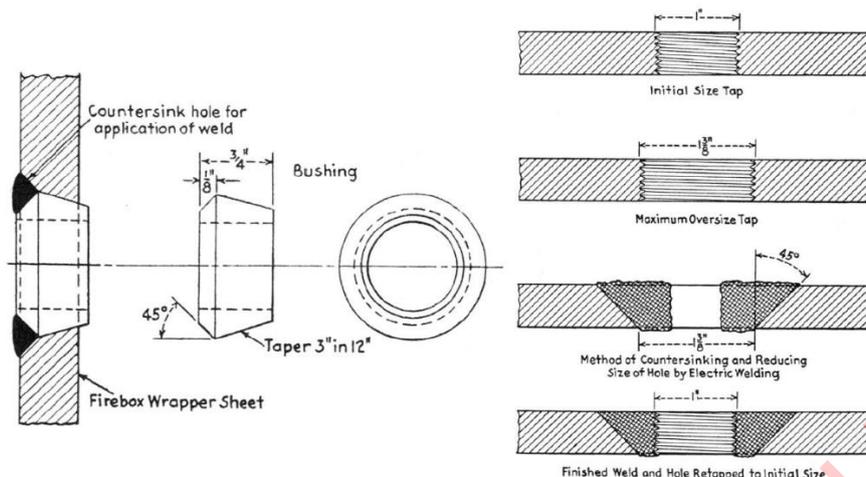


Figure 18 Repair of stay holes

5.9.2 Threaded stays

All threaded stays shall ensure that thread pitch is as per original design unless a design change is proposed and agreed to. Typical stay pitch is 11 TPI and 12 TPI for steel boxes and 10 TPI for copper fireboxes.

Stay threads shall have a good close fit in plates. Good fit can be described as no shake and no bind.

All stays shall have telltale holes in accordance with AS 1228:2016 or the registered design or construction standards.

Ball socket-type flexible stays may have telltale holes that extend from the threaded end of the bolt into the bolt head, according to original design practice.

Telltale holes shall be reopened after completing fitting.

Stay design shall be sized in accordance with AS 1228:2016 or the registered design or construction standard. Threads on the stay and through the two plates shall be cut to maintain continuity of the thread pitch.

When driving stay heads after screwing in, the stay shall be braced to prevent damage to the threads during the work. For example, hammers at each end or double gunning using a pneumatic hammer at each end.

Stay heads may be sealed using a fillet weld as an alternative to driving the stay head.

Installation of large diameter stays shall be considered a repair. Smaller diameter stays represent a design modification and shall be assessed as such.

Examples of stays are provided in Figure 19 and Figure 20.

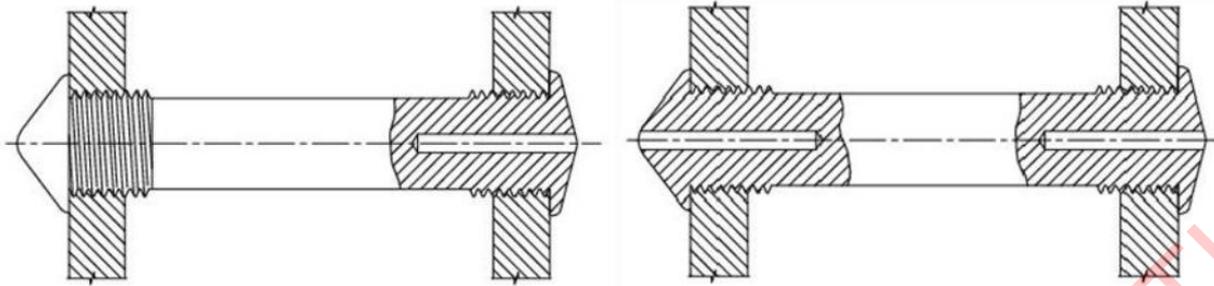


Figure 19 Threaded stay

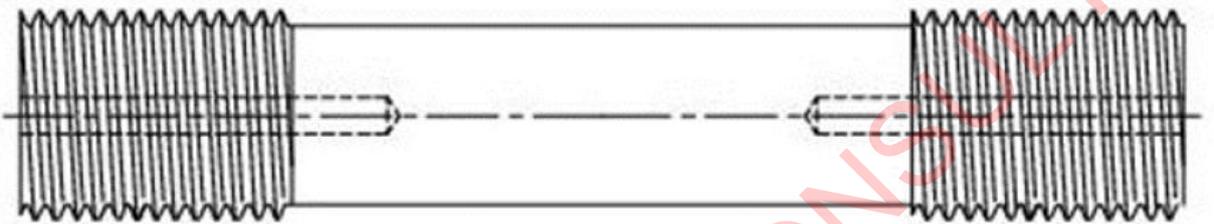


Figure 20 Typical threaded wall stay (Not installed)

5.9.3 Ball socket-type flexible stays, cup, and caps

NOTE:

All cups are considered to contain boiler pressure.

Welded flexible stay cups shall be applied as described in Clause 11.5. Cup axis shall be in alignment with the stay centreline through holes in wrapper and firebox plates.

Ball socket-type flexible stay-bolts may have tell-tale holes that extend from the welded end of the bolt into the bolt head, as per original design.

Typical ball type stays, cups and caps are shown in Figure 21.



Figure 21 Typical flexible stay, cap, and cup design

Welded cups and welded caps that leak at the welds or the cup shall be repaired.

Wasted caps and cups shall not be repaired by weld build-up. If cups and caps walls are wasted to more than 60% of their original thickness, they shall be replaced.

Welded cups that have damaged cap threads shall be reconditioned using the correct tap. If at least 60% of the thread form cannot be recovered, the cup shall be replaced.

Cup bodies that are cracked shall be replaced. Stay caps that leak shall not be seal welded.

Ball socket-type flexible stays may have tell-tale holes that extend from the threaded end of the bolt into the bolt head, according to original design practice. Substitution of one type of flexible stay cup by another type shall be considered a design change and shall be approved.

Where individual stays are replaced, care should be taken to ensure that the stress load of the new stay is compatible to the loading on adjacent bolts.

See Clause 4.9.6 for material requirements. The ball end of the flexible stay shall not be braced by inserting packing under the cap when driving the head. A specially designed fitting cap may be used for driving the head. This cap shall be replaced by the proper fitted cap directly after the driving down is completed. The driving down cap shall be visually different to the normal caps to distinguish it.

The individual design of the boiler may specify that the flexible stay be screwed down hard onto the base of the cup or set back a specified distance. The requirement shall be confirmed before installation.

5.9.4 Seal welded stays

Replacement threaded stays can be seal welded in accordance with AS 1228 or the registered design or construction standard. Seal welding shall only be carried out after hydrostatic testing. Prior to seal welding the joint should be preheated to dry the joint and minimise hydrogen within the weldment.

Existing threaded stays that leak along the thread may be repaired by seal welding (see Figure 22). Seal welding shall only be performed after it has been proved that the leakage is not due to wasted plate, wasted stay or cracks in the stay. This is typically indicated when repeated leaks are found in a location. Stays that repeatedly leak shall be removed and the cause of the leak determined before a full repair.

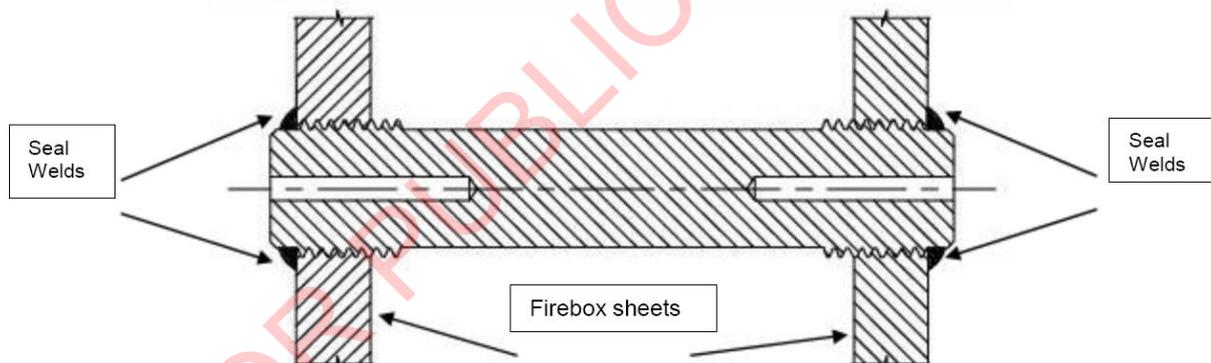


Figure 22 Cross-sectional view of a typical seal welded stay

5.9.5 Welded installation of stays

The installation of unthreaded stays using welds is permitted as per AS 1228 or the registered design or construction standard.

All stays shall have tell-tale holes in accordance with AS 1228:2016 or the registered design or construction standard.

Where individual stays are replaced, care should be taken to ensure that the stress load of the new stay is compatible to the loading on adjacent bolts.

The individual design of the boiler may specify that the flexible stay be screwed down hard onto the base of the cup or set back a specified distance. The requirement shall be confirmed before installation.

Installation of different diameter stays shall only be done in line with AS 1228:2016 or registered design or construction standard.

5.9.6 Construction material for wall stays

Steel fireboxes may be fitted with steel and/or monel wall stays while copper fireboxes are fitted with copper and/or monel wall stays. Copper wall stays shall not be fitted into a steel firebox. Steel used for firebox stays shall be as per AS 1228:2016 or registered design or construction standard, to ensure it is mild in character with maximum ductility, free from work hardening, and that it exhibits good riveting qualities. In addition, the material should not embrittle when subjected to service conditions.

The steel shall conform to the required mechanical properties as well as possess the correct chemical properties.

The material used for replacement stays should have the equivalent material specifications of the original material. If in doubt a metallurgist should review the original material specifications to establish a suitable material for the replacement stays. Modern materials are not generally designed for riveting processes (such as knocking down stay heads) and therefore it is important that the proposed material is mechanically and chemically tested for fitness for purpose.

Copper round bar for use as stay material in boilers shall be chemically and mechanically tested to ensure that the properties are within the design specifications of the boiler, with a typical elongation of 40%. If in doubt about the original copper specification for the boiler, an original stay should be analysed by a metallurgist to get a comparable, modern grade. Refer to AS CB1.3-1957 for more information on material properties of copper for wall stays.

Monel metal is a nickel copper alloy widely employed for water space stays in both copper and steel fireboxes. A metallurgist shall be consulted to ensure that a suitable grade of monel is sourced for the application required.

5.9.7 Diagonal braces, gusset braces and throat sheet/tube sheet braces

Loose or damaged braces shall be repaired or replaced.

Only braces fabricated from steel may be repaired by welding. All such welds shall be full penetration. Wrought iron braces shall not be repaired by welding. When repairs or alterations are completed, the tightness and condition of the braces and their stays, rivets, clevises, eyes and pins shall be verified.

Examples of braces are provided in Figure 23, Figure 24 and Figure 25.

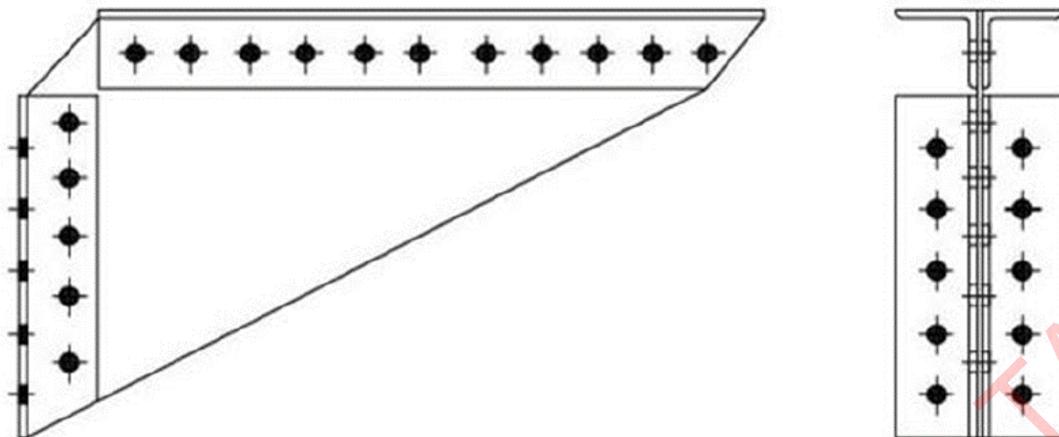


Figure 23 Gusset brace

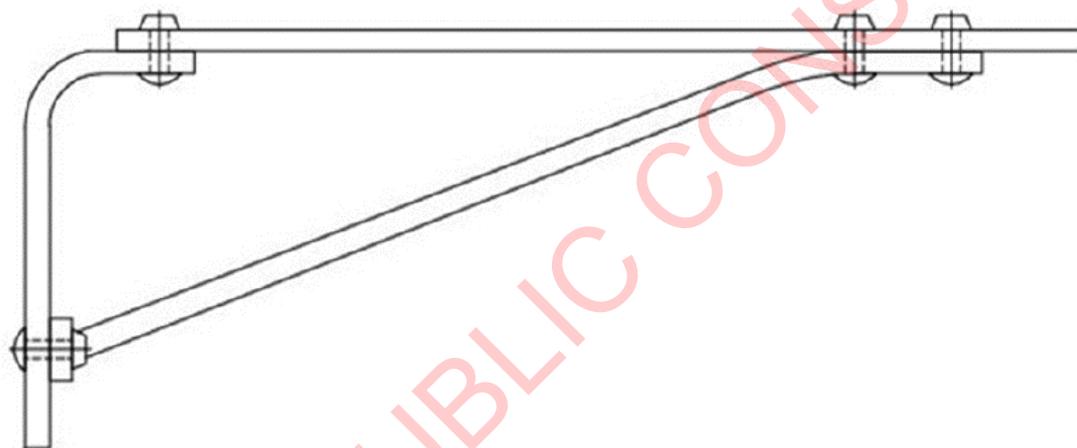


Figure 24 Diagonal brace

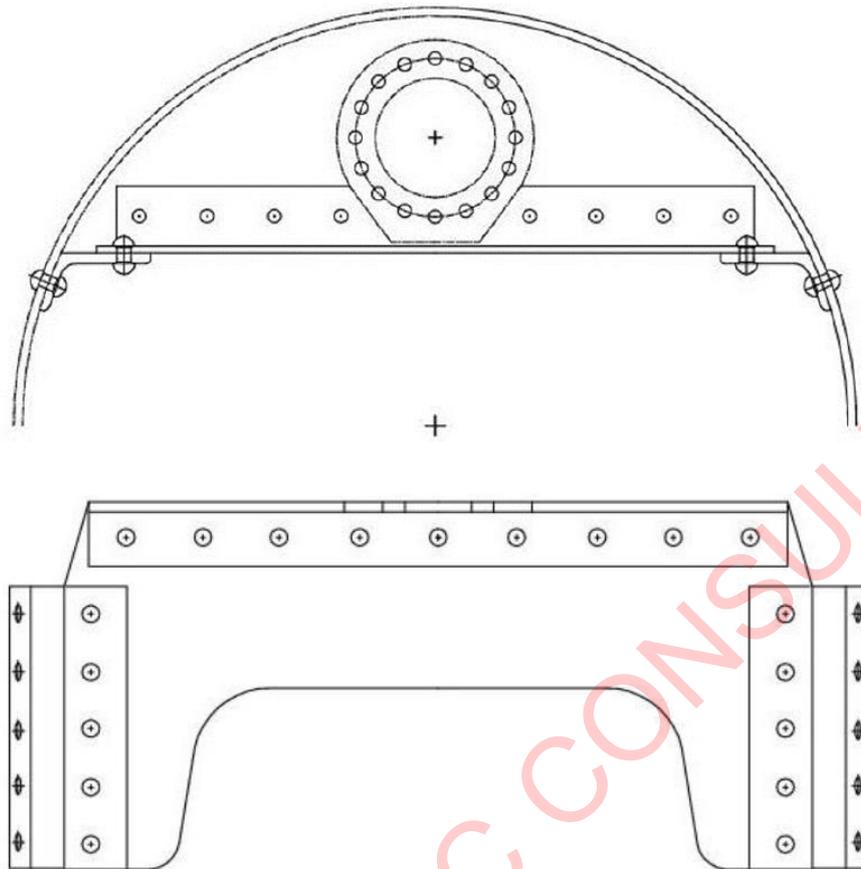


Figure 25 Tube sheet brace

5.9.8 Steam-tight threaded stud

Steam-tight studs shall be fitted to any attachment to the boiler where the pressure part has been penetrated.

Steam-tight studs are those that penetrate any pressure part of the boiler into the steam space and are therefore subjected to boiler pressure.

Studs shall be machined 0.125 mm (0.005") larger than the nominal outside diameter of the threaded hole and fitted using a stud driver (stud box). See Figure 26.

They may be fitted using a minimal amount of a graphite-based sealing thread paste or gland packing rope strand. Seal welding shall not be permitted.

Steel used for studs shall be as per AS 1228:2016 to ensure it is mild in character with maximum ductility, free from work hardening, and that it exhibits good riveting qualities. In addition, the material should not embrittle when subjected to service conditions.

The steel shall conform to the required mechanical properties as well as possess the correct chemical properties:

- (a) Carbon, not more than 0.20% (per cent carbon shall not be exceeded)
- (b) Manganese, not less than 0.40%
- (c) Sulphur, not more than 0.05%
- (d) Phosphorus, not more than 0.05%
- (e) Elongation, not less than 25%

- (f) Ultimate tensile strength, 400 MPa to 460 MPa
- (g) Yield strength, 50% of the tensile strength.

Material test certificates shall be supplied.

Commercial, off-the-shelf studs shall not be used for this purpose, as the material is not suitable for this application.

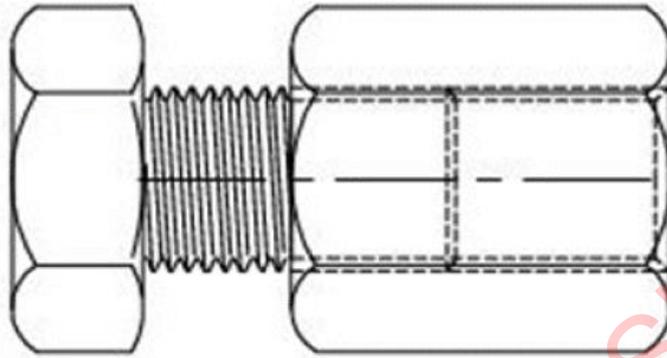


Figure 26 Stud driver

5.9.9 Patch screws

Patch screws (see Figure 27) are fitted in lieu of rivets in places where access is restricted. Some are original design (e.g., corners of fireboxes on foundation bars) and some are used in repairs where the other side of the rivet cannot be accessed for holding up (e.g., inner firebox seams).

Steel used for patch screws shall be as per AS 1228:2016 or registered design or construction standard, to ensure it is mild in character with maximum ductility, free from work hardening, and that it exhibits good riveting qualities. In addition, the material should not embrittle when subjected to service conditions.

The steel shall conform to the required mechanical properties as well as possess the correct chemical properties in AS 1228:2016

Modern materials are not generally designed for riveting processes (such as knocking down heads) and therefore it is imperative that the proposed material is mechanically and chemically tested for fitness for purpose.

Material test certificates shall be supplied, and a copy shall be retained in the boiler history file.



Figure 27 Patch screws

**5.9.10 Smoke tube, flues, arch tubes, thermic siphons smoke tube, flue and tube re-
ending**

Refer to AS 3788 for repairs and alterations. Requirements for developing a scope, setting an inspection plan and review by competent personnel as per Section 2.

Each smoke tube or flue that is re-ended (also known as safe ended) by welding is limited to one circumferential welded joint. This weld shall be carried out in line with an approved weld procedure and be subjected to 100% radiography. Such work is a change that shall be reviewed and approved.

Re-ending is only permitted when the thickness of the tube or flue to be re-ended is not less than 90% of that required by the original design.

Re-end pieces shall be new material that is proven to be compatible with the original tube material and meet the thickness requirements of the design standard. This material shall have the appropriate test certificates.

5.9.11 Arch tubes

Arch tubes that are damaged or reduced to less than minimum required wall thickness shall be replaced totally by new seamless one-piece arch tubes. Welded repairs or partial replacement is not allowed. Damage includes defects such as bulging, burns, and cracks.

Common practice in Australian railways when expanding arch tubes is that the tube end projects through the firebox sheet not less than 6 mm (1/4 in) and not more than 19 mm (3/4 in) before flaring. After the tube is expanded, it is flared at least 3 mm (1/8 in) greater than the diameter of the tube hole.

An arch tube installed by welding shall be assessed as a welded nozzle and shall comply with AS 1228:2016

A change in tube attachment from expanded to welded, or from welded to expanded, shall be assessed as an alteration and be approved by the independent boiler inspector and competent person before the change is made. The change may also require a verification by a suitably qualified engineer to ensure the design is safe to progress.

5.9.12 Tube wall thickness for arch tube

The minimum wall thickness of arch tubes shall comply with AS 1228:2016

5.9.13 Thermic siphons

Refer to AS 3788 for repairs and alterations. Requirements for developing a scope, setting an inspection plan and review by competent personnel as per Section 2.

For repairs to siphon knuckles, see Section 9.

All weld repairs to the unstayed sections of the siphon neck and body shall be radiographically examined. See Section 9.

5.9.14 Repairs and alterations to boiler barrels unstayed areas

Refer to AS 3788 for repairs and alterations. All requirements of developing a scope, setting an inspection plan and review by competent personnel apply.

The preferred methods of repairing wastage are with an inserted welded patch or a riveted patch. Weld build-up may also be allowed under certain circumstances and with the approval of the competent person.

Weld build up may be used at the discretion of the competent person after a full review to show the extent of the repair necessary. Pad welding shall not be applied to plates wasted below the minimum allowable thickness. Under no circumstances shall pad welding run over stay heads or rivet heads.

The size and location of any patch, and identification of whether the size of the patch will affect the integrity of the boiler, shall be assessed.

Prior to installation and welding of a patch the overall structural integrity of the boiler where the patch is to be installed shall be assessed. The impacts of residual weld stresses based on the location of the patch and other stresses that will be placed on the boiler shall be assessed.

Prior to commencing work the details of the proposed patch and any assessments shall be reviewed by a competent welder and the independent boiler inspector.

Prior to repairing cracks, the plate shall be examined for defects. Affected sections shall be repaired or replaced, according to the defect. If the cracked section of plate is to be kept and repaired by installation of a riveted patch, the crack shall be ground out and repaired by full penetration welding and then a doubling patch riveted over it. Results of crack removal and repair shall be verified by an acceptable non-destructive examination technique.

If the cracked section of plate is to be kept and repaired by welding alone, the crack shall be ground out and repaired with full-penetration welding, followed by NDE to prove satisfactory weld result and ductility for ongoing service.

When welded repairs are to be affected at or near riveted seams, the rivets adjacent to the repair shall be removed before the repair and be replaced once the repair has been completed. Reusing rivets and stays shall be prohibited.

All welded repairs to boiler barrel unstayed areas shall be radiographically examined in accordance with AS 4037:2016

5.10 Repairs and alterations to boiler stayed area

5.10.1 Firebox sheet repair

Cracks in all stayed firebox plates may be repaired by installation of an inserted patch or by grinding out and welding. A riveted patch shall not be used for this type of repair.

If the crack extends into a stay or rivet hole, the stay or rivet shall be removed prior to making the repair. Rivets adjacent to the repair shall be removed and replaced after the repair is complete.

Fire cracks or thermal fatigue cracks in riveted seams located in the firebox that run from the edge of the plate into the rivet holes may be left in place provided they do not leak and there is no identification that the seam or rivets are loose. The competent person shall be advised, and the inspection plan shall be updated to include this item as an ongoing inspection item, to ensure that the crack does not propagate further.

5.10.2 Firebox patches

Patches may be any shape, provided they have rounded corners of a minimum of 50 mm radius and are adequately supported by stays, rivets, tubes or any other form of construction.

Patches on stayed surfaces should be designed so weld seams pass between stay rows.

Patches are to be the inserted type using full penetration welds. Appropriate NDE is required, such as ultrasonics, magnetic particle, dye penetrant and radiography.

Short sheeting a firebox side with a weld above the foundation ring should be avoided. Where possible the sheet down to the foundation ring should be replaced and re-riveted. Otherwise high bending stress could act on the weld seam and there is a potential for grooving in this area will remain undetected or unresolved.

If the patch includes an existing riveted seam, the patch shall be riveted at that seam. Changing a riveted seam to a welded seam is an alteration and shall be approved.

Inserted patches shall fit flush on the water side of the plate. If the original thickness plate cannot be obtained, a thicker plate may be used. The fire side of the plate shall be tapered 1-in-4. A thicker plate may be machined to the correct thickness.

Stays and rivets should be installed after welding of the patch is completed. Reusing stays and rivets shall be prohibited.

Weld seams parallel to a knuckle shall be in accordance with AS 1228:2016 or registered design or construction standard. Weld seams shall not be in the knuckle.

Patches shall be made from a material that is compatible with the existing material and fulfils the requirements of the original design.

Welding, regardless of material, shall be carried out in a manner to manage contraction caused by constrained welds, such as this. All welding specifications shall include the sequence and NDE requirements and shall be designed by a person competent to carry out such a task.

5.10.3 Repair of stay firebox plates or wasted at the foundation ring/bar.

An example of foundation ring is shown in Figure 28.

Firebox plates that are grooved or wasted to less than the minimum allowable plate thickness shall be replaced.

Grooving or wastage may be pad welded, provided the plate has not wasted to less than the minimum allowable plate thickness, and provided the strength of the structure will not be impaired. If extensive welding is required, the affected area shall be removed and replaced with an inserted patch.

Inserted patches shall be arranged to include the foundation ring rivets and at least the first row of stays above the foundation ring. The corners of the patch shall have a minimum radius of 50 mm.

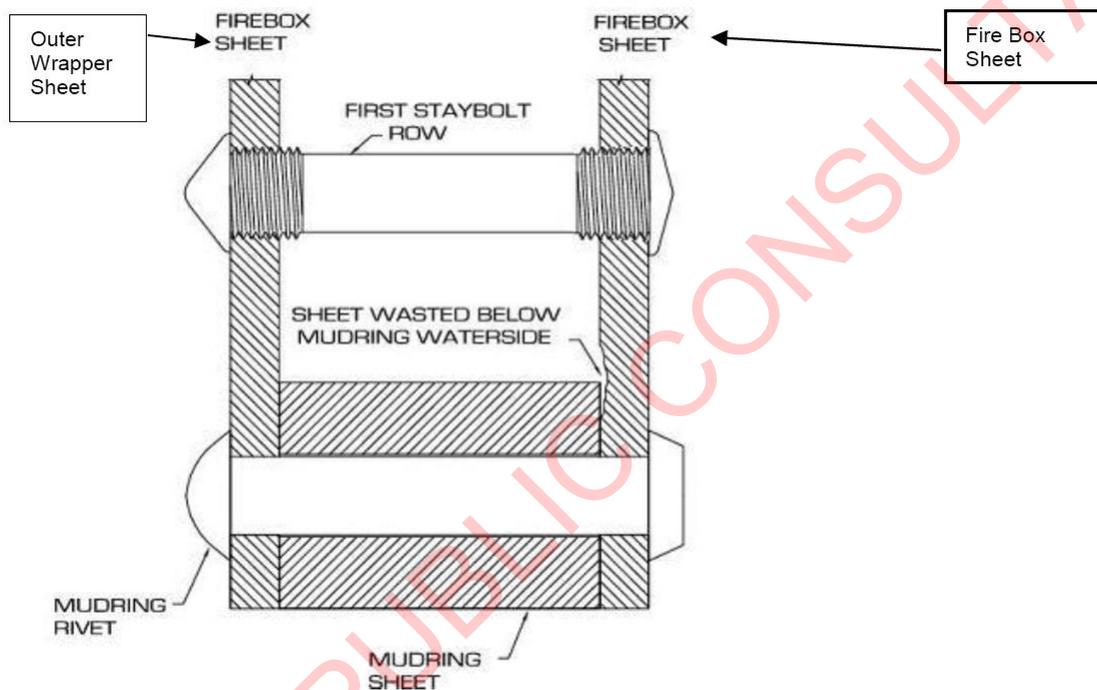


Figure 28 Foundation or mud ring

5.10.4 Foundation ring repairs

Pitted and wasted sections of foundation rings may be built up by welding provided the strength of the foundation ring will not be impaired. Where extensive weld builds up is employed, the inspector may need an appropriate method of NDE for the repair.

Cracked or broken foundation rings may be repaired by grinding out the fault and full-penetration welding conforming to AS 1228. Firebox sheets on both sides of the defect shall be removed to provide access for inspection and welding.

5.10.5 Repair of firebox and tube sheet knuckles

The knuckle areas are highly stressed. Therefore a doubling plate shall not be inserted in this area. The only repairs that shall be carried out in these areas are by the insertion of a flush, butt-welded patch.

Welds to repair cracking within the points of tangency of a knuckle are permitted. All welds shall be radiographically examined.

Any patches fitted shall be formed to proper shape and curvature.

Section of knuckles that are wasted below the minimum allowable thickness shall be replaced or have an inserted patch fitted.

5.10.6 Tube plate repair

Cracked tubeplate ligaments may be repaired by grinding out and welding using full penetration welds. Damaged tubeplate holes may be repaired by welding.

Sections of tubeplates damaged or wasted to less than the minimum required thickness shall be repaired by installing an inserted patch using full penetration welds. Before repairing an assessment should be made, in consultation with the competent person, whether it would be beneficial to replace the entire tubeplate, or a single, larger section.

Sections of tubeplates that have not wasted below the minimum allowable thickness may be pad welded to recover the corrosion allowance. When applying pad welding to the seams, care should be taken to ensure that the areas around the seams and the rivets are not affected by heat from the welding. These repairs require review and approval by the competent person.

5.11 Caulking riveted seam and rivet heads

Caulking refers to the sealing of plate seams and rivet heads by driving the edge of one surface onto the other by use of an impact tool.

This is a subtle activity that requires experience, finesse and a sense of feel for the material. It is an activity that should only be carried out by suitably trained and competent persons.

If these skills are not available within the organisation, advice should be sought from a person competent in these skills, who might suggest that a light seal weld is appropriate. This weld is subject to review and approval.

Caulking can be done using hand tools or by mechanical means (air-operated tools). The tools are extremely specialised and are made to suit this job.

Caulking is divided into two main processes:

- (a) Fullering, where the entire thickness of the exposed edges of the joint is compressed with a tool operated by hand or machine.
- (b) Split caulking, which uses a tool that has a face that is thinner than the plate being caulked and leaves a groove on the face of the caulked edge.

Caulking shall not be done with steam pressure in the boiler.

5.12 Threaded openings in vessel walls, bushing and welded nozzles (washout plug holes and other connections)

Threaded openings in vessel walls with damaged threads shall be repaired by re-tapping. If this fails to recover the thread, the hole shall be reamed with a suitable reamer, and the hole re-tapped to give a minimum of four (4) full threads of engagement in the plate. Threads shall be removed prior to any welding repair.

If the thread cannot be recovered by retapping, consideration should be given implementing an appropriate weld repair.

Threaded bushings and nozzles (where fitted) that are found to be defective shall be replaced. Seal welding is not permitted.

Section 6 Fusible Plugs

6.1 General

This section provides requirements, recommendations, and guidance on the inspection, maintenance and repairs to fusible plugs. Requirements in this section shall be adhered to unless it can be proven that another process or material is equal to or better than the practices and materials laid down in this document.

This document does not comment on the operational procedures in regard to dealing with a blown fusible plug in-service but does specify what is required before the boiler can be used again should such an incident happen.

Examples of fusible plugs are provided in figures 29 to 31.

6.2 Introduction

One or more fusible plugs shall be fitted to the firebox crown sheet. They are designed to create a significant discharge of steam in the firebox to suppress the fire and reduce the heat being generated. This will minimize damage to the crown sheet in the event that there is insufficient water to cover the crown sheet.

Fusible plugs fitted in the crown sheet of a locomotive boiler are a safety critical device and, as such, shall be inspected and maintained to ensure that they will operate correctly.

Fusible plugs shall be in good condition and correctly installed (see Figure 29). Failure to correctly maintain and install a fusible plug can result in catastrophic failure, which could lead to serious injury or death and severe boiler damage.

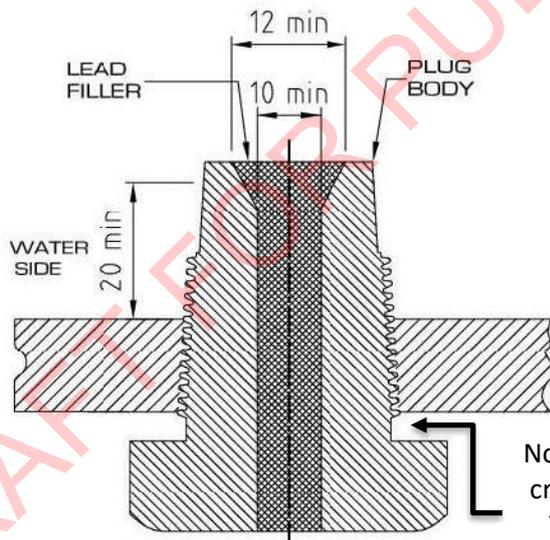


Figure 29 Fusible plug

6.3 Body and fusible filler metal

AS 1732:1997, Clause 3.1 specifies that the fusible plug body material shall be of brass or bronze conforming to AS 1565 or other suitable non-ferrous alloy, for example, Grade LG2 Bronze.

The use of other nonferrous alloys that are specified in original railway documents or in current railway procedures and/or drawings that have proven satisfactory in-service are also acceptable.

The fusible material requirements are specified in AS 1732:1997, Clause 3.2. The standard sets out the maximum melting temperatures for the fusible filler metal.

For locomotive applications, filler material should be 99% or greater pure lead. A certificate verifying the lead purity should be obtained from the supplier to ensure the lead meets the recommendations of this document.

Material used for tinning may comprise of both tin and lead.

This reduces the risk of the wrong filler metal finding its way into a higher-pressure boiler and is a practice that was followed by a number of rail systems in Australia.

Fusible plugs shall not be stamped with identification marks once installed as this may damage the fitting of the plug.

6.4 Operational inspection

Inspection at regular intervals is essential to ensure that fusible plugs are in satisfactory condition and are not degraded or otherwise affected by the action of the fire or waterside deposits (e.g., leaking, fire worn or scale accumulations) to such a state to make them unable to work properly.

See Appendix E for an example of a fusible plug inspection checklist.

Examples of damaged fusible plug are provided in figures 32 to 37.

AS 3788:2024, Clause 9.6 refers to inspection intervals.

A fire-side inspection of fusible plugs shall be carried out during the operational inspection of the boiler before a fire is lit in the boiler. This inspection shall be specified as part of the operational standards of the RSO and the necessary equipment should be provided to carry out the task, for example, a torch and mirror. Boilers with damaged, leaking or suspect fusible plugs shall not be lit up until the situation is corrected.

A fire-side inspection should be completed at any time that a banked boiler under steam is being prepared for full service. This inspection shall be specified as part of the operational standards of the RSO.

Whilst it is recognised that it is difficult to conduct a detailed examination of the condition of the plugs with a fire in the firebox, a reasonable attempt should be made to determine if any obvious faults are evident, for example, a leaking fusible plug.

This inspection shall not be done in a way that endangers the personnel involved.

Inspection of fusible plugs shall also be carried out:

- (a) as set out in the operational standard of the RSO;
- (b) at specified intervals; or
- (c) if sufficient distance or hours of operation are run.

For example, when an RSO operates high locomotive distances or operating hours, the inspection of fusible plugs shall be included in the distance/hours of operation-based maintenance activities. The original locomotive operator's inspection schedules should be referred to in setting these intervals. The

details of the inspections at these intervals shall be as per Clause 6.5. For example, the Victorian Railways' broad-gauge locomotives had AB exam every 3,000 miles (approx. 5,000 km).

In all cases, the replacement fusible plug shall be either new, or reconditioned, fully inspected and deemed fit for purpose as per the RSOs work instructions.

If a leaking fusible plug is found at any time, a boiler is in steam the boiler shall be shut down.

Any fusible plug that has melted due to a low-water condition shall be immediately reported to the responsible person and the boiler removed from service until the independent boiler inspector has conducted an examination, determined the boilers fitness for service and any repairs required.

A boiler that has suffered a failed fusible plug shall not be operated until the independent boiler inspector has deemed it fit for service.

6.5 Annual and periodic inspection requirements

The annual and periodic inspections shall be documented in controlled work instructions(s) that detail all the relevant requirements for fusible plug inspections.

All fusible plugs shall be removed and fully inspected, and replaced or renewed if necessary:

- (a) any time the boiler is washed out;
- (b) at lesser intervals as set out by the RSO's periodic maintenance procedures;
- (c) at any time that its condition may be suspect due to operational or other irregularities;
- (d) an annual inspection is carried out; or
- (e) the boiler is removed from service for boiler repairs in between periodic or annual inspections.

Fusible plugs may remain removed where the boiler is not expected to re-enter service in the immediate future.

The fusible plugs and the mountings in the crown sheet (including the boss/socket, where fitted) shall be thoroughly inspected and the findings recorded in the boiler history file.

The exact details of the inspection can vary for the particular design of fusible plug but the common components include the following:

- (f) The amount of fusible filler metal left in the plug.
- (g) The condition of the plating of the lead on the water side (if applied).
- (h) Any signs of leakage through the plug, or corrosion of the filler metal.
- (i) The condition of the body or filler metal on the water side.
- (j) Fire wear on the plug body.
- (k) Distortion of the body.
- (l) Cracking of the body.
- (m) Worn, cracked, distorted or damaged threads.
- (n) Shape and diameter of the hole in the fusible plug is as shown on the component drawing, for example, retaining ridges or threads (This inspection requires the fusible metal to be removed).
- (o) Condition of the mounting point in the crown sheet including:
 - (i) that the required number of threads remain for re-fitting a fusible plug (AS1732 requires a minimum of four (4) full threads engagement);
 - (ii) worn, cracked, distorted or damaged threads;

- (iii) thickness of the crown sheet, with particular attention to metal loss on the water side; and/or
- (iv) signs of overheating of the crown sheet, such as deformation of the plates, bulging, sagging, blisters etc.

Any fusible plug that appears to have been damaged due to a low water level condition in the boiler shall be immediately reported to the responsible person and the independent boiler. The responsible person shall consider the implications of this information and, as necessary, conduct any additional inspections or NDE examinations of the boiler to identify any potential damage. The inspector shall be consulted if any damage is suspected.

It is the responsibility of the RSO to specify the conditions that render the fusible plug unserviceable, for example, limits of thread wear, distortion of the body, loss of filler material, etc.

These shall be documented in controlled work instructions, which will refer to any relevant drawings and other work instructions. Furthermore, the work instructions shall nominate the conditions that render the fusible plug unable to be reconditioned.

Any of the following conditions shall render the fusible plug quarantined and requiring repair:

- (p) Less than four (4) full threads of engagement.
- (q) Any loss of fusible filler metal from the plug above the crown sheet (fire side).
- (r) Damaged plating of the lead on the water side (if applied).
- (s) Any sign of leakage through the plug, or corrosion of the filler metal.

Any of the following conditions shall render the fusible plug unrepairable (to be disposed of):

- (t) Any deterioration of the condition of the body.
- (u) A fire damaged plug body or head.
- (v) Any distortion of the body.
- (w) Any cracking of the body.
- (x) Any worn, cracked, distorted or damaged threads.
- (y) If the hole in the fusible plug is not the correct shape and diameter as shown on the component drawing.
- (z) Incorrect fusible plug type has been in-service.

Unserviceable fusible plugs, if repairable, shall be placed in a clearly labelled quarantine location for later attention or, if irreparable, shall be immediately scrapped or otherwise made unable to be reconditioned.

If the crown sheet mounting point is in unacceptable condition, the boiler is not to be returned to service until the necessary repairs are made, for example, tapping out to a larger permitted size, welding in a boss and drilling and tapping a new hole of minimum size or replacing the sleeve.

6.6 Reconditioning of used plug body

Reconditioning shall be documented in controlled work instructions(s) that detail how to recondition fusible plugs to a fully serviceable condition.

Reconditioning of used fusible plugs shall only take place when the specified dimensions and condition of the body can be achieved.

Under no circumstances shall any attempt be made to recondition or refill plugs that are not able to meet the specified standards.

The reconditioning of plug bodies shall only extend to basic machining or hand tool work to address minor defects that can be remedied to restore the plug to the correct dimensions shown on the engineering drawings or in relevant work instructions. Rotary wire brushing of the threads shall be prohibited, as this leads to rapid deterioration of thread form.

Under no circumstances shall any plug body be built up to recover lost material.

6.7 New fusible plug bodies

New fusible plug bodies shall be made in accordance with relevant, approved, engineering drawing(s) and controlled work instructions that shall conform to AS 1732:1997

The majority of fusible plugs in service have a similar tapered thread form to washout plugs, and seal into the hole on that tapered thread. Some commercially available plugs have a thread tapered to pipe thread taper, and these are discouraged unless sound processes are in place to ensure they are never used in the steeper taper normally used in service.

New plug bodies shall be manufactured from the material(s) specified and no substitutes are allowed.

Fusible plugs may be manufactured in a series of progressively increasing sizes to facilitate the replacement of worn or damaged plugs or crown sheet mountings with a larger size up to a predetermined maximum. Fusible plugs, when necessary, shall be identified by clear and unambiguous means, such as stamping, to identify the type (e.g., locomotive type) and size in the size range. Sleeves held in store shall be similarly identified. The hole for the filler metal shall remain unchanged in shape and dimension throughout the range of plug sizes.

The original drawings and work instructions should be used but, when current experience and practices dictate, modified to ensure the most appropriate engineering practice is used.

New plug bodies shall be filled as described in Clause 6.8

6.8 Filling of fusible plugs

The filling of fusible plugs shall be documented in controlled work instructions(s) that detail how to produce a plug that is in a ready to install condition. All filler material shall be the specified material, supported by appropriate certification.

Work instructions for filling the plug should contain the following:

- (a) Correct materials, tools and jigs required.
- (b) Safe work instructions and practices.
- (c) Additional equipment and services required.

Preparation of the plug shall include the following:

- (d) Melting out the old fill.
- (e) Cleaning the body.
- (f) Inspecting the internals of the plug (e.g., cracks, incorrect dimensions, distortion).
- (g) Preheating.
- (h) Tinning.
- (i) Melting the new filler metal.
- (j) Work sequence to fill the plug.
- (k) Descriptions of conditions that show a satisfactory or unsatisfactory filling of the plug.

- (l) Compression of the partly set filler to ensure complete filling of the body has been achieved.
- (m) Application of water side anti-corrosive plating (if applied).
- (n) Any post-filling stamping or other identification requirements.

Fusible plugs that are filled and ready for use shall not have any lubricant or any other substance applied to the threads until they are to be fitted in a boiler. This is to prevent contaminants, such as grit, being caught on the threads which can lead to binding of the thread in the crown sheet hole. In this case the thread is not properly tightened and is likely to become loose in-service, leading to leakage and possibly a blow-out. Cleanliness is best achieved by a second person handling the plug for the lubrication process and then handing it direct to the installer in such a way that the installer does not touch the threaded section.

6.9 Installation

The installation of fusible plugs shall be documented in controlled work instructions that detail how to install the plug so that will function properly and will not blow out in-service.

Fusible plug mounting holes shall have a minimum of four (4), consecutive, complete threads (as specified in AS 1732:1997).

Documentation and measuring aids shall be available to the installer, so they can ensure that the plug is inserted within the specified tolerances so that there are adequate threads of engagement without the plug binding on the thread ends.

Mounting holes in the crown sheet that have insufficient, worn, rolled, nicked, cracked or damaged threads or any other visible damage shall not be used until the necessary repairs have been made, for example, tapping out to a larger permitted size, welding in a boss or replacing the bush. Fusible plugs shall never be loosely or temporarily fitted and tightened later. The fitting and tightening of fusible plugs shall be completed as a single operation.

Work instructions for installing the plug should contain the following:

- (a) Reference drawings.
- (b) Tools required.
- (c) Any specific safety instructions.
- (d) The sparing application of a suitable, graphite-based thread sealant, and any precautions to prevent contamination of the threads.
- (e) Fitting and tightening procedure to ensure no cross threading, under- or overtightening occurs.
- (f) Any requirement to apply fire cement to protect the head of the plug.
- (g) The installed position required to achieve sealing on the tapered thread, not on the head, of the plug.

Fusible plug heads shall never touch the crown sheet; there shall always be a gap between the head and the crown sheet as shown in Figure 26, or as designated in the original design.

Some form of plugs (e.g., as used by the Western Australian Government Railways) do not have a head but are inserted/removed by an internal socket type drive square. In this case, correct insertion depth shall be within the original design specification.

The body of the fusible plug shall protrude into the water space a minimum of 20 mm from the water side of the crown sheet plate, as per Figure 29.

6.10 Drawing, work instructions and record keeping

All originals of relevant work instructions (or procedures) shall be controlled documents. Copies made for workshop use shall be made from a controlled document and be marked uncontrolled.

All fusible plugs and crown sheet mounting points shall be fully described in detailed, controlled engineering drawings.

All fusible plug inspections shall be recorded in a specific written record. Details of the locomotive and the person conducting the inspection and date shall be included.

Fitting of fusible plugs shall be recorded in a specified written record. Details of the locomotive, person conducting the installation, person inspecting the installation and date shall be included.

The record forms of inspections and fitting shall be controlled documents. Copies made for workshop use shall be made from a controlled document and be marked uncontrolled.

6.11 Responsibilities

The RSO shall assign responsibilities and authority for the various tasks described above, for example, inspection, repair, filling, installation, checking of work and record keeping.

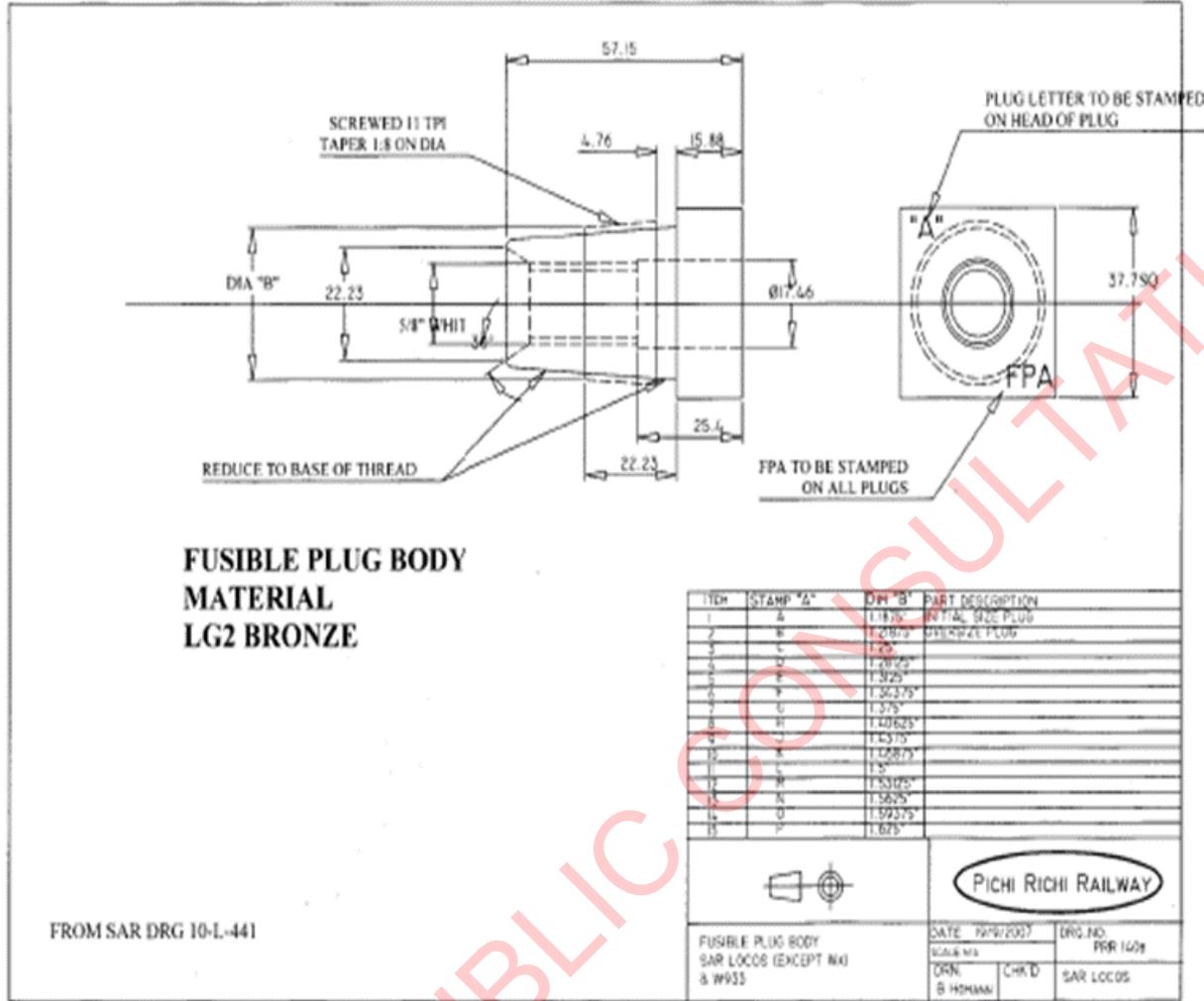


Figure 30 Example of current drawing of a fusible plug

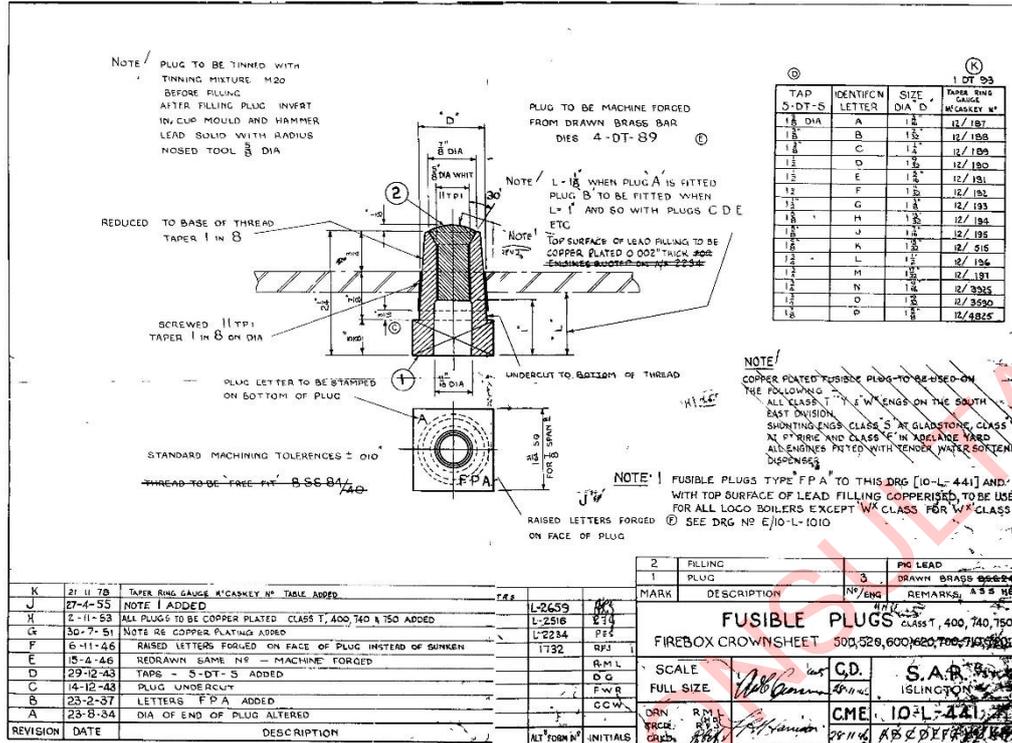


Figure 31 Example of an original drawing of plug with fitting dimensions

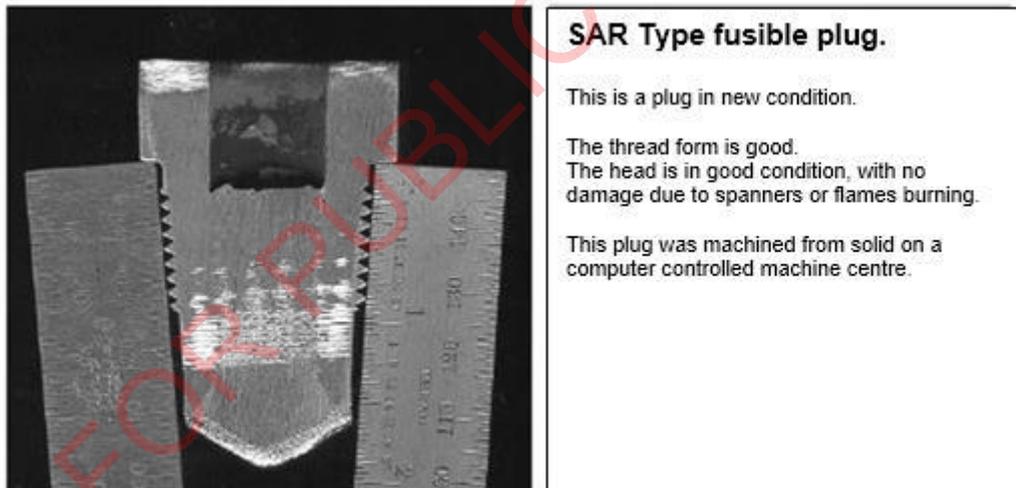


Figure 32 SAR type fusible plug in new condition

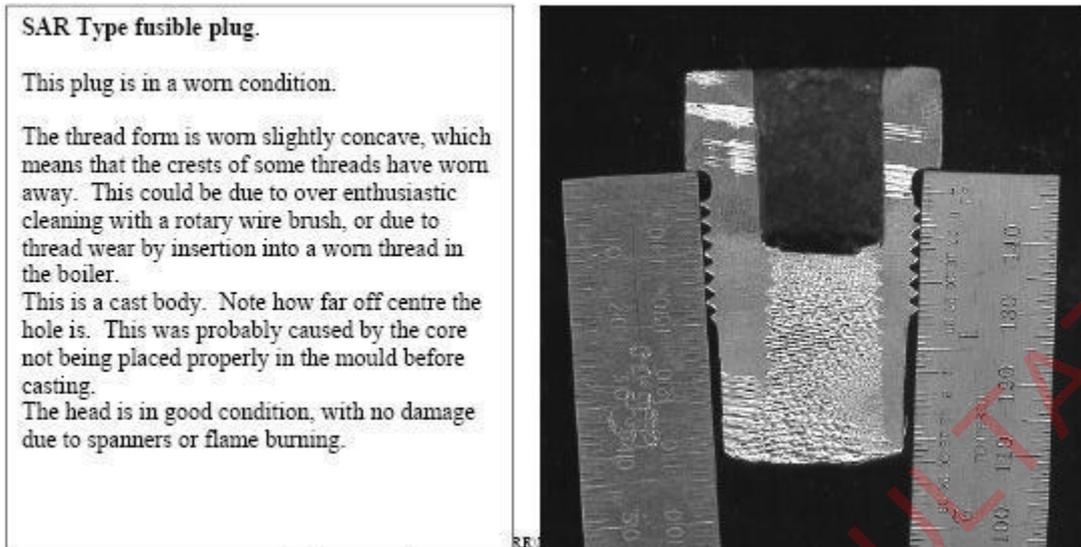


Figure 33 SAR type fusible plug in worn condition

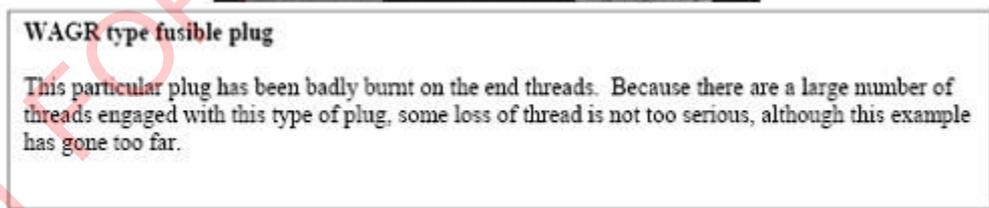
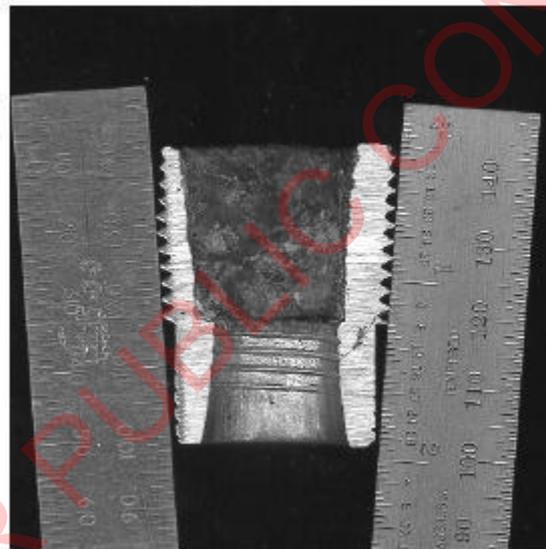


Figure 34 WAGR type fusible plug badly burnt end threads

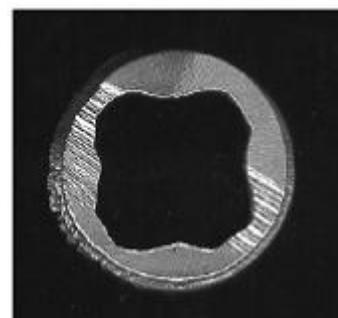
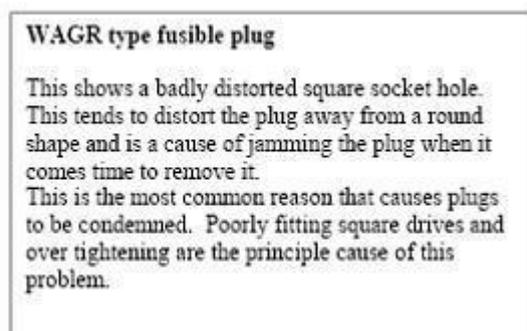
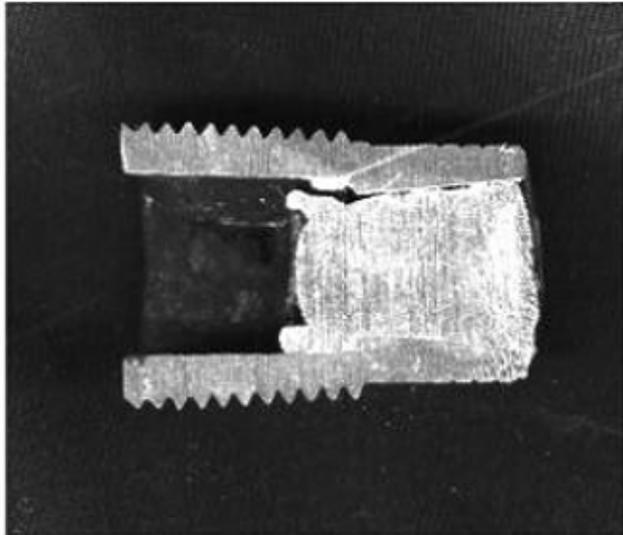


Figure 35 WAGR type fusible plug badly distorted square socket hole



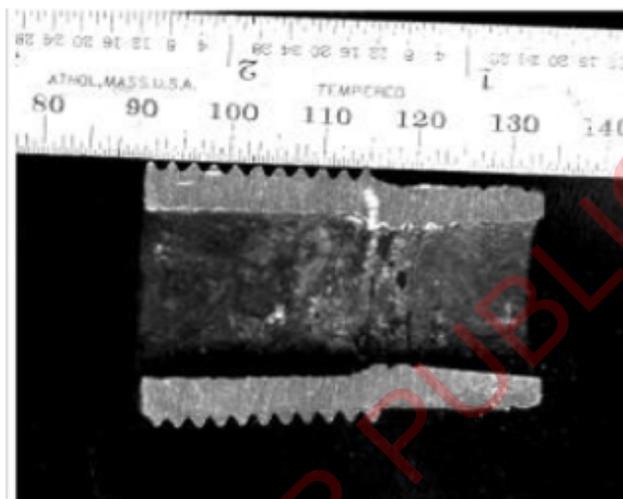
WAGRb type fusible plug.

This is an example of a plug that has partly melted. This is probably due to the crew going over summit with insufficient water level in the gauge glass. This could occur by not wishing to be seen to have stop (the alternative consequence that were so close would have been even more ego damage), or by misreading a high level due to working the engine hard with water prone to priming.

You can see where the top of the lead dome has collapsed. Also note the doming of the area where we punch in to the lead during manufacture to consolidate any shrinkage defects. It is very apparent that the lead has pulled away from the wall of the plug at the top and that there was precious little preventing a serious leak.

This example should be of great interest to all engine crew and it would be well for this picture to imprint on the brain when considering whether to go over summit or stop for a little while.

Figure 36 WAGR type fusible plug partly melted



WAGR type plug

This is an example (rare) where the inside threads are crest worn where compared with the end threads.

You can note that even though this has occurred, it is a general wear rather than localised.

The danger of reusing the plug such as this, is the possibility of the tightening force being concentrated on one or the other end (depending on how far in the plug goes).

This then increases the risk of the plug coming loose, or leaking, if the localised load is sufficient to deform the one thread.

Figure 37 WAGR type fusible plug inside threads crest worn

Section 7 External Corrosion

7.1 General

This section provides guidance on the inspection of exterior surfaces of locomotive boilers only. Other factors may require inspection or maintenance or repair activities at different intervals.

Damaging external corrosion of locomotive boilers will occur when wet materials are allowed to sit against the steel structure of the boiler for extended periods.

In these circumstances, if the corrosion is not detected and/or addressed, substantial areas of the boiler are likely to be affected, which will lead to leakage that could result in excessive plate wastage over a short period of time. This plate wastage could then lead to a catastrophic failure.

The existence of or the extent of corrosion under wet materials is not able to be detected effectively without the removal of the offending material and the preparation of the surface for inspection and testing.

On a steam locomotive boiler there are numerous areas susceptible to external corrosion and the likelihood of its occurrence is high due to the design, fuels used and operating cycle.

7.2 External corrosion locations on a locomotive boiler

External corrosion commonly occurs in the following locations when water is present:

- (a) Under external cladding of the boiler shell.
- (b) Under insulation.
- (c) Under deposits.
- (d) Under ash resting on tube plates.
- (e) Under ash resting between boiler plates and fire grate components.
- (f) At the interface between the brick arch and the boiler plates.
- (g) Between the locomotive frame and the outer firebox on narrow firebox locos.
- (h) At and under the cab floor.
- (i) At any other location where dirt, ash and brake block dust may accumulate.

Corrosion under lagging occurs when the lagging is wet, and the steel is in the temperature range -5°C to 150°C. There are many factors that increase or decrease the likelihood of corrosion and these are discussed below.

Corrosion under the deposits noted above can be aggressive due to the composition of the material and the corrosive properties when wet.

The locations where water can enter the lagging or saturate deposits and continuous sources of moisture are likely corrosion sites. Note that water can enter at a particular location but the corrosion site(s) could be at a quite different location due to the migration of the water and the influence of shapes and orientations of the surfaces.

7.3 Damage from external corrosion

This corrosion will ultimately result in a hole. The hole may be in an isolated location but if the area of wet material is widespread, there could also be a loss of metal thickness over a larger area and other pitting sites.

Extensive metal loss over a large area could result in a loss of strength to the extent that a major structural failure may occur.

The corrosion is most aggressive at ledges, corners, small fittings and attachments, for example, flexible stay cups and studs and on surfaces that are uncoated.

7.4 Conditions affecting the likelihood of external corrosion

There are many factors that increase the likelihood and severity of external corrosion of a locomotive boiler, including rainwater exposure and water ingress. Other factors include:

- (a) leaking valves, fittings, stays, stay cups and joints that wet the lagging or deposits;
- (b) outside storage;
- (c) openings and gaps in the cladding;
- (d) cyclic operation (from in steam to not in steam to in steam, etc.);
- (e) washing the external surfaces of the boiler;
- (f) buildup of ashes on the smoke box tube plate;
- (g) buildup of coal dust at or below the cab floor against the boiler;
- (h) washing down in cabs;
- (i) washing out ashes in the ash pan, smokebox or firebox;
- (j) uncovered funnels when stored;
- (k) narrow fireboxes in between frames;
- (l) buildup of material between the frame and outer firebox plates;
- (m) unpainted surfaces and/or degraded paint;
- (n) cladding and lagging never removed or not removed periodically to facilitate inspection;
- (o) cladding design allowing water ingress or not allowing egress;
- (p) cladding not maintained to prevent water ingress or egress;
- (q) boiler never removed from between the frames; and
- (r) climatic conditions of storage location.

Small diameter piping standpipes and other components, due to required thickness for design pressure, can corrode and hole through sooner than a larger diameter component which is thicker.

7.5 Inspection

Inspection of areas subject to external corrosion shall be included in the inspection plan for the locomotive.

Any factors that increase the likelihood of corrosion shall be noted.

Boilers shall be inspected as far as is practicable for external corrosion at the times noted below:

- (a) At specified periodic inspections (see Clause 7.7).
- (b) At each annual inspection of the boiler (refer to AS 3788:2024, Clause 9.6).
- (c) At specified intervals when lagging is to be fully or partially removed (see chart below).
- (d) At specified intervals when the boiler is to be removed from between the frames to inspect the outer firebox plates and clean the space between.
- (e) At any time the boiler is washed out or removed from service for boiler repairs in between specified periodic or annual inspections.

7.6 Recommended practices

The following practices are recommended to minimize the occurrence and extent of external corrosion:

- (a) Operational practices that require reporting of leaks or the signs of leaks.
- (b) Prompt attention to leaks.
- (c) Undercover storage.
- (d) Covering of funnel when out of service, when stored outside. In a dry climate, it can be advantageous for in-doors storage to have the smokebox and firebox doors open to allow air circulation after the boiler has cooled. In very cool, damp, conditions, warming of the boiler metal may assist in preventing condensation.
- (e) Maintaining a quality protective coating (paint) on the boiler.
- (f) Cladding design and maintenance that minimises the openings that allow water ingress and allows water egress.
- (g) Using no lagging at all (air-gap insulation between boiler and cladding).

NOTE:

Removal of cladding can result in high temperatures on the external cladding of the boiler when the boiler is in steam.

- (h) A lagging design that, where possible, has the lagging separated from the surface of the boiler, for example, expanded mesh between the boiler and the lagging or using metal-backed lagging. Beware of the possibility of galvanic corrosion in these designs.
- (i) An inspection plan requirement for periodic lagging removal. The extent and interval of the lagging removal will vary depending on the locomotive and cladding design as well as operational, storage, inspection and leakage history.
- (j) Inspection of the boiler plates at any time lagging is removed. Attention to active corrosion is mandatory on these occasions.
- (k) An inspection plan requirement to inspect the boiler plates between frames.

Annual or periodic inspection of components such as:

- (l) cladding for damage or displacement;
- (m) cladding for corrosion (particularly below the centreline of the boiler);
- (n) cladding for staining from water deposits;
- (o) signs of valve and fitting leaks and external water trails that disappear under the cladding;
- (p) removal of built-up material; and
- (q) areas susceptible to corrosion under deposits.

7.7 Intervals and extent of inspections under lagging or between the frames for boiler corrosion

Issue	Specific Conditions	Recommended Action/Interval
Corrosion Under Insulation	Not in annual inspection program regardless of whether or not the lagging has been removed within the previous 10 years.	<p>Include an item in the annual inspection - immediately.</p> <p>Conduct an inspection to determine if there are indicators of water ingress and/or possible active corrosion under insulation - immediately.</p> <p>Remove the lagging at site(s) indicating water ingress and/or possible active corrosion under insulation - immediately.</p> <p>Care is to be taken to ascertain the type of material used for lagging, as it may be hazardous (e.g., asbestos). All lagging should be examined as a combination of types could have been installed.</p> <p>Inspect the boiler and conduct any necessary repairs before the locomotive returned to service.</p>
	Included in annual inspection and this finds indicators of water ingress and/or active corrosion.	<p>Remove the lagging at site(s) indicative of water ingress and/or possible active corrosion under insulation - remove and investigate immediately.</p> <p>Care is to be taken to ascertain the type of material used for lagging, as it may be hazardous (e.g., asbestos). All lagging should be examined as a combination of types could have been installed.</p> <p>Repair any leaks - immediately.</p>
	Operating locomotives, regardless of condition of protective coating, and regardless of storage conditions. No lagging has been removed as result of observations from annual inspections.	<p>Remove the lagging in identified high risk areas - every 10 years.</p> <p>Interval may be restarted for areas where lagging has been removed as a result of annual inspections.</p>

Issue	Specific Conditions	Recommended Action/Interval
	<p>Locomotive has not been in-service since withdrawn from original owner's service, i.e. an un-restored locomotive.</p> <p>Previously operational but out of service and stored for five (5) years or more and the locomotive is to be returned to operation.</p>	<p>Remove all cladding and lagging, inspect and act on observations as part of return to service.</p> <p>Care is to be taken to ascertain the type of material used for lagging, as it may be hazardous (e.g., asbestos). All lagging should be examined as a combination of types could have been installed.</p> <p>Remove all cladding and lagging in identified high risk areas, inspect and act on observations as part of return to service.</p>
<p>Corrosion between boiler and frames (narrow fireboxes)</p>	<p>Not in annual inspection program, regardless of whether or not the boiler has been removed from between frames in previous 20 years.</p>	<p>Include an item in the annual inspection - immediately.</p>
	<p>Included in annual inspection and this finds a build-up of deposits, indicative of active corrosion.</p>	<p>Attempt to remove deposits and determine the extent of the corrosion or leakage.</p> <p>If unable to definitively establish that the plates remain above condemning thickness, remove the boiler from between the frames to conduct a detailed inspection, including necessary NDE.</p>
	<p>Locomotive has not been in-service since withdrawn from original owners' service, i.e. an un-restored locomotive.</p> <p>Previously operational but out of service and stored for five (5) years or more and the locomotive is to be returned to operation.</p>	<p>Conduct detailed inspection and act on observations as part of return to service.</p> <p>Care is to be taken to ascertain the type of material used for lagging, as it may be hazardous (e.g., asbestos). All lagging should be examined as a combination of types could have been installed.</p> <p>Attempt to remove the deposits and determine the extent of the corrosion.</p> <p>If unable to definitively establish that the plates remain above condemning thickness, remove the boiler from between the frames to conduct a detailed inspection, including necessary NDE.</p>

7.8 Assessment and repair of corroded areas

Boilers, or part thereof, stripped of lagging for inspection or any other location being inspected for external corrosion shall be fully cleaned of any material or corrosion products before inspection.

All exposed areas shall be assessed to determine the nature and extent of any corrosion.

In all cases, a written and photographic record shall be made of the location, extent, nature and amount of any metal loss. The results of the NDE conducted shall be included in the record.

Corrosion of the outside surface of the boiler shall be assessed to determine if the boiler is fit for service. Applicable techniques to make such an assessment are provided in AS 3788

Fitness for service assessments shall be conducted by a competent person and the results shall be provided in writing and filed in the boiler history file.

The results of the fitness for service assessment shall be reviewed by the RSO and the independent boiler inspector, who will decide together with any other required engineering advisors what repairs, if any, will be conducted. All repairs shall comply with the requirements of AS 3788:2024

A detailed written and photographic record of all repairs shall be made, including but not limited to repair procedures (including application of coatings), welding management records, NDE tests, material certificates, hydrostatic test records and the inspectors report on the outcome of the repairs. This record shall be filed in the boiler history file.

Section 8 Expansion Brackets

8.1 General

This section provides guidance on the inspection and maintenance of expansion brackets on steam locomotive boilers.

Locomotive boilers are fixed to the locomotive frame at the smoke box and supported by the frame at various points along its length.

The locomotive boiler operates at an elevated temperature and therefore the effects of thermal expansion and contraction need to be accommodated by the supports.

To appreciate the amount of expansion to be accommodated the following example is provided.

A boiler operating at 1240 kPa (180 psi) has a saturated steam temperature of 193°C (380°F) which can be assumed to be the temperature of the boiler plates. So, for a boiler 10 m (30 ft) long operating at 1240 kPa, and assuming an ambient temperature of 20°C, there is about 20 mm (0.78-inch) overall expansion from ambient to operating temperature.

The operation of a steam locomotive invariably results in wide swings of boiler pressure and hence the repeated expansion and contraction associated with the change of temperature has to be accommodated.

These expansion brackets are required to move freely to prevent the stresses being transferred to the boiler structure. Seized or tight expansion brackets will cause damage to the boiler over an extended time depending on how many expansion and contraction cycles the boiler goes through.

8.2 Expansion bracket types and locations on a locomotive boiler

There are two common types of expansion brackets used on locomotive boilers:

- (a) sliding brackets, which also maintain the lateral position of the boiler in the frame (see Figure 38); and
- (b) diaphragm plates.



Figure 38 Sliding expansion brackets on a VR J Class

These expansion brackets are typically located as follows:

- (c) Sliding brackets are substantial assemblies fitted to the outer firebox side plates of between-the-frame fireboxes, or to the foundation ring above the frame on wide firebox boilers. All locomotives have these sliding brackets at the firebox.
- (d) Diaphragm plates are flat plates fitted between the frame and the underside of the boiler barrel laterally across the centreline of the boiler. They may also be fitted between the frame and the rear section of the foundation ring.

8.3 Damage from seized expansion brackets

A regular check shall be made of any laminated plate diaphragms to monitor for corrosion between the plates. Maintenance of this item may include disassembly, cleaning of corrosion products and painting. Plates may be replaced to restore the flexibility at this location if the condition of the plates warrants this. The mounting bolts shall be regularly inspected to ensure their security.

The sliding type expansion brackets can become seized or tight and will, in that state, transmit substantial stresses and deflections into the boiler structure around the brackets.

For those brackets above the frame firebox the deflections and stresses are created in the foundation ring, throat plate and inner firebox front plate.

In narrow firebox boilers the deflections and stresses will be created in the outer firebox plates around the bracket.

In summary, seized expansion brackets will induce high stresses in the vicinity of the bracket that are not accounted for in the boiler design and as they are cyclic, fatigue-type failures will eventuate over time if the problem is left unresolved.

8.4 Indicators of tight or seized expansion brackets

A tight sliding expansion bracket will typically advertise its condition by a series of loud noises (i.e. bangs) as it lets go when the expansion is sufficient to overcome the resistance. These noises will be heard during light-up, when the boiler pressure has a substantial change and on cooling down of the boiler. The loud noise will be felt by personnel standing on the footplate. The greater the noise and the greater the time between noises the greater the tightness of the bracket.

The noises emitted by tight expansion joints should be reported to the responsible person.

Totally seized expansion brackets are not likely to give any indication apart from there being no witness of their movement in the bracket (i.e. sliding marks showing the different cold and hot positions).

8.5 Inspection

Inspection of expansion brackets shall be a component of the operational and annual inspection. The inspection should confirm that there is an indication of the free movement of the brackets. If it is not possible to determine this, the competent person should arrange for specific observations to be made when the boiler is next steamed.

Movement of expansion brackets may be identified using position markers (see Clause 3.5.33).

Any indication of tight or seized brackets at the steaming should be inspected as soon as practical. Following the inspection the competent person and independent boiler inspector should determine when repairs, if any, are to be carried out. This may include removing the boiler from service if the risks associated with tight or seized brackets are deemed unacceptable.

The independent boiler inspector should also attempt to determine if the brackets are lubricated. If this is not apparent, the Inspector shall issue instructions that the lack of lubrication is to be corrected.

The independent boiler inspector should also confirm that the fastening of diaphragm plates is tight. When the boiler is open for inspection, the condition of the plates around the sliding brackets should be inspected.

Whenever there is an opportunity to inspect the water side of the boiler plates around the brackets, for example, when an inner firebox plate is removed, the outer plate should be cleaned to bare metal and checked for cracking or grooving. This shall be done for any boiler that has had a history of tight or seized expansion brackets.

8.6 Recommended practices

Sliding expansion brackets should be fitted with effective lubrication arrangements, such as grease lubrication. Lubrication of these points should be included in the lubrication procedure for that locomotive.

Section 9 Thermic siphons

9.1 General

This section shall serve as the guide when inspecting and repairing thermic siphons and shall be adhered to unless it can be proven that another process or material is equal to or better than the practices and materials laid down in this document.

9.2 Inspection

In the event of finding the thermic siphons are suspect seek guidance from the independent boiler inspector before proceeding with any repair or replacement.

9.3 Material Specifications

Thermic siphons shall be manufactured from equivalent materials to those specified in the original drawings or design; Metallurgical opinion shall be sought if in doubt. All material is to be supplied with relevant test certificates attesting to quality and conformance with AS 1228:2016

9.4 Introduction

Typically, thermic siphons are only fitted to larger boilers to facilitate good circulation of water around the firebox area. As the firebox area is subject to very high cyclic stresses, the thermic siphons shall be visually examined at every opportunity, including before each light up, during wash outs and annual inspections.

9.5 Procurement

When placing an order for the purchase of thermic siphon material, it is essential that the order clearly states the required standards to be met, including the specific test category required for the service application. The order shall also mandate that all test certificates for the required material be supplied. Accurate drawings of components shall be supplied. Any post-working heat treatment shall be accurately detailed. In this event, additional compliance documentation shall be supplied.

9.6 Cleaning thermic siphons

Siphons fitted to locomotive boilers shall be cleaned correctly in order to maintain them in a safe and satisfactory condition and to prolong the life of the device (see Figure 39). Special care shall be taken to ensure the cleanliness of thermic siphon water surfaces, particularly in areas where water quality may be poor.

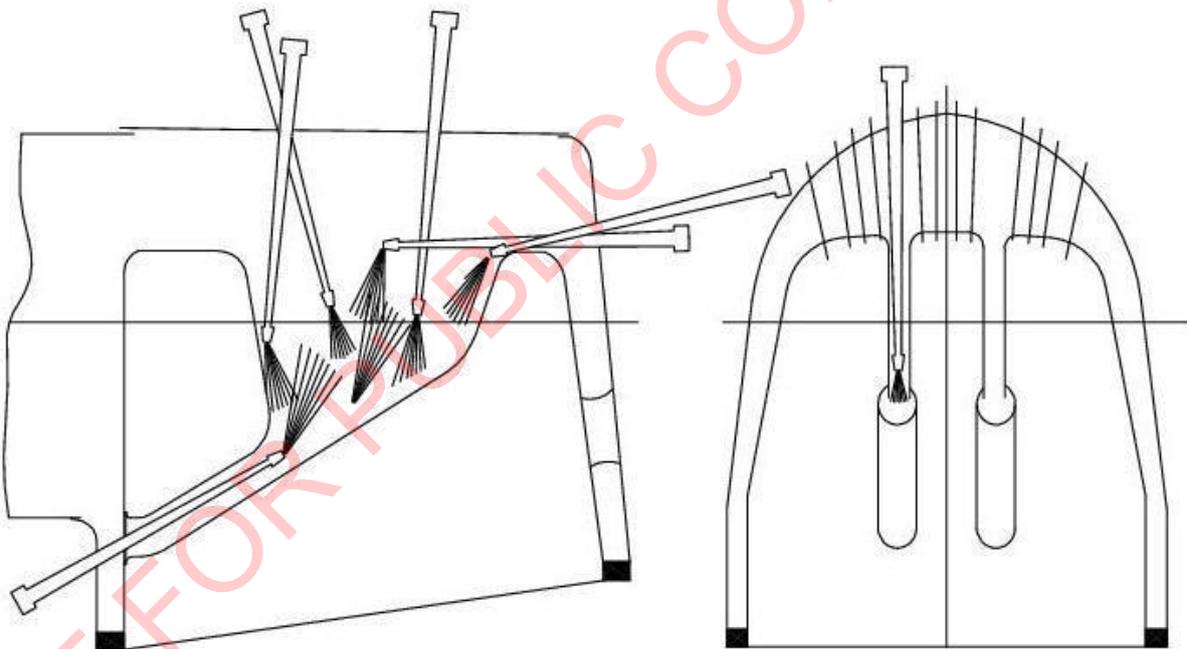


Figure 39 Thermic siphon washing out

9.7 Examination

Thermic siphons shall be examined whenever possible both internally and externally. It is recommended that after all washouts an examination should be completed for cracks, broken stays, mud burns, mud or scale deposits or other defects. Thermic siphons shall be kept clean and free of scale. No boiler fitted with thermic siphons shall be operated with scale deposits that inhibit the heat transfer or circulation of water. If any thermic siphon is suspect, the boiler shall be immediately removed from service, and the inspector shall be consulted to determine its suitability for continuing service. A suitable method of rectification shall be decided in consultation with the competent person and the independent boiler inspector and any design changes shall be approved in accordance with AS 3788:2024. All repairs shall

be documented in the boiler history file. This shall include the weld procedures, NDE and other test procedures and the welder's qualification. No boiler shall be operated with defective thermic siphons. See Clause 3.5.20 for further information on inspections of thermic siphons.

9.8 Weld repairs

All weld repairs shall be carried out in consultation with the competent person and independent boiler inspector and as prescribed in AS 3788:2024. All welds shall be 100% radiographically examined after welding and assessed in accordance with AS 4037:2016. All repairs, testing procedures and test results shall be documented in the boiler history file.

For competencies of welders, see Clause 5.4

9.9 Diaphragm defects in thermic siphons

Fractures usually develop in the lower half of firebox diaphragms, as shown in Figure 40. When such fractures occur, they should be bevelled and welded. This repair will usually render satisfactory service for a considerable length of time, but if further fractures develop the diaphragm should be renewed entirely.

9.10 Examination of diaphragms

The water side of the diaphragms shall be inspected at regular intervals to determine the condition and whether repairs or renewals are necessary. Diaphragms can show slight surface breaking irregularity on the water side after service and mild irregularities in this area may not be recognised as needing renewal.

The competent person and independent boiler inspector shall be consulted about any such irregularities.

All irregularities shall be recorded in the boiler history file.

As inspection of the water side shall be made through the washout hole in the throat plate, the surface of the diaphragm should be cleaned to allow accurate examination of the condition of the diaphragm.

Prominent surface-breaking irregularities could indicate early fracture. In these cases renewal or major repairs should be undertaken in consultation with the competent person and the independent boiler inspector. Repairs shall be carried out in accordance with AS 3788:2024 to avoid the possibility of fracture occurring while the locomotive is in-service. All repairs shall be recorded in the boiler history file.

Wall stays adjacent to the neck of the thermic siphon shall be thoroughly and particularly examined for breakage, necking and other defects, as stays in these areas are particularly prone to stress.

9.11 Neck fractures in thermic siphons

Due to the movement of the firebox plates under working conditions, stress is produced in the siphon neck that eventually produces a fracture as shown in Figure 40. Such fractures are usually progressive, starting with a short crack on top of the neck. These are principally brought on by the cyclic stresses induced by sudden temperature changes during light up and shut down of the boiler and exacerbated by sudden temperature changes due to severe terminal handling (forcing a boiler during light up or rapidly cooling it during shut down).

To repair such a defect, the fracture is ground out and welded (as shown in Figure 40) in accordance with AS 3788 and in consultation with the competent person and the independent boiler inspector. All repairs shall be recorded in the boiler history.

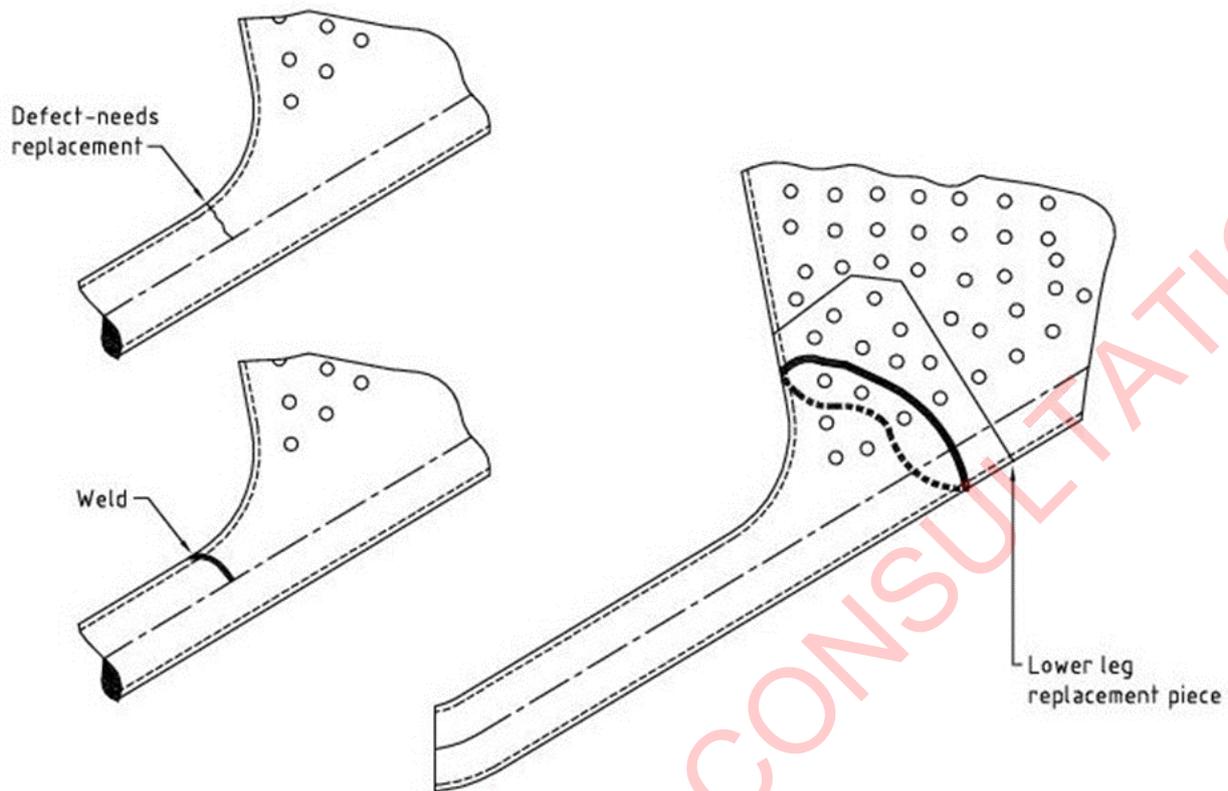


Figure 40 Thermic siphon neck fractures

9.12 Renewing siphons neck

It is not unusual for multiple neck fractures to appear, and these can be repaired as above in consultation with the competent person and the independent boiler. If successive or repeated defects are detected, it will be necessary to renew the siphon neck, as shown in Figure 41.

When renewing siphon necks, the physical condition of the diaphragm shall be considered and, if necessary, it shall be renewed at the same time.

9.13 Siphon barrel defects

New siphon-equipped boilers and existing boilers equipped with new fireboxes or having undergone heavy repairs should be carefully cleaned before being placed into service. Swarf (also called borings) and other foreign matter shall be removed from a boiler as far as possible before the firing up test. The boiler shall be subjected to repeated thorough washing until it is clean. After the firing up test, the interior of the siphons shall be inspected to detect and remove deposits that may have accumulated in the siphon barrel. The principal cause of these deposits is fine steel swarf left in the boiler after tapping and reaming holes, which gets drawn into the siphon from the boiler barrel and throat by the rapid siphon-induced circulation when a boiler is fired.

As the velocity of the water is reduced after passing through the siphon neck by reason of the larger area of siphon body, the circulation is not sufficient to carry the heavy swarf out over the crown sheet. The swarf is, therefore, deposited just back of the siphon neck, sometimes up to a depth of around 25 mm and from 100 mm to 150 mm across. If allowed to remain, the swarf will cause overheating and pocketing (or bulging) of the siphon barrel.

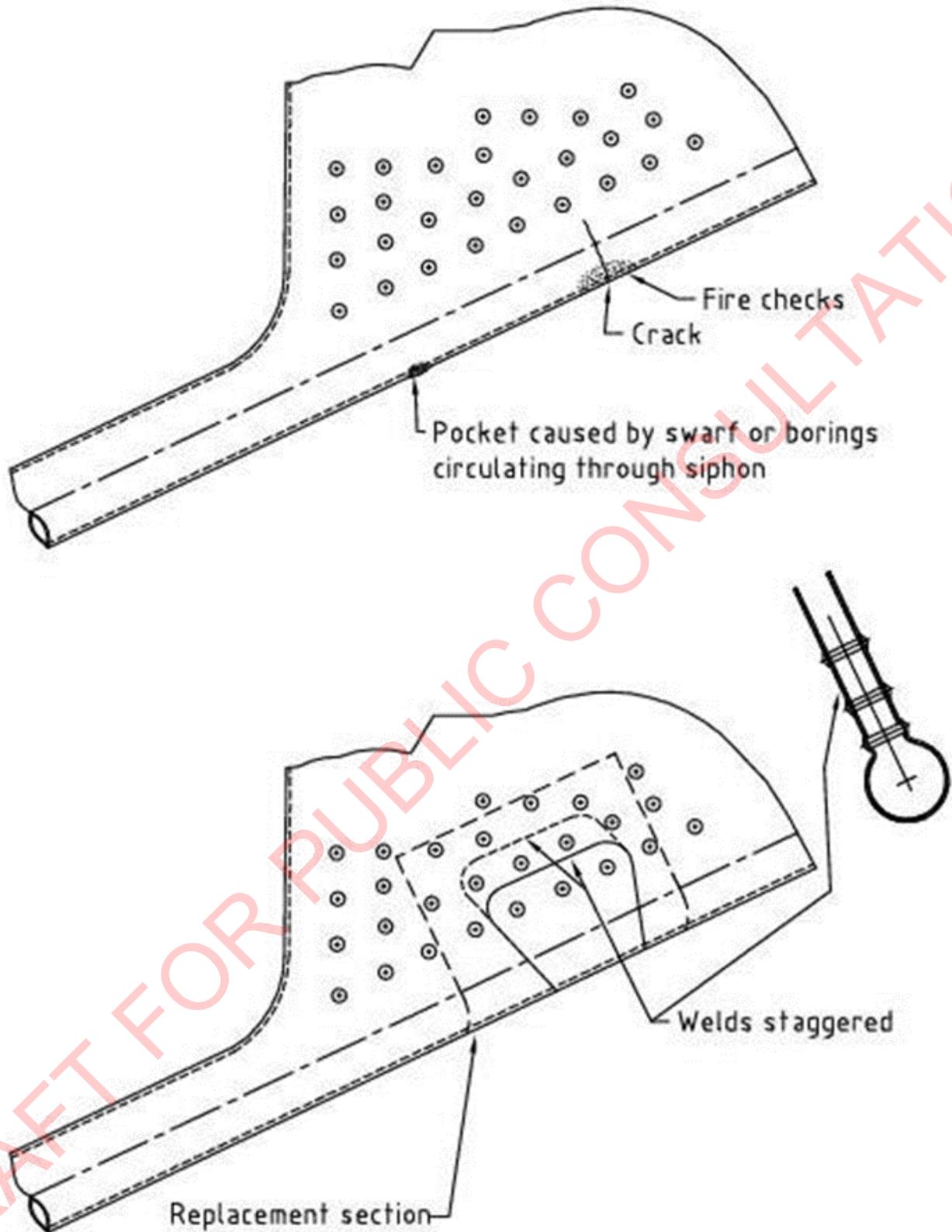


Figure 41 Thermic siphon barrel defects

In some cases, a portion of the siphon barrel deteriorates or is damaged due to the application of high temperatures in the presence of scale or the accumulation of localized pitting. All such deterioration shall be closely examined to determine the extent of the damage. All such deterioration, when found, shall be assessed according to AS 3788:2024 for its fitness for continuing service.

Repairs shall be made if it is deemed necessary for safe operation in the next inspection interval. All repairs shall be made in accordance with AS 3788:2024 and in consultation with the boiler competent person and the independent boiler inspector. All repairs shall be recorded in the boiler history file.

In other cases, small surface cracks (sometimes called fire checks) develop on the fireside and eventually a transverse crack will appear, which may be ground out and welded up as a temporary repair. It is preferable, however, to apply a barrel patch as shown in Figure 39.

This patch should be long enough to replace all the defective area of the barrel. It extends up into the stayed area for reinforcement and the two sides shall be staggered (i.e. not at the same stay level) as shown in Figure 41 and Figure 42. All repairs shall be made in accordance with AS 3788:2024 and in consultation with the boiler competent person and the independent boiler inspector. All repairs shall be recorded in the boiler history file.

Laminations found in the siphon barrel may also be repaired by application of the same type of patch, or by inserting larger siphon sections.

9.14 Siphon body defects

Failures of vertical welds in the front or back of the water leg are repaired by grinding and re-welding, which usually corrects the defects. Transverse fractures in the same area and fractures in the flange can be similarly repaired. However, if further repairs become necessary in these locations, patches should be applied in accordance with AS 3788 and in consultation with the boiler competent person and the independent boiler inspector.

All repairs shall be recorded in the boiler history file. However, serious consideration should be given to replacing thermic siphons (or replacing larger sections of the thermic siphons) in this condition, particularly if siphons continue to crack in the same location. Repairs should not occur over the top of earlier repairs and formal engineering analysis (including NDE and destructive testing) should be conducted to decide on the nature and extent of the repairs required. Metallurgical examinations of thermic siphons exhibiting repeat cracking should be conducted to determine the condition of the material and its suitability to undergo further repairs.

9.15 Part siphons renewals

When the necessity of repairing a cracked neck and a barrel defect occurs at the same time consideration should be given to the application of a half siphon instead of applying neck and barrel patches. The renewal of major portions of the siphons is generally governed by the physical condition of the plates in the lower sections of the siphon as found during inspection and the subsequent fitness-for-service assessment.

Renewing any substantial sections of a siphon is a significant structural repair and shall only be undertaken after a detailed plan is developed in accordance with AS 3788:2024 and in consultation with the competent person and the independent boiler inspector. All repairs shall be recorded in the boiler history file.

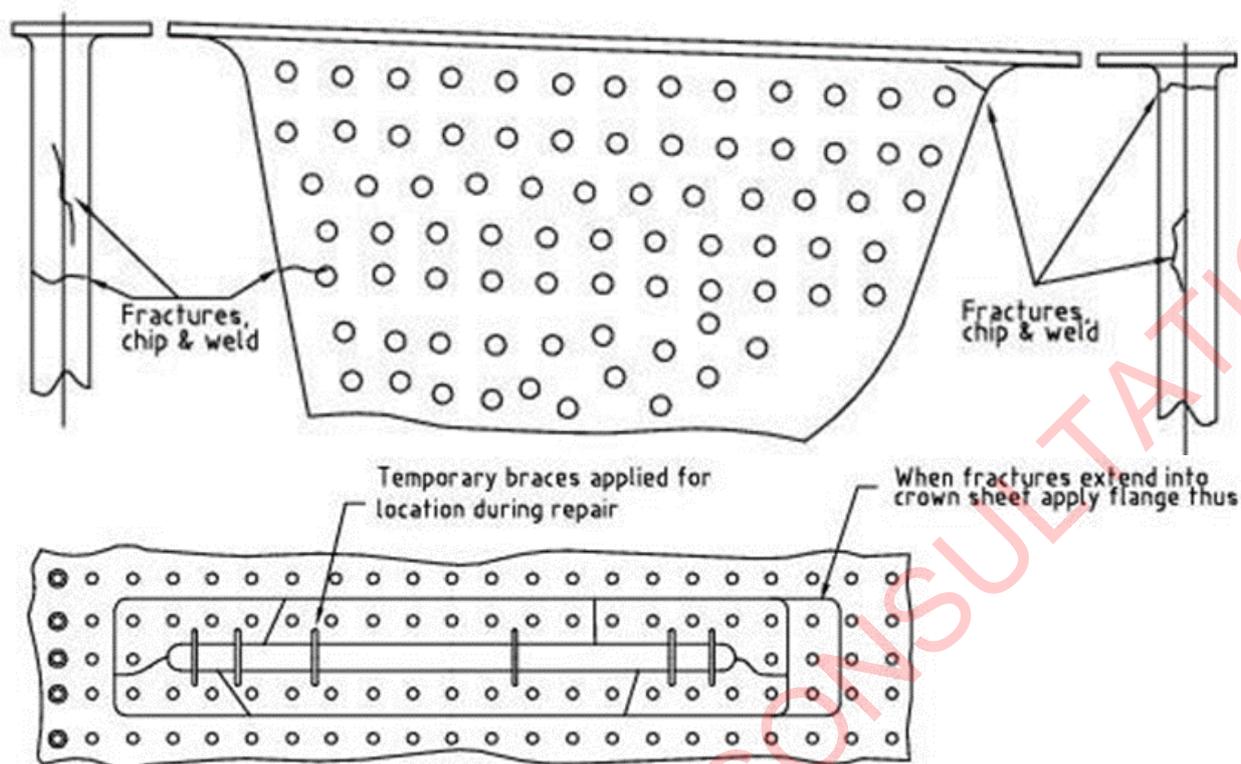


Figure 42 Part siphon renewals

9.16 Siphon renewals

The renewal of an entire siphon depends on the physical condition of the siphon and the firebox sheets generally, and each case should be considered individually.

Renewing an entire siphon is a significant structural repair and shall only be undertaken after a detailed plan is developed in accordance with AS 3788:2024 and in consultation with the boiler competent person, the independent boiler inspector and any other engineering advisor/s necessary to fully specify the requirements of the work. All repairs shall be recorded in the boiler history file.

The procedure for installing siphons is as follows:

- (a) Prepare the openings in the crown sheet and siphon flanges so that they fit correctly and are properly bevelled for welding.
- (b) The siphon is temporarily fitted into the firebox and bolted into position in order to determine how much of the surplus stock at the end of the siphon neck, where it projects into the diaphragm flange, should be cut off. When this has been determined, the siphon is partially removed, and the excess metal cut off, after which the siphon is restored to its proper position in the firebox. The flanges are then securely clamped and bolted to the crown sheet, so that when the siphon is in its correct position the neck is centrally located in the diaphragm flange leaving the same clearance all around. If a new diaphragm is being fitted at this time it should be clamped into position ready for welding, before the siphon has been finally located.
- (c) Proceed to weld the top flange of the siphon to the crown sheet leaving the neck free to move about in the diaphragm flange. Any method of welding siphons to the crown sheet that will properly provide for expansion and prevent creeping as

the welding progresses is satisfactory. If a new diaphragm has been fitted it should next be welded to the tube sheet.

- (d) The final operation is to heat and lay up the diaphragm flange to the siphon neck. Before laying up the diaphragm flange, however, it shall be seen that an equal clearance exists all around between the siphon neck and diaphragm flange to prevent undue strains being locked up in the neck after it has been welded to the diaphragm flange.

The procedure considered acceptable in welding the neck to the diaphragm of a thermic siphon is not suitable for use in any other parts of a boiler.

Figures 43 to 47 provide further guidance.

9.17 Relieving strain in siphon necks

Cracking in the diaphragm (water and/or fire side) may indicate that there are significant stresses between the siphon diaphragm and neck that need to be relieved. A thorough engineering analysis shall be conducted to determine a suitable stress-relieving method.

9.18 Use of thermic syphons in preserved locomotives

In preserved service, the benefits of siphons may not be considered substantial enough to warrant their renewal and it may be considered reasonable to undergo a design change and replace the thermic siphons with arch tubes or eliminate the siphons entirely. Any such changes are to be considered major structural changes and shall only be done with a full design review, in accordance with AS 3788:2024 and AS 1228:2016 or registered design and construction standards and in consultation with the independent boiler inspector and the boiler competent person. All changes and engineering assessments shall be recorded in the boiler history file.

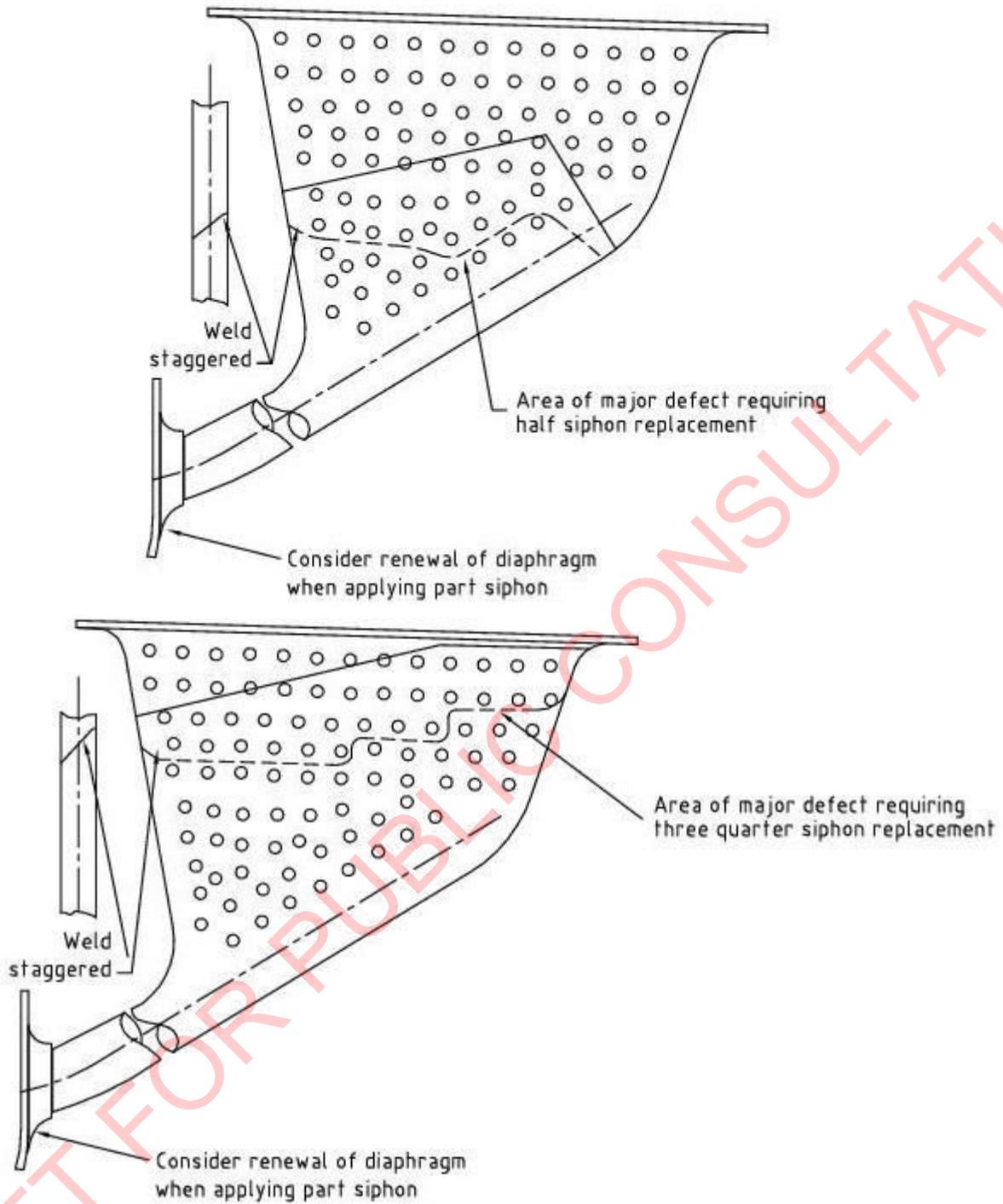


Figure 43 Siphon renewals

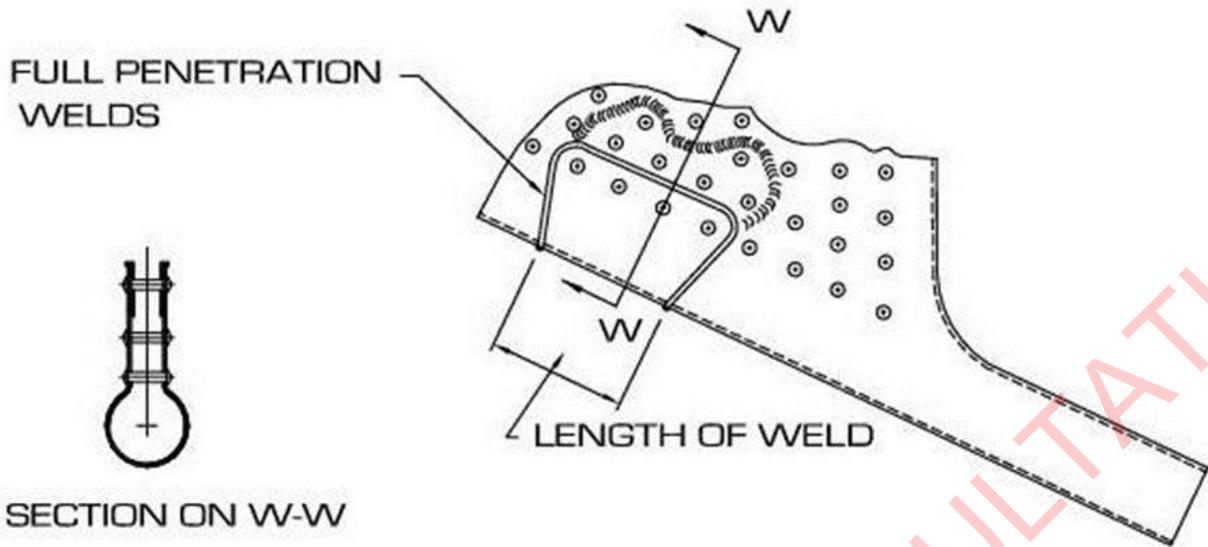


Figure 44 Flush patch on stay bolt siphon body

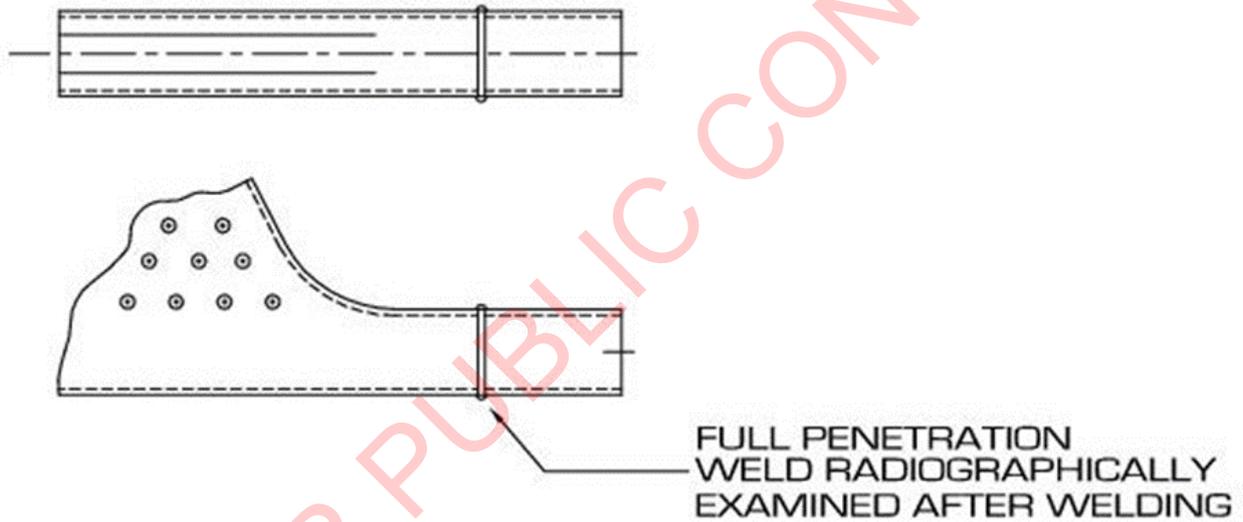
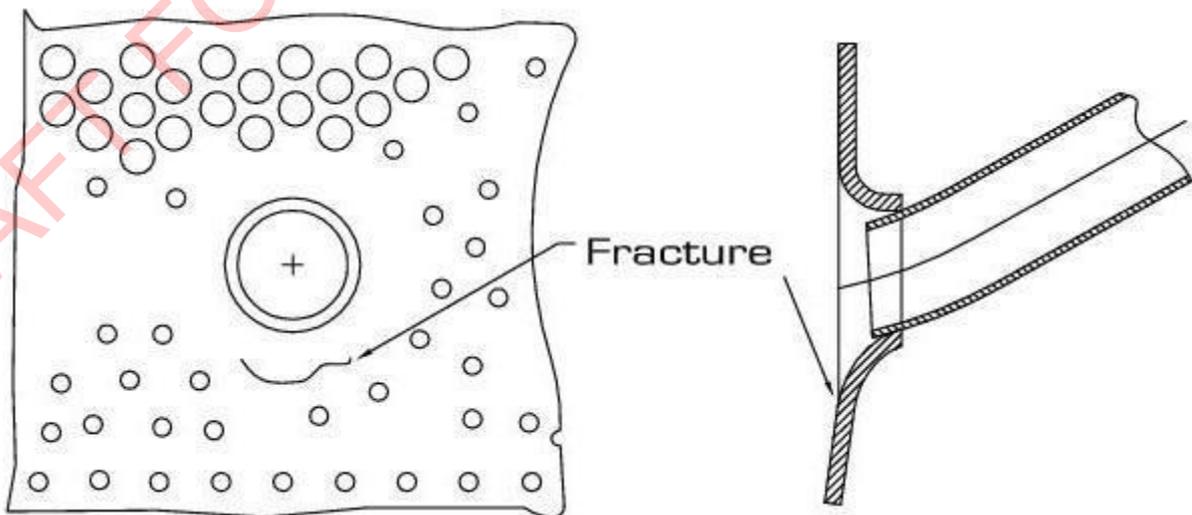


Figure 45 Siphon neck repair



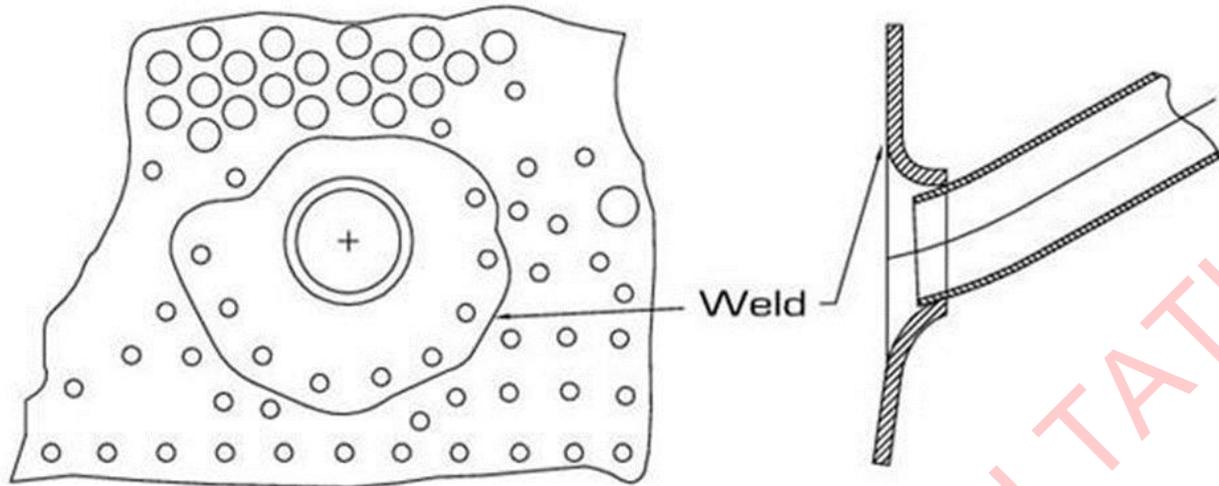


Figure 46 Tube plate defect

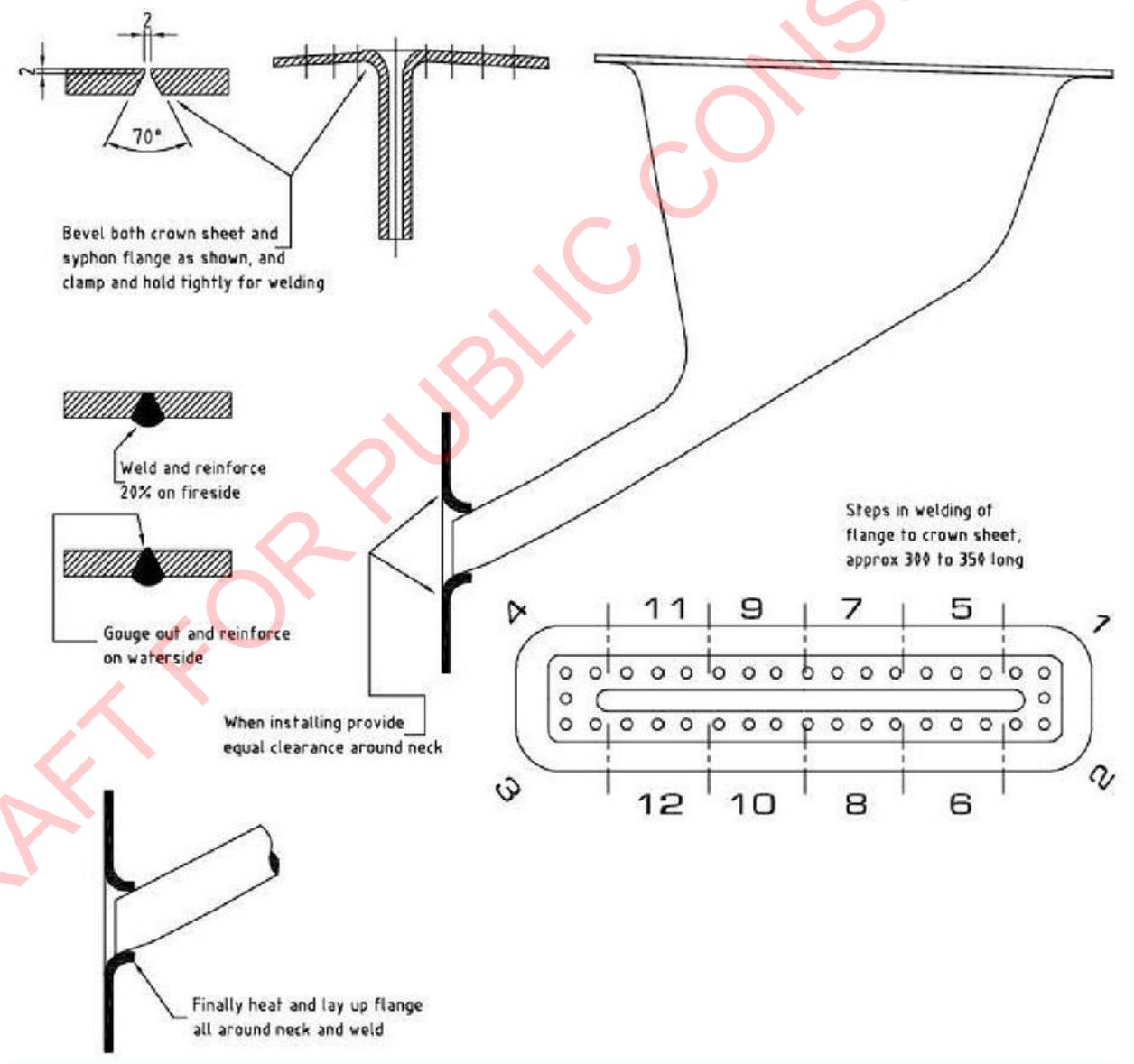


Figure 47 Siphon welding procedure

Section 10 Arch tubes

10.1 General

Arch tubes are found in the firebox of some of the larger locomotive boilers, extending from the back plate of the inner firebox to the throat plate at the front, and are open to the water spaces at both ends, carrying water through the hottest part of the firebox.

They have two functions: to support the brick arch and improve water circulation in the boiler and are probably the most dangerous of all the tubes in a boiler. No boiler shall be operated with defective arch tubes or if defects are suspected.

Arch tubes shall be made of seamless drawn tube in accordance with AS 1228:2016

Arch tubes may be welded when installed. Arch tubes shall not be safe-ended by welding or any other means.

Weld repairs are not permitted on arch tubes.

The competent person shall perform a thorough visual examination of all visible external surfaces of arch tubes every six (6) months, or whenever any signs of leaks, bulges or blisters are evident, regardless of the frequency of use of the boiler. The visible areas of the arch tubes shall be examined by operating personnel before each boiler light up.

At each time the brick arch is removed, a full visual examination of the external surfaces of the arch tubes shall be carried out by the competent person.

It shall be impressed upon all working on arch tubes that they are probably the most dangerous tube in the boiler and that the failure of an arch tube will be catastrophic and could cause fatalities.

10.2 Cleaning

Due to the nature of the function of these tubes, they may be subject to a larger build-up of scale during their normal operation than the water side of other heating surfaces, particularly when water quality is poor. A build-up of scale within the tubes reduces the heat transfer by insulating the heating surface. This can lead to overheating, cracking and rupture of the tubes. An adherence of clinker to the fire (or external) side of the tubes can be an indication that there is a build-up of mud and scale on the water (or internal) side.

Hard scale on arch tubes can be cleaned internally using a pneumatic cleaner, such as the one in Figure 48. This is a rotating machine, whose motion causes the three cutters to centrifugally open out to the diameter of the arch tube, clearing scale from the internal surfaces. The feed is manual.

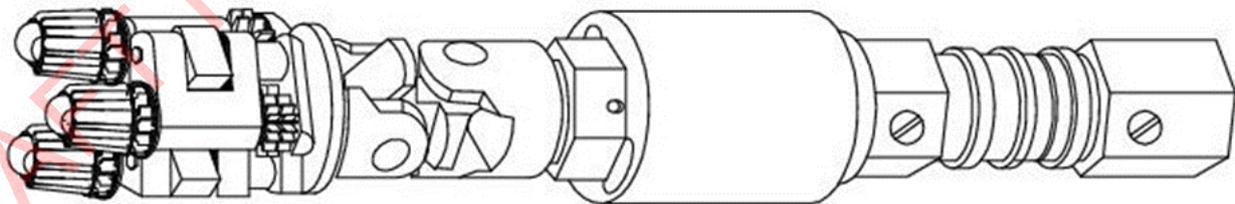


Figure 48 Arch tube cleaner

The cleaner and air line should be measured and marked to show the operator when the cleaner has reached the far end of the arch tube, ensuring that the entire length of the tube is cleaned without allowing the cutters to come free of the tube at the far end and cause damage to the ends or to the plates. One easy method of determining the exact length of hose is to ensure that the cleaner has been

isolated from the air supply, and feed the hose down the arch tube until it can be seen from the other end that the cutters are level with the end of the tube.

Mark the air hose with a paint marker or by tying a piece of rag at the operators end to show the exact length of air hose that needs to be fed down the tube. Only once the length has been accurately determined and it has been ascertained that no personnel have any body part near the cutter should the air supply to the cleaner be turned on. The cleaner should never be operated until the cutters are safely in place within the arch tube.

Arch tube cleaners such as the one illustrated should be fed in from the top, or cab, where gravity can assist in the feeding process. The cleaner should be fed up and down the tube in a continual motion to prevent localized grooving in the tubes caused by the cutters. A visual examination should be made of each tube to determine when the cleaning process is complete.

The cutters should be removed from the universal joint and cleaned at the end of each session, and stored submerged in a kerosene bath to keep them in good working order.

Care should be taken to protect the arch tube plug threads during the cleaning process. This can be done using a section of curved sheet metal to shield the threads when putting the cutter down the tube or when withdrawing it.

The cleaner should always be in place within the tube before the air supply is turned on; The cleaner shall never be introduced to the tube when already rotating.

An alternative to the pneumatic cleaner may be to use a high-pressure water jet for mud and scale that can be washed off.

After cleaning and examination, the internal surfaces of the arch tubes may be painted with a specialty paint, such as Apexior Boiler Compound No. 1, to protect against corrosion on the water side. This painting can be carried out by exchanging the cutters on the pneumatic cleaner with a circular paint brush head (see Figure 49).

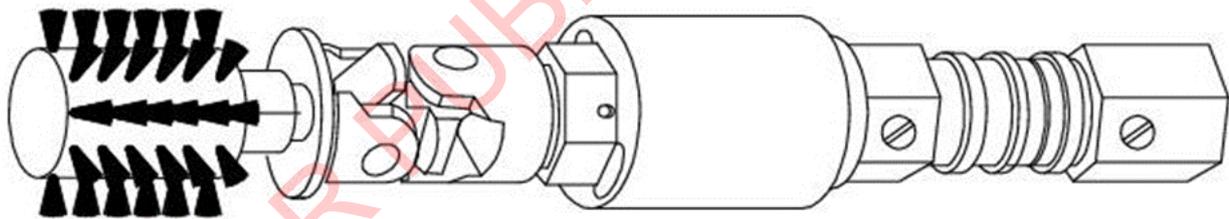


Figure 49 Arch tube paint brush

A measured amount of paint can be poured down the arch tube using a piece of shaped sheet metal for a funnel to aim it correctly, and then the painting head inserted and turned on and run up and down the interior of the tubes in the same motion as the cutting head.

A visual examination of the inside of each tube shall be made to determine when full paint coverage has been achieved.

Care should be taken to ensure that not too much paint is poured down an arch tube, as it will tend to coagulate and hang off the bottom ends of the arch tubes and create a fouling point for scale and debris during boiler operations, or drop off and stick to the foundation ring, causing possible hot spot locations.

10.3 External examination

Full examination of the external surfaces of the arch tubes requires the removal of the bricks. The tubes can then be wire brushed by hand and thoroughly examined for pitting, cracking, brick wear, erosion, grooving, cracking, bulging and leaking at the ends where the tubes are fitted into the plates. The results and actions shall be recorded in the boiler history file.

10.4 Internal examination

The tubes shall be cleaned and examined internally for signs of lamination, cracks, blisters or pitting, to ensure that they have not been cut or otherwise damaged by the arch tube cleaner and that they are free of scale.

Internal examination shall be conducted as part of the annual boiler inspection. Additional inspections (such as during wash outs) may be conducted where required.

Attention shall be paid to the ends of the tubes to see that they are properly belled or beaded.

10.5 Non-destructive evaluation

NDE shall take place as set out in the boiler maintenance plan, or at any time that defects in the tubes are suspected in consultation with the independent boiler inspector and competent person. They shall be examined for cracking and thinning of the tube walls by erosion or corrosion. The results and actions shall be recorded in the boiler history file.

10.6 Bending arch tube

Arch tubes shall be bent according to the specifications of the boiler drawing, and in consultation with the competent person. Care shall be taken to ensure that the tube walls are not thinned or creased during the bending process.

It is considered good practice to set up a jig to ensure that each tube is set to the same angle and in the right place. It is also sensible to wait until after the bending process has been completed before cutting the tubes to length.

10.7 Fitting arch tube

Tubes shall be cut square, with no ragged edges, burrs or tool marks. The tubes shall be at 90° (or normal) to the plate that they are fitted into. Tubes shall project a minimum of 10 mm (3/8") and a maximum of 13 mm (1/2") into the water space.

After the tubes have been cut to the correct length, the ends shall be annealed between 75 mm (3") and 100 mm (4") from each end by heating to cherry red and cooling in powdered lime.

A jig can be manufactured to ensure that each tube is fitted in the correct alignment with the firebox and the other arch tubes. Tube clamps (see Figure 50) can be fitted to the ends of tubes and used to ensure the tubes are fitted in the correct position and help to guard against slippage during setting and expanding.

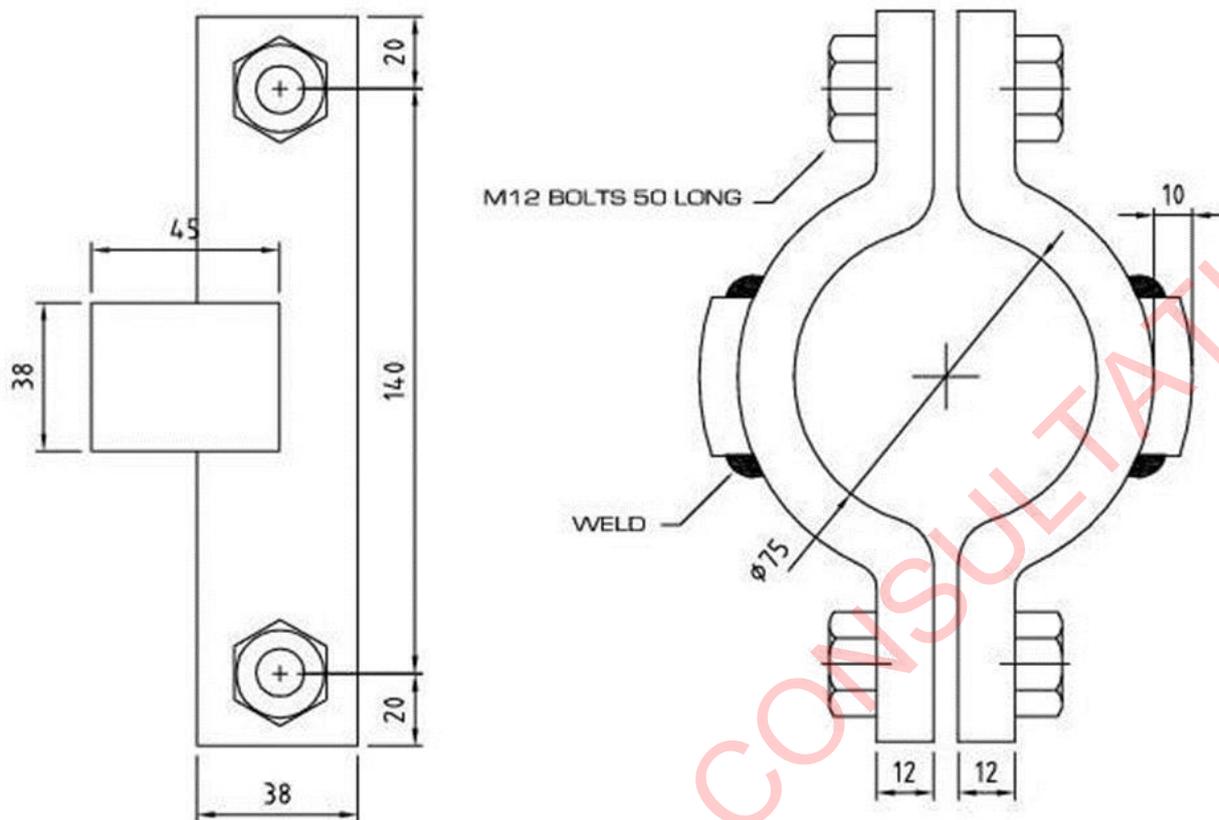


Figure 50 Clamp for holding arch tubes against slippage during setting

After the tubes have been set and expanded into their holes (see guidance on expanding tubes in Clause 16.14 and figures 51 to 59), the ends shall be flared with a flaring tool and then lightly re-rolled.

Welded-in arch tubes do not require expanding and shall be fitted as a set-through branch, in accordance with the design.

A change from expanded to welded-in arch tubes, or welded-in to expanded arch tubes, shall be considered a major design change and requires engineering design and approval.

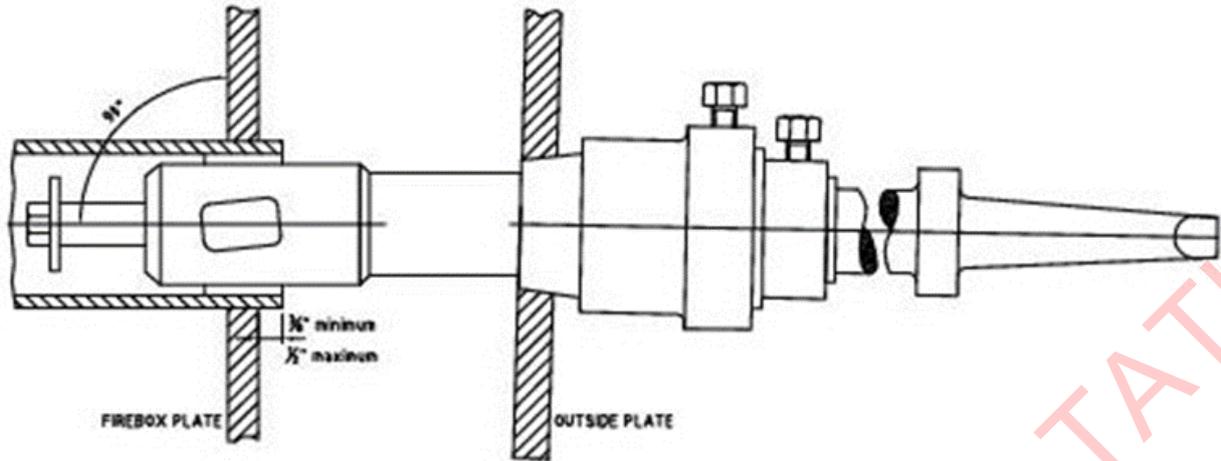


Figure 51 Expanding arch tubes in firebox plates with roller tube expander

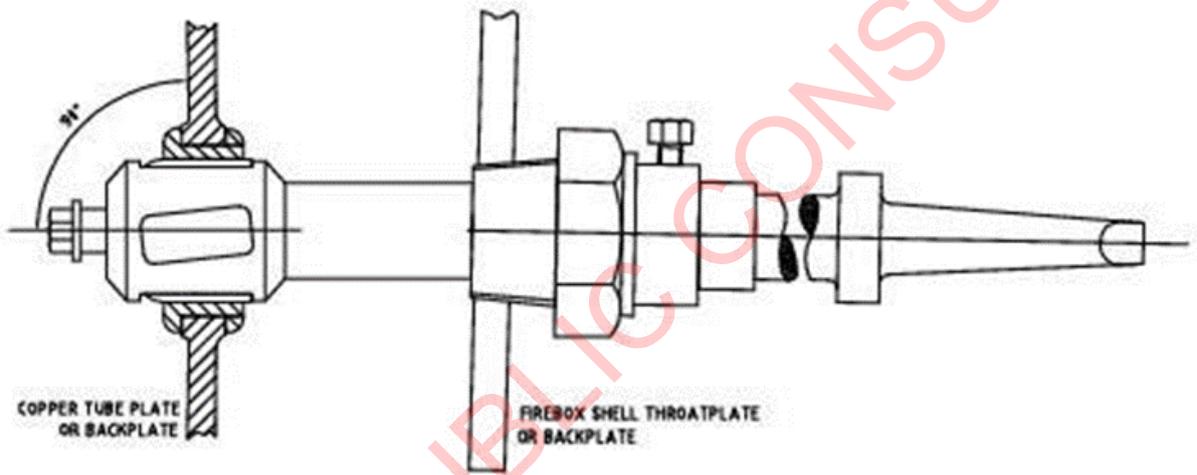


Figure 52 Expanding arch tubes in firebox plates with roller tube expanders

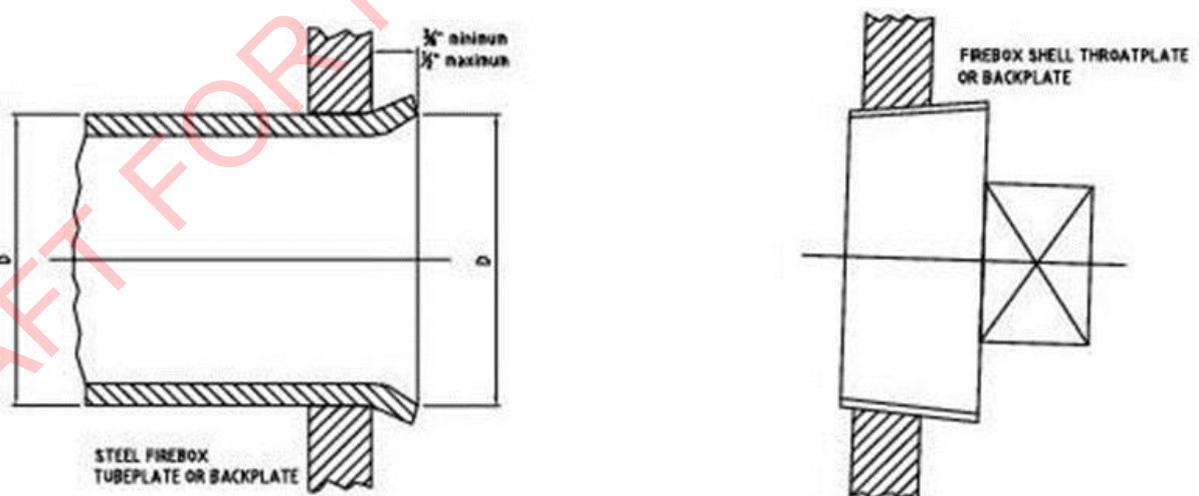


Figure 53 Method of applying arch tubes to steel firebox plates

Commentary C10.7-1

Arch tubes are to be expanded into the plate and then flared using the standard flaring tool.

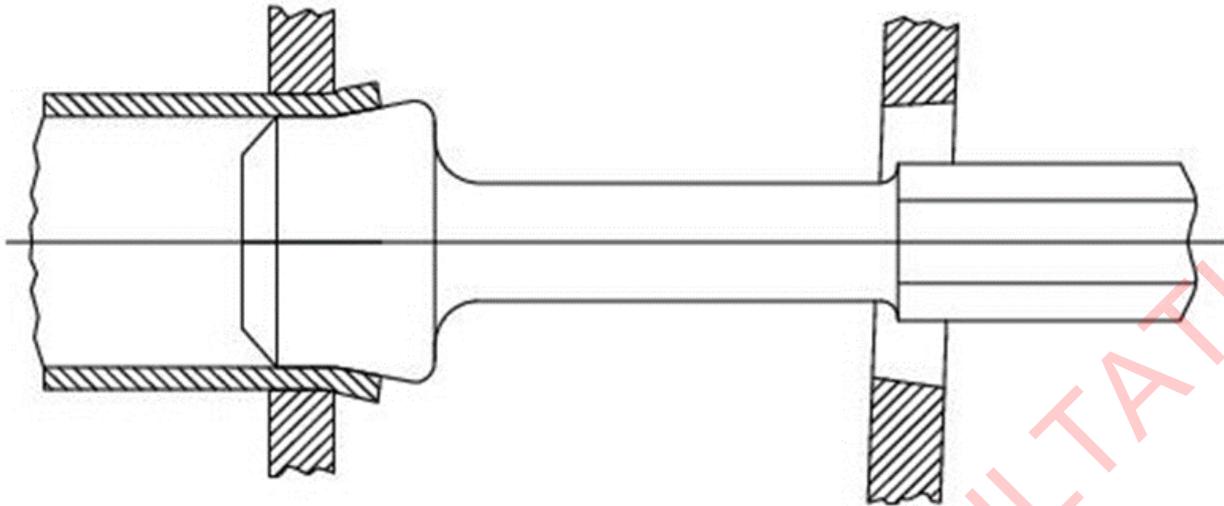


Figure 54 Flaring tool for arch tubes

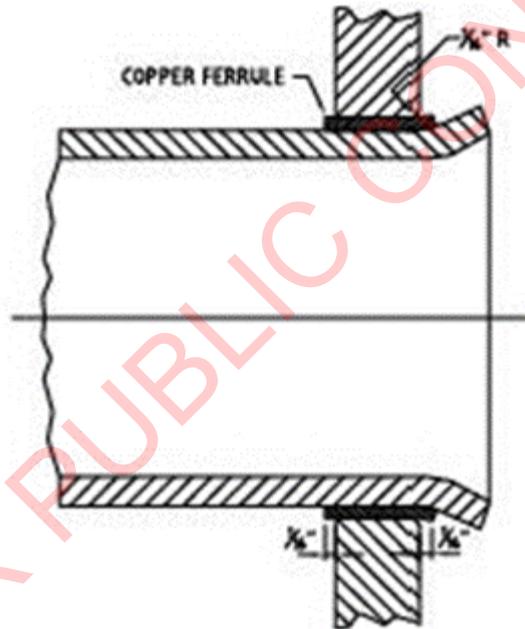


Figure 55 Application of ferrules to oversize arch tube holes

Ferrules shall be a neat fit in arch tube holes and secured by means of a roller expander.
 Arch tubes shall be made a neat fit in the ferrules, expanded and flared.

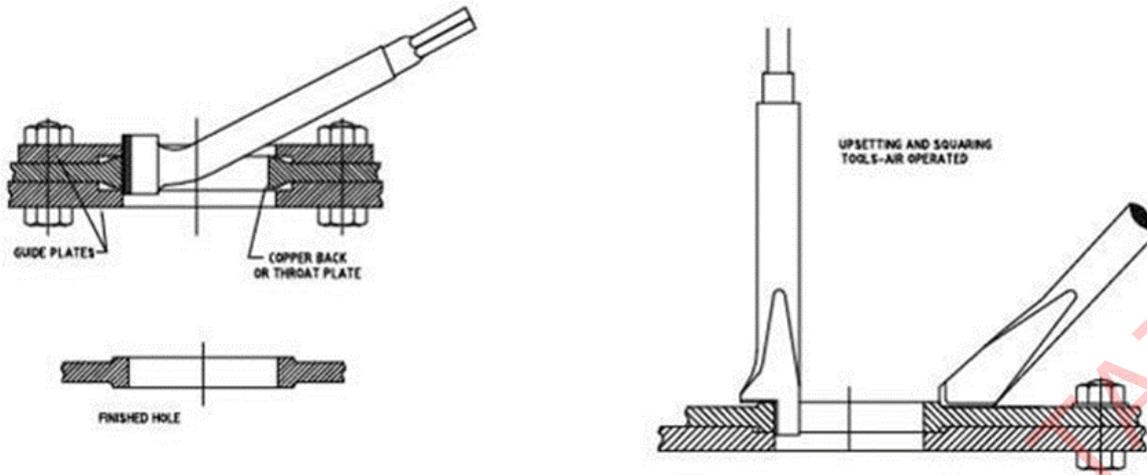


Figure 56 Forming bossed holes for arch tube bushes in firebox plates

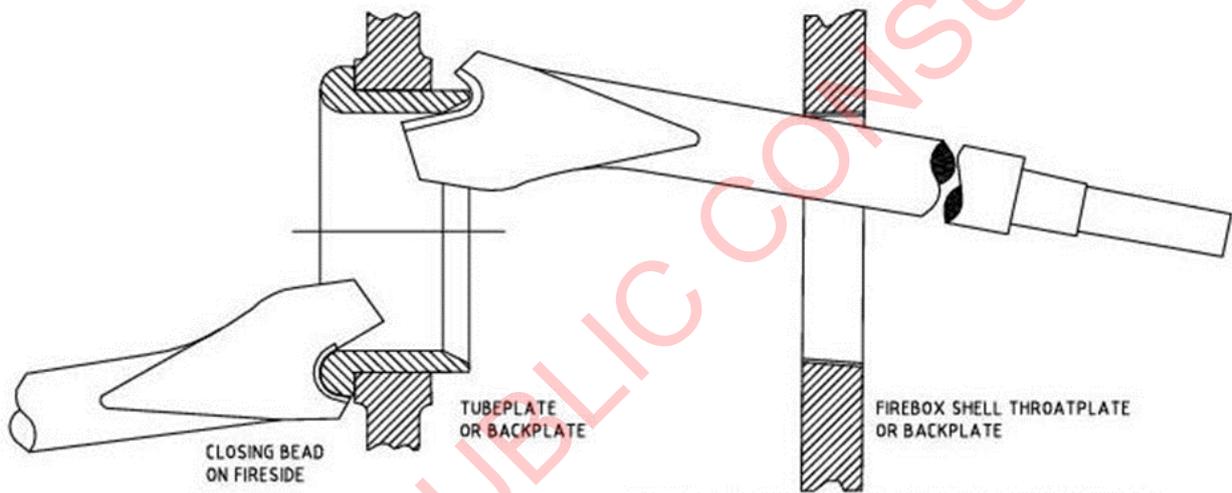


Figure 57 Method of beading arch tube ferrule (or bush) to firebox plates

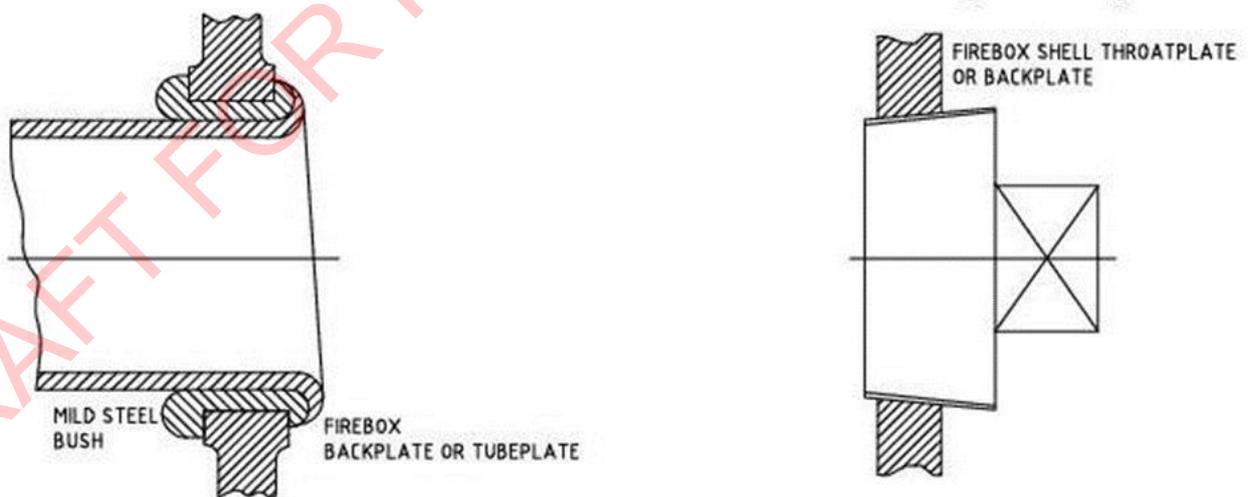


Figure 58 Method of applying arch tubes to firebox plates

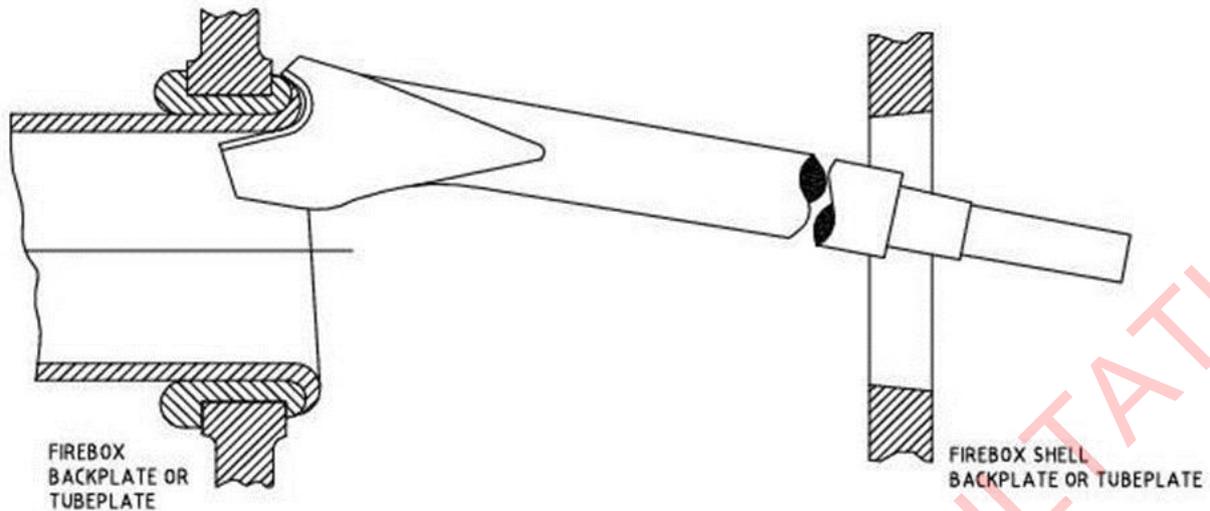


Figure 59 Method of beading arch tubes to firebox plates

Arch tubes shall not be removed or replaced without the approval of the responsible person, and work on arch tubes shall only be carried out by properly trained and competent people. Arch tubes shall not be repaired. All work shall be recorded in the boiler history file, including copies of material certificates and NDE results.

Section 11 Stays

11.1 General

This section shall serve as the guide for the maintenance, replacement and fitting of locomotive boiler stays and shall be adhered to unless it can be proven that another process or material is equal to or better than the practices and materials laid down in this document.

11.2 Introduction

The locomotive boiler, because of its flat surfaces, requires considerable staying, and the pitch and the size of the stays is dependent on the working pressure, the material, and the thickness of the plates. Many different types of stay can be found in a locomotive boiler and these typically include the following:

- (a) Wall stays provide staying support to the inner and outer fireboxes and may be rigid or flexible.
- (b) Crown stays support the crown 'or roof of the firebox and are suspended from the outer wrapper and may be rigid or flexible.
- (c) Transverse, or cross stays are fitted horizontally across the firebox above the crown sheet and stay both sides of the outer wrapper.
- (d) Longitudinal stays are fitted longitudinally in the boiler to stay the back head and smokebox tube plate.
- (e) Palm stays attach the inner firebox tube sheet to the bottom of the boiler barrel.
- (f) Sling or link stays support the crown sheet.
- (g) Other variations of staying may be found.

See Figure 60 for general stay arrangements, and Figure 61 for stay arrangements on Belpaire-type boilers.

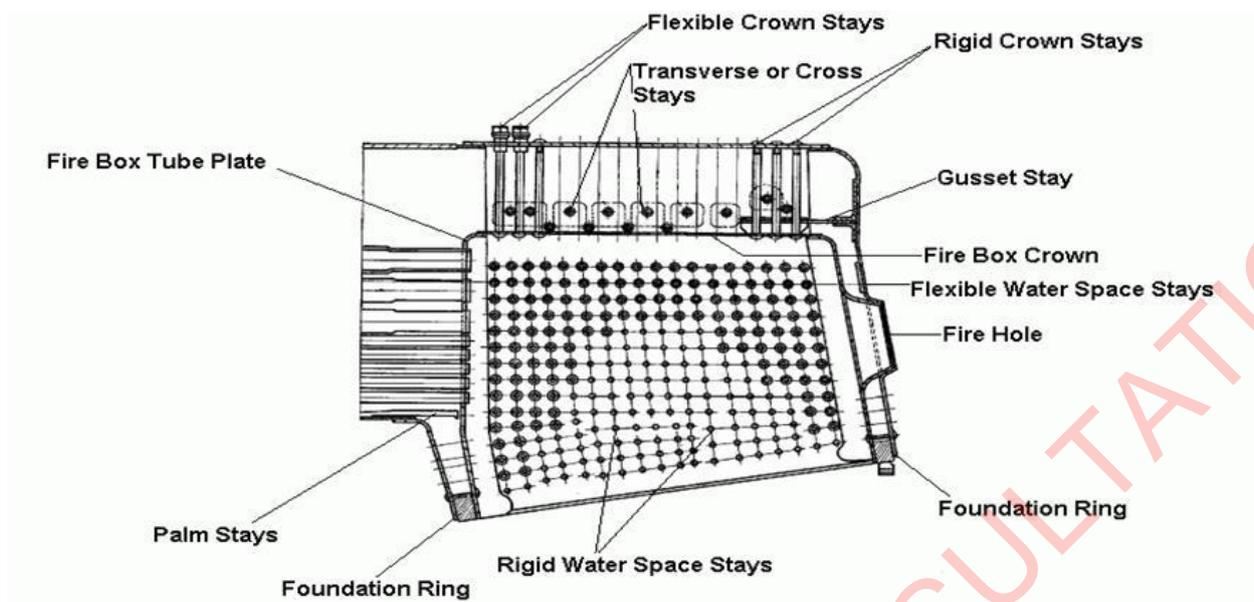


Figure 60 General stay arrangement

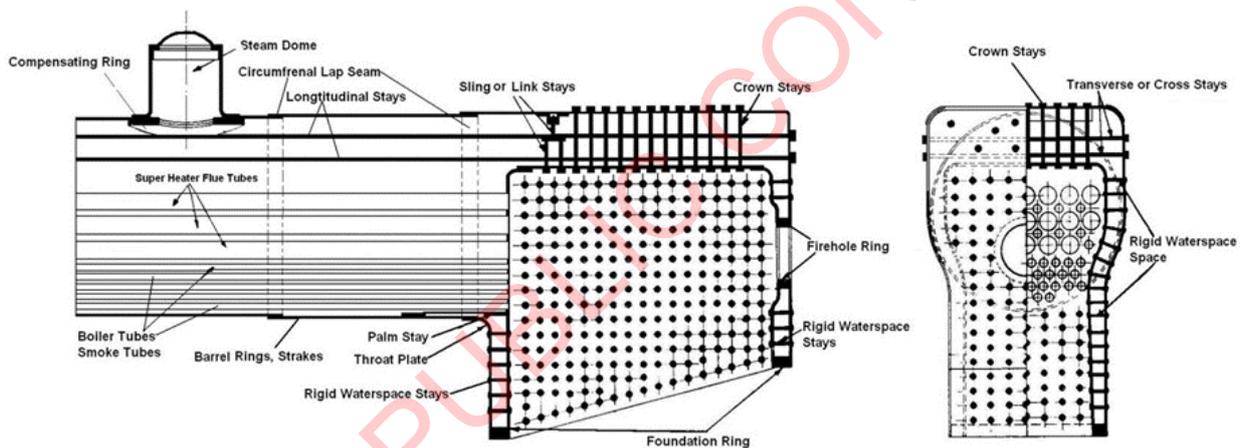


Figure 61 Narrow Belpaire firebox showing tubes, stays and sheets

11.3 Wall stays

Steel fireboxes may be fitted with steel and/or monel wall stays while copper fireboxes are fitted with copper and/or monel wall stays. Copper wall stays shall not be fitted into a steel firebox. Steel used for firebox stays shall be as per AS 1228:2016 or AS 3679.1:2016 to ensure it is mild in character with maximum ductility, free from work hardening and that it exhibits good riveting qualities. In addition, the material should not embrittle when subjected to service conditions. See Figure 62 for a typical stay.

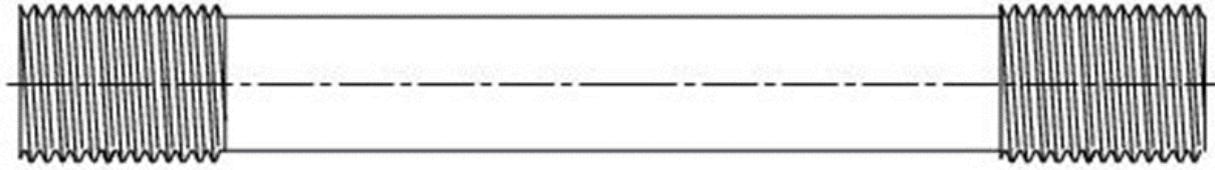


Figure 62 Typical wall stay without tell tale

The steel shall conform to the required mechanical properties as well as possess the correct chemical properties stated in AS 1228:2016 and AS 3679.1:2016. The steel shall possess the correct chemical properties as below:

- (a) Carbon, not more than 0.20% (per cent carbon shall not be exceeded)
- (b) Manganese, not less than 0.40%
- (c) Sulphur, not more than 0.05%
- (d) Phosphorus, not more than 0.05%
- (e) Elongation, not less than 20%
- (f) Ultimate tensile strength, 400 MPa — 460 MPa
- (g) Yield strength, 50% of the tensile strength

Modern materials are not generally designed for riveting processes (such as knocking down stay heads) and therefore the proposed material shall be mechanically and chemically tested for fitness for purpose.

Copper may be used for wall stays in accordance with AS 1228:2016, Appendix K.

Copper round bar for use as stay material in boilers shall be chemically and mechanically tested to ensure that the properties are within the design specifications of the boiler, with a typical elongation of 40%. If in doubt about the original copper specification for the boiler, the original stay should be analyzed by a metallurgist to get a comparable, modern grade. The material properties of the copper shall be in accordance with AS 1210:2010

Monel metal is a nickel copper alloy used for water space stays in both copper and steel fireboxes. A metallurgist shall be consulted to ensure that a suitable grade of monel is sourced for the application required.

11.4 Tell-tale holes

A hole shall be axially drilled in the ends of the stay in accordance with AS 1228:2016 or registered design and construction standards. It acts as an indicator to show when the stay is broken by allowing a visible discharge of steam or water.

Examples are shown in Figure 63 and Figure 64.

Tell-tale holes shall be kept open and clear at all times. Accumulated ash and detritus shall be drilled out on a regular basis to ensure a break is clearly indicated. For tell-tale holes beneath the arch in proximity to the fire, where the accumulated ash is hard baked and sometimes difficult to drill out, a masonry drill bit can be used with good effect to clear the holes.

NOTE:

Tell-tale holes in normal rigid wall stays are not to be confused with hollow rigid wall stays, which have a hole through the entire length of the stay.

Stays behind permanent brickwork, frame braces, or grate bearers may, where practicable, have tell-tale holes for their entire length; such holes shall be kept open at all times.

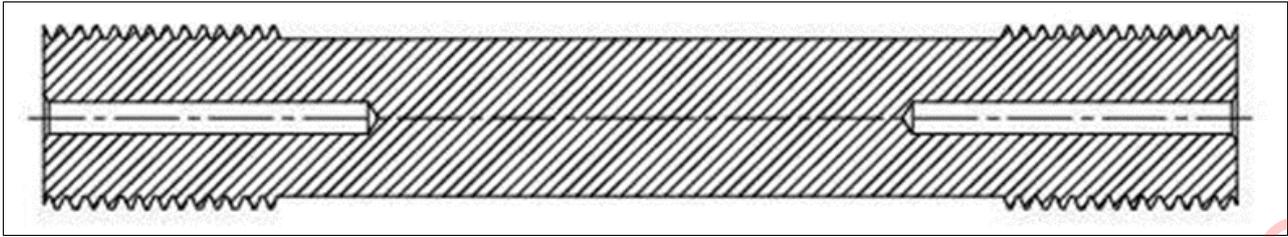


Figure 63 Rigid screwed water space stay

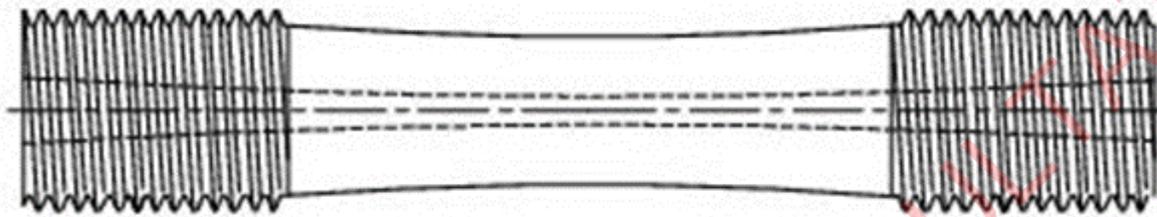


Figure 64 Hollow rigid stay with reduced diameter

11.5 Flexible stays

Flexible wall stays (see Figure 65) are fitted in breakage zones of some fireboxes where rigid stays are likely to break. They may comprise several components: the stay, the cup, the cap and the sealing washer.

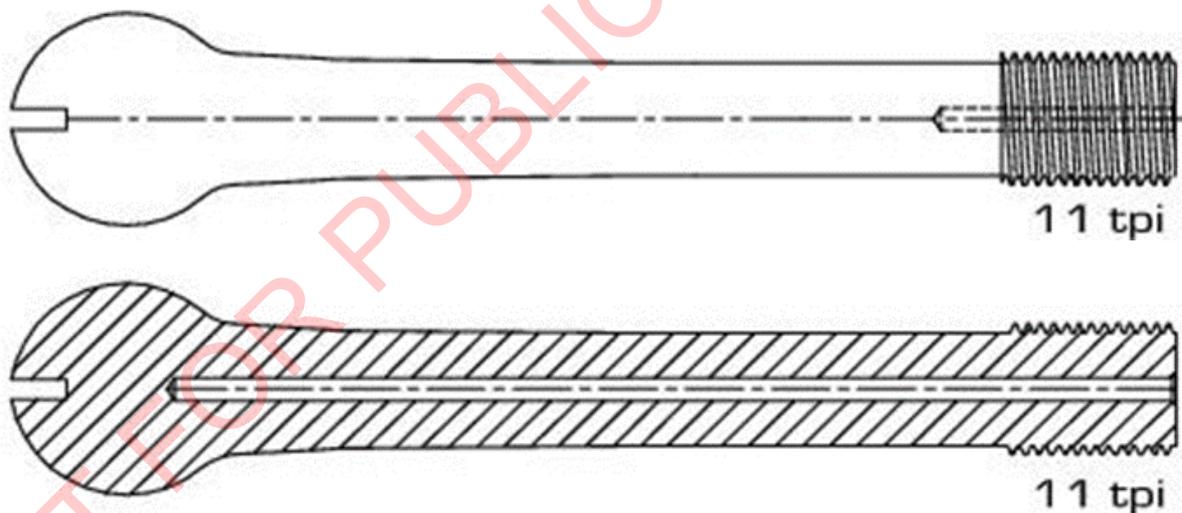
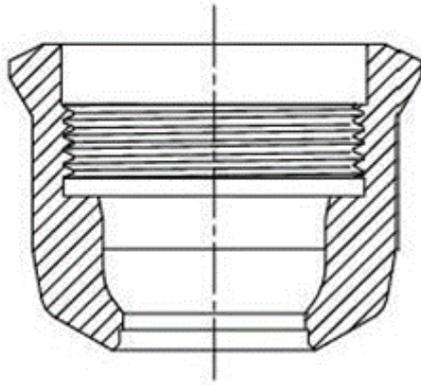


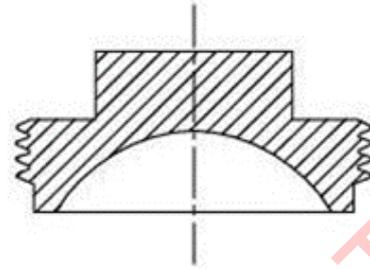
Figure 65 Ball ended flexible stay

Flexible stays have a ball formed at the head, which seats into a spherical socket (see Figure 66) that is either screwed or welded to, or machined into, the outer plates. A cap tightens down onto a washer into this cup to provide a seal on the outside of the plate.

Flexible stays shall also be drilled with co-axial tell-tale holes. In some cases, these may extend as far as the ball head of the stay; some RTOs practice has been to drill them in the same manner as the rigid stays. Refer to the original drawings for correct practice.



TYPICAL FLEXIBLE STAY CUP



FLEXIBLE STAY CAP

Figure 66 Flexible stay cup and cap

There are several designs of cup, cap and seating positions of these spherical head stays. It is essential that the detail of these designs is understood and that the original drawings are referred to before any inspection, maintenance or repairs are attempted.

11.6 Longitudinal stays

Longitudinal stays (Figure 67) are rigid stays that are fitted longitudinally in the boiler from:

- (a) smokebox tube plate to back head;
- (b) smokebox tube plate to an anchor point within the barrel from the back head to an anchor point within the barrel; and
- (c) the back head to the top corners of some Belpaire fireboxes.

There are several designs of fitting these stays into a boiler; Refer to the original boiler design for correct fitment method.

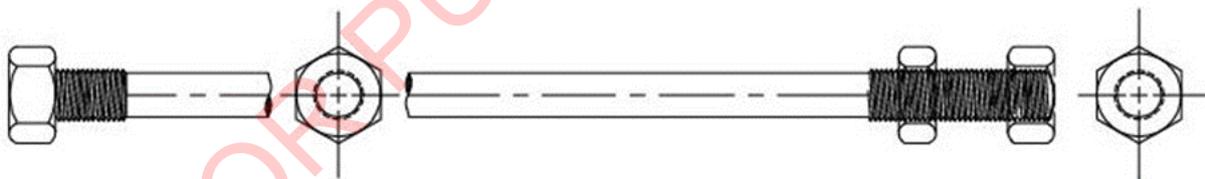


Figure 67 Longitudinal stays

11.7 Transverse or cross stays

Transverse, or cross, stays are rigid stays that are fitted transversely in the water space above the firebox crown sheet.

There are several designs of fitting these stays into a boiler; refer to the original boiler design for the correct fitment method.

11.8 Palm stays

Palm stays (Figure 68) are used to give support to the firebox tube plate at a point between the lowest smoke tubes and the uppermost water-space stays.

Palm stays were traditionally steel forgings, but may be fabricated or machined from solid material in accordance with AS 1228 or registered design and construction standards.

The round-section wall stay that secures the tube plate to the palm stay shall be made of material as detailed above in Wall Stays.

The attachment of a palm stay to a shell shall be in accordance with the original drawings.

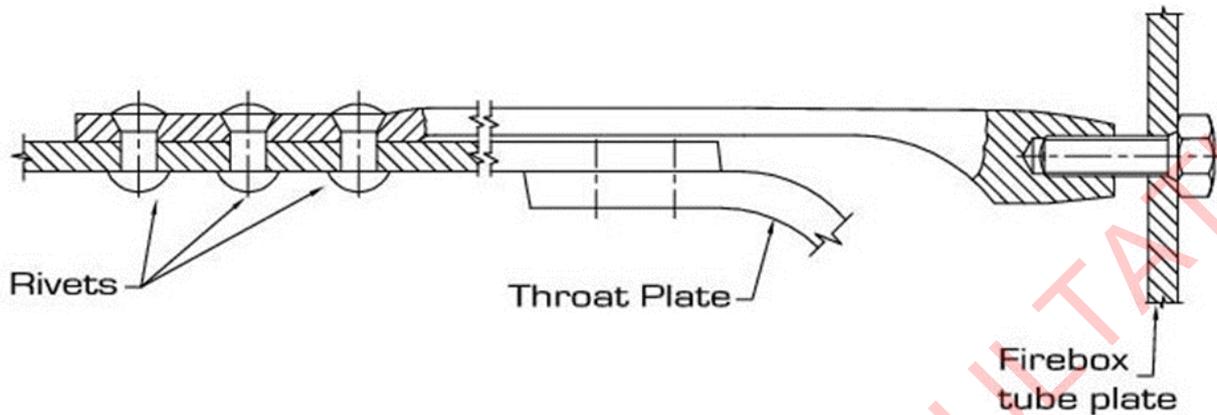


Figure 68 Palm stays

11.9 Girder stays

Typically fitted to smaller boilers, girder stays (Figure 69) were used for firebox crowns. The girder is bolted or stayed to the crown plate and slung by means of sling stays from the outer wrapper. This arrangement provides for easy vertical breathing of the crown, but renders washing out difficult.

Girder stays are designed to transfer the load and, as such, should be inspected to ensure that the load bearing is in accordance with the original design.

Locomotives fitted with girder stays on the crown sheet shall be closely examined at each annual inspection to check for any overheating damage due to inferior washouts.

Girder stays shall be manufactured and installed in accordance with the original design drawings and using original material specifications. A metallurgical opinion should be sought when sourcing modern equivalents to original materials.

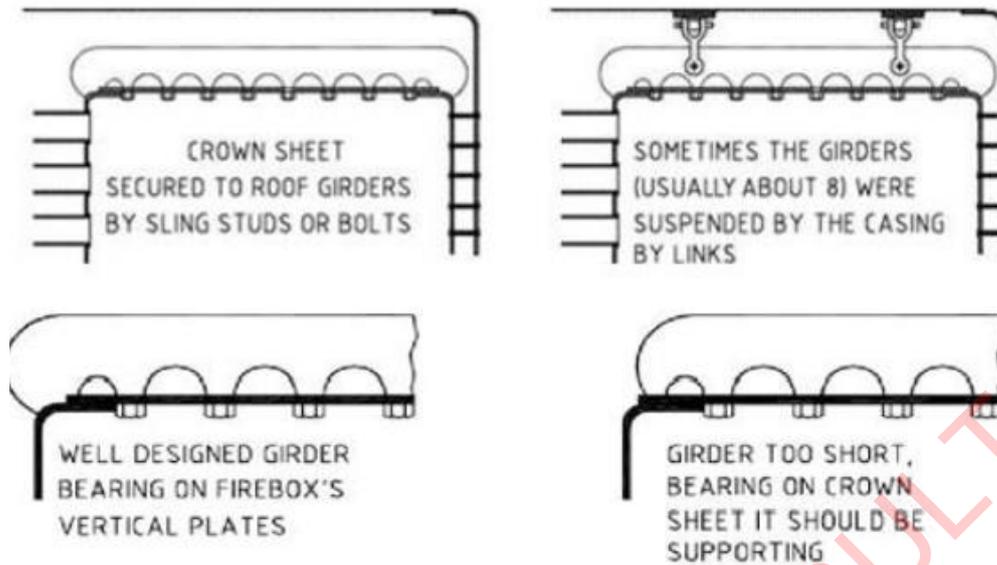


Figure 69 Girder stays

11.10 Gusset stays

Gusset stays (Figure 70), manufactured from plate, are sometimes used to assist in tying the back head to the outside wrapper plate, or the smokebox tube plate to the first course of the boiler barrel.

Gusset stays shall be manufactured and installed in accordance with the original design drawings and using original material specifications. A metallurgical opinion should be sought when sourcing modern equivalents to original materials.

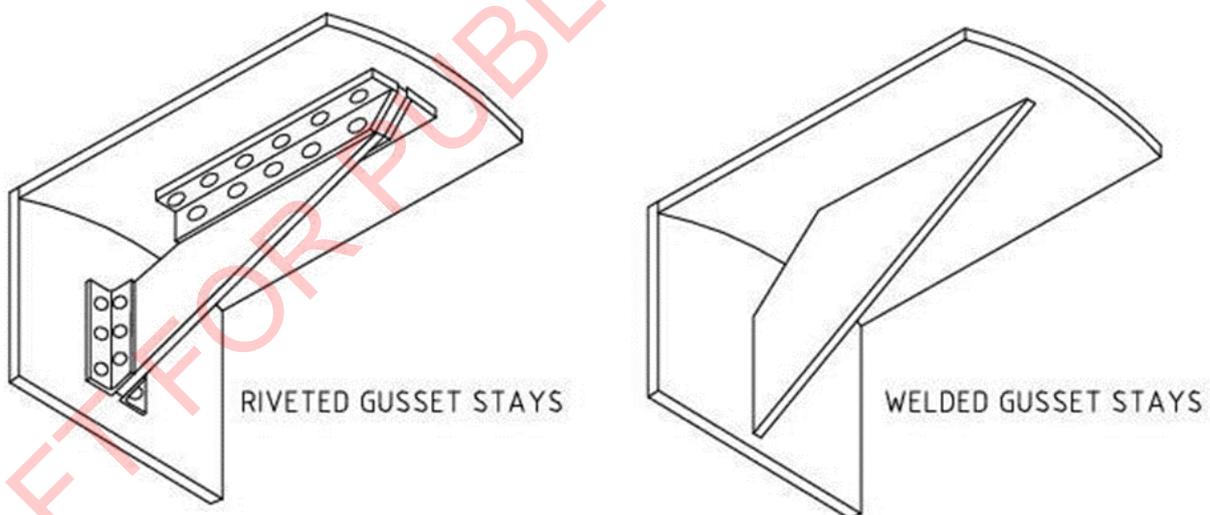


Figure 70 Gusset stays

11.11 Diagonal link stays

Diagonal link stays (Figure 71) are sometimes used to assist in tying the back head to the outside wrapper plate, or the smokebox tube plate to the first course of the boiler barrel.

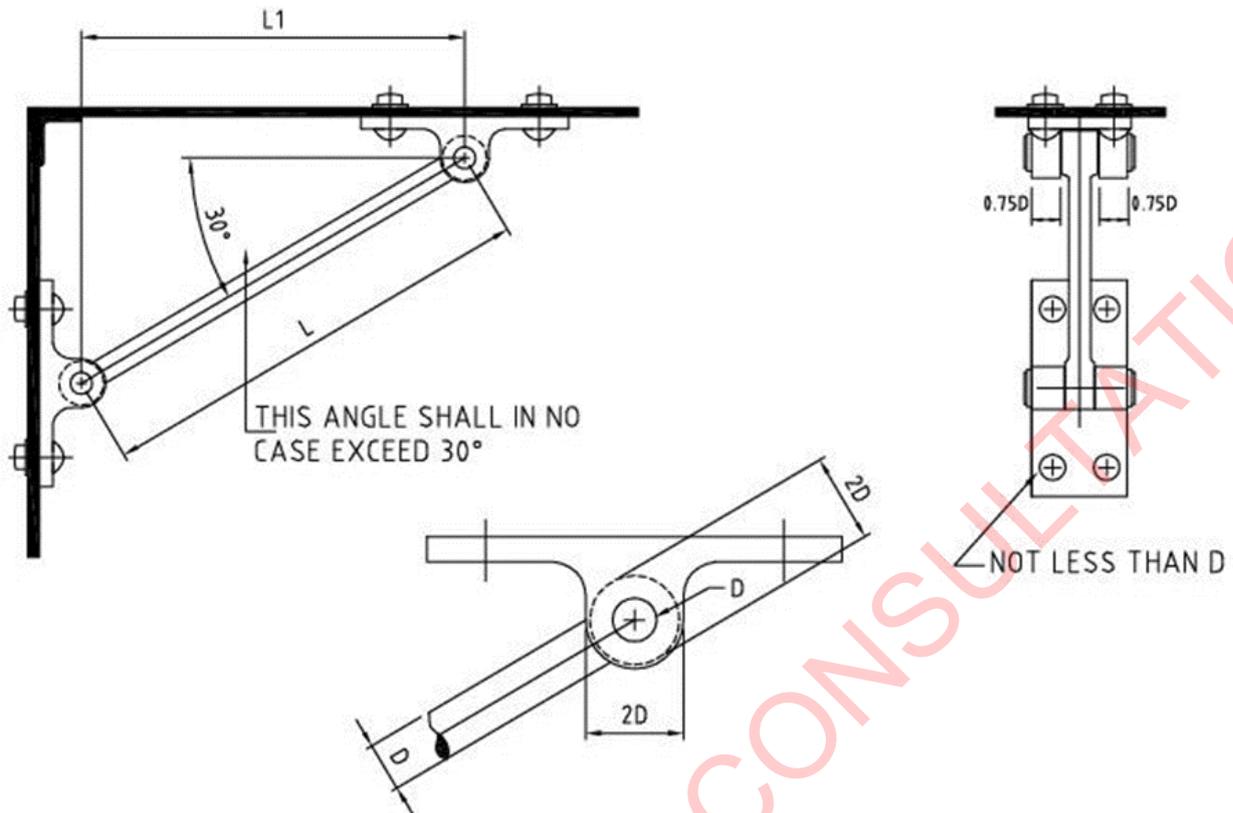


Figure 71 Diagonal link stays

Where diagonal link stays are employed, they shall be applied so as to make an angle of not more than 30° with the shell.

Diagonal link stays shall be manufactured and installed in accordance with the original design drawings and using original material specifications. A metallurgical opinion should be sought when sourcing modern equivalents to original materials.

11.12 Crown stays

Crown stays (Figure 72) are installed to support the large, flat surface of the crown sheet and the firebox outer wrapper.

Crown stay manufacture and fitting varies widely, according to local practices and boiler design, and all inspection, maintenance, repair and replacements shall be done in accordance with the original design drawings and using original material specifications. The material employed in crown bolt manufacture, in most cases, is the same as the material in the wall stays. See Clause 11.3 for more detail.

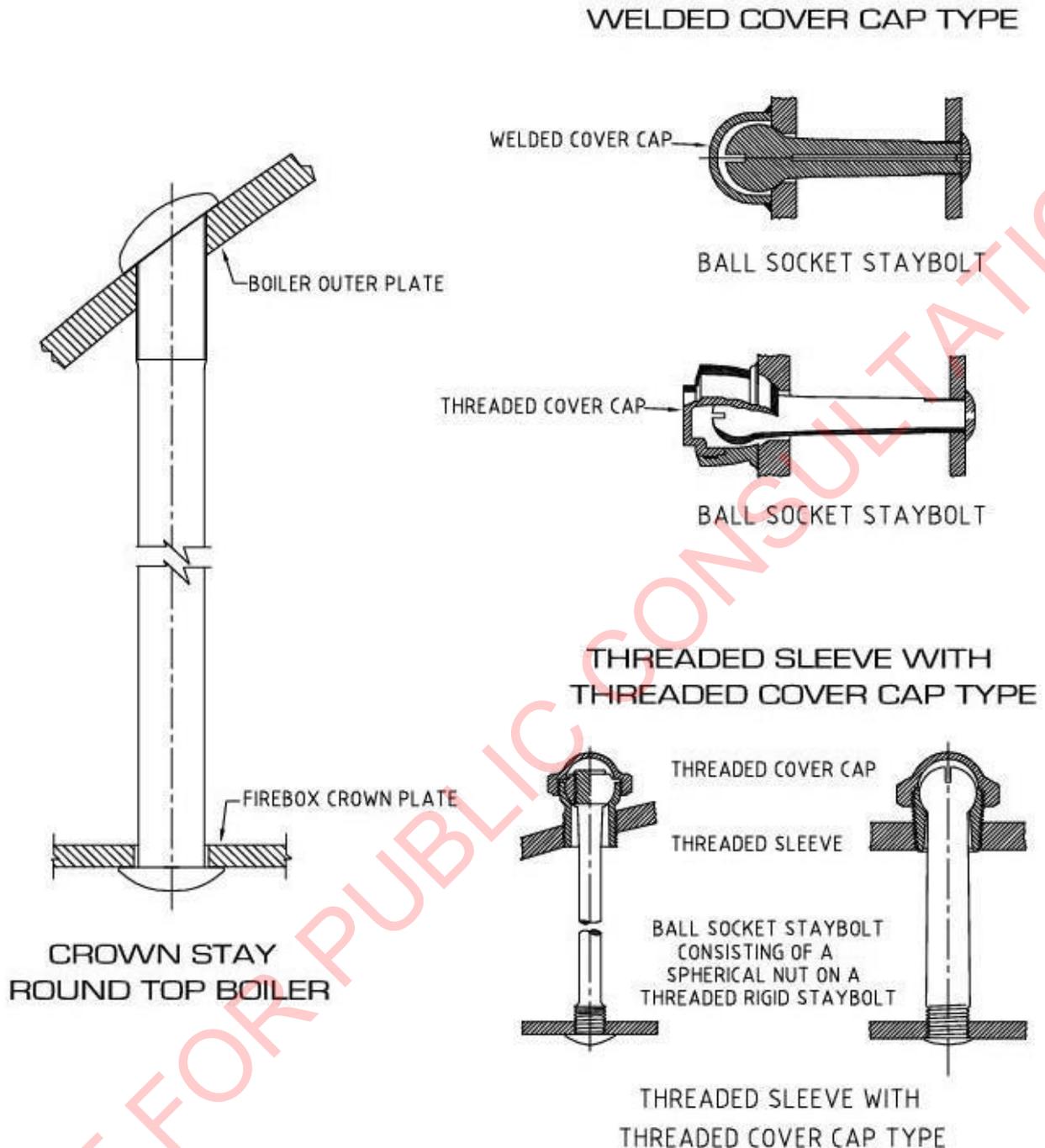


Figure 72 Crown stays

11.13 Smoke tube and flute stays

Tubes in some boilers are designed to provide a staying effect on the tube plates. Only tubes that are specifically designed and fitted as stay tubes provide a staying effect. Boiler design drawings shall be consulted to determine whether this type of tube is fitted. See Section 16 for more information.

Elongation of steels used for stay materials should be no less than 25%. Where elongation is less than 25% the material shall be assessed by a suitable mechanical engineer and the competent person for suitability for use in stays.

11.14 Mode of failure of stays

The principal modes of stay failures are:

- (a) corrosion (causing reduction in diameter of the stay);
- (b) fatigue (causing transverse cracking in the stay);
- (c) flame impingement on heads (burning of the heads from the fire);
- (d) overworking of heads (too many attempts to reseal a leaking head); and
- (e) plate failure around stays (corrosion on the water side thinning the plate around the stay).

11.15 Detection of broken stays

Broken wall stays are detectable by the evidence of water leakage from the tell-tale hole, or a growth or accumulation of scale or wet ash in the hole. If it is suspected that a stay is broken, a drill should be used to clear the hole. If the drill is wet or covered in wet ash/scale/mud when it is removed, the stay is cracked or broken and shall be replaced before the boiler is returned to operation.

Flexible wall stays could fail at the threaded end or the ball end and unless tell-tale holes are drilled all the way into the head they may break in an area in which there is no tell-tale to give an indication to show that the stay is broken. Flexible stay caps shall be removed on a regular basis for inspection for breakage in accordance with experience in the particular boiler design. This inspection regime shall be laid down in the boiler maintenance schedule.

All flexible stay caps shall be removed to allow stay inspection at any time the boiler is shopped for major repairs and before the recommissioning of any out-of-service boiler.

NOTE:

The through drilling of tell-tale holes is considered to provide sufficient indication of all methods of stay fracture; Hence caps on through-drilled tell-tale flexible wall stays do not need removal on a regular basis.

Once caps of flexible wall stays have been removed, a T-handled tool shall be fitted into the flexible stay slot and a turning force applied vigorously by hand. A broken flexible wall stay will be obvious by its movement under this examination; a wall stay that is not broken remains solid in the hole.

11.16 Broken stays

When broken stays are detected, the boiler shall not be put into steam.

If a broken stay is discovered in a boiler already in steam, it shall be allowed to work back to its maintenance base for repair.

If two (2) broken stays are discovered while the boiler is working, the locomotive should be worked back to its maintenance base on light engine with a low boiler pressure.

The fire should be dropped immediately and another method of transporting the locomotive back to the maintenance depot should be used if:

- (a) more than two (2) broken stays are identified; or
- (b) two (2) identified broken stays are adjacent to each other.

11.17 Removal of broken stays

11.17.1 Screwed boiler stays

Screwed boiler stays can be removed using the following procedure:

NOTE:

Before commencing any work on stay replacement, ensure that the correct tooling and equipment is available to complete the job.

- (a) Chisel or grind off the heads of the stay.
- (b) Clean tell-tale holes to use as drilling guide.
- (c) Select a drill approximately 1.5 mm to 2 mm smaller than the root diameter of the stay.
- (d) Drill metal from the stay until the hole depth is about 13 mm past the inner plate edge.
- (e) With a small round-nose chisel or pneumatic punch, collapse the remaining thin walls of the stay on both sides.
- (f) When broken through the remaining stay should drop to the foundation ring, from where it should be removed through the most convenient washout hole before the boiler is returned to service.

Oxy-acetylene cutting after drilling the stay is an alternative if the stay cannot be removed as above. The use of oxy-acetylene cutting gear for removal of boiler stays shall only be carried out by a person deemed competent by the competent person.

It should be possible using the same round nose chisel to collapse the remaining threaded portions left in the plates. Use the correct wall stay tap to clean out the threads. If a full thread cannot be obtained, re-tap the hole to the next size (note that there shall be a minimum of four (4) full, consecutive threads of engagement).

The removal of any stay shall only be undertaken by competent persons in consultation with the boiler competent person and the independent boiler inspector. All repairs and replacements shall be recorded in the boiler history file, along with all material certificates. It is strongly recommended that stay diagrams showing the history of replaced stays are also added to the boiler history file.

11.17.2 Welded stays

Where fully welded stays are fitted, the method of removal will be dependent on the original design of the welded joint. This shall be investigated, and the proper method of removal determined before attempting to remove this type of stay.

The use of oxy-acetylene cutting gear for removal of boiler stays shall only be carried out by suitably qualified and competent people.

11.17.3 Turning of threaded stays

When threaded stays are to be turned, a gauge should be made from the stay tap used to tap (re-tap) stay holes to enable the correct fit of the stay into the plates. Screwed stays are generally reduced to the root diameter of the threads between the threaded portions in the plates. This gives the stay a degree of flexibility, reduces the ability of foreign matter to adhere to the stay and aids washing out. Where a larger stay has to be fitted, the plain portion of the stay shall be made to the original stay diameter with a smooth transition from the larger thread root to the plain diameter.

11.18 Steam-tight stays

Steam-tight stays is the term given to screwed stays that are fitted with an interference fit to the outer plate fitted from the firebox side. This is because access to both sides of the stay is not possible i.e. narrow firebox stays below frame level or above the frame level behind side tanks. Broken stays in these positions should be carefully and completely drilled out from the firebox side and both halves of the stay

collapsed; the outer hole will require the use of a long chisel through the firebox hole to clean out, as access to the outer hole is not possible from the exterior because of the locomotive frame or tank. The threads in the walls should be re-tapped with the correct tap from the firebox side.

Steam-tight wall stays are specially turned with the thread for the outer, inaccessible hole approximately 0.005" oversize, but should not be so tight that the threads pick up while screwing in; if too tight, the threads of the stay should be eased. A thread sealant should be applied to the stay threads to assist with sealing and provide lubrication.

A good guide to appropriate tightness is to use a long spanner on an appropriate stay driver. Once the stay is in place, the firebox side can be formed as normal.

11.19 Diameters of screwed wall stays

The maximum diameter of a screw stay shall be taken at the root of the thread, or at the body of the stay between the threads, whichever is the lesser.

A screwed stay's nominal diameter shall be not less than that shown on the boiler drawings and not more than prescribed by the original practices.

Traditionally, the method for recovery of thread form in stay holes when stays require replacement is to progress to the next incremental diameter of stay (as per local RTO practice), while maintaining the same thread pitch. Stay diameter shall not exceed the maximum proscribed limits as set out in the original practice.

Should the information on local RTO practice or original practice not be available, a determination of these limits shall be made in consultation with a competent boiler design engineer. Once a hole has reached the maximum allowable size (as set out in the RSO practice) it may be recovered by the use of a weld-in bush to the original (starting) design. Any such repair shall only be carried out with an appropriate weld procedure and in consultation with the boiler competent person and the independent boiler inspector and all repairs shall be recorded in the boiler history file.

11.20 Welding stays

Boiler stays may be welded in accordance to AS 1228 or registered design standard.

This type of stay is a straight rod of appropriate steel, complete with appropriate mechanical and chemical analysis certificates.

The stay is fillet-welded on either end onto the plate, a job that shall be done by a certified pressure welder.

NOTE:

When a weld procedure is developed for this process, countersinking may lead to cracking in the plate, which makes subsequent removal and replacement of stays difficult.

11.21 Welding of steel longitudinal stays in their length

Where longitudinal stays are used, they shall be solid drawn, forged, or electrically resistance welded as specified below. This welding refers to the welding of stays in their length only, and not to the welding of attachments. When welded, no stay shall have more than two (2) joints in its entire length.

When mild steel stays are electric resistance welded, the method and operation shall be approved and a heat-treatment process shall be carried out immediately after welding.

This welding shall be done in accordance with AS 1228:2016 or registered design and construction standards, a weld procedure shall be produced and adhered to.

Welding shall be carried out by a pressure welder certified in accordance with AS 3992:2020. All such welds shall be subject to NDE, assessed in accordance with AS 4037:2016, and all results shall be recorded in the boiler history file.

NOTE:

While many boilers were designed using AS CB1.3-1957, which prohibits the welding of longitudinal steel stays in their length, the development of modern materials and welding procedures and processes means that a long stay fabricated with a proven technique that ensures the necessary mechanical integrity is achieved should not be excluded.

11.22 Fitting of stays

Where screwed stays are to be riveted through plates, the length of the stay shall be determined taking into account the amount of material that will be required to form a full head. The minimum amount of stay protruding past the plate shall comply with AS 1228:2016 or registered design and construction standards. When stays are fitted with nuts, the stay length shall provide for a full nut and washer. All stays not normal (square) to the stayed surface shall have full engagement according to the original design.

11.23 Time of inspection and testing

All boiler stays shall be visually inspected in accordance with each RSO's boiler maintenance plan, which has been prepared in accordance with this document and at other times including:

- (a) at time of boiler washouts;
- (b) at annual inspections;
- (c) at any other time where it is suspected that a stay may be broken; or
- (d) when the boiler has been shopped for any major work.

Section 12 Wash out plugs

12.1 General

This section shall serve as the guide when manufacturing, fitting, removing or inspecting washout plugs in boilers and shall be adhered to unless it can be proven that another process or material is equal to or better than the practices and materials laid down in this document.

12.2 Introduction

Washout plugs are tapered, threaded, bronze plugs with a square head that are fitted in strategic locations in a boiler to facilitate its washing out and the inspection of its internal surfaces. The precise number and location of washout plugs are dependent on the locomotive and the boiler design.

Several different sizes of washout plugs may be found on a single boiler because of differing functions, size restrictions because of location, or because of damage to the washout plug hole that has seen a new, oversized thread tapped and a new plug made to suit.

In the event of finding a suspect washout plug or hole, guidance shall be sought from the competent person before proceeding with repair, recovery or replacement.

Washout plugs are a safety critical item. The failure or miss-fitting of a washout plug can lead to rapid disengagement of boiler contents and may cause serious injury or damage to property or persons. Only those trained, deemed competent and authorized should be responsible for the inspection of plugs and plug holes and the refitting of washout plugs. Records should be kept of the action taken at each washout and by whom.

12.3 Inspection

An inspection regime for washout plugs shall be developed. This shall provide guidance for inspectors and competent persons.

Defects that plugs and holes shall be examined for include:

- (a) thread condition (e.g., wear, damage, form, cleanliness);
- (b) spanner square condition (e.g., cracked, twisted);
- (c) casting defects;
- (d) cracking of plug body (longitudinal and circumferential);
- (e) condition of hole and threads; and
- (f) deformities.

Wash out plugs should be periodically dye checked for signs of cracking.

12.4 Maintenance plans

The location and number of each plug should be recorded so plugs can be returned to their original position. This may be through markings on the plug and crown sheet, or by a documented record such as a pictorial drawing.

Each plug shall be marked with a reference number to assist in replacing the plug in the correct location.

The plugs shall be stored such that each plug can be returned to the hole whence it came.

12.5 Materials

Washout plug material shall be immune to the effects of corrosion caused by boiler water. Brass and alloys containing significant zinc shall not be used. Washout plugs shall be manufactured from material as per AS 1565:1996, or a suitable, equivalent alloy.

It should be noted that bronze alloys can, with age, become weak due to inter-granular corrosion, giving them a crumbly appearance when broken. If this occurs among a batch of plugs, an engineering assessment shall be made of others within that batch. Defective plugs shall be destroyed.

12.6 Tabulation of standard plug sizes

To accommodate the progressive wear of the threads in boiler plates, washout plugs are manufactured in a range of sizes. The plugs associated with each locomotive boiler need to be ascertained, where possible, from documentation from the original drawings/boiler specifications. Where this is not possible, or the information is unreliable, the thread form and sizes are to be determined by the competent person, who should make the necessary engineering measurements and assessment.

The boiler records and plug diagram (where used) should detail which plug type(s) is (are) currently in use on the boiler. Where the RTO has boilers originating from different operators or plugs shall be clearly identified and recorded to ensure that plugs of incorrect size and thread are not inadvertently inserted into the wrong boiler.

12.7 Thread form

Threads sizes will vary according to design, but usually the threads are of Whitworth form. The pitch of the thread is always measured along the centre line of the plug. There are two methods of cutting the threads on the tapered portion of the plug, either:

- (a) square to the taper of the thread – this allows modern full form threading tips to be used; or
- (b) square to the centre line of the plug – this requires especially ground full form chasers to cut the correct profile thread.

Both methods are acceptable, however it is vitally important that the two thread forms are not mixed up and that both boiler thread and plug are to the same form; only one type should be used on any single boiler.

Washout plug taps can be manufactured to either form. It is important that the boiler records and plug diagram specify which thread form is in use on a boiler and that the plugs and any spares are appropriately marked.

Where, due to a variety of locomotives being used, there are different thread forms, or pitches used, it is vital that processes are in place to ensure that the different plugs are kept separate from each other and that they are clearly identified. Documentation shall be readily available to ensure that only matching plugs and holes go together.

12.8 Thread sealant

Plug threads should be sealed with a lubricating sealant such as graphite and linseed oil as hard-setting sealants or jointing compounds build up over time in the thread forms and is difficult to remove from plug and hole.

The use of PTFE (Teflon) and PTFE tapes shall not be used.

12.9 Removal and cleaning

12.9.1 Period of removal

It is essential to ensure, by way of open valves, that there is no pressure or vacuum in the boiler at the time of plug removal.

A list of plugs to be removed at each and every washout should form part of the boiler records and plug diagram. All plugs shall be removed at the annual examination and overhaul. Should the plugs be too tight to remove easily by hand tools, they may be gently warmed and either allowed to cool out or chilled water used to help break the seal. In these instances, great care should be taken not to overheat the plug.

Under no circumstances is the boiler plate to be heated, as this may create leaks elsewhere. On no account shall the heat be applied to the boiler metal to expand the hole. This could lead to disturbance of adjacent stays or rivets, resulting in leaks.

A plug should not be removed while hot, as this could lead to it breaking off. If a jammed plug is to be scrapped, a large section of the centre may be drilled out prior to heating to make the removal easier. After heating, let the metal cool naturally to room temperature.

Annealing washout plugs to relieve work-hardening caused by fitment and removal may be considered an appropriate maintenance procedure. This could be called for in original documentation, but metallurgical opinion shall be obtained before annealing any washout plugs.

12.9.2 Plug cleaning

Plugs are to be cleaned with a fine, hard wire brush to remove all deposits of sealant and scale to leave a bright surface suitable for inspection. Plugs shall not be cleaned with rotary, power-driven brushes, as this will give rise to rapid wear on the thread crests. Some RTOs have employed a practice of mounting the plugs in a slow-moving lathe and using a hand-held thread chaser. Care is needed to ensure that

the thread form and taper are not deformed over time. Plugs shall be inspected after cleaning to ensure that threads are not damaged.

12.9.3 Hole cleaning

Holes are to be cleaned with small wire brush or tap if necessary. Paraffin or similar solvent used with a brush will leave a surface suitable for inspection.

12.10 Inspection and faults

Washout plugs shall be inspected before and during each steam raising, while the pressure is relatively low. In the event of finding any plugs that are, or appear to have been, leaking, seek guidance from the boiler competent person before proceeding with any further steam raising.

Worn threads gradually result from the removal, cleaning and refitting of washout plugs. Plugs are likely to suffer from pulled threads, ripped or missing threads, wasting in the centre section and twisted squares. Any such defect may render the plug unsafe, make it unfit for purpose and it shall not be used. Some defects, such as damaged threads, may be re-worked if the plug is salvageable. If the RSO has a standardized set of progressive sized reamers and taps, the plug may be re-worked to a standard size by a competent person, and the plug re-identified. The Competent person shall determine, through reference to the design drawings, whether the threads on the plug are to be cut square to the taper or the axis.

The limit of wastage in the centre can be gauged by using a straight edge from end to end of the thread, and the maximum permitted clearance is 0.010", which can be measured using an accurate feeler gauge.

Examination shall be made for pulled (stretched) threads, and this can be determined using a suitable thread- pitch gauge. This shall be specially manufactured to suit the purpose for threads cut square to axis, and should only be three (3) threads long. For threads cut square to the taper, a normal gauge will suffice.

Should a plug not be recoverable as listed above, it shall be destroyed to avoid being reused.

When inspecting holes, sufficient light shall be available to illuminate all the surfaces and, if necessary, a mirror used to inspect parts of the thread not visible directly.

Holes may suffer from ripped or missing threads, corroded threads, cracking in plate and cross threading. There shall be a minimum of four (4) complete consecutive turns of full form thread in the boiler plate without any damage. If because of corrosion or erosion, the localised plate thickness is such that four (4) complete threads are not possible, the hole is to be tapped out.

Should tapping out to the next suitable size not be possible, it may be rebuilt by welding, plate replacement, or bushing as approved by the independent boiler inspector.

Commentary C12.10

A tapered thread cut by a tap will always leave a line where the tap stopped cutting; this can on occasions be mistaken for a crack. If necessary, use the tap to advance the point of cut by a small amount and re-inspect.

Any holes with signs of damage or being tapped cross threaded should be reamed to the correct starting size with the correct tapered reamer, re-tapped on the correct alignment to the next size up, removing all trace of the damage or cross threading. When tapping threads, use a sharp tap in conjunction with a cutting compound, ensure the tap is perpendicular to the plate and advance the tap by up to ¼ turn per cut and back off as required to free swarf. Avoid the end of the tap causing damage to internal components within the boiler, such as pipes and stays.

For threads in new plate, an appropriate taper reamer should be used to prepare the hole to the correct taper prior to tapping to avoid excessive use of the tap.

Tapping holes can be physically difficult when the boiler is on the loco. There is risk that the hole will not be tapped to a true taper if excessive leverage on the tap driver is always from the same direction, as this will have both a twisting torque (which turns the tap) and an overturning moment, which tries to pull the tap off the perpendicular axis to the plate (see Figure 73). The location could preclude altering the position that the leverage is applied. It is recommended that a temporary tap guide be fixed in place to resist the sideways component of the applied force. If it is possible to employ a Tee handle, instead of an L, this overturning tendency is much reduced.

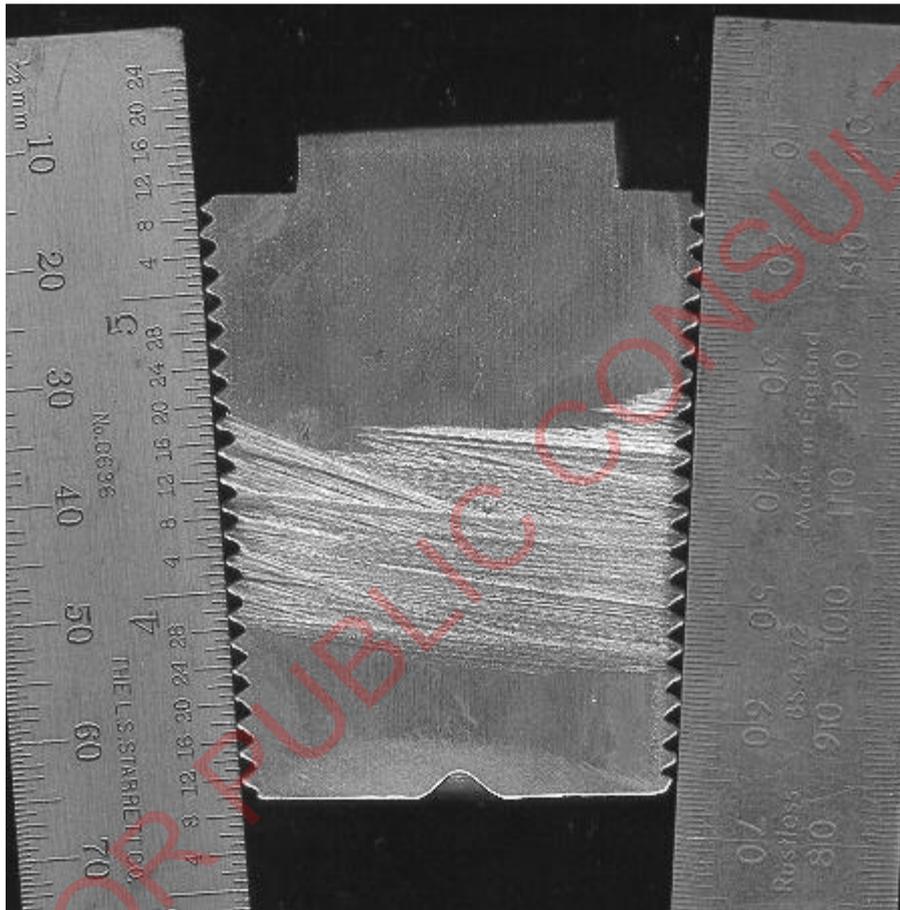


Figure 73 Condemned plug with 45° twist in the drive square

While it is not apparent in the above figure, the main reason for condemning this plug was a 45° twist in the drive square. This is caused by excessive tightening, which in turn generally requires hammering and large levers to remove the plug.

The thread form exhibits some wear about six (6) threads to ten (10) threads from the top. This is a normal wear pattern associated with using the same plug in the same hole. They mate closely to each other and provided the threads are left alone, little problem is had with sealing. The boiler thread should also be inspected, as it is possible that both threads have wearing of the thread crest. If this happens, there is increased risk of the threads failing due to insufficient bearing area.

If the boiler thread has to be re-cut for some reason, a plug with significant concavity may not seal as the thread forms will then be different. It is best to use a new, or thread re-conditioned plug whenever a hole is re-cut.

12.11 Fitting

The plug shall always enter the water space by at least four (4) full threads. Plugs that do not go all the way to the inner side of the hole allow the build-up of scale in the exposed threads, against which a plug may bottom if a subsequent cleaning is not done properly, particularly where a doubling plate may be fitted to the boiler and there are many engaged threads. If necessary, relieve the threads in the doubling plate to avoid the plug bottoming. When fitted, the plug should have at least four (4) full threads clear on the outside of the boiler. The plug should not protrude so far into the boiler that there is a risk of it fouling any internal components.

The boiler records and plug diagram should be consulted during re-fitting to ensure that the correct plug number is always refitted into the correct hole number; this avoids fitting the wrong plug to a hole. Plug threads should be coated with graphite grease or a non-hardening pipe-jointing compound. No hard-setting lubricant or jointing compound, or thread tapes are permitted.

Firstly, insert the plug into the hole and tighten by hand (this means no tools); if cross threading is suspected rock the plug by hand when it is about four (4) turns from tight, if satisfactory it should have the same amount of play in every direction, continue to tighten by hand as far as possible. To fully tighten, use a purpose made square socket which is a good fit on the square of the plug, push the socket hard up against the end of the square to avoid damaging the plug or twisting the square.

When fitting plugs, it is important that it is done as a single operation on each and every individual plug without distraction; the plug is either out in the tray or fitted tight. Do not put all the plugs in hand tight and follow around with the socket, as this may lead to plugs being missed.

For most standard sized plugs, an 18" T-bar on the square socket will give an appropriate torque when operated by hand (approximately 250 Nm (185 ft. lbs.)). Do not over tighten by using an extension on the T bar handle, or by hitting the tool with a hammer.

12.12 Testing

Plugs are to be inspected for leakage when the boiler is refilled, and again during the warming process. They may still be tightened before steam is raised.

Under no circumstances shall an attempt be made to tighten the plug while the boiler is in steam, as plugs have been known to spiral out of the boiler if disturbed under pressure, with potentially fatal consequences. A leaking plug may be made tightened when the boiler is cold and not under pressure. If the leaking cannot be stopped through re-tightening within the parameters above, it will be necessary to drain the boiler, remove the plug, inspect it and the hole, rectify any problems and clean and refit.

12.13 Cap-type washout plugs

Some boilers use a cap-type washout plug where the boiler thread is male and the cap thread is female and blind. Most of the above guidance applies to these, however, in addition it is important to ensure that the face end of the male section is free of deformity, as it shall be able to seat adequately against the sealing material in the cap. Commonly used sealing material is a gasket or a lead melted into the pre-tinned cavity at the end of the female thread that seals in the bottom of the cap. This seal needs to be re-melted each removal to present a new flat sealing surface. Care shall be taken to ensure tinning or lead does not impede the female thread form. It is important with gaskets to ensure that they are of the maximum size possible, as the space below the female thread is enlarged to the thread root diameter, which can allow it to displace to one side.

While inspecting the threads on the nozzle piece, care should be taken to ensure that the area where the nozzle comes through the plate is examined for corrosion, especially where it is surrounded by lagging.

12.14 Plug hole taps

Taps for cutting plug hole thread may be available from various manufacturers. When specifying the tap required the following details are to be provided to the supplier:

- (a) Small end diameter
- (b) TPI along the centreline
- (c) Inclusive angle of thread
- (d) Length of cut (usually 3")
- (e) Number of flutes (usually five (5))
- (f) Pitch tolerance (usually plus or minus 0.001" over one (1) inch)
- (g) Material to be cut
- (h) Thread form
- (i) Taper (making it perfectly clear that the figures given are the total taper)
- (j) Thread, square to centreline (PC) or square to taper (PT)

Commentary C12.14

The tap is to be clearly identified with the details marked.

All these dimensions are to be determined from the original boiler drawings or design. Where this is not possible, or the information is unreliable, the thread form and sizes are to be determined by a person competent to make the necessary engineering measurements and assessment.

A tap list is provided at Figure 74, with drawing provided at Figure 75.

12.15 Record keeping

All washout plugs, and hole inspections shall be recorded in a specific written record and maintained in the boiler history file (see Appendix B). Details of the locomotive, competent person and date shall be included.

Fitting of washout plugs may be recorded in a specified written record and maintained in the boiler history file (see Appendix C). Details of the locomotive, competent person/s and date shall be included.

See Figure 76 for a sample of a wash plug map and inspection sheet

WEIGHT		WHERE USED		No. REQD.	
ESTIMATED		See Sheet 1.			
ACTUAL					

A Dia.	B Dia.	C Dia.	D Square	E Flutes	F Core Dia.	G Angle	R Radius	Tool No.
1 1/2"	1 1/2"	1 1/2"	1"	5	.500"	20°	1/2"	
1 3/4"	1 3/4"	1 3/4"	1"	5	.562"	20°	1/2"	
1 7/8"	1 7/8"	1 7/8"	1"	5	.625"	17°	1/2"	
2"	2"	2"	1"	5	.750"	18°	1/2"	
2 1/8"	2 1/8"	2 1/8"	1"	5	.875"	17°	1/2"	
2 1/4"	2 1/4"	2 1/4"	1"	5	.907"	16°	1/2"	
2 1/2"	2 1/2"	2 1/2"	1"	5	.968"	18°	1/2"	
2 3/4"	2 3/4"	2 3/4"	1"	5	1.093"	17°	1/2"	
2 7/8"	2 7/8"	2 7/8"	1"	5	1.150"	16°	1/2"	
3"	3"	3"	1"	5	1.153"	15°	1/2"	
3 1/8"	3 1/8"	3 1/8"	1"	5	1.332"	16°	1/2"	
3 1/4"	3 1/4"	3 1/4"	1"	5	1.383"	16°	1/2"	

TAPER TAPS (TABLE & TOOL NOS.)		SCALE	S.A. RAILWAY WORKSHOPS MELBOURNE, SOUTH AUSTRALIA
FOR WASHOUT & FUSIBLE PLUGS		DRAWN M.G.W.	
MATERIAL AND SPECIFICATION See Sheet 1.		CHECKED K.K.K.	PRODUCTION CHIEF CRAFTSMAN
ALTERNATION		TOOL NO.	5-DT-5 Sheet 2 of 2
ASSEMBLY DRG. No.		REFERENCE See Sheet 1.	CHIEF MECHANICAL ENGINEER

Figure 74 Tap chart

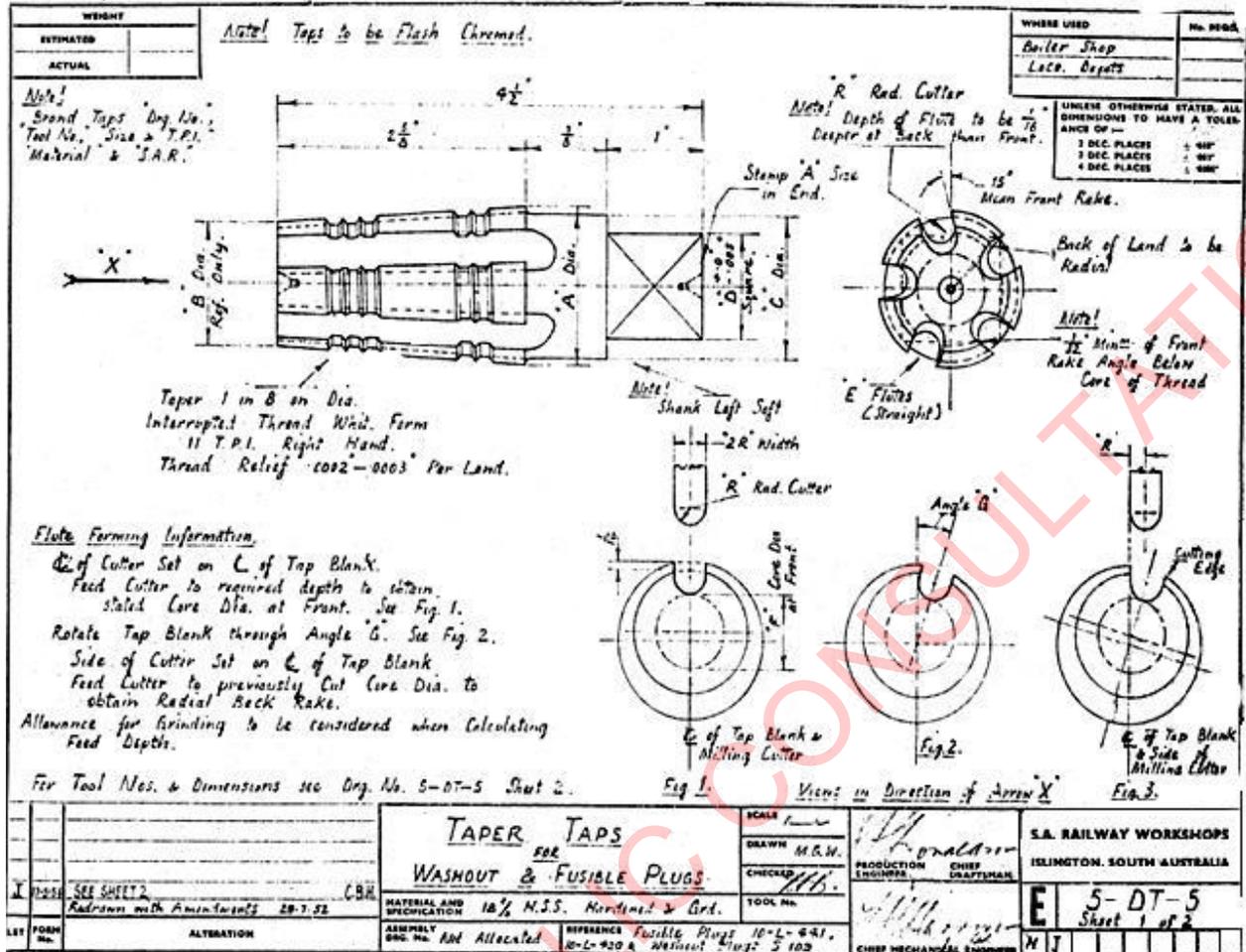


Figure 75 Taper taps for washout and fusible plugs

THE RAILWAY PRESERVATION SOCIETY INC
LOCOMOTIVE DEPARTMENT - STANDARD PROCEDURE No XX

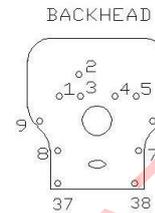
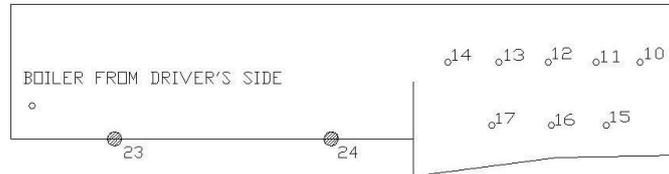
RETURN THE FORM TO THE LOCO OFFICE SHEET TRAY WHEN
ALL OF THE PLUGS IN THE ENGINE HAVE BEEN COMPLETED
STAPLE ALL SHEETS RELATING TO ONE ENGINE TOGETHER

WASHOUT PLUG REMOVAL AND INSPECTION FORM P1 of 2
T CLASS LOCOMOTIVES

Loco No

5/2/98 DRAFT

- = WASHOUT PLUGS FIREMAN'S SIDE
- ◐ = WASHOUT PLUGS ON BOILER CENTRE
- ◑ = WASHOUT PLUGS ON DRIVER'S SIDE



PLUGS REMOVED BY;	SIGN
PLUGS INSPECTED BY;	SIGN

		PLUG NUMBER																												
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	
INSPECTION PRIOR TO REMOVAL	LEAKAGE PAST THREAD																													
EASE OF REMOVAL	VERY HARD																													
	HARD																													
	FIRM																													
	EASY (LOOSE)																													
PLUG INSPECTION AFTER REMOVAL																														
PLUG BODY	CRACKED																													
	DISTORTED																													
	WASTED																													
THREADS	DRIVE SQUARE TWISTED																													
	CRACKS																													
	NICKS/BRUISES																													
	WASTED																													
	ROUNDED FORM																													
	REDUCED THREAD																													
PLUG FUTURE; REUSE 'OK', SCRAP 'S', RECONDITION 'R'																														
THREAD IN BOILER	CLEANED WITH TAP																													
	No. OF FULL THREADS																													
THREAD CONDITION	ROUNDED FORM																													
	REDUCED DEPTH																													
	NICKS/BRUISES																													
	WASTED																													

Figure 76 Samples of washout plug map and inspection sheet

Section 13 Boiler mountings

13.1 General

This section provides guidance on the inspection and repair of boiler mountings.

This section shall be adhered to unless it can be proven that another process or material is equal to or better than the practices and materials laid down in this document.

The phrase boiler mountings generally refers to the valves and fittings that assist in the safe operation of the boiler and should be included in the boiler maintenance plan.

13.2 Materials

Materials used in valves or cocks shall comply with AS 1210:2010

13.3 New valves

All new valves and cocks shall comply with AS 1271:2003. All valves and cocks used on and in conjunction with steam locomotive boilers shall be suitable for their intended uses.

13.4 Repair of valve bodies

Guidance to the repair of some valve bodies can be found in AS 3788

13.5 Inspection and testing of valves and fittings

All valves and fittings attached to the boiler shall be inspected at the annual internal inspection as set out in Section 3.

Removal of valves and fittings from the boiler for detailed inspection, for example, the passages in the boiler and attachment studs, shall be done periodically in accordance with the inspection plan but it is recommended that all valves and fittings are removed from the boiler at the full internal inspection (nominally every ten (10) years).

Valves and fittings removed from a boiler at any time shall be visually inspected for defects and damage. Any valve or fitting removed from a boiler because of a defect identified when in-service shall be tagged as defective noting also the nature of the defect(s). Defective valves and fittings shall be repaired before use on any boiler.

Valves and fittings that are to be restored after an extended period out of use, or when the condition of the item is unknown, shall be dismantled, thoroughly cleaned and subjected to a detailed inspection before reassembly and use on a boiler.

A detailed inspection of a valve or fitting consists of the following;

- (a) A detailed visual inspection of all surfaces.
- (b) All threads inspected for wear, cracking and other defects.
- (c) Gasket surfaces inspected for appropriate surface condition.
- (d) All passages clear and of the correct size.
- (e) Inspection for any loss of metal due to corrosion or erosion.

Valves and fittings being restored should be subjected to dye penetrant NDE of all surfaces to check for cracking and other degradation such as dezincification. This may be difficult where the surface finish is poor due to the manufacturing technique and the results difficult to interpret.

All defects shall be rectified.

All restored valves and fittings shall be hydrostatically tested before use on any boiler in steam. This may be achieved by testing the valves on an assembled boiler being hydrostatically tested at a pressure above the design pressure, for example, 125%. Otherwise, the item shall be separately hydrostatically tested at 150% of the design pressure of the boiler it is intended for.

13.6 Valve seats

Ball valves: Almost all the internal parts in ball valves are replaceable with commercially available valve repair kits.

Flat-faced valves: The seats of flat-faced valves should be maintained to the tolerances as stated in the drawing, where drawings do not exist, not greater than 3 mm ($\frac{1}{8}$ ").

Angled seated valves: The seats of angled seated valves should be maintained to the tolerances as stated in the drawing, or, where drawings do not exist, not greater than 3 mm ($\frac{1}{8}$ ").

As seats wear greater than 3 mm ($\frac{1}{8}$ "), their ability to maintain steam- and water-tightness diminishes.

13.7 Flange mounted valves and stands

The neck between the flange and the body of the mounting or valve should be NDE tested for fatigue cracking. Whilst flange-mounted valves are removed from the boiler, the mounting studs shall be examined for necking, thread wear and stretching and other potential fatigue failures.

13.8 Screwed valves

Refers to valves that are screwed into part of a boiler. The neck of a screwed valve shall be NDE tested for fatigue cracking. A screw thread-type valve shall have a minimum of four (4) full threads of engagement (no chipped or broken threads); where this cannot be achieved the valve shall be replaced, the screwed opening in the boiler shall be inspected for thread damage.

13.9 Valve bonnets

Cast iron valve bonnets shall be held by studs. Screwed valve bonnets shall be held by a minimum of four (4) full threads of engagement.

New screwed bonnet valves are fitted with a grub set screw (of similar metal to the valve) to prevent the valve from being accidentally unwound while opening the valve.

Wherever possible, older style valves should be similarly fitted to prevent a similar accident. When removing a valve bonnet, it is essential that the valve be released from its seat first. Because of the different pitch of bonnet and stem threads, failure to do this can result in serious jamming of the valve on the seat, and damage to the stem thread.

13.10 Valve types

13.10.1 Clack valves

Clack valves, also known as retention valves, non-return valves or back pressure valves, are used to stop the reversal of flow and are generally fitted in conjunction with stop valves (or are a combination clack/stop valve in the one body). They are commonly found in back plate injectors and top feed clack boxes. Some examples are provided in Figure 77.

They may have conical seating's and straight wings (guide), or flat seating and curved wings (guide).



Figure 77 Angle seat straight winged non-return valve and flat faced non-return valve

The usual lift is between 4.5 mm and 6 mm (3/16" to 1/4") but should not be greater than 10 mm (3/8") and the clearance of the wings (guides) should not be greater than 0.25 mm to 0.38 mm (0.010" to 0.015").

13.10.2 Blowdown valves

Blowdown valves shall be of robust construction to allow for the handling of liquids containing scale and sediment.

Blowdown valves shall be clearly marked to show their open and closed position.

Modern replacement blowdown valves for locomotive boilers have a key handle that cannot be removed whilst the valve is open.

These valves often have Teflon seats, which have temperature/pressure limits. The valve ratings shall be checked against the anticipated working pressure and temperature.

The neck (i.e. the part of the blowdown valve between the flange and the valve body proper) should be NDE tested for cracking defects.

Examples of blow down values are provided in Figure 78 and Figure 79. A typical plug cock for blow down valve in provided in Figure 80.

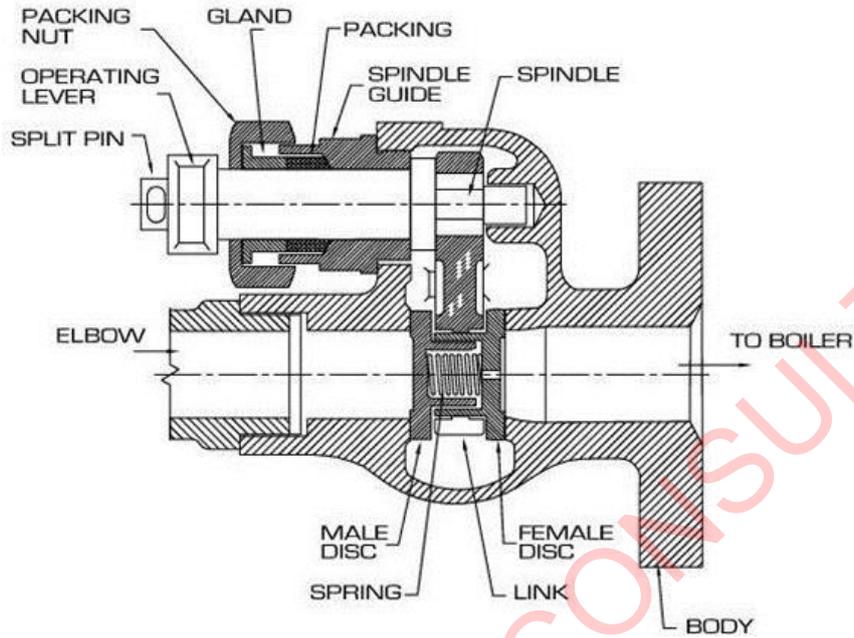


Figure 78 Hopkinson blowdown valve

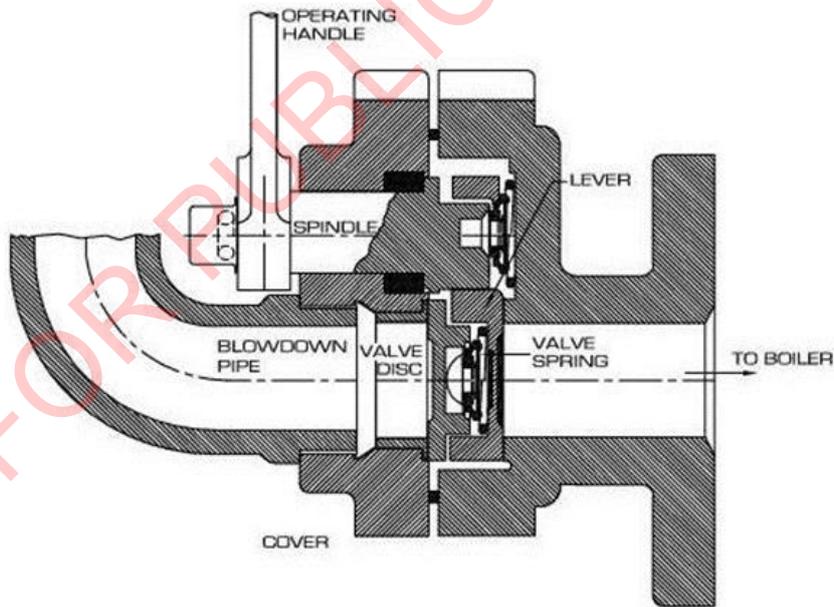


Figure 79 Everlasting blowdown valve

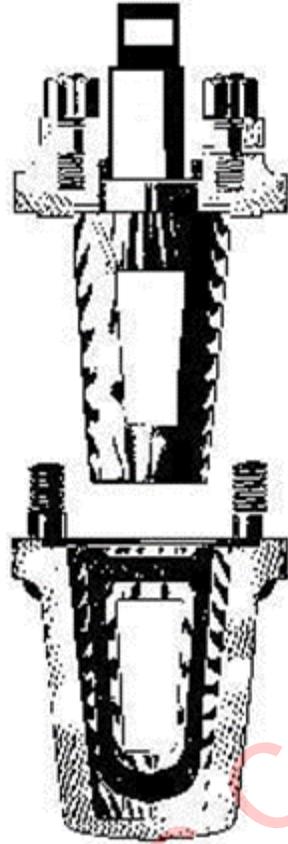


Figure 80 Typical plug cock for blow down valve

13.10.3 Manifold valves

Manifold valves, also known as turret valves or main steam stop valves, are generally of the screw-down, screw-lift type where the valve stem and the inside of the bonnet are threaded.

Generally, screwing clockwise closes the valve, while screwing anticlockwise lifts (opens) the valve from its seat; there are, however, exceptions where the opposite is true. Appropriate drawings should be consulted to determine which way the screw thread should open and close.

Manifold valves and seats are generally arranged at 45°, although there are exceptions where the seats are radiused.

The seats should be maintained to the tolerances as per drawing or, where drawings do not exist, not greater than 3 mm ($\frac{1}{8}$ "); as seats wear greater than 3 mm, their ability to maintain steam- and water-tightness diminishes.

All parts of a manifold valve should be NDE tested for fatigue and cracking failures, and the condition of threaded parts noted

13.10.4 Linear action valves

Some examples of linear action valves include whistle valves and some types of injector starting valves. One is shown in Figure 81.

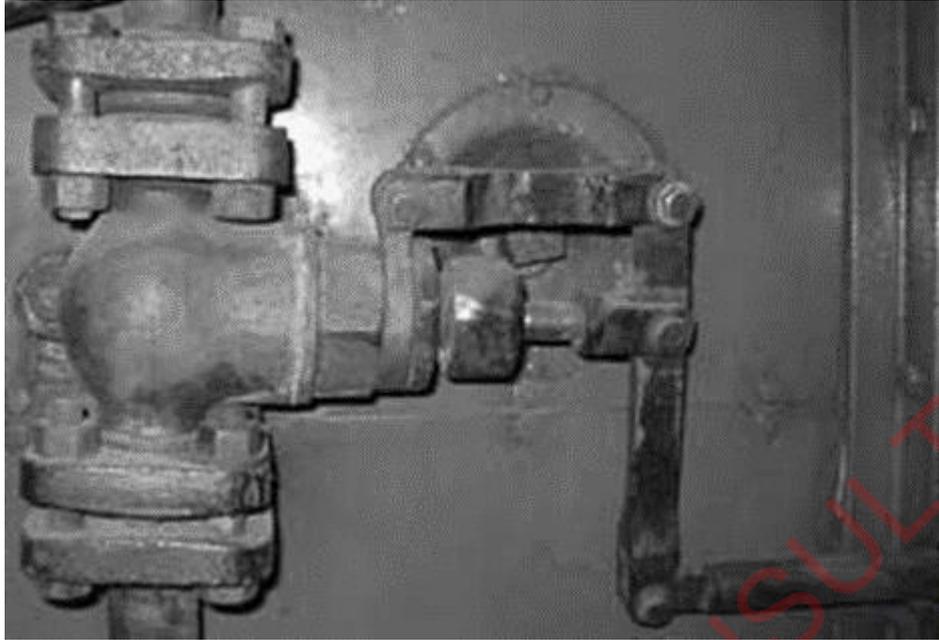


Figure 81 Linear action valve

These valves are stop valves and are described as linear action because the valve stem is not threaded into the valve bonnet, but slides parallel within the bonnet, opening and closing the valve on or off its seat.

Linear action valves should be NDE tested around the mounting bolt holes, the lever action pivot assembly and the bonnet, and the condition of threaded parts noted.

13.10.5 Mushroom valves

Mushroom valves are generally used in snifting or drifting valves. These valves, where fitted in superheater headers, should be checked at each annual inspection for fatigue and cracking around the mushroom shoulder. A typical mushroom valve is shown in Figure 82.

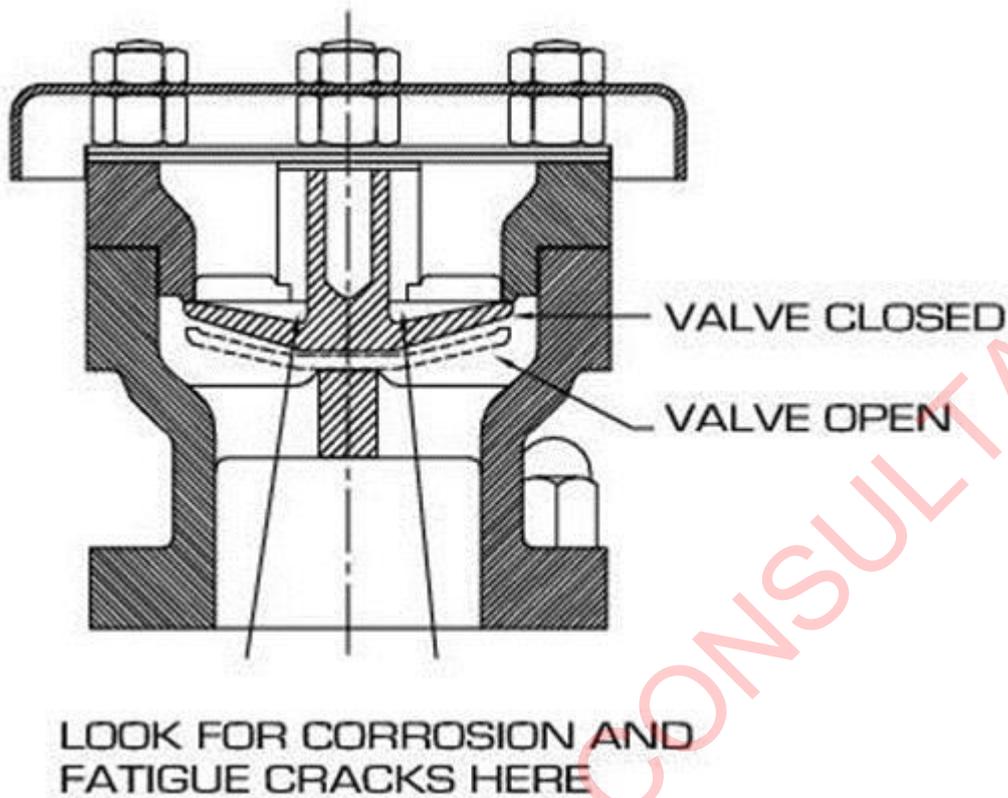


Figure 82 Mushroom valve

13.10.6 Ball valves

A ball valve (Figure 83) is a quarter-turn valve that opens by turning a handle attached to a ball inside the valve.

The ball has a hole, or port, through the middle so that when the port is in line with both ends of the valve, flow will occur.

When the valve is closed, the hole is perpendicular to the ends of the valve and flow is blocked. The handle or lever is typically in line with the port position, and the spindle should be marked to show the port position.

These valves often have Teflon seats, which have temperature/pressure limits and the valve ratings shall be checked against the anticipated working pressure and temperature.

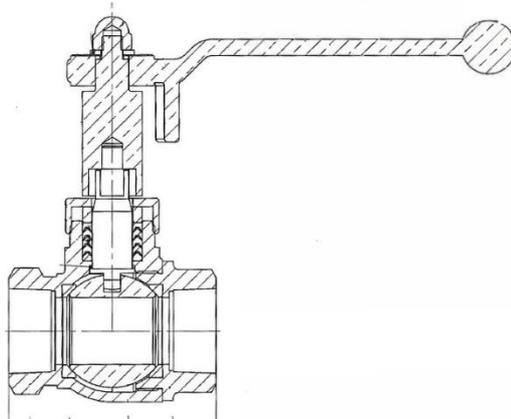


Figure 83 Ball valve

13.10.7 Other types of valves:

13.10.7.1 Globe valves

A globe valve consists of a movable plug or disc element and a stationary ring seat in a generally spherical body.

The globe valve has two halves of the body being separated by an internal baffle, incorporates a seat onto which a movable plug can be screwed in to close (or shut) the valve. The plug is also known as a disc. The plug is connected to a stem which is operated by screw action using a handwheel.

Due to their inherent design, globe valves have a wide control range and can be used both for isolation purposes (on/off) as well as for throttling flow and flow regulation.

13.10.7.2 Gate valves

A gate valve is a valve that opens by lifting a barrier (gate) out of the path of the fluid. Gate valves require very little space along the pipe axis and hardly restrict the flow of fluid when the gate is fully opened. The gate faces can be parallel but are most commonly wedge-shaped (in order to be able to apply pressure on the sealing surface). Gate valves are generally used with larger pipe diameters (over 50 mm).

Gate valves are only suitable for isolation purposes (on/off) as gate valves left partially open are susceptible to mechanical damage.

13.10.7.3 Needle valves

A needle valve is a type of valve with a small port and a threaded, needle-shaped plunger. It allows precise regulation of flow, although it is generally only capable of relatively low flow rates.

Needle valves are usually used when a constant, calibrated, low flow rate must be maintained for a period of time.

13.10.8 Plug cocks

Plug cocks are valves that have cylindrical or conically tapered plugs that can be rotated inside the valve body to control flow through the valve. These plugs have one or more hollow passageways going sideways through the plug to allow fluid to flow through when the valve is open.

These valves should have an indication mark on the top of the stem to indicate the port position. In some cases, these valves have tee-type (three-way) porting enabling multi-directional flow control. It is essential that these have port position indication.

These valves may perform several functions i.e. isolating (stop valves) for lubricators, pressure gauges, turbo generators, test cocks and some types of blowdown valves. They could also be found as isolating (stop valves) for water injectors.

An example plug cock valve is shown in Figure 84.

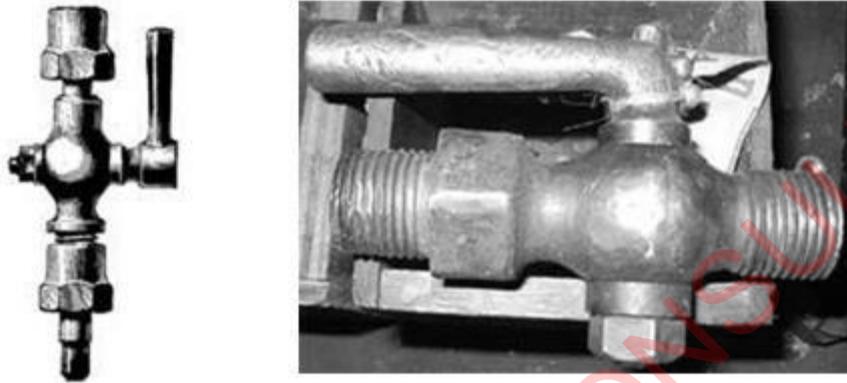


Figure 84 Plug cock valves

13.10.9 Sleeve-packed plug cock

The principle of the sleeve-packed plug cock is that the packing consists of a renewable sleeve of that is inserted in the body as a single unit (as shown in the diagram). A ridge on one side of the sleeve fits into a corresponding groove in the body and ensures that the ports are always in line. An example is provided in Figure 85. An example sleeve is shown in Figure 86.

The plug is parallel and is ground to size, so that there is no risk of the cock jamming when it is tightened up.

Eyelets recessed in the sleeve prevent the packing from squeezing into the ports when tightening up and at the same time prevent the passing fluid from cutting the packing. These eyelets are conical in section, so that when the bottom tightening nut is followed up, the tendency is to squeeze the fibre packing more tightly around the plug, and at the same time the eyelet is pushed towards the cock body, so that there is no risk of it scoring the plug.

In some jurisdictions, the gauge glass cocks are similar, for example the WAGR W class, which use a crumbled-up packing material. Care shall be taken to ensure that the ports are in line.

Some packing shall be inserted into the hole before the plug is inserted so that packing is not squeezed into the ports when tightening up. The rest of the packing is then tamped into place and compressed with a sleeve nut.

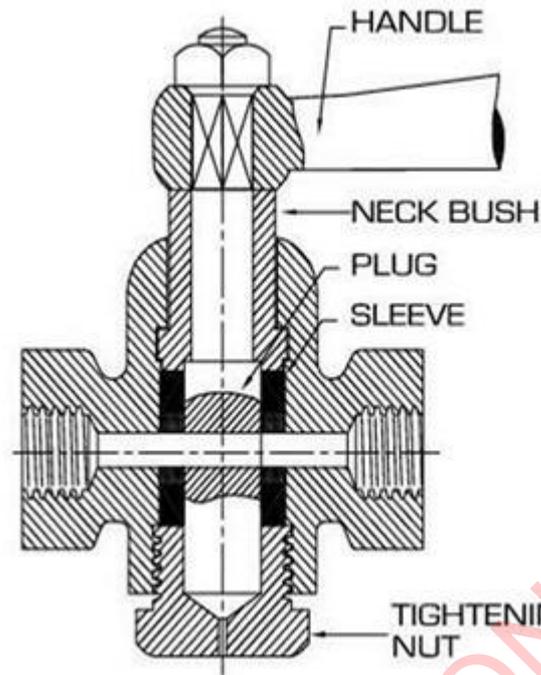


Figure 85 Sleeved packed valve with push in type neck bush

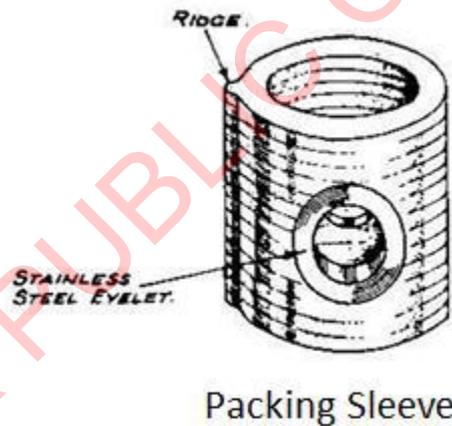


Figure 86 Packing sleeve

To effect a repair:

- (a) remove lower tightening nut;
- (b) tap spindle from the top, through the neck bush and packing and remove same;
- (c) remove packing by tapping neck bush, with suitable soft dolly;
- (d) replace neck bush;
- (e) fit new packing sleeve by tapping home with a soft, stepped dolly, making sure the ridge lines up with the slot in the cock, also noting the eyelets are correctly seated;
- (f) replace spindle and lower tightening nut and ensure passage is clear; and
- (g) when pressure is placed on cock, follow up on the lower tightening nut.

13.11 Packing of valve glands

Most older style valves seal the operating shaft of the valve with packing located in a stuffing box (see Figure 87). This packing material is typically fibreglass type cord/rope.

To pack a gland satisfactorily, the packing shall be properly compressed in the stuffing box so that it offers a smooth cylindrical surface pressing evenly on the spindle throughout the whole depth of the stuffing box.

Each ring shall be compressed in place separately, ensuring that the joints are staggered. It is not acceptable to insert a coil of packing material – it shall be cut into rings.

When a fully packed gland is followed up, the outer ring is compressed most and the inner ring not at all, so that the pressure of the packing on the spindle is greater on the outer end of the gland, although the fluid and gas pressure is in the opposite direction and on the inside ring. In the case of a revolving spindle this can cause grooving.

The spindle and gland should be as mechanically perfect as possible. The spindle shall be kept clean and true, the stuffing box shall be smooth. Where possible, always remove the bridge and gland, and follow each turn home separately with a hollow distance piece that fits the spindle and stuffing box. Where this is not possible, the distance piece may be fabricated in halves.

The gland and neck bush should be a reasonable fit on the spindle, with a clearance of not more than 0.8 mm (1/32") on the diameter. The gland should be 0.8 mm (1/32") clear on the outside diameter from the stuffing box.

Square-section, plaited packing is preferable to round. When using plaited packing, cut each ring carefully and fit it to the spindle.

Pay attention that it is not too long.

Scarf the joints at a 45° angle to the axis with no butt clearance.

Press home each ring in succession firmly, particularly the innermost ring. Stagger the butts at 120°.

When the box is full, pull up gland evenly finger tight. Test gland for clearance all around the shaft, and for squareness with the box. Follow up when in use.

For glands with rotary spindles slacken back the gland and again nip it up. Again test gland for clearance.

Flexible packing extractors are the best tools to use for withdrawing old packing if the shaft or spindle cannot be first moved. If possible, it is better to take the trouble to remove the spindle before removing the packing to ensure that the spindle does not get scratched or damaged. This applies particularly to high pressure superheated steam.

The spindle should be parallel as possible to the gland with minimal clearance.

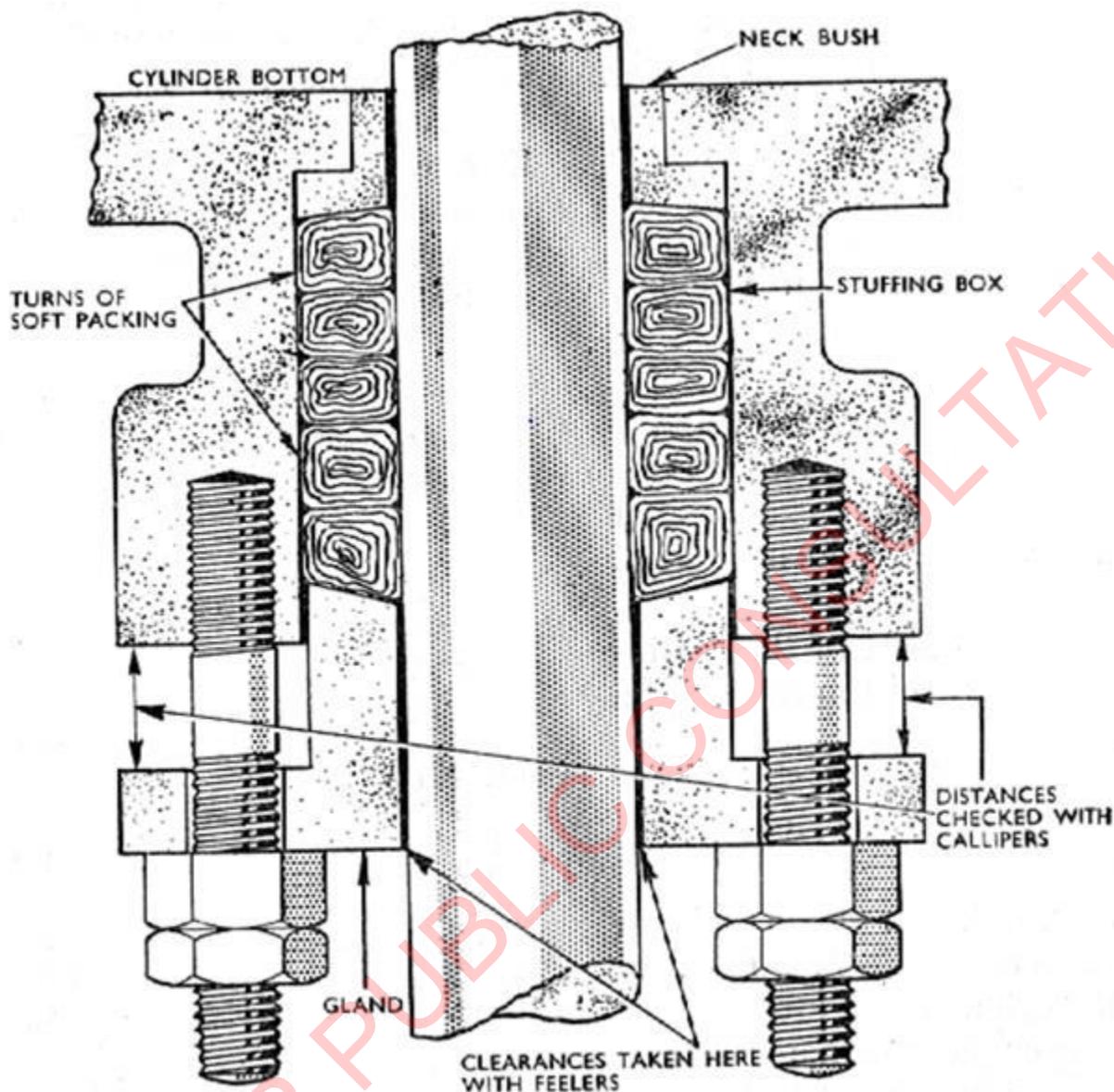


Figure 87 Soft packing gland

Section 14 Storage

14.1 General

This section shall serve as the guide on the storage of steam locomotive boilers and shall be adhered to unless it can be proven that another is equal to or better than the practices and materials laid down in this document.

14.2 Introduction

Waterside corrosion can progress rapidly while a boiler is in long term storage and the RSO shall put a procedure in place to mitigate corrosion. Each RSO shall set out a procedure for each method of storage and a guideline for when each method shall be used. The choice of storage method depends on the length of down-time expected.

For the purposes of this section long term storage is longer than one month.

An assessment should be carried out on boilers after long term storage prior to placing the boiler back into service. The level of assessment will depend on the term of storage and the risks associated with potential degradation of the boiler.

For boilers short-term stored (i.e. less than one (1) month), an operational inspection as per Clause 3.3.3 should be conducted prior to operating the boiler.

14.3 Storage methods

The methods for preparing a boiler for storage depend upon several factors, including:

- (a) the anticipated length of time the boiler will be stored;
- (b) whether storage will be indoors or outdoors;
- (c) anticipated weather conditions during the storage period;
- (d) the availability of climate-controlled storage;
- (e) type of fuel used; and
- (f) equipment available at the storage site.

Indoor storage can be categorised into two types: indoor with climate control and indoor without climate control.

Outdoor storage can also be categorized into two types: outdoors during a warm time of year or in a geographic location where it can reasonably be expected to be above freezing during storage, and outdoors during a time period or in a geographic location where it can be expected that freezing temperatures will occur during storage.

Locomotive boilers may be stored using the wet method or the dry method.

Before any method of storage, the boiler shall be thoroughly washed out to remove mud and scale, with attention paid to the foundation ring, crown sheet, bottom of the barrel, arch tubes, thermic siphons, combustion chamber and the top of the fire hole ring (see Appendix D). The smokebox, firebox and ashpan shall be thoroughly cleaned, paying attention to any point where residual material may have accumulated, such as behind the grate supports, at the front tube sheet rivet line and in the combustion chamber. Consideration should be given to the removal of the brick arch if long-term storage is envisaged, as the brick arch material can attract and trap moisture.

14.4 Wet storage method

NOTE:

This method cannot be used if there is any likelihood that the boiler water could freeze during cold periods.

Any wet storage method shall be developed in consultation with the boiler water treatment supplier or other specialist consultant. Some boiler water treatments are not designed for cold water storage and it is recommended that the boiler water treatment specialist be consulted before choosing a treatment for this purpose.

Wet storage is not generally suitable for storage beyond two (2) months, as it is difficult to maintain the correct levels of treatment to reduce oxygen levels in the water,

The boiler shall be filled with treated water to the highest point, ensuring that any air has been purged. This minimizes corrosion caused by trapped oxygen.

In order to maintain this water level against small leaks, a header tank filled with treated water will ensure that the boiler remains fully flooded and provides an easy method of monitoring leakage.

Regular water samples shall be taken to monitor the boiler water condition and adjustments shall be made to the treatment levels as specified by the water treatment specialist

14.5 Dry storage methods

The primary objective of dry storage is to reduce the amount of moisture in the boiler to the absolute minimum achievable, as air that comes into contact with moisture sets up an extremely corrosive environment.

While boilers internal and external surfaces remain dry, significant corrosion is unlikely to occur. The temperature of the boiler surfaces shall not drop below dew point at any time while the boiler is in dry storage. The dew point will vary due to seasonal changes and geographical location, and this should be taken into consideration when designing a dry storage program.

In order to dry store a boiler, it shall be completely emptied of water, dried out and allowed to stand empty.

Consideration may be given to the use of a suitable, portable heater placed in the firebox to help with the drying process. Care should be taken to ensure that the heater used does not produce moisture during its combustion processes, such as with wood or gas fires.

Care shall be exercised when using a heater to dry the boiler that the temperature within the firebox does not rise to a point that may induce damage to the boiler structure.

Several variations of the dry method may be used including:

- (a) closed storage with moisture-absorbent materials placed inside the boiler;
- (b) filling the boiler with plain water just above the crown sheet, lighting a small timber fire and bringing the water up to 60°C, then dropping the fire and water through the plugs whilst hot. The residual heat can then dry out the boiler. Small fans may be used to keep the boiler dry by drawing air through the plug holes and out the dome;
- (c) open storage with sufficient openings to enable air circulation, but ensuring no water or foreign matter can enter any of the openings of the boiler;
- (d) partially open storage using heated, dehumidified air circulated through the boiler to establish a stable atmosphere within the confines of the boiler.

Each method of dry storage has advantages and disadvantages depending on variable factors including the length of dry storage required, the facilities available and the available financial resources. The storage procedure shall include a suitable method of removal of any material introduced during the storage process from the water space before the boiler is returned to service.

Oil shall not be applied to water-side surfaces in an attempt to preserve the interior surfaces. Regular monitoring of the condition of a dry-stored boiler shall be conducted.

14.6 External surfaces

External boiler surfaces will corrode significantly should the boiler be stored with wet lagging, or water allowed to enter the lagging and cladding during storage periods. The boiler shall be inspected for wet lagging at points of entry and where any leaks have been reported or observed. All wet lagging shall be removed, and the boiler surface suitably treated. For guidance on the occurrence and prevention of external corrosion, see Section 7.

14.7 Fireside surfaces of firebox plates

Fireside surfaces of firebox plates need to be protected during long-term storage from the effects of corrosion from two aspects:

- (a) Corrosion from ash – Generally found around the lower part of the firebox plates and is especially damaging to the foundation ring rivet heads. To protect these parts, firebars, support brackets and castings that rest alongside the firebox plates should be dismantled, after which the lower areas should be thoroughly cleaned of ash or other products of combustion, needle-gunned and painted.
- (b) Brick arch – Should be removed from the firebox to expose the surfaces where the fire bricks may rest (firebox plate, thermic siphons or arch tubes) in order that moisture does not collect behind these surfaces.

Regular monitoring of the external surfaces of any stored boiler (whether wet or dry stored) shall be conducted and any issues shall be addressed as part of the ongoing maintenance procedure.

14.8 Storage of superheater elements

Superheater elements and headers present particular storage challenges due to their design. Two methods of storage are available: flooded and dry.

Flooded storage may be applied regardless of the storage method chosen for the boiler (i.e. a dry-stored boiler may have wet-stored superheater elements). It requires the elements to be filled with a suitable preservative, and a suitable means to fill and drain the elements. The type and quantity of the preservative used should be determined in consultation with a suitably qualified water treatment specialist.

Dry storage of elements requires that each element is individually removed, dried out and treated with a desiccant.

14.9 Desiccants

Desiccants are drying agents that can be placed in accessible areas to absorb water vapour and thus control relative humidity. They are not commonly used due to the difficulty in maintaining and removing them.

Common desiccants are silica gel, activated alumina and quick lime (e.g., Limil). Material data safety sheets should be obtained for any chemical or desiccant used.

Indicative volumes of desiccants are as follows:

- (a) Quick lime used at a rate of 1 Kg to 1 cubic metres of volume.
- (b) Silica gel used at a rate of 1.3 Kg to 1 cubic metres of volume
- (c) Activated alumina used at a rate of 1.3 Kg to 1 cubic metres of volume

Trays of desiccants may be placed in areas large enough to accept them (i.e. smokebox, firebox, steam dome).

If desiccants are used care needs to be taken to remove all traces of desiccants prior to filling the boiler with water to prevent corrosion.

In long-term dry storage, desiccants shall be monitored. They could require drying out or replacement, the regularity of this will depend on environmental and geographic factors.

Nitrogen blanketing is another form of dry storage, however this requires special equipment and management. A full risk assessment shall be conducted and risk mitigation measures put in place prior to using nitrogen blanketing.

14.10 Outdoor storage

If the locomotive is stored outdoors, the following should be completed:

- (a) Inspect the boiler cladding and confirm it is tight with no gaps leading into the lagging or shell. Pay close attention to areas at shell openings such as for studs, safety valves etc.
- (b) Repair all gaps or damaged cladding sections as necessary. Consideration should be given to covering the entire locomotive and tender with a tarp. Otherwise, all jacket openings should be covered to prevent the entrance of rain or snow. Where necessary, apply a waterproof covering over the exposed or open sections.
- (c) The chimney sealed.
- (d) The safety valves either covered or removed and blanked.
- (e) The smoke box door sealed by applying a gasket or sealant and any other air openings in the smoke box sealed.

Heavy oil, unrefined oil or used motor oil shall not be used for preservation of any components because the sulphur and other contaminants contained in it can accelerate corrosion.

14.11 Return to service

When a stored boiler is to be returned to service a thorough inspection of the boiler shall be conducted in accordance with AS 3788:2024, Clause 9.6 and as recommended by this document.

When returning a boiler to service, the boiler and firebox shall be ventilated to remove potentially hazardous atmosphere (including the storage gases, if used) and any desiccants removed from the boiler interior before personnel enter.

14.12 Records

The type and method of storage used, and the length of storage shall be recorded in the boiler history file (see Appendix C), along with boiler monitoring results and any issues addressed during the storage period.

Section 15 Pressure Gauges

15.1 General

This section shall serve as the guide the use and maintenance of pressure gauges and shall be adhered to unless it can be proven that another process or material is equal to or better than the practices and materials laid down in this document.

15.2 Introduction

Pressure gauges for steam locomotive boilers operate on the Bourdon principle.

A Bourdon gauge uses a coiled tube, which, as it expands due to pressure increase, causes a rotation of an arm connected to the tube. As the gauge pressure increases, the tube will tend to uncoil, while a reduced gauge pressure allows the coil to return to its normal position. This motion is transferred through a linkage to a gear train connected to an indicating needle. The needle is presented in front of a card face inscribed with the pressure indications associated with needle deflections.

These are generally reliable and require only a siphon tube before the pressure gauge to operate correctly.

15.3 Application

At least one pressure gauge shall be fitted to each boiler.

Gauges shall comply with AS 1349:1986 (i.e. bourdon tube pressure and vacuum gauges, see Figure 88) or other standards as agreed by the parties concerned.

As an alternative, digital-type pressure gauges may be used provided they have clear readability, reliability and accuracy equivalent to AS 1349

Gauges shall have a unique identifier and records shall be kept.

15.4 Terminology

15.4.1 Pressure gauge

An instrument giving a visual indication, by means of a pointer relative to a scale, of the amount by which the pressure of a fluid applied to it exceeds the pressure of the surrounding atmosphere.

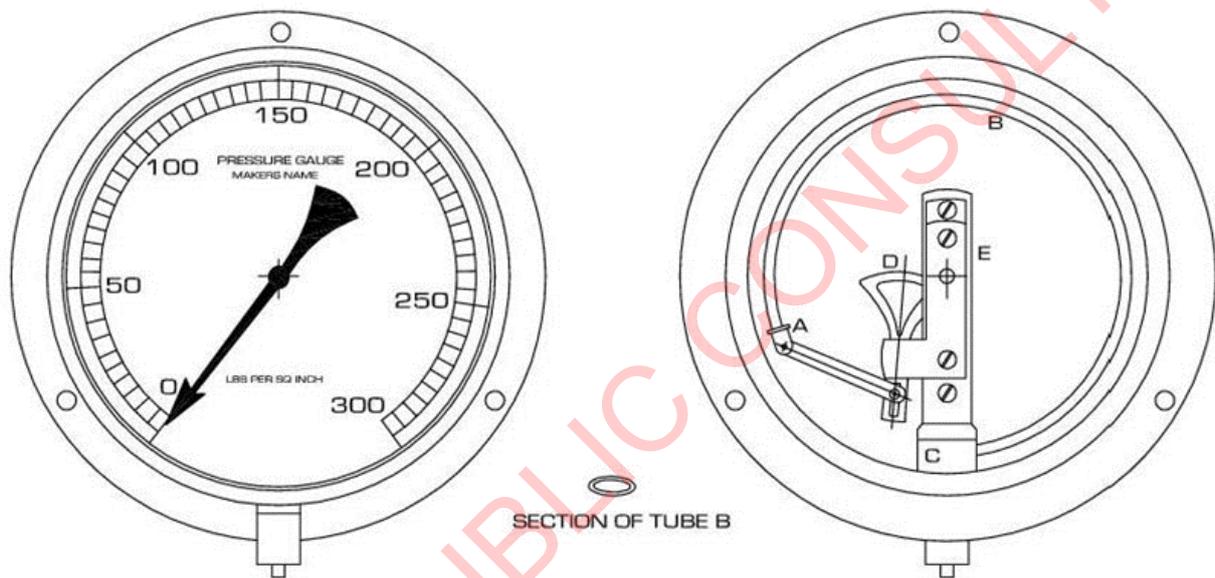


Figure 88 Bourdon type pressure gauge

Legend: A: Tube End Plug; B: Curved Spring Tube C: Hollow Casting; D: Toothed Quadrant; E: Pinion

15.4.2 Test gauge (master gauge)

A gauge of which the accuracy is such that the gauge is suitable for calibrating service gauges and intended primarily for this purpose. Only gauges that have been tested by a NATA- accredited organization shall be used for calibration and testing purposes. A log shall be kept of the usage of the test gauge so that calibration intervals may be set appropriately. A test gauge used for testing a service gauge shall have a maximum scale value of not more than 1.5 times the pressure of the service gauge (as per AS 1349:1986).

15.4.3 Service gauge

A service gauge is that which is used on the boiler for day-to-day operation. All service pressure gauges shall have a red line painted on them to indicate the registered working pressure.

15.5 Timing of testing

Each service pressure gauge shall be checked regularly for accuracy at each annual inspection or at any time that the gauge operation appears to be suspect. The RTO shall appoint a competent person to test service gauges against the NATA-calibrated test gauge. If there is any variation larger than +/- 3%

between the indication on the test gauge and the service gauge, the service gauge shall be sent to a NATA- approved organisation for repair and recalibration. The results shall be recorded in the boiler history file and all reports filed in the boiler history file.

All test gauges (master gauges) shall be calibrated every two (2) years by a NATA-approved organization.

15.6 Siphon pipes

The gauge shall have a siphon of ample capacity to prevent steam from entering the gauge. The pipe shall enter the boiler direct and shall be maintained steam tight between boiler and gauge. The siphon pipe and its connection to the boiler shall be cleaned each time the gauge is disconnected for inspection and testing.

The siphon pipe shall be refilled with water before being placed back in-service to prevent steam being admitted directly to the pressure gauge.

Siphon pipes are to be annealed, as per the boiler management plan.

No steam locomotive boiler shall be returned to service from annual inspection or overhaul without the service pressure gauge being tested against a test gauge.

15.7 Test reports

A test report shall be provided with each test gauge.

A test report is not required for a service gauge unless specified by the party submitting the gauge for testing. Details for test reports can be found in AS 1349

Appendix B of AS 1349:1986 gives recommendations for the installation and use of pressure gauges

Section 16 Retubing locomotive boilers

16.1 General

This section provides guidance when tubing boilers. This section shall be adhered to unless it can be proven that another process or material is equal to or better than the practices and materials laid down in this document.

16.2 Replacement of tubes

Prior to replacing tubes within the boiler guidance should be obtained from the competent person.

16.3 Material specification

No smoke tubes should be replaced without prior approval of the competent person. All tubes obtained as replacements should comply with AS 1228. Specific requirements are provided in Table 16.1

RTOs could have tube stock that meet the requirements at the time of manufacture but are not compliant with current standards, for example, stock from the original boiler owner. Prior to use the tube stock shall be tested to ensure it is suitable for use.

It is permissible to use tubing to other standards systems (such as ASTM), provided it can be established that the material has been manufactured, tested and certified to an equivalence of AS 1228:2016

Due to rationalization of commercially available tube sizes, it may be necessary to source outside the above standards. In this case, an engineering assessment process will be determined (which may require all or some of physical/chemical/non-destructive testing), and carried out by persons competent to do so to establish fitness for purpose at least as good as AS 1228 requirements. This same requirement

shall apply to the use of tubes believed to be of boiler quality, but having no traceable compliance certification.

All tubes shall be sound, round, well finished, free from surface defects, rust and scale and the ends shall be faced clean and square, and de-burred, or lightly chamfered.

Steel tubes shall be normalized and cooled in still air and copper tubes shall be annealed for a length of 150 mm from the end before fitting (refer to relevant code for temperature range). This may be specified as part of the manufacturing process.

The responsible person should retain the relevant material and test certificates for such tubes for as long as the tubes are in use and these records shall be kept in the boiler history file.

Table 16-1 Material Specification Table

Detail	Material	Tensile strength MPa	Tensile strength Tons/sq inch	Grade
Boiler tubes and flue tubes	Steel	275 to 386	20 to 28	2602-320 BS 3059 PT2 320 HFS/CFS or ERW
Boiler tubes	Copper	200 min	14.5 min	BS 2871 PT3C107-PA3

16.4 Procurement

When placing an order for purchase of smoke tube, it is essential that the order clearly states the required standards to be met, including the specific test category required for the service application. The order should also make supply of all required material test certificates mandatory. Should additional work (such as belling or swaging of superheater flues) be ordered from the original supplier or others, accurate drawings of the requirement are to be supplied.

Consideration shall be given to any post-working heat treatment and this is to be accurately detailed. In this event, additional compliance documentation is to be specified as mandatory.

16.5 Removal of fire tubes

16.5.1 General

There are two distinct methods of tube removal, with variations depending on the tools and skills available:

- (a) One method involves loosening the tubes from both tube plates and removing each tube through its own hole in the smokebox tube plate.
- (b) In the other procedure, tubes are cut at each end and allowed to fall into the boiler barrel, with the tubes and cut ends removed later.

Flue tubes should be removed first to allow the smoke tubes to support the flue tubes.

16.5.2 Method One

The first method can be carried out substantially with hand tools (such as a collapsing tool and/or drift) if shop facilities and power tools are not available, although the use of power tools will speed up the process and require less physical exertion. Removing the tubes through their own holes is also particularly advantageous if only a small number of tubes are to be removed - such as when replacing a group of thin or leaking tubes as a maintenance procedure or when removing two (2) or more sample tubes from near the boiler bottom for examination to help determine general tube condition.

Work begins in the firebox where the bead (formed by riveting the end of the tube over so it bears against the plate) or seal weld is carefully removed from the tube end by using a hand chisel, an angle-grinder, an oxy-fuel cutting torch or special chisel in a small pneumatic hammer. A tube drift is then inserted into the tube and the tube driven forward, loosening its grip where it has been rolled into both tube plates. Where a tube does not come loose by this process, longitudinal slits to beyond the tube plate can be cut in the tube by chisel or oxy-fuel gas torch. Usually three (3) slits allow adequate all round shrinkage. Serious damage can occur to the tube plate if the hot cutting process is employed by unskilled operatives, and only competent persons shall carry out these tasks. An alternative to slitting may be the use of a collapsing tool. Once loosened, the tube is easily removed unless heavily coated with scale, in which case it may be slid back and forth to knock off the scale. It is easier to drive the tube out if the smokebox end of the tube is also slit along its length for several inches using a square-ended ripping chisel, or the oxy-fuel torch, thus allowing the tube to collapse slightly.

An alternative is to slit both ends of the tubes in two or more places and fully collapse the ends with chisels, then insert a long bar into the tube at the smokebox end and use it to draw the tube out far enough to be grasped by hand.

Three (3) slits is recommended, as this allows easy collapsing of the tube. Two slits can still require considerable hammering as the tube will not collapse into itself as easily as with three (3).

16.5.3 Method two

The second method involves cutting each tube at both tube plates using either an oxy-fuel cutting torch, or an internal tube cutter driven by a powerful pneumatic motor. If the cutting torch is used, tubes should be cut far enough back to avoid accidental damage to the plate.

Cut tubes are removed through suitable boiler openings such as a large superheater flue hole. A protective sleeve inserted into the hole can assist in reducing hole wear. The remaining tube ends in both tube plates are then removed by collapsing them with chisels and knocking them out of their holes. Collapsing can be aided by slitting the tube ends with an oxy-fuel torch (using a small cutting tip). Another method is to heat the end of the tube that is still in the plate; then bend it away from the tube hole by striking with a chisel. The tube end may then be drawn clear through with little risk of damaging the hole. An inspection of the hole after the tube has been removed is recommended.

Extreme care shall be exercised when using a cutting torch in case the flame nicks or gouges the seating surface of the tube hole. Because tube material is thin, only a small oxy-fuel torch equipped with a tip designed for this type of work should be used in order to reduce the chance of accidental damage. The operator shall be skilled - this is not a job for the inexperienced.

Careful work at this time will reduce the amount of time and effort needed to repair damaged tube plate holes later.

Avoid cutting too many tubes off at one end without cutting them free at the opposite end, as the hanging weight may strain the tube plates and cause cracks. This is especially true when cutting off the heavy superheater flues.

It is a little more difficult to remove tubes when the firebox end beads have been seal welded to the tube plate, because either the bead or the weld (or both) shall be cut through to permit tube removal.

16.5.4 Weld removal

Three methods of weld and bead removal may be used:

- (a) Grinding through the tube bead using a small disk or die grinder.
- (b) Chipping off the weld and bead with a special angled chisel used in a pneumatic hammer.
- (c) Cutting off the weld and bead with an oxy-fuel cutting torch.

The last two processes require considerable skill to remove enough of the weld and bead so the tube can be removed while at the same time avoiding damage to the rear tube plate by either undercutting with the chisel or nicking with the torch. Once the weld and bead have been removed the procedure is the same as for non-welded tubes. Care shall be taken with method a) to avoid grinding away parent tube plate metal.

Superheater flue removal presents additional problems of its own. Flues are made of thicker, less workable material than are tubes (making collapsing difficult) and their greater weight creates handling problems. The top row is generally very close to the flanged section of the tube plate, where it meets the crown. This can provide a risk of damage to the plate when using all types of removal tools. There can be some advantages, too, in finding both a left and a right handed worker. Often these flues are removed through their own holes in the smokebox tube plate, but this may be difficult if heavy scale has built up on them. It may be necessary to remove the scale first using chemical cleaning prior to removing the tubes. If chemical cleaners are used the boiler shall be thoroughly washed out to ensure all traces of the chemical is removed.

16.6 Cleaning and inspection of tube holes and plates

The front and rear tube plate condition should be checked for cracks, cuts and gouges around tube holes, paying particular attention to the ligaments and to the tube holes for roundness.

Figure 89 and Figure 90 provide examples of corrosion and cracking.

Look also at the water side using a mirror and light, if necessary, as cracking and wastage may also be evident only on that side. Also check for damage caused by tube removal, such as chisel or torch nicks not only on the faces of the plates but also on the surfaces of the holes themselves. Carefully grind the fire side of the tube plate (especially if tubes have been welded to the rear tube plate), removing as little material as possible in order to provide a fresh, smooth surface against which the tubes can be beaded. Grinding will reveal a narrow band or ridge around each tube hole, an indication that the tube plate is thicker where the metal has been forced outwards by the previous expanding process and where it has been protected from fire by the bead. It is not necessary to remove these bands by grinding them down to the same thickness as the rest of the plate.

The tube holes will require cleaning and polishing, which is best done with a high speed fine wire, flap or sanding wheel. The edges of each hole should be rounded slightly 1.6 mm (1/16 radius is suggested) on both faces to prevent the tube from being cut when it is expanded and beaded. This job is best done using a large diameter 45° grinding stone in a high-speed grinder. Holes shall be measured for size and out of round once the cleaning and polishing has been completed. Ligament width shall also be checked at this time to confirm that they are within design.

Nicks, gouges, wastage and cracks on the tube plates will require attention. In order that tube holes are not excessively enlarged (thereby increasing the amount of cold work done during expanding, and simultaneously reducing the ligament between tube holes), gouges may be welded up and ground back. A suitable weld procedure is to be developed and adhered to



Figure 89 Examples of corrosion and cracking on the water side of a tube plate



Figure 90 Examples of corrosion and cracking on the water side of a tube plate

16.7 Fractures or cracks in ligaments

16.7.1 Fractured plates

Fractured or cracked tube plate ligaments shall be repaired by welding. Only welders properly qualified and certificated and competent for this type of welding can undertake the task of building up the tube hole. It is recommended that welders practice on test pieces prior to conducting the work on the tube plate

16.7.2 Reclaiming of out-of-round tube plate holes

Any holes for small tubes that are out of round by 0.8 mm (1/32") or more shall be dealt with in the following manner, provided that the minimum acceptable ligament thickness is not compromised.

16.7.3 For copper tube plates

Ream out to take a new tube or build up the hole by an approved welding process (such as oxygen welding, TIG or MIG) and ream back to original size. Only welders properly qualified and certificated and competent for this type of welding can undertake the task of building up the tube hole. It is recommended that welders practice on test pieces prior to conducting the work on the tube plate.

Alternatively, an annealed copper liner can be fitted to bring the tube hole back to the original size (see Section 16.11).

Expanding holes by using a roller or drift in order to bring the hole back to round is prohibited.

Reference shall always be made back to the construction standards to ensure that the ligament dimension is not reduced below the minimum.

16.8 For steel tube plates

Ream out to take a new tube or build up by welding then finish by reaming or boring to the correct size; subject to the agreement of the competent person and suitable NDE. Only welders properly qualified and certificated and competent for this type of welding can undertake the task of building up the tube hole. It is recommended that welders practice on test pieces prior to conducting the work on the tube plate.

Reference shall always be made back to the construction standards to ensure that the ligament dimension is not reduced below the minimum.

16.9 Tube holes out of specification

There are many recommended procedures to address tube holes that are oversize:

Weld up and ream hole back to original specification. Only welders properly qualified and certificated and competent for this type of welding can undertake the task of building up the tube hole. It is recommended that welders practice on test pieces prior to conducting the work on the tube plate.

Fit oversize tubes, ensuring that ligament dimensions are not compromised, and that tube wall thickness is comparable with the existing tubes in the tube nest and in discussion with the competent person.

Swage the tube ends to fit the oversize holes, ensuring that ligament dimensions are not compromised.

Fit ferrules to the tube holes as per the following instructions, ensuring that ligament dimensions are not compromised.

16.10 Use of external ferrules

To use standard tubes in tube plate holes that have been reamed out, annealed ferrules may be used, in accordance with original drawings or historical, proven practice.

Where it is considered a possibility to fit ferrules, it should be established that there is sufficient material to support the tubes. Past railway practice mandates that:

- (a) the ferrules shall be of sufficient thickness to be able to be expanded into the hole; the minimum thickness shall be 0.8 mm (1/32");
- (b) a hole that cannot take a ferrule of this minimum thickness shall have one of the other procedures implemented; and
- (c) in no circumstances should the thickness of a ferrule exceed 3.2 mm (1/8").

The ferrules shall be lightly driven in flush with the tube plate and then expanded into position. Fitting of ferrules shall not be undertaken without the authority of the responsible person

16.11 Use of internal ferrules

Ferrules shall not be used as a repair for tubes that are worn thin or leaking. The purpose of an internal ferrule is to protect the tube end not to reinforce it as per AS CB1.3-1957

16.12 Tube ends

The ends of old tubes (whether in stock or second-hand), or tubes that have been swaged down (whether by hot or cold processes) will require annealing—heating their ends to bright cherry red (840°C – 870°C) and cooling them slowly to soften the material—not only to ease rolling and beading, but also to prevent cracking during the installation process. A regulated gas oven is the best annealing tool, but a forge or heating torch will also work if care is taken to prevent burning the tubes, which results in heavy slag build-up, pitting and possible brittleness. The tube ends are cooled in a bed of lime, which not only insulates, but also helps to minimize oxidation (scale). It's not necessary to anneal the ends of new tubes if they are delivered in an annealed state, provided no further working is carried out. If you have difficulty rolling new tubes, or if cracking occurs during rolling or beading, reject the tubes and contact the tube supplier for an explanation.

The tube ends shall be free of any burrs left over from cutting and should be lightly polished both inside and out for a length of 50 mm (2") to 75 mm (3") on both ends to remove mill scale or scale resulting from annealing. It is a misconception that tubes should be roughed to assist in gripping the tube plate. This practice only serves to provide ridges and valleys that will crush down during expanding and subsequent heat induced forces, making for a weaker and potentially leaking joint. Clean and polished surfaces will achieve a bond closer to molecular level attraction.

After being cut to length, cleaned and swaged (if necessary), the tubes are ready to be fitted into the boiler. Wipe the tubes just before inserting to remove dirt, loose scale, and any remaining oil or rust preventative, then inspect the tubes a final time, rejecting those that are dented, deeply scratched or gouged, or have damaged ends.

16.13 Screw tubes

Screwed tubes are uncommon in Australia. Should a boiler contain screwed tubes, a procedure for removing and replacing these shall need to be developed in consultation with the independent boiler inspector or responsible person and in accordance with the design specifications

16.14 Tube expanding

16.14.1 General

Three-roller expanders should not be used in copper tubeplates due to the potential for deformation. Current practice favours the five-roller expander in copper plates. While five-roller expanders are preferable in steel tubeplates for ease of use, it is appropriate to use three- or four-roller expanders in these circumstances.

NOTE:

Be certain that all boiler repairs and inspections that cannot be performed after the tubes are in have been completed. Ensure that all equipment and foreign matter has been removed before fitting the tubes. If access allows, thoroughly clean the boiler barrel while the tubes are out.

The firebox end of the tube shall be expanded first.

Each tube shall project from the firebox and smokebox tube plates. The exact length that the tube projects is determined by the finishing method, but is typically between 5 mm (3/16") and 8 mm (5/16"). A small plate-metal gauge can be used to ensure the correct length is maintained while the tubes are driven into position. The projection of the tube at both the firebox and smokebox ends shall be checked to verify correct tube length before expanding commences.

The roller expander tends to pull the tube into the firebox as well as rotate it, so the tube shall be anchored to the smokebox tube plate. A good method is to grasp the projecting portion of the tube at the smokebox end with two pairs of locking pliers, so that the lips of the plier's rest against the tube plate when the tube is in its proper position (as gauged in the firebox); the pliers also prevent the tube from spinning. Take care not to bruise the tube or an adjacent hole. Other devices, such as a tube clamp, which is similar to a heavy gauge toolmakers clamp with the clamping corners rounded, or small steel wedges at the smokebox end to start the expansion, have been used with success.

The expander should be lubricated, taking care that oil does not come between the tube and hole, which can cause a hydraulic lock and prevent the tube from sealing properly, and the expander should be cleaned periodically to remove foreign matter. Compressed air may be used to blow dirt from the interior of the tube and from between the tube and its hole.

To avoid distortion of the tube plates, it is advisable to follow some systematic method in the fitting of the flues.

Original order drawings shall be used to set out the sequence in which tubes are to be expanded and this shall be adhered to. If the original order drawings are no longer available, one the following methods may be adopted:

16.14.2 Method one

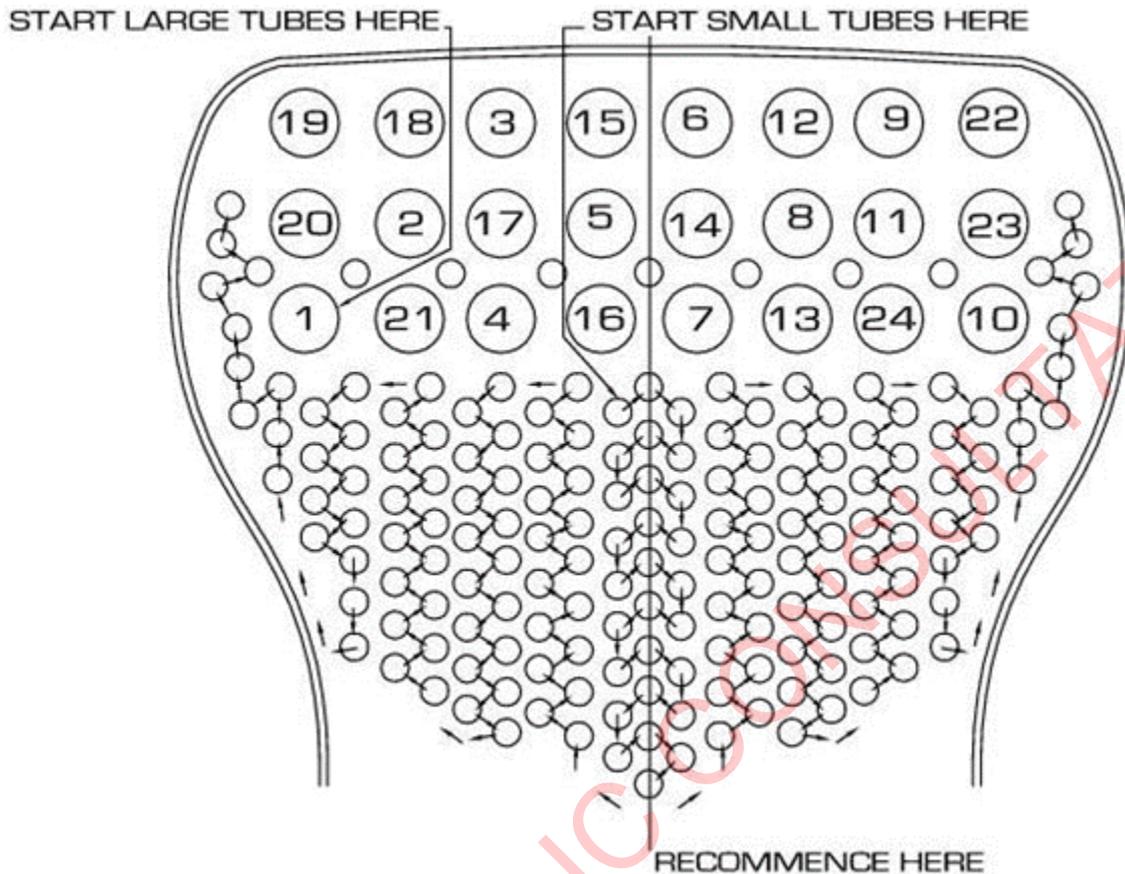


Figure 91 Order of expanding and beading tubes

The large tubes are to be expanded first starting at No. 1 and working in numerical order as shown in Figure 91. Then beaded in the same order and finally tightened up with an expander. The small tubes are then to be done in a similar manner, following the order shown in the arrows in the diagram. The small tubes placed among the large ones are to be done last.

16.14.3 Method Two

Finish a vertical central row, followed by a horizontal central row. Then finish each quadrant, successively working from the outside towards the centre.

16.14.4 Method Three

Start expanding at the outside rows and work inward in a spiral manner to finish in the centre of the tube plate.

The outer and bottom tubes are expanded first, gradually working inwards and upward towards the centre of the tube plate; the object being to distribute the compressing action of the expander as evenly as possible over the entire plate without distorting the tube plate.

16.14.5 Use of tube expanders

The correct sized expander shall be selected for the tubes.

Be sure to select the tapered mandrel that will fully engage the rollers at the start. The mandrel may be turned by hand, when necessary, but is generally driven pneumatically. Impact devices shall not be used under any circumstances. Use of driven tools in the confines of either the firebox or smokebox is

hazardous because the high torque developed can easily cause the operator to lose control of the machine. Whenever possible brace the motor against the side or crown plate, or upon a bar inserted into a convenient tube, and hold onto the motor's trigger in such a way as to avoid pinning the controlling hand in the event of a problem, or use an extension bar to drive from outside the firebox or smokebox.

Once the mandrel has been placed in the expander and the expansion process begun, watch the action of the rollers against the tube wall as stretching begins. Most rollers are designed to self-feed the tapered mandrel, making it unnecessary to push it into the expander. As the mandrel is fed, the tube will slowly grow in diameter and fill the hole. The rippling action of the tube will slowly diminish and then stop, accompanied by a slight straining of the motor, both indications that the tube has tightened in its hole.

Experience is necessary to determine if rolling should be continued beyond this degree of tightness. Sometimes a standard such as one-half turn more or one turn more is applied; alternatively the degree of expansion can be calculated for optimum tube joints.

- (a) For steel tubes, once the tube has expanded until it just fills the hole (i.e. has just become tight), further expansion is required until the tube wall has been reduced by approximately 7% to 8 %.
- (b) For copper tubes, approximately 8% to 10% wall reduction is required to produce a proper tube joint.

To remove the expander, reverse the direction of the drive and pull the mandrel back while turning, releasing it from the rollers. If the drive will not reverse, remove the mandrel by turning it backwards with a spanner.

When the firebox end is finished, proceed to the other end. Using the same sequence as followed in the firebox, begin the expanding procedure again. Be careful of the pulling action on the first tubes, because the tube plates may be pulled closer together at the centre, becoming dish-shaped. An expander with a thrust collar will help reduce this pulling tendency.

Superheater flues require larger rollers and may demand higher torque. It may be found necessary to finish off superheater flues using hand driven equipment if the mechanical equipment does not have adequate torque limiting control. If possible, a large torque wrench will assist in repeatability. Careful consideration needs to be given to the method employed, as the forces required are considerable and careless work can result in injury due to levers etc slipping.

Due to the effort required to seal superheater flues and their sometimes-awkward positioning, it can be difficult to ensure the expander is working parallel to the tube axis. Care shall be taken to expand parallel to the hole axis (especially until the tube bites into the hole), and to not over expand. Failure to do this can result in local thinning of the tube wall. A combination of this and the long-term movement of the heavy tube due to operational vibration can induce grooving in the tube.

The accompanying photographs (Figure 92 and Figure 93) show an example of this type of grooving, and an example of a tube excessively thinned by heavy expanding. In the grooving case illustrated, failure was only evident via a minute crack in the tube end at the smokebox. In the event that this mode of failure occurred on an evenly rolled tube, the potential exists for catastrophic failure, although it would take longer to occur than with a thinned tube. This failure took several years to develop, and should therefore be of concern to operators who have boilers with old flues. It should be noted that water treatment will not inhibit grooving corrosion. It can be seen in the photograph, that the metal is actually very clean in the grooving location, an indication of active metal removal. The location of the grooving is one of the least accessible of a loco boiler for routine visual inspection and other investigative processes should be considered.



Figure 92 Corroded superheater flue



Figure 93 Grooving of superheater flue at smokebox end

The white dots in Figure 93 surround the location where leakage became visually evident

Further consideration will show that, regardless of the variation in clearance between the outside diameter of the tube and the tube hole, the work done in expanding the tube up to the inside diameter of the hole is relatively small compared with the work in reducing the wall thickness. Hence the degree of expansion can be controlled by measuring the amount of work necessary to give the required amount of wall thinning (which is, in fact, directly related to the torque exerted by the mandrel itself for any specific size of tube joint). Once the initial joint is measured and related to the torque on the mandrel, then the expansion of the other joints to the same torque reading give consistent results in line with that of the first expansion.

Keep in mind that the desired result is to seal the tubes while producing the least amount of stress in the tube plate. A tube which has been expanded slightly less than fully has a much better bond than a tube which has been stressed by over-expansion. It is better to under expand than over expand. Over expansion will cause the outer parts of the joint to part company slightly, lessening the area of good contact between tube and hole.

16.15 Finishing

Once all tubes and flues are properly expanded, the ends may be belled (or flared), welded, or beaded (or riveted over against the tube plates), or a combination of the above, as per the design. Any variations in design shall be verified through the control-of-change system.

A hydrostatic leak test (see Section 20) shall be carried out to ensure the integrity of the tube expanding process after beading or belling, but before any seal welding.

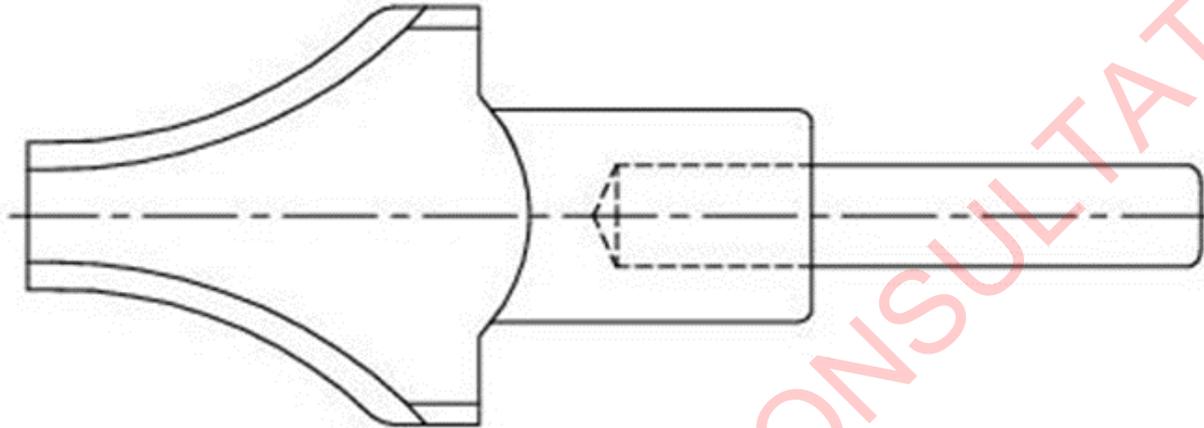


Figure 94 First operation, pneumatic tool for flaring tubes

The first operation is to bead over the edge of the flared tube with a beading tool (Figure 94).

Beaded begins in the firebox and should follow the same pattern used when expanding the tubes. The projecting end of each tube shall first be belled or flared to between 35° and 45°.

If the expander used has extra flaring rollers, beading is completed as the tubes are expanded. If not, a beading tool (as shown in the diagram below), driven by hand or pneumatic hammers, can be used.

The second operation is to bead over the edge of the flared tube with a beading tool (See Figure 95).

A beading or thumb tool can be used by hand or in a small-to-medium pneumatic hammer. Beading further seals or caulks the expanded joint; to produce the correct bead, hammer both the end of the tube and the tube interior, bending the tube out against the hole in the plate, as shown below.

Start the air flow to the hammer slowly and work the beading tool around the tube several times, gradually hammering the belled tip over and producing the finished bead. The bead shall be formed without allowing the tip of the thumb to cut into the plate. As the tool wears, this tip will need to be ground back. Select tools with the proper radius for the tube thickness and allowed projection. Excessive air pressure will result in a very poor finish. If doing this for the first time, it is recommended to set up a very firm test arrangement and experiment with air pressure for your tooling.

Be aware that beading tools, like many other pneumatic tools of the steam age, are not retained in the driving gun, and can become highly dangerous missiles. Ensure that the other end of the tube is clear of people when doing this work.

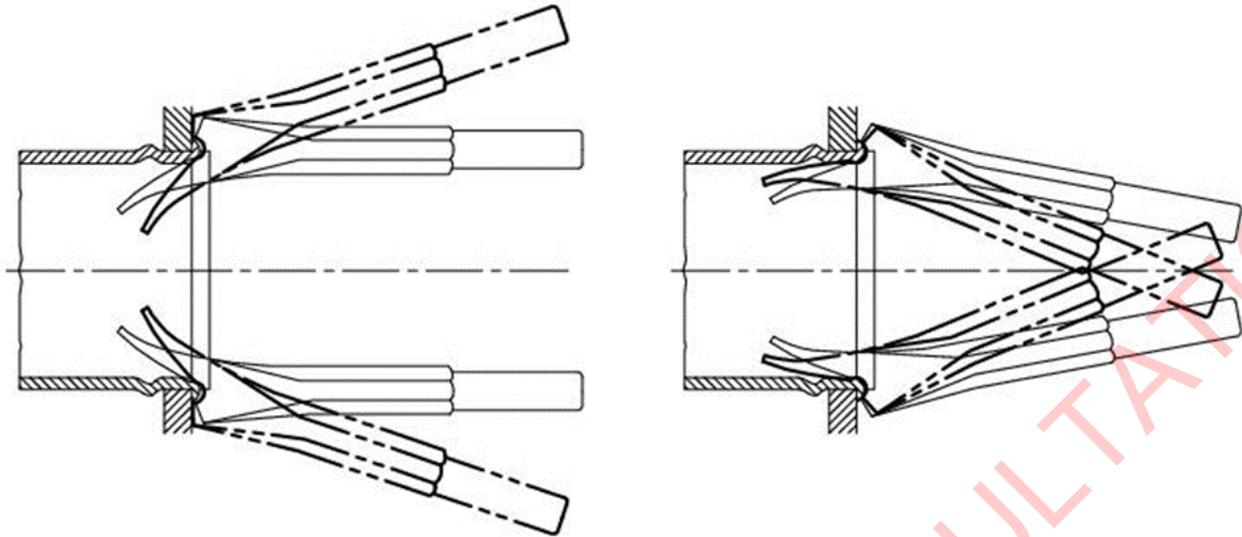


Figure 95 Incorrect use of beading tool (left). Correct use of beading tool (right)

In some boilers, the design requires that some or all smokebox tube ends are beaded to achieve the required structural integrity. Refer to the design. Generally, a few rows of small tubes at the bottom are beaded for ease of cleaning; the tubes around the washout plugs are beaded to prevent damage from spanners and the small tubes in the area around the flues. Tubes that require beading but project too far from the plate should be trimmed off with a grinder before beading, using a gauge to ensure uniform length. It is common to at least flare the small tubes at the smokebox end, even if no beading is done.

16.16 Seal welding of expanded tube to tube plates

16.16.1 Overview

This section describes the welding of tubes in place after they have been expanded into the tube plate. This provides a better seal than only beading and expanding.

This welding is designed to reduce burning of the tube ends. It is not designed to cover up substandard tube fitting and expanding work. The responsible person may decide not to undertake this task, if this does not compromise the original design criteria. Any changes shall be processed through the control-of-change procedure.

An approved welding procedure shall be used that includes the pattern of welding and considers pre-heating the tube plates to prevent localized stresses. Only welders properly qualified and certificated and competent for this type of welding can undertake this task.

The tubes shall be expanded, and the boiler hydrostatically leak tested (see Section 20) before welding and the tubes shall be lightly re-expanded after welding to help relieve stresses and prevent leakage caused by the welding heat.

The tube plate and tube ends shall be cleaned to remove ash, oil and any other contaminants. It is essential that the expanding and beading work be completed to a leak-free status before welding.

Holes in tubeplate not to exceed diameter of tube 0.4 mm (Preferably to be a push fit).

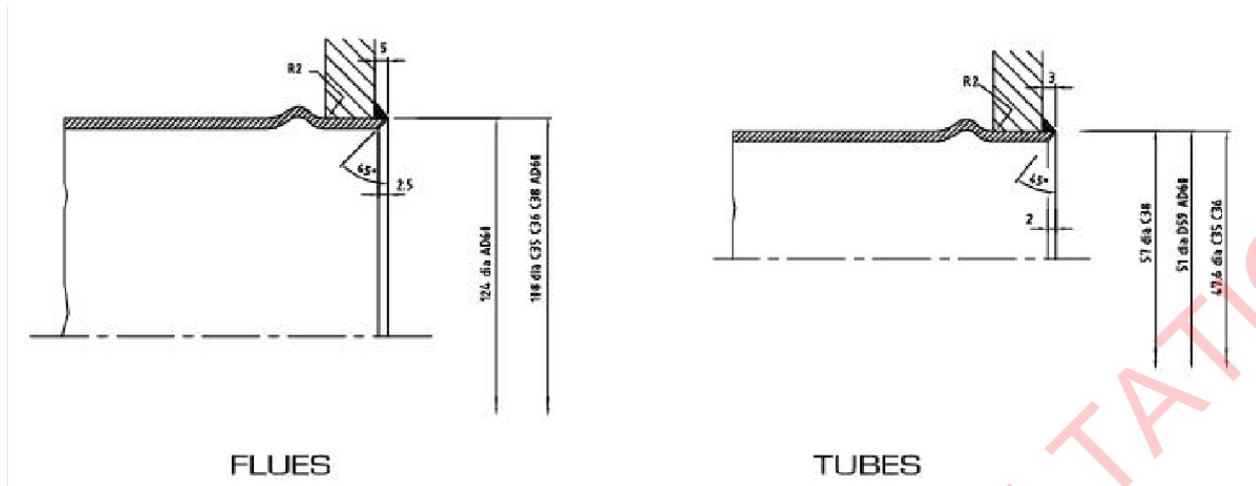


Figure 95 NSW Government Railway tube welding practice for non-beaded tube ends

16.16.2 Procedure

The following process should be applied to welding expanded tubes to tube plates:

- (a) Roll
- (b) Hydraulic test
- (c) Weld
- (d) Lightly re-roll

When applying steel flues and tubes to steel tube plates, the following sequence of operations shall be observed:

- (e) Round edges of flue and smoke tube holes to 2 mm (R2 as per Figure 82) and thoroughly clean.
- (f) Apply copper ferrules in holes in firebox tubeplate, 1 mm under flush with fireside of plate. Set copper ferrules in flue tube holes with hand operated roller expander.
- (g) Set copper ferrules in smoke tube holes with air operated Prosser expander.
- (h) Clean ends of smoke tubes and place in position.
- (i) Clean ends of flue tubes and place in position.
- (j) Adjust flue and smoke tubes to project the correct amount for beading and lightly fasten smoke tubes in smokebox tube plate with drift.
- (k) Expand boiler and smokebox end with air operated roller expander.
- (l) Expand flue and smokebox end with hand operated roller expander.
- (m) Expand boiler and firebox end with hand operated roller expander.
- (n) Expand flue and firebox end with hand operated roller expander.
- (o) Prosser expand all flue and smoke tubes at firebox end. Lightly bellemouth firebox end of smoke tubes.
- (p) Bead all fire and smoke tubes.
- (q) Hydrostatically test boiler with hot water to 25% above working pressure.
- (r) Fill boiler with hot water to above the level of the flues and smoke tubes and arc seal weld the beads of flues and smoke tubes.
- (s) Hydrostatically test the boiler again for a minimum of 30 min.

- (t) Steam test boiler at working pressure for at least three (3) hours to prove welding.

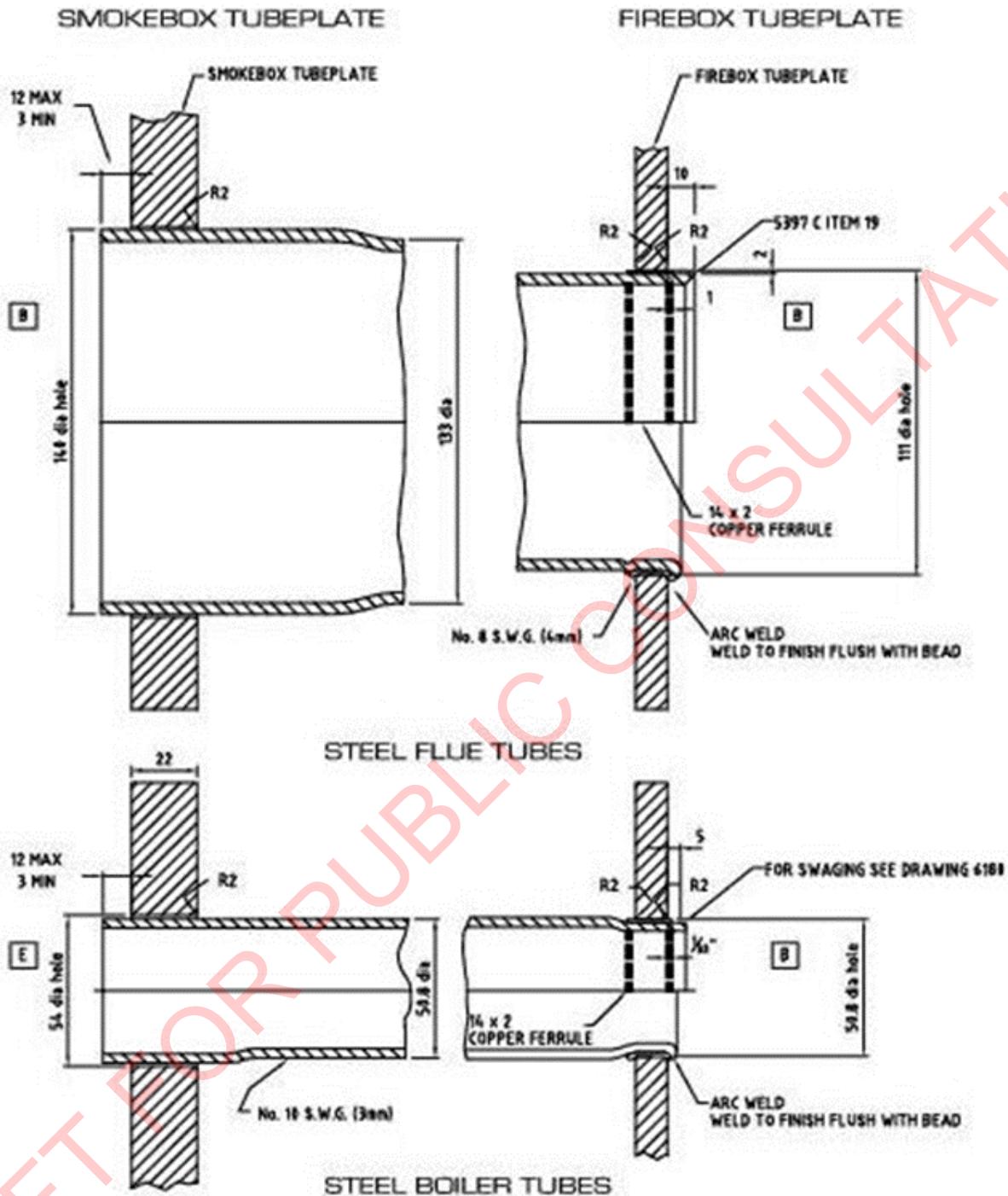


Figure 96 Typical steel tube welding at firebox end

16.16.3 Welding procedure

A welding procedure shall be agreed with the competent person, the independent boiler inspector, and a qualified and competent welder before commencement. Only welders properly qualified and certificated for this type of welding as per AS 3992:2020 shall undertake the task. The completed weld to be subjected to suitable NDE, unless agreed otherwise by the competent person.

A guide to the order of welding is given in Figure 97. This should be verified with the qualified and competent welder prior to commencement of work.

Order of Welding

Start weld at "A" and work
in direction of 'X' to "B"

Then return to "A" and weld
in direction of 'Y' to "B"

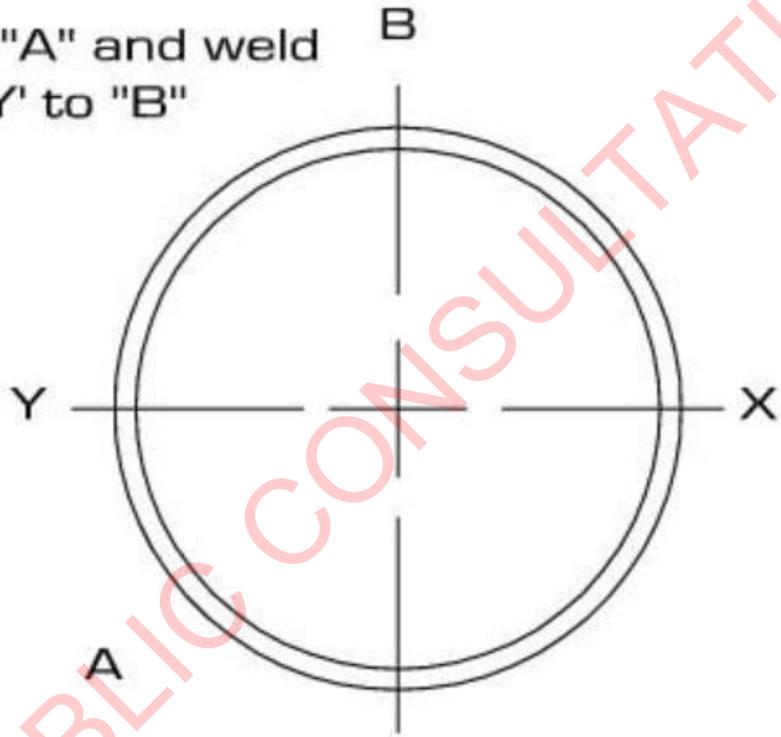


Figure 97 Weld order diagram

Start weld at (A) and work in direction of (X) to (B); then return to (A) and weld in direction of (Y) to (B).

16.16.4 Leaks

If leakages occur around the tube ends the tubes shall be lightly re-expanded.

A significant leak that does not readily seal could indicate a cracked tube or a crack developing in the tube plate ligament next to the tube. Significant leaks shall be investigated and remedied.

If leakage occurs from the inside of the tube it is most likely due to corrosion or cracking. In this situation a thorough examination of all the tubes shall be carried out and, with the approval of the responsible person, the defective tube(s) replaced.

The use of any type of tube plug or blank is not permitted unless specifically agreed with the responsible person.

16.17 Testing

See Section 20.

16.18 Other tubes employed in a locomotive boiler

16.18.1 Main internal steam pipe to or from regulator.

The main steam pipe takes steam from the regulator and/or dome to the smokebox tube plate. Failure of this pipe can lead to uncontrolled release of steam to the locomotive cylinders. It shall be manufactured to the same standards as listed in Clause 16.3

Removal of a main steam pipe generally requires removal of the regulator (when fitted in the dome), and extraction through the smokebox. There is generally either a double flange arrangement where the superheater or steam pipes are fitted against a flange that is in turn fitted to the tube plate, or the main internal pipe finishes flush with the outside of the smokebox tube plate and is expanded into the tubeplate. An internal ferrule is then fitted to reinforce the expansion.

When re-installing either a new pipe, or an existing one, it is vital that the flange faces on both the steam pipe and the tube plate are a sound metal to metal seal. This may be achieved by machine grinding (if accessible) or more likely by hand scraping. Where allowed in the design an appropriate gasket may be used.

16.18.2 Pipes to auxiliaries.

In some locomotives, steam is taken via a dry pipe through the smokebox tube plate to fittings such as the blower. A pipe is used to connect from the tube plate connection to the control valve. As such, the pipe forms part of the pressure vessel, and shall be subject to all the applicable requirements of this guidance note. Pipes are subject to work hardening from normal operational vibration.

Annealing of copper piping shall be carried out as determined by engineering assessment by a competent person, based on the usage of the locomotive. The frequency of the annealing should also be determined.

Failure of such a pipe in the smokebox could lead to hot gas and steam being propelled into the cab through the fire-hole door. Pipes, where used external to the boiler for steam transfer, are subject to the same work hardening and failure here could result in burns to operators or bystanders.

Pipes that deliver feed water from back head injectors to the front of the boiler, or dry steam from the dome to auxiliaries, such as the manifold. While not directly exposed to pressure through them, these pipes/tubes serve valuable functions. The frequency and methodology for inspecting them shall be included in the boiler inspection plan.

16.19 Record keeping

It is essential that accurate records are kept of all work carried out in the boiler history file. Providing a drawing of the tubeplate or firebox backplate/throatplate will enable unambiguous recording of which tubes were replaced or worked on.

Section 17 Welded boiler inspection

17.1 General

This section provides guidance on the inspection of welded boilers. This section shall be adhered to unless it can be proven that another process or material is equal to or better than the practices and materials laid down in this document.

17.2 Inspection

For the purposes of this appendix, the term welded boilers will refer to a locomotive boiler that has been fabricated primarily with welded joints. In some cases, modern welded boilers may have riveted

joints in selected locations, for example, at the foundation ring. Wherever rivets are used in a welded boiler, the inspection guidance provided in other parts of this document for that type of construction should be followed.

Inspection of the welded joints of a boiler beyond a visual inspection is not necessary during annual inspections due to the high level of NDE carried out during its manufacture and commissioning. However, the boiler is subject to the same degradation as a riveted boiler as a result of the high heat flux in the firebox and the rapid cyclic operation of a locomotive boiler.

Hence, all of the locations that may suffer fatigue cracking and grooving on the water side from these operating conditions need to be inspected as set out in Section 3.

This includes, at the very least:

- (a) above the foundation ring;
- (b) in the radius of flanged plates of the firebox;
- (c) at the butt-jointed corners of fireboxes;
- (d) at the smokebox tube plate; and
- (e) wall stays.

Because they are in an area of high-cyclical stresses NDE inspections shall be performed on full-penetration tee-weld joints as part of the inspection plan.

All other common inspections dictated by this COP and general good inspection practice shall apply.

A boiler that has not had a consistent good water management program is likely to give rise to substantial deposits in the lower parts of the boiler and undesirable water chemistry. In rare cases this can lead to preferential corrosion in the welded joints.

Although weld defects are unlikely, given the modern construction and inspection techniques, it is important to visually inspect all welds in the boiler as far as possible at the annual inspection and particularly in the water spaces of the boiler when the detailed internal inspection at the extended interval (nominally 10 years) is conducted. Special attention shall be given to weld repairs that have been conducted previously and that have uncertain provenance. In these cases, NDE should be conducted to examine the integrity of these repairs. Similarly, the weld surfaces on the outside of the boiler shall be closely examined for visible defects when any or all of the external cladding and lagging is removed.

Any visible surface breaking defects shall be further examined to determine the full extent of the defect and an analysis conducted of the impact of the defect on the structural integrity of the boiler by a competent person.

Any repairs shall be specified and carried out in accordance with Section 5 of this document.

All details of the defect, NDE and repairs conducted shall be recorded in the boiler history file.

If a composite boiler (with both welded and riveted construction) shows a structurally unsound defect in a riveted joint, it shall be repaired by riveting. A design review shall be conducted for any proposed alternative repair method. This does not include seal welding of joints.

Conversely, a welded joint shall not be repaired or replaced with a riveted joint unless a design review is carried out and the change is approved.

Section 18 Boiler water treatment

18.1 General

This section provides guidance on boiler water treatment. Boiler water treatment is an essential safeguard that significantly minimizes corrosion (compared to no treatment). Boiler water treatment reduces the repair requirements and costs, particularly on stays and boiler tubes and extends overall boiler life.

This section shall be adhered to unless it can be proven that another process or material is equal to or better than the practices and materials laid down in this document.

18.2 Introduction

All water contains impurities that may vary considerably according to the location of its source. These impurities may make the water alkaline or acidic and, dependent on mineral content, will form scale or sludge with widely varying characteristics.

Excessive acidity can cause problems with corrosion of tubes and steel plates and an early indication of acidity is the disengagement of existing scale from plates, stays and tubes.

Excessive alkalinity may lead to stress corrosion cracking (also known as caustic embrittlement), particularly when minute leakage paths exist at riveted joints and other high stress locations.

NOTE:

Tannin has been shown to be an excellent embrittlement inhibitor. Different tannins have different inhibiting properties, with tannin from South African quebracho timber currently found to have the best properties.

Some waters will deposit heavy quantities of hard scale on heating surfaces (i.e. fireboxes and tubes), which may become burned, thinned and mechanically weakened due to the insulating properties of scale. Excessive scale deposits, particularly around the firebox tube plate, foundation ring and fire hole, will impede water circulation, leading to accelerated scale build up, plate burning and corrosion.

Boiler water contaminants can be broken down into three groups: dissolved solids, suspended solids and dissolved gases.

- (a) Dissolved solids cause scale formation (which may lead to overheating) and are a main cause of priming.
- (b) Suspended solids cause mud and sludge to form in the boiler and are a main cause of foaming and priming.
- (c) Dissolved gases (such as oxygen) cause pitting corrosion and reduce the life of the boiler.

There are a number of different controls that can be applied for each of these contaminants, and water treatment specialists can design a specified treatment regime to address these issues relevant to the operating conditions of the locomotives.

RSOs shall consult with a boiler water treatment specialist competent in the area of locomotive boiler water treatment and accounting for the different materials and construction methods that may be encountered.

Some boiler water treatments are not designed for cold, wet water storage, and it is recommended that the boiler water treatment specialist be consulted before choosing treatment for this purpose.

Each RSO should appoint a competent person to manage the regular testing of boiler water, adjustment of treatment dosage and recording of results. These results shall be recorded in the boiler history file.

18.3 Chemical cleaning

In addition to routine boiler water chemistry monitoring and periodic washing out, some boiler operators conduct chemical cleaning of boiler waterside surfaces using inhibited acids to dissolve scales and corrosion products.

While chemical cleaning is an effective method to remove waterside fouling, particularly for a boiler which has not been restored in the preservation era or a boiler about to undergo major works, cleaning shall be conducted in consultation with a boiler water treatment specialist, competent in industrial chemistry and accounting for the different materials and construction methods that could be encountered.

Care shall be exercised to avoid causing irreversible damage due to ill-informed chemical cleaning treatment regimes.

Section 19 Safety valves

19.1 General

This section provides guidance on the use and maintenance of safety valves. It will also be useful to those in a supervisory role, however no work should be undertaken unless the people concerned are deemed competent to do so (see Section 2 for classification of accountable, responsible and competent persons).

Safety valves are a critical safety device, and as such, need to be inspected and maintained to ensure that they will operate correctly when required

19.2 Use

This section shall be adhered to unless it can be proven that another process or material is equal to or better than the practices and materials laid down in this document.

19.3 Introduction

The safety valve is a device designed to protect the boiler from overpressure by relieving pressure in the boiler above the registered working pressure.

There are many different types. The most common examples fitted to locomotive boilers are pop valves and Ramsbottom. Some very early locomotive boilers were fitted with Salter safety valves; these should be treated with extreme caution as they are not tamper proof.

Each safety valve shall be uniquely identified so its history can be tracked. The identification number of the safety valve fitted to the boiler shall be recorded in the boiler history file.

Valve maintenance that involves dismantling or repairs shall be carried out only by a competent valve repairer or competent personnel of the user/owner/operator. A maintenance report shall be prepared by this competent person for each valve, listing the maintenance, repair, testing and adjustments, and this report shall be added to the boiler history file.

All maintenance, repair, testing and adjustment shall be carried out in accordance with AS 3788:2024

Care shall be taken, when repairing or restoring locomotive boilers with an uncertain history, that the safety valves fitted are fit for purpose and of the correct capacity. An accumulation test shall be conducted and witnessed by the independent boiler inspector to prove that the safety valves have the necessary relief capacity.

The safety valve capacity shall be sufficient to prevent an increase in pressure more than 6% above the maximum allowable working pressure in accordance with AS 2593:2021, Clause 12.2.4

19.4 Materials and manufacture

Material used in manufacture of any component of a safety valve shall be to the original specifications, and the drawings manufacturing tolerances shall be strictly adhered to. Metallurgical advice shall be sought to select alternative materials if the original materials are no longer available. Safety valves are fine-tolerance devices and require a high level of skill and attention to detail to manufacture and assemble.

19.5 In-service (operational) inspection of safety valves

In-service inspections shall be carried out by operational personnel during each operation, and any defect shall be recorded and immediately reported to the boiler competent person.

Some defects that may be observed during normal operating conditions are:

- (a) failure to lift at the correct pressure;
- (b) failing to reseat at the correct pressure;
- (c) failing to reseat correctly; and
- (d) leaks around base, body, cap or seat.

NOTE:

Depending on the severity of any defect, the boiler competent person may declare the locomotive a failure. This is particularly important if safety valves are not lifting before or at the prescribed pressure.

19.6 Maintenance and repair of safety valves

Maintenance and repair of safety valves shall only be carried out by competent persons.

Before dismantling a safety valve, the critical setting dimensions shall be recorded to assist in the bench setting during re-assembly.

All safety valves shall be maintained and repaired according to procedures that set out the activities required, measurements to be made and records to be kept.

The procedure shall cover the following:

- (e) Dismantling including visual inspection, recording critical measurements.
- (f) Overhauling and repairing, including re-assembly.

Areas that should be particularly covered in the procedure are:

- (g) Dimensional details, such as seat dimensions, body dimensions, blow-back ring dimensions, spring lengths, spring diameters and spring sections, bushes and pins.
- (h) Corrosion in the fixing mechanisms, springs etc. Attention shall be paid to the main spring- fixing stud on Ramsbottom valves.
- (i) Erosion in the blow-back area, the seat area and the cap.

Fixing studs shall be maintained and replaced as set out in Maintenance, Repairs and Alterations in the main body of this document.

19.7 Setting and testing of safety valves

Safety valve(s) shall be compliant with AS 1228:2016 and this document.

This is a specialized field since conversion factors between a cold and hot test shall be established, and so should only be undertaken by a competent safety valve setter.

The valve design, construction and markings shall comply with AS 1271:2003 or its equivalent, for example, ASME, BS or CE standards. Valve set pressure, applicable standard of construction, manufacturers identification, valve flow shall be clearly affixed or engraved on the valve.

Primary safety valves shall be set to commence to lift at or below the design pressure of the boiler with remaining valves to lift within 3% of the primary valve.

Safety valves shall be sized and set such that the discharge capacity of safety valves limits the accumulation pressure (rise in pressure) to not more than 106% of the design pressure of the boiler. The reseal pressure (i.e. blowdown) to be not less than 14 kPa below the lift pressure of the primary valve.

A tamper indicating seal or equivalent valve adjustment locking, is required to be on valve, valve is considered not certified if missing.

If valve does not have a tamper indicating seal or equivalent, valve will require certification prior to use and have a tamper indicating seal fitted, a certificate of test/certification to be made available and filed with this plant items unique file.

Safety valves will still need to be demonstrated for the independent boiler inspector once fitted to the boiler, and may require final adjustment under steam pressure in accordance with AS 3788

Commentary *C19.7*

Some safety valves are fitted with adjustable blow-down rings.

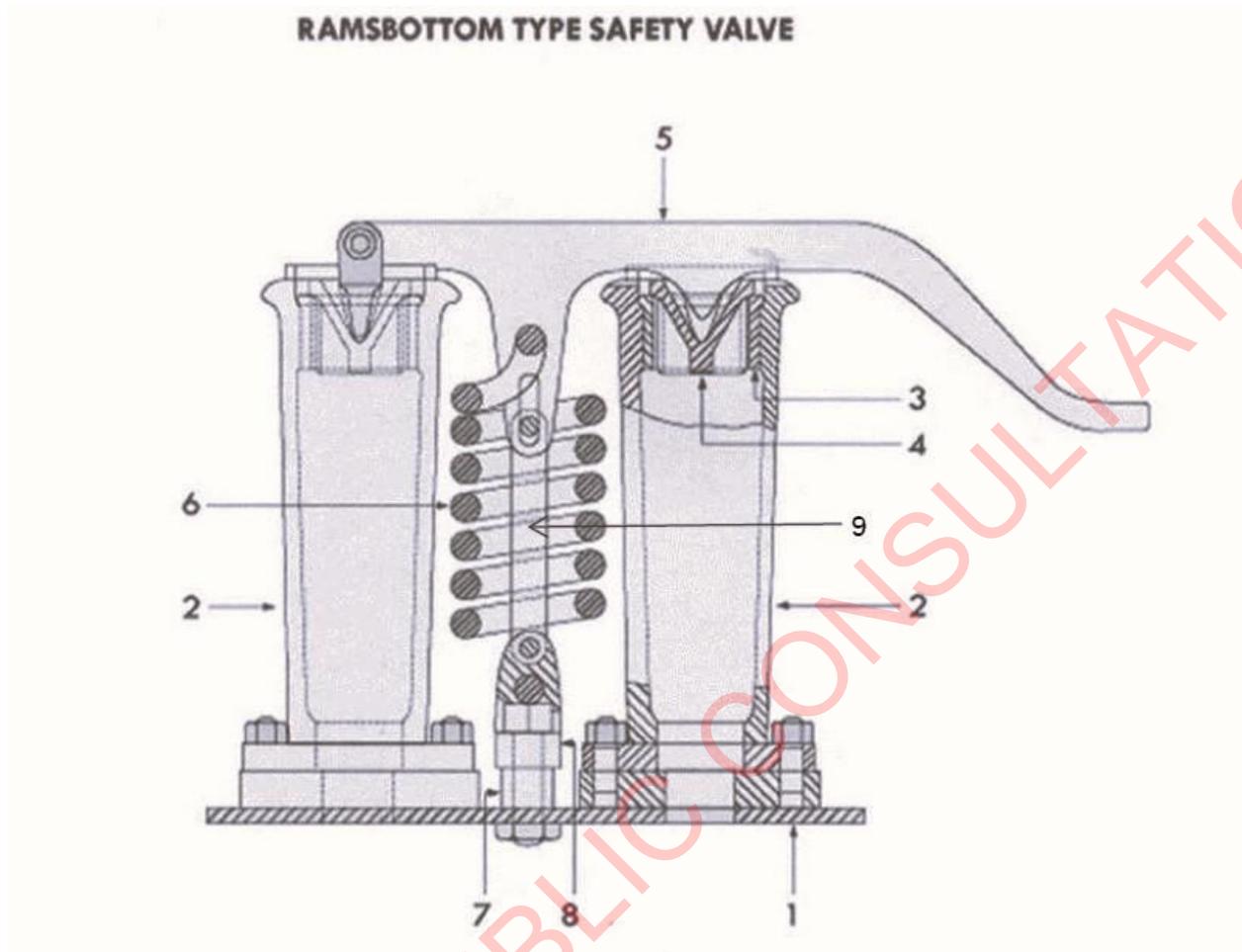
Safety valves that are going to be set on the boiler can be re-assembled on a workshop bench or on the boiler itself using, as a starting point, the measurements made of the adjusting screw and blow-down ring (where fitted) before disassembly.

Safety valves shall be set by the competent person under steam on the boiler against a calibrated test pressure gauge using the procedure set out by the railway for this purpose.

19.8 Replacement of safety valves

Where a safety valve is replaced with one other than the boiler design the safety valve shall be assessed and proven to meet the requirements of AS 1228:2016 and this document before installation onto the boiler.

19.9 Example of typical locomotive boiler safety valves



1. Firebox outer wrapper or top of steam dome	6. Spring
2. Pillars	7. Pressure regulating washers
3. Valve seats	8. Anchor plate
4. Valves	9. Safety straps
5. Easing lever	

Figure 98 Typical Ramsbottom type safety valve

Ramsbottom-type safety valves can be fitted with pressure regulating washers locked by a nut under the anchor plate as shown in Figure 98, or with a spring tensioner attached to the top of the spring through the centre of the easing lever and locked with a nut for setting the working pressure.

In both cases the safety valve shall be sealed by a competent person with a tamper proof lead seal or ferrule between the lock nut and anchor plate or lock nut and spring tensioner to prevent the valve being screwed down beyond the blowing off pressure.

Other types of safety valve are shown in figures 99 to 101.

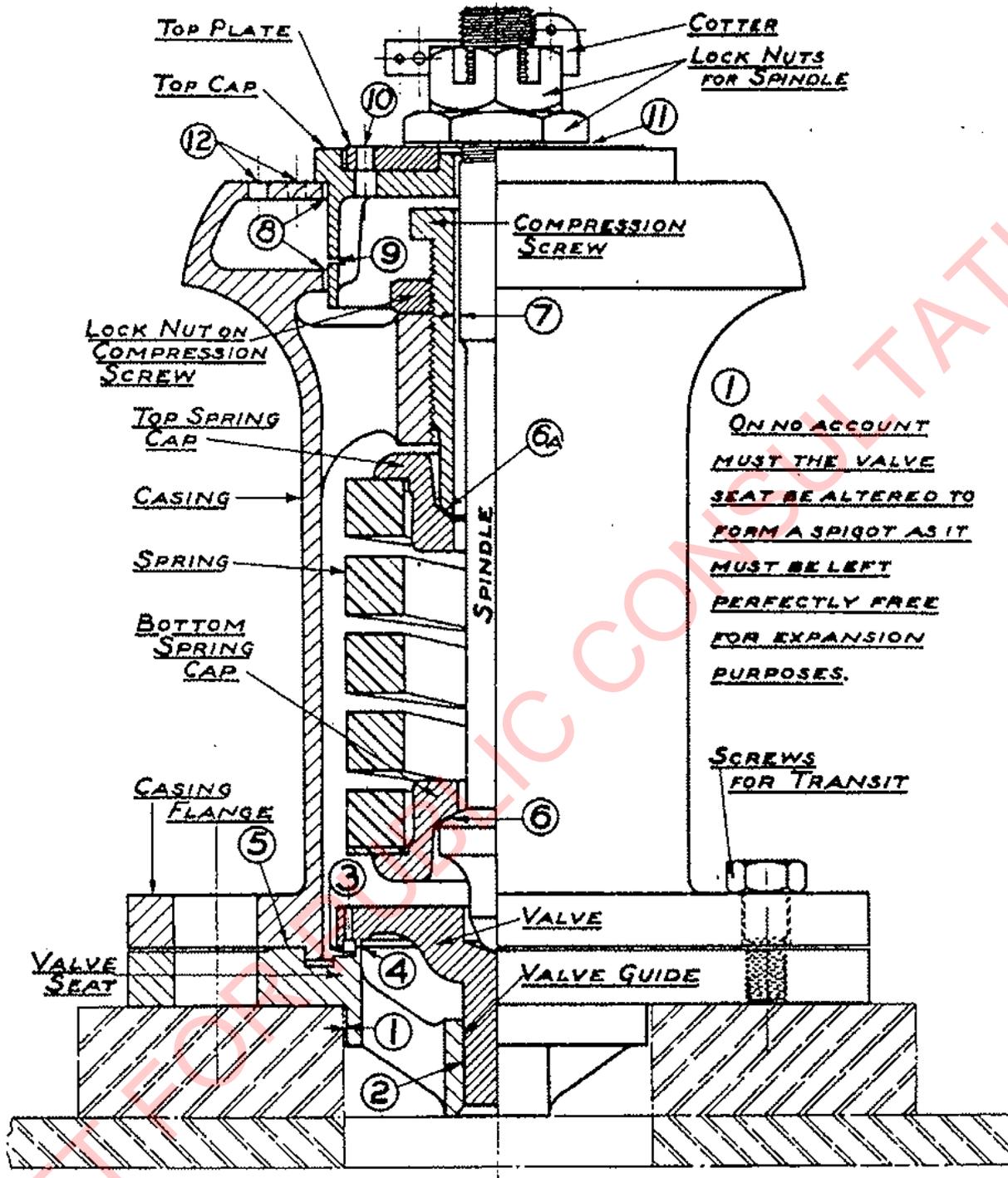


Figure 99 Pop 2½-inch safety valve

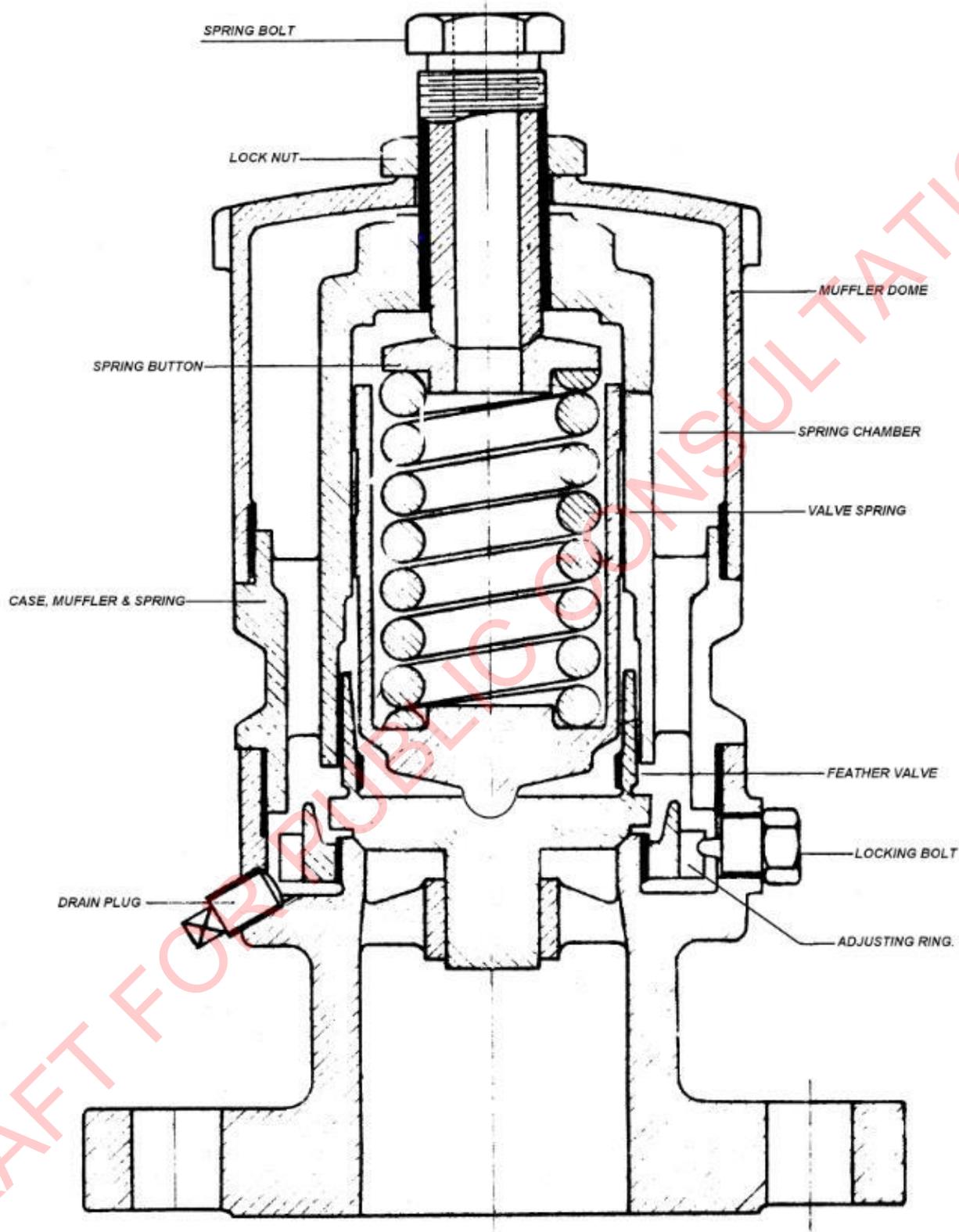
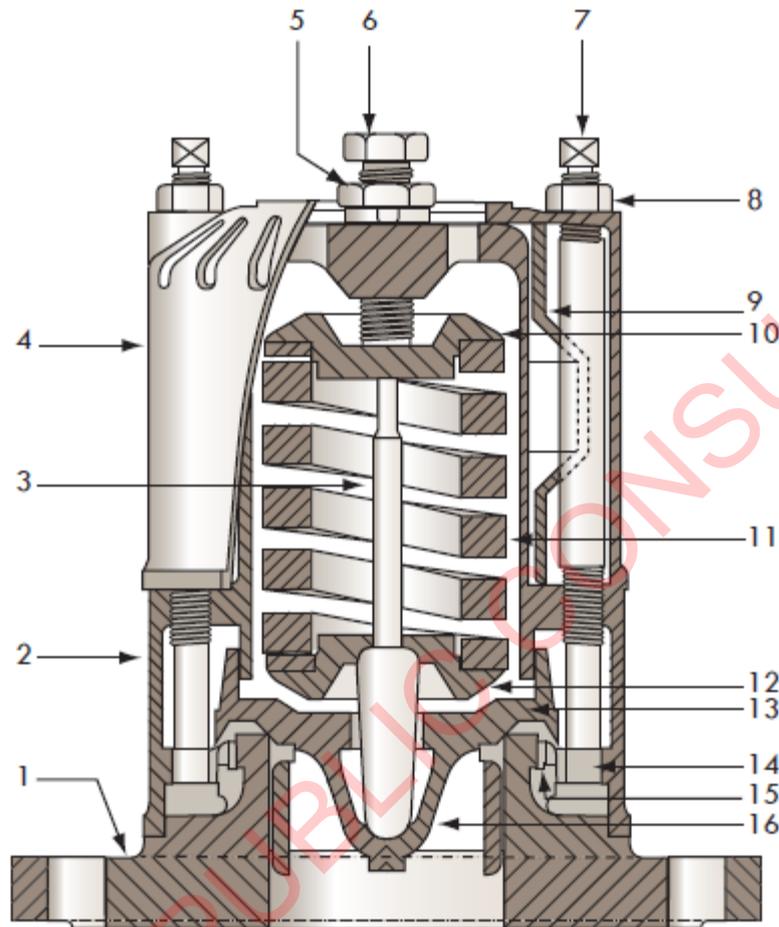


Figure 100 Coale safety valves

ASHTON 'POP' SAFETY VALVE



No	DESCRIPTION	No	DESCRIPTION	No	DESCRIPTION
1	BASE	7	POP REGULATOR	13	VALVE UP
2	HEAD	8	REGULATOR CHECK NUT	14	CAVITY DISCHARGE HOLES
3	SPINDLE	9	MUFLER PLATE	15	CAVITY
4	SOME TOP	10	UPPER PLATE	16	VALVE
5	PRESSURE SCREW CHECK NUT	11	SPRING		
6	PRESSURE SCREW	12	LOWER DISC		

Figure 101 Ashton pop safety valve

Section 20 Pressure testing boilers

20.1 General

This section provides guidance on the pressure testing of boilers.

This section shall be adhered to unless it can be proven that another process or material is equal to or better than the practices and materials laid down in this document.

20.2 Application

Pressure testing of new locomotive boilers shall be conducted in accordance with the relevant construction code for new boilers.

Pneumatic testing (i.e. using a compressed gas) is extremely dangerous due to the amount of stored energy and shall not be conducted on locomotive boilers.

Steam testing is conducted after a satisfactory hydrostatic pressure test has been completed when all leaks and other defects have been addressed and is used for an accumulation test for the safety valves. Although the boiler is under steam pressure during these tests, they are not considered pressure tests.

All pressure testing of locomotive boilers shall be done hydrostatically (i.e. using water under pressure). All hydrostatic pressure tests on heritage boilers shall be conducted with water that is between 20°C and 50°C to protect against brittle failure.

A calibrated test gauge shall be used.

A detailed record of all pressure tests shall be made and filed in the boiler history file.

A hydrostatic test is conducted with water under static pressure and proves the integrity of the boiler. A hydrostatic test conducted with air trapped is dangerous, and every effort shall be made to remove air when conducting hydrostatic tests. There are two different types of hydrostatic pressure tests that might be conducted on a boiler – a leak test and a strength test.

A leak test is a hydrostatic pressure test that is conducted at a pressure equal to or below the design pressure of the boiler (i.e. safety valve set pressure). This test is used to find leaks in the boiler assembly. Leak tests may be conducted at any time and are typically used for fault finding and after reassembly of a boiler following an inspection or minor repair (as defined in AS 3788).

A strength test is a hydrostatic pressure test that is conducted at a pressure above the design operating pressure of the boiler. A strength test is used to test the structural integrity of the boiler. It is used to find faults in the structure that would be unacceptable and potentially dangerous when the boiler is in steam.

New, modified and repaired boilers shall be subjected to a hydrostatic strength test before the boiler is steamed as required in AS 1228:2016 and AS 3788:2024 or registered design and construction standards.

Testing above the design pressure is dependent on the circumstances, for example, for new fabrication or a repair/modification. The independent boiler inspector and the referenced standards shall be consulted to establish the test pressure.

Care shall be taken to ensure that the boiler is not subjected to a pressure above the specified test pressure as undetected damage may occur.

Section 21 Hand hole door and similar opening

21.1 General

This section provides guidance on the use and maintenance of hand hole doors and similar openings.

Hand Hole Door Assembly

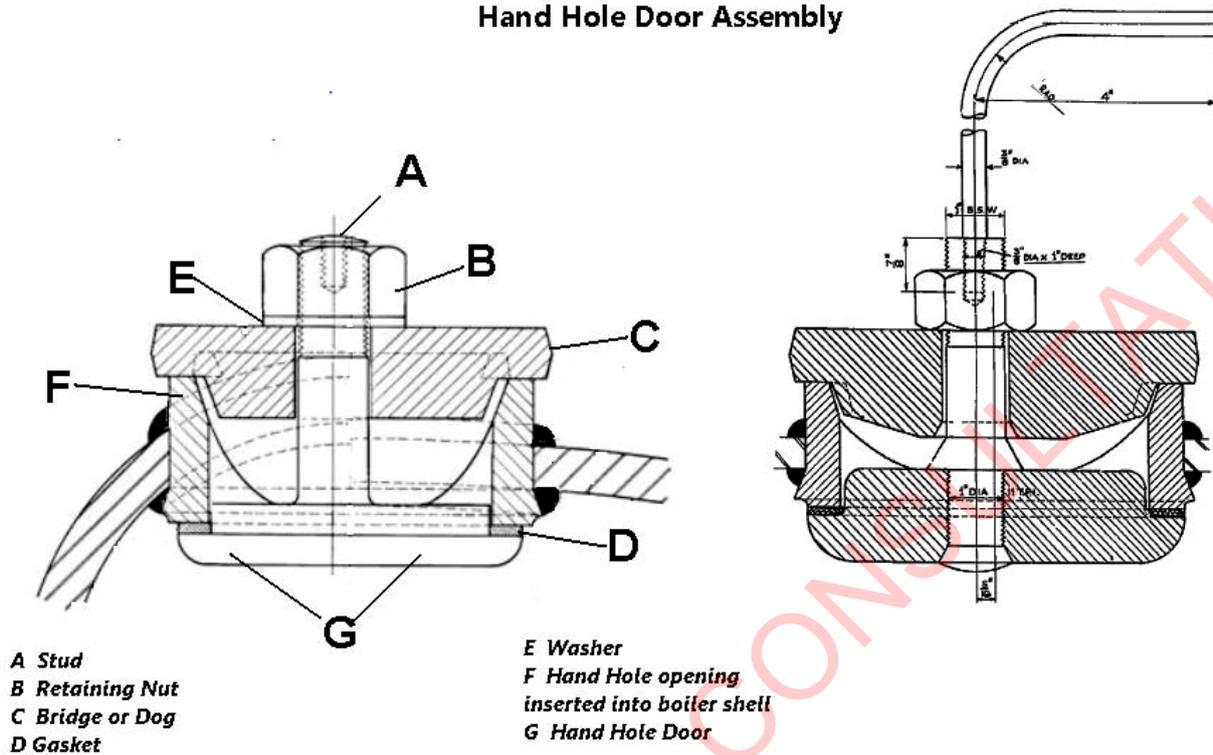


Figure 102 Hand hole door assembly

21.2 Scope

This section shall be adhered to unless it can be proven that another process or material is equal to or better than the practices and materials laid down in this document.

21.3 Introduction

To facilitate the inspection and cleaning of boilers at regular intervals some designs of boiler incorporate several hand hole doors, the number and location of which will vary with the boiler design. These doors are fitted internally, so that boiler pressure assists in holding them against their seats. Some boilers have similar but larger openings intended for personnel access.

The manufacture, inspection, reconditioning and fitting of hand hole doors are safety critical tasks. Only those trained, deemed competent and authorized shall be responsible for the inspection, and reconditioning of doors and door holes, and refitting of hand hole doors.

Records shall be kept of the action taken at each washout and by whom.

21.4 Materials and manufacture

Hand hole doors shall be manufactured from equivalent materials to that of the boiler shell and mounting studs. All material is to be supplied with relevant test certificates attesting to quality and conformance with AS 1228 and registered design and construction standards.

New doors shall be cast in a single process, or forged or be manufactured from a single piece of plate as per AS 1228:2016, Clause 3.9.3 and registered design and construction standards. Hand hole doors shall not be fabricated by sandwiching two pieces of plate as this does not have adequate strength at the

mating face to ensure that it remains flat, and distortion can also occur due to corrosion or wastage between the plates.

Where the shank is manufactured in a separate process to the door, it shall be of material that complies with AS 1228:2016, Clause 3.9.3 and registered design and construction standards, as shall the nut; the threading arrangements and material of off-the-shelf engineering studs and nuts generally will not comply with the specifications.

Hand hole gaskets shall be of a suitable material that will not extrude between the hole and the upstand of the door under the operating conditions (pressure and temperature) of the boiler.

There are some commercially available plasticized gaskets, especially made for hand holes (and some larger inspection openings). It is important that the owner/operator ensure that the boiler operating pressure and temperature is within the gasket manufacturers recommendations as some locomotive boilers work above the range of these gaskets. As these gaskets are around 6 mm thick (uncompressed), they can have a significant influence on the door upstand/hole gap when the doors and hole are aged. Incidents have been known where these gaskets have extruded, with sudden release of steam/water, causing operator injury.

The bridge shall be cast, forged, or fabricated from a single piece of material that complies with AS 1228:2016, Clause 3.9.3 and registered design and construction standards.

21.5 Cautionary note

Hand hole doors are to be inspected before and during each steam raising, while the pressure is relatively low. In the event of finding any doors that are, or appear to have been, leaking, seek guidance from the boiler competent person before proceeding with any further steam raising.

21.6 Removal

It is essential to ensure, by way of open valves, that there is no pressure or vacuum in the boiler at the time of door removal.

Hand hole doors shall be removed at every washout and internal inspection. Doors shall be identified so that they can be returned to the original opening. To aid installation/removal, it may also be desirable to record the specific orientation of the door; Doors may have been made specifically to suit a worn opening and may not be symmetrical.

Some doors have a small thread in the end of the stud section. A piece of threaded rod fitted to act as a handle before knocking the door in is useful to reduce the risk of dropping the door into the boiler. The nut, washer, and bridge can be slid over the threaded rod before trying to remove the door. The threaded rod may need to be bent to allow adequate movement to turn the door into a position to be removed. It is frequently necessary to prise off the gasket before attempting removal, as the gasket, if extruded into the water space, can be sufficient to make removal a difficult task.

NOTE:

When removing large doors, it is considered good practice to engage more than one person to complete the job to reduce the risks of injury to personnel, dropping the door into the water space or causing damage to the door.

21.7 Door cleaning

The mating face and the thread shall be cleaned to ensure ease of refitting into the correct position. A dulled scraper made from a power hacksaw blade is a useful tool for cleaning the mating face. Files or grinders shall not be used on these faces, as they tend to make the mating surface convex and destroy the sealing capabilities of the door. This makes for uneven pressure on the gasket, and this can lead to premature and sudden failure.

The mating faces of the door shall be inspected for wastage, cracking, scores and other defects.

The threaded section and shank can be cleaned using a hand wire brush and a pointed tool to remove deposits. The shank and threaded section shall be inspected closely for defects such as:

- (a) stretched threads;
- (b) bent shank;
- (c) corroded shank;
- (d) torn, worn or corroded threads;
- (e) cracks; and/or
- (f) general deformations in the threads.

It may be necessary on occasion to run a die nut down the thread. When doing so, inspect the cleaned thread closely. If the door has suffered from severe over-tightening, the shank may have stretched, and there will be a tell-tale significant cutting of the thread on one side as the die nut attempts to correct the pitch change. A door with a shank in this condition is not fit for purpose and shall be repaired in consultation with the boiler competent person before reuse and this work shall be noted in the boiler history file. Damaged doors awaiting repair shall be quarantined until they are repaired. Doors that cannot be repaired shall be destroyed.

21.8 Door opening and closing

As the jointing surface is inside the boiler, cleaning can be awkward and tedious, but it is essential that this is completed properly. A suitably shaped scraper can assist, and inspection shall be via mirror and feel. The edge of the hole shall be clean, free of all surface corrosion, old gasket material and other detritus.

NOTE:

Sealants, such as some graphite-based pipe-jointing compounds, are incompatible with some modern gaskets. If in doubt, consult the gasket manufacturer.

21.9 Faults

The fit of door in hole is a vital part of the inspection. When fitted with a gasket, there shall be no more than a total of 1.5 mm clearance between the perimeter of the door upstand and the hole (see Figure 104). Excessive clearance allows a door to be offset, such that the gasket bearing surface can be locally reduced. With some forms of commercially available gaskets, excessive gap can lead to gasket extrusion and a sudden and significant steam/water leak.

Over a period, the upstand of the door will wear away due to over-enthusiastic cleaning and corrosion, such that its edge is no longer square to the mating face. Combined with similar erosion of the hole and thick gaskets, this can lead to the gap becoming excessive. When this occurs, the hole shall be built up (a difficult job to re-work the internal mating face), or an oversized door shall be manufactured. The width of the mating surface shall not be allowed to reduce to less than 80% of the original specification during any reconditioning processes. The upstand shall engage at least 3 mm into the hole, with the gasket in place. If thick gaskets are used, this condition is even more crucial because any wear on the upstand will increase the chances of a large gap being present.

The left-side photograph in Figure shows a poorly fitting door while the right-side photograph shows the beginning of extrusion of the gasket. Other faults are shown in Figure 104.



Figure 103 Poorly fitting door (left) and beginning of extrusion of the gasket (right)

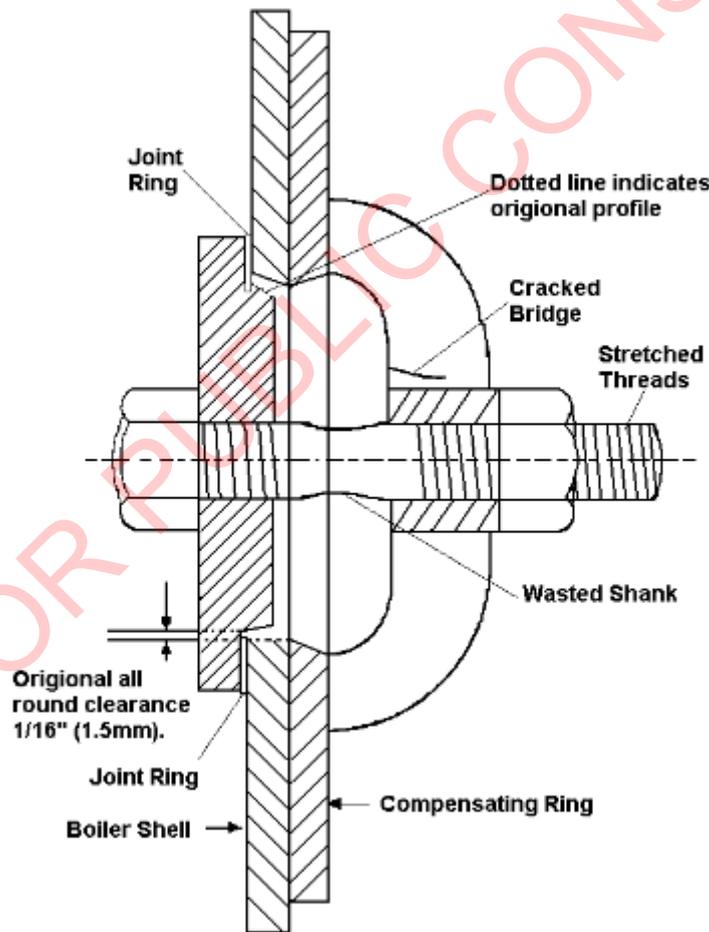


Figure 104 Door defect drawing

In some cases, boilers have been fitted with curved doors to match the shape of the boiler plate. These doors are of difficulty, as any change in curvature due to over enthusiastic tightening on thick gaskets can risk changing the shape of the door, such that even pressure cannot be obtained on the gasket. Therefore, much care needs to be exercised in inspecting these doors to ensure that they will be satisfactory in-service.

If satisfactory sealing cannot be obtained with doors of this type, serious consideration should be given to re-engineering such openings to replace them with a more reliable arrangement; any such consideration shall be in consultation with the boiler competent person and the independent boiler inspector.

21.10 Fitting

The boiler records and door diagram (see Figure 105) shall be consulted during re-fitting to ensure that the correct door is always refitted into the correct hole and in the correct orientation.

Fitting is essentially a reversal of the removal process. It may be necessary to get the door inside before feeding the gasket over the threaded rod. The gasket thickness should be the minimum necessary to achieve a secure, leak-free joint.

Once the gasket is in place on the door, the door is to be correctly located in the hole, with the gasket against the mating face in the boiler. Once it has been determined that the door fits with the correct clearance and is properly located, the bridge, washer and nut can be fed into place. The nut, smothered in a suitable anti-seize type compound, is then done up hand tight (which is why it is necessary to have clean and easy-to-run threads). The door is then centralised in the hole to provide an even gap. It can then be tightened by spanner. It is not necessary to do more than a firm hand tighten, without leaning onto the spanner. When the boiler is readied for steaming, the doors are to be checked for water tightness while the boiler is cold. Minor seepage may be addressed by further tightening. Running leaks are likely to indicate a damaged gasket, poor cleaning, or mis-alignment. This situation requires removal and re- inspection.

Once steaming has commenced, the doors can be lightly tightened, as before, when the pressure is approximately 30 psi. This only applies to internally fitted doors, and no other mountings shall be tightened.

The gasket may compress under pressure, so it should be inspected at full working pressure to ensure that the nut is snug against the bridge. Excessive tightening will put significant stress on the gasket and the shank due to contraction on cooling at the end of the steaming.

21.11 Sample form

MUDHOLE DOOR REMOVAL, INSPECTION AND INSERTION FORM

LOCO _____

/ / DOORS REMOVED BY:	SIGN
/ / DOORS INSPECTED BY:	SIGN
/ / DOORS INSTALLED BY:	SIGN
/ / INSTALLATION INSPECTOR:	SIGN

RETURN THE FORM TO THE LOCO OFFICE SHEET TRAY WHEN ALL OF THE PLUGS IN THE LOCOMOTIVE HAVE BEEN COMPLETED. STAPLE ALL SHEETS RELATING TO ONE LOCOMOTIVE TOGETHER

	DOOR NUMBER	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
INSPECTION PRIOR TO REMOVAL	LEAKAGE PAST SEAL																	
CONDITION OF DOOR FACE IN BOILER	PITS/GROOVES																	
	OPENING TO GO/NO GO GAUGE																	
CONDITION OF MUDHOLE DOOR	PITS/GROOVES IN SEALING FACE																	
	SEALING FACE OK TO GO/NO GO GAUGE																	
	SHANK THREAD OK FOR RE-USE																	
	CORROSION DEFECTS ON DOOR																	
	CORROSION DEFECTS ON SHANK																	
BOILER SEATING OK TO CLOSE UP																		
MUDHOLE DOOR OK TO RE-USE "OK", SCRAP "S", RECONDITION "R"																		
DOOR INSERTED AND NIPPED TIGHT WITH SPANNER																		
RETIGHTENED AT 30 PSI																		
MUDHOLE DOOR INSPECTED UNDER STEAM – FREE OF LEAKS																		

COMMENTS:

Figure 105 Hand and hole door sample map and inspection sheet

21.12 Metal to metal sealed door

Figure 106 shows a type of door where the sealing face is a tapered metal-to-metal joint, with the flange being constrained by studs and nuts. In this particular case, a washout plug has been installed as well. Due to some access issues re-work of these doors shall be included in any boiler lift program.

Removal of these doors is a simple matter of undoing the stud nuts, and (possibly) giving the fitting a tap with a hammer to crack the seal, taking care not to damage the fitting. Note the orientation of the door and always put them back to the same opening.

It is not normal to remove this type of door at every internal inspection, so consideration shall be given in the boiler inspection plan for a suitable periodic examination, taking into account stud affecting conditions such as exposure to corrosion.

Inspection requires that the two (2) mating seats be checked for good contact and that the door has not been distorted due to over tightening of the nuts. If fitted with a washout plug, it, and the hole threads shall be treated as per Section 12.

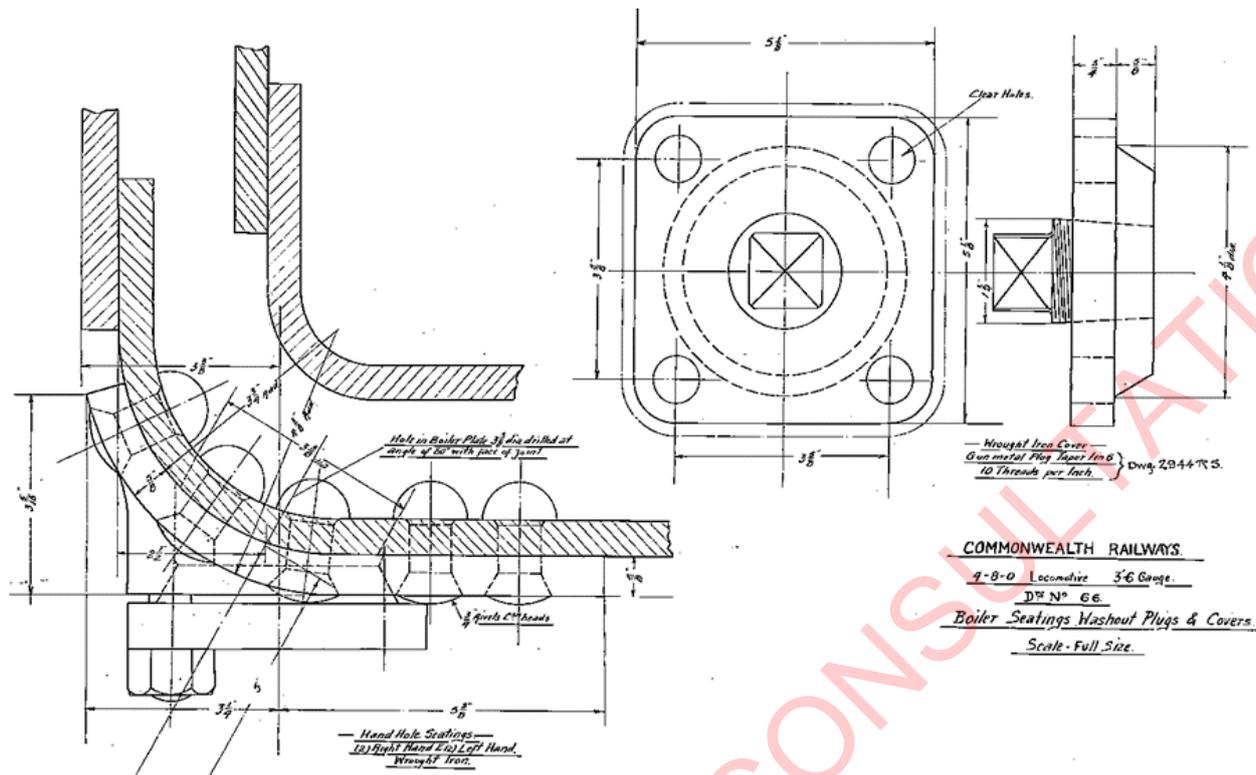


Figure 106 Corner external doors

So that the door can be offered up and rotated slightly, the studs should be removed. The mating surfaces shall be cleaned of any scale or corrosion products. Rotary wire brushes, and hand applied wet rub paper should only be used. A light coating of bluing is applied to one of the faces. They are then mated and an indication of the amount of contact can be made. Care shall be taken to offer up the door so that the mating surfaces are parallel. Correcting any deficiencies that prevent a complete line of contact may require a combination of hand valve grinding techniques and precision scraping.

As it is likely that there will be an extended period between removal of these doors, the studs and the mounting hole threads shall be carefully checked for any defects before re-installing. Damaged studs shall be replaced if any defects are found, and mounting-hole threads repaired or renewed as necessary.

Installation of the door requires careful tightening up of the studs to a repeated pattern such as 1-3-2-4, starting with finger tightening while establishing by hand feel whether the door is seated snugly.

Careful note shall be taken during the hydrostatic test for leaks and some adjustment of the nut tensions might be necessary. This may require judicious backing off, rather than excessively loading up the studs by ongoing tightening.

21.13 Belly plates

In some boilers, larger access doors are set up in the same way; notably for belly openings in the barrel. These belly plates are generally found towards the lowest part of the boiler barrel, and facilitate cleaning and inspection.

They seal on a tapered, metal-to-metal face, bolted into the mounting flange with T bolts, which locate in square-edged slots.

The mounting flange shall be inspected to ensure that the slot edges remain square and are not deformed or worn. Worn or deformed slots shall be repaired before the boiler is returned to service.

Where mounting flanges are secured to the barrel with rivets, the rivet heads within the water space shall be regularly inspected for corrosion and wastage.

The tapered seat shall be inspected for grooves, nicks or other damage. These shall be repaired before attempting to lap the belly plate into it.

The T bolts shall be of forged manufacture from steel as per AS 1228:2016 to ensure that it contains no more than 0.2% carbon, is mild in character with maximum ductility and is free from work hardening. In addition, the material should not embrittle when subjected to service conditions and shall have a minimum of 25% elongation.

T bolts shall be inspected for worn or damaged heads, damaged threads, stretching, and general defects. Should any defects be found, the bolts shall be destroyed, and new ones fitted. Weld repairs on T bolts are not permitted.

Likewise, the nuts shall be of suitable grade (as above), and these shall also be inspected for fit, thread and general condition. Only flat washers are to be fitted.

Two types of belly plate were in use on New South Wales Government Railways boilers, depending on the pressure of the boiler. It is imperative that the correct type of belly plate is used, as a lower pressure-rated belly plate can be wrongly fitted to a high-pressure boiler.

The belly plate shall be inspected for grooving, distortion and general damage and flange thickness. Machining of the belly plate is permissible, however condemning limits shall be observed.

The belly plate is lapped to the mounting flange, ensuring pressure-tight joint. When correctly fitted, a uniform, visible gap shall be observed between the two components to ensure that the tapered faces have correct engagement. Gaskets are not permitted between these faces, but graphite-based jointing compounds are.

Under no circumstances shall belly plate bolts be tightened when the boiler is under pressure.

21.14 Copper rings

A third form of opening utilizes two copper rings as the sealing medium, between two flat surfaces, where the rings are held in grooves (see Figure 107). The inner ring seals against pressure and the outer ring balances the tightening force so that the flange is not bent.

At flange removal, the grooves shall be carefully and completely cleaned of any debris. Similarly, the mating face of the boiler seat shall also be carefully cleaned. Inspection shall include checking for corrosion pits, or physical damage that may interfere with locating and compressing the copper ring. In addition to inspection at removal, further inspection shall be done at the time of installation to ensure no damage has occurred during the maintenance period. The rings are manufactured from copper rod, brazed or copper welded into a ring.

Welding is preferred, (it is necessary if it is proposed to re-anneal and re-use rings more than once) as the ring will have more even softness. The rings are annealed, and scale removed before installation. Excess material is removed from the joint area so that it is the same diameter as the parent material. A control system shall be in place to segregate rings ready for immediate use from all others.

Note that the outer ring is slightly deeper, so that the inner ring is always loaded first, when tightening. Care shall be taken with tightening to ensure the ring is not excessively compressed in one location.

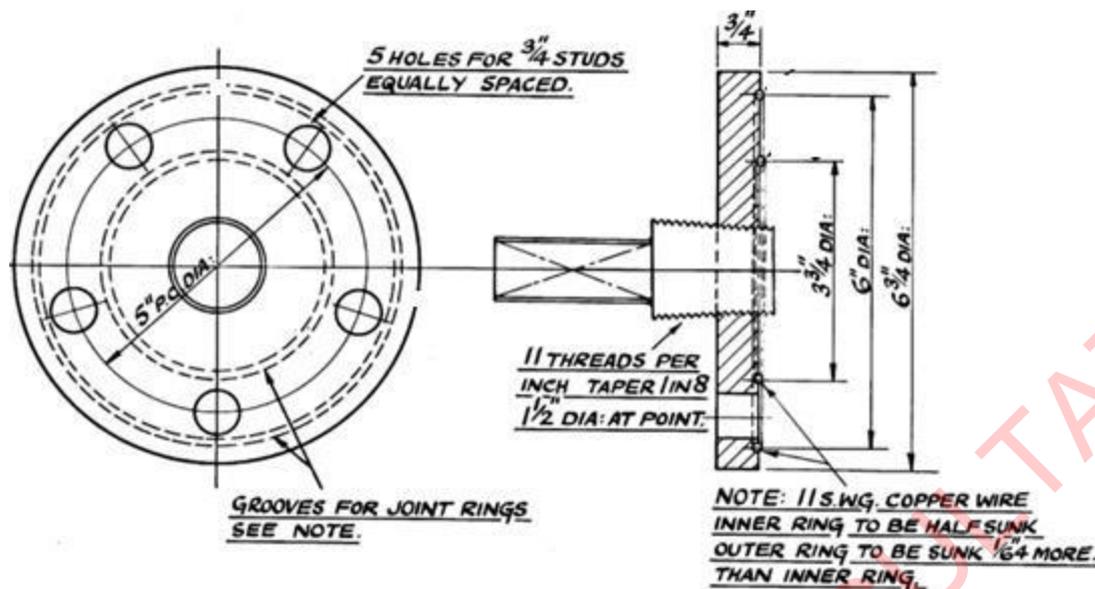


Figure 107 Copper rings for sealing

21.15 Gasket joint

The two flat mating surfaces are sealed with an appropriate gasket, which may be annealed copper, or a proprietary material or type of gasket. The suitability of the gasket for the service conditions shall be ascertained from the supplier and any special installation instructions shall be included in the boiler management plan.

When the fitting being secured is made from bronze or similar alloy, consideration should be given to using the flat metal to metal sealing method. Over-tightened gaskets, especially if too thick, can result in deformation of the fitting base, making it ever more difficult to re-seal.

Gaskets, while able to seal over less than perfect surfaces, should not be used in place of properly finishing surfaces. The surfaces shall still be inspected, and defects remedied before re-use.

21.16 Drawings, work instructions and record keeping

All originals of relevant work instructions (or procedures) shall be controlled documents. Copies made for shop floor use shall be made from a controlled document and be marked uncontrolled.

All handhole doors shall be fully described in detailed, controlled engineering drawings.

All handhole door inspections shall be recorded in a specific written record. Details of the locomotive, competent person and date shall be included.

Fitting of handhole doors shall be recorded in a specified written record. Details of the locomotive, competent person/s and date shall be included.

The record forms of inspections and fitting shall be controlled documents. Copies made for shop floor use shall be made from a controlled document and be marked uncontrolled.

21.17 Responsibilities

The RSO shall assign responsibilities and authority for the various tasks described above, for example, inspection, repair, filling, installation, checking of work and record keeping.

Section 22 Water gauge columns

22.1 General

This section provides guidance when inspecting, fitting and repairing water gauge columns.

Gauge glasses are a critical safety device and, as such, need to be inspected and maintained to ensure that they will operate correctly

22.2 Scope

This section shall be adhered to unless it can be proven that another process or material is equal to or better than the practices and materials laid down in this section.

22.3 Inspection

In the event of finding a water gauge is suspect, seek guidance from the boiler competent person before proceeding with any replacement. Only competent persons should replace gauge glasses.

22.4 Introduction

In accordance with the requirements of AS 2592:2004, there shall be two (2) independent means of checking the level of water in a boiler.

A gauge glass is the most reliable method of indicating the height of the water in the boiler above the critical point (which is the crown sheet in a locomotive boiler).

There are two main types of water gauge commonly found on Australian locomotive boilers: the sleeve-packed tubular gauge glass type, and the reflex type.

To ensure that the correct functioning of the water gauges, it is necessary to test them regularly and correctly. This should be recognized by all persons concerned in the operation of boilers, both operating personnel and management.

Spare gauge glasses and seals/rubbers shall be available to replace broken glasses on operating boilers. These may be kept onboard where the competent person operating the boiler is authorised to change gauge glasses on an operating boiler.

Examples of gauge glasses are provided in Figure 108.

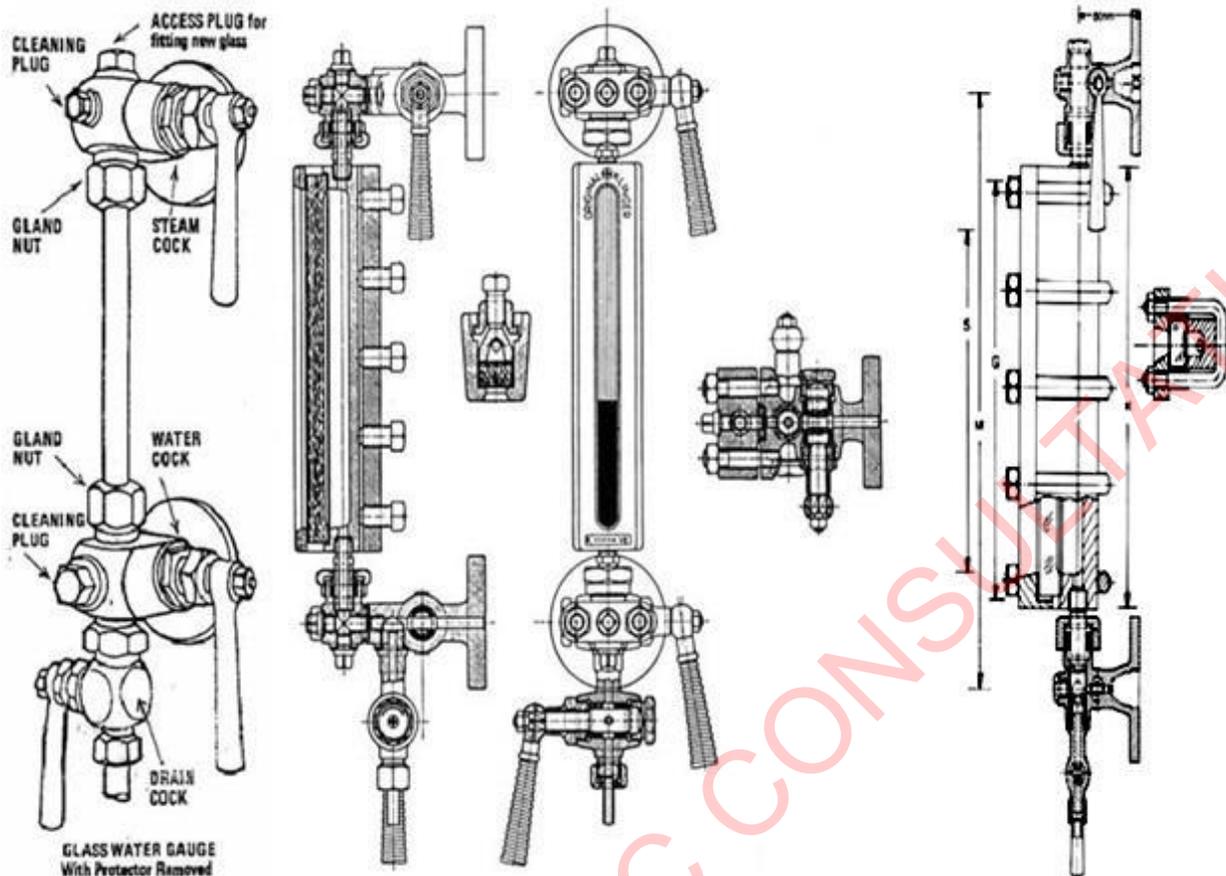


Figure 108 Examples of water gauges (Glass tube type on left, reflex glass type middle and right)

22.5 Water gauge column steam pipes

Water gauge columns of the type fitted with an independent steam pipe connection between the boiler and the top of the gauge column mounting shall be given periodical attention as follows:

During the annual examination:

- (a) carefully examine the top steam pipe connection, and also the water and steamway connections, including studs and nuts. Where any of these is found to be in a defective or wasted condition, they shall be renewed. Replacement studs shall only be manufactured from the correct grade of steel; and
- (b) generally, examine the water gauge columns. If defects be found, they are to be remedied immediately to maintain this important mounting in a safe and satisfactory working condition. All repairs or replacements shall be carried out in consultation with the boiler competent person and the independent boiler inspector, and all actions shall be recorded in the boiler history file.

Where deemed necessary by the independent boiler inspector the steam way connecting pipe shall be removed, annealed, and thoroughly examined. The union nuts, collars and flanges should also be examined for defects. Any pipe found with flats, kinks, flaws, fractures, faulty connections, weak or thin area, shall be discarded and replaced with another that is in satisfactory condition. All replacement pipes shall comply with the original manufacturer's specifications (chemically and mechanically).

It is essential that the bore of steam pipes be unrestricted, and all scale or other deposits shall be removed.

Steam pipes shall not be repaired by brazing on patches or other means either in the body of the pipe or at the junction of the collars or flanges to strengthen flaws, thin areas, or fractures.

Steam way pipes, after having been annealed and examined, shall be subjected to a hydrostatic test of 1.5 times the working pressure. Whilst under this test pressure, they shall be again examined and if found satisfactory, passed for service. This test shall be carried out on the pipe while disconnected from the water gauge column;

22.6 Maintenance of water gauge cocks

At each annual inspection, or at any time that it is suspected that the gauge glass is not operating correctly or that there is a blockage, the plugs opposite to the ends of steam and water passages in the water gauge mountings shall be removed and a suitably-sized rod or wooden dowel passed through each passage to remove any obstruction, scale or sediment that may cause a false water level.

This procedure shall not be attempted with steam in the boiler.

At each annual inspection, or at any time that it is suspected that there is not a clear path between the steam and water ends of the gauge, the drainpipe and top access plug shall be removed, and a wooden dowel of suitable diameter and length to suit the gauge shall be passed right through the gauge glass to test for restrictions.

In order for this test to be carried out, the ball and any other restrictions (where fitted) shall be removed. Care shall be taken to ensure that the ball and other restrictions are correctly refitted at the completion of this test.

All passages shall be kept clean and clear, and the gauge cocks tested for satisfactory operating condition before declaring a water gauge fit for service.

Coincident with the annual boiler inspection, the gauge cock plugs and test cock spindles shall be removed, thoroughly cleaned, lapped if necessary, and greased with a graphite lubricant.

In some tapered plug cocks, where sealing is achieved by metal-to-metal contact, the plug is adjusted by tightening a plug on the small end. Care shall be taken not to overtighten, as there generally little strength in the threaded portion. If the cock does not seal while allowing an easy motion, then it shall be removed, thoroughly cleaned, lapped if found necessary, and greased with a graphite lubricant.

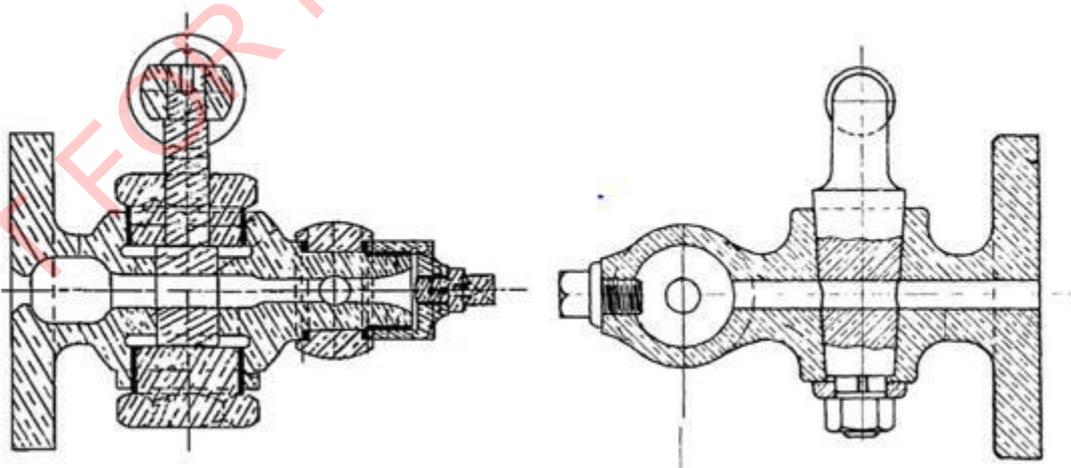


Figure 109 Packed cocks (left side) and plug cock (right side)

Gauge glass cocks on some boilers could have been packed with a loose asbestos-type packing. The RSO shall be familiar with the type of packing in their boilers, and put appropriate procedures in place to

safely deal with this type of packing. Such packing shall be appropriately removed and disposed of and replaced with a suitable modern material.

Tubular gauge glasses shall be removed for inspection to check for wastage of the walls, discoloration and chipping of the ends as determined by the responsible person. The frequency of inspection should be based on the amount of work the boiler has done and the likelihood to need to replace any components. When refitting these glasses, new sealing rings shall be used.

Evidence of the inspection shall be maintained for review by the independent boiler inspector. This could reduce the need to remove the gauge glasses during a boiler inspection.

The ribs on the back of a reflex-type glass may suffer from wastage on the water side and the condition of these shall be visually checked in situ during operations and stripped and fully inspected and a new glass fitted whenever the water level indication becomes indistinct. When refitting these glasses, new sealing rings and gaskets shall be used.

Should the cocks be stiff to operate, they shall be attended to.

When gauge cocks are found to be in satisfactory working condition—not difficult to operate and not leaking there is no need to remove them.

Appendix A Historical information (Informative)

The heritage and tourist sector are represented by many operators, maintainers and repairers across Australia. In 2010 there were over 100 steam locomotives working across Australia. They range in size from very small types (like those used in the sugar industry) operating in a leisurely tourist or heritage environment, through to main-line express locomotives running at high speeds on tight schedules on the Australian commercial main- line network.

Most steam locomotives are equipped with a boiler rated under AS 1343 as a hazard level B pressure vessel. Their design is covered by AS 1228:2016 which also references some original design standards (such as CB1—1957, part 3) where applicable. Their inspection and assessment of fitness for service is covered by AS 3788:2024. There are several other standards covering similar items, such as pressure piping and smaller attached equipment, like pressure relief valves.

Locomotive boiler design, construction, operation, inspection and maintenance practice dates to the early days of the Industrial Revolution in the 19th Century. Except for a few isolated cases, the locomotive boiler design was removed from commercial service in Australia by the early 1970s when dieselisation of the railways was completed.

During the steam era, Australian railways were mainly owned, operated and maintained by state government agencies. Also, dotted across Australia were many small, private operators, such as those in the sugar and coal industries.

Inspection, maintenance and repairs to boilers were carried out at local depots, and major rebuilds and new construction occurred at major workshops. This was supported by specialised staff and infrastructure. The staff was specifically trained in their specialist fields, backed up by many years of experience working with locomotive boilers.

With the advent of the diesel and electric locomotive age, this large engineering work was shut down from the late 1960s, and the personnel moved into other roles to support the new locomotive technology. Today, most of the people who had direct experience with these boilers have retired or passed away.

As the steam locomotive was being phased out in Australia, many examples were preserved by government, local councils, volunteer organisations, private individuals and museums. Many of the organisations aimed to keep the steam locomotive operating. Many have been successful.

These organisations have ranged from government railway operating departments, through organisations working from an entirely volunteer base that operate intermittently, to those with a mixture of full-time paid and volunteer staff maintaining a year-round daily operation.

Away from the main line, the heritage and tourist railways sector has over 80 recognised accredited operators in Australia.

Appendix B Rivets, Riveting and Riveted Joints (Normative)

B.1 General

The purpose of this appendix is to provide as much information as possible about a topic that has a diminishing knowledge base, with the view that it may assist RSOs in the maintenance and repair of riveted steam locomotive boilers in their care.

Most of this information has been sourced from historical documents. To ensure the meaning and context of this information is not lost the original wording is retained.

It will prove useful for those doing the work and those in a supervisory role, however, no work should be undertaken unless the people concerned are deemed competent to do so.

Riveting is a highly skilled task, which is only developed through years of experience, and it should not be undertaken lightly. There are many benchmarks in successful riveting that cannot be defined in text and can only be learned through practice with experienced persons. There are numerous mistakes or omissions that can be made by the inexperienced, and these could lead to catastrophic failure.

B.2 Scope

This appendix shall serve as guidance and be adhered to unless it can be proven that another process or material is equal to or better than the practices and materials laid down in this document.

B.3 Introduction

A rivet is a metal fastener with one pre-formed head, the shank of which is inserted through two or more plates. The unformed end is worked into the appropriate shape to fill the hole and secure the plates.

Rivets were commonly used to manufacture and repair steam locomotive boilers until the end of commercial steam operations on Australian railways.

B.4 Design references

The modern Australian standards do not cover rivets or riveting. The RSO will need to refer to the older standards:

- (a) CB1 Part iii – 1957.
- (b) Australian Standard. No. G.3 – 1961 Carbon Steel Bars for the Manufacture of Hot Forged Rivets. (Withdrawn). Specifications for the manufacture of carbon steel bars up to 2" in diameter for the manufacture of hot forged rivets.

B.5 Rivet material

The material used for making rivets shall be sufficiently ductile to allow the rivet head to be formed and the shank deformed to fill the hole without cracks forming in the rivet that may lead to catastrophic rivet failure in-service.

The properties of material suitable for the manufacture of hot forged rivets shall comply with the following limits:

- (a) carbon, not more than 0.20% (per cent carbon shall not be exceeded)
- (b) manganese, not less than 0.40%
- (c) sulphur, not more than 0.05%
- (d) phosphorus, not more than 0.05%

- (e) elongation, not less than 25%
- (f) ultimate tensile strength, 400 MPa — 460 MPa
- (g) yield strength, 50% of the tensile strength

NOTE:

Many modern steels are cold worked, and although they may have the correct chemical composition, they will not comply with the mechanical properties. It is worthwhile to consult with a metallurgist to find a modern steel to meet all the above parameters.

B.6 Test certificates

Test certificates are required with the purchase of steel used in rivet manufacture and for rivets to prove compliance with standards.

Test certificates shall be kept in the boiler history file of the locomotive boiler in which the rivets were used

B.7 Heating of rivets

Correct heating of rivets is a sensitive operation. Rivets shall be heated right through to their plastic state in order to be hot enough to be effectively knocked down, but may be overheated to the point where a rivet is no longer fit for purpose because the composition of the steel has been irreversibly altered. Generally, rivets need to be white hot, but not heated so far that the material is sparking; this is a very fine line.

B.8 Method of riveting

The act of joining pieces of metal by means of rivets is known as riveting; and it consists of passing a rivet through holes in the metal and then forming a second head. The part of the shank from which a second head is formed is usually known as the neck of the rivet.

The rivet head may be formed entirely by hammering with a light hammer, in which case this process is called hand riveting.

If the head is formed by striking a die with a heavy hammer, this process is called snap riveting, which is a modification of hand riveting.

The die, also called a set, or snap, is made of hardened steel shaped to the desired form of the rivet head.

If the head is formed by striking comparatively light rapid blows with an air or pneumatic hammer, this process is called pneumatic riveting.

If the head is formed by squeezing or upsetting the metal of the neck under high pressure in a machine, this process is called machine riveting.

If in doubt, do not be afraid to seek guidance from persons experienced in the field.

For boiler work in general machine riveting has important advantages over hand riveting, and should be employed wherever possible.

The advantages are that:

- (a) the holes in the plates can be better filled because the shank is made to spread out by the pressure applied to upset the rivet to form the head; and
- (b) each rivet may be driven with exactly the same pressure, and if the temperature of the rivets is the same, a very uniform, and better joint will result.

It is impossible, however, to get a machine riveter into most locations on a steam locomotive boiler. In these instances, pneumatic riveting is the best alternative.

NOTE:

Hot riveting is possibly the most hazardous activity that occurs during boiler repairs, and is therefore worthy of special safety precautions.

Pneumatic rivet guns generally contain an unrestrained, or non-captive, bullet, which strikes the shaft of the head-forming snap to create the riveting action and form the head (refer to drawing below). Should the gun be discharged when the snap is not against the rivet, the snap and bullet can become dangerous projectiles and cause serious injury. For this reason, any personnel not directly involved in the riveting process shall stay well clear. Rivet guns shall not be pointed at any person. Operators shall also take care that the trigger is never engaged when the snap is not against the rivet and plate.

Any person within a direct line of the rivet gun (such as the holder up or the rivet catcher) is in a vulnerable position, and the operator shall take every precaution to ensure their safety.

When using a riveting gun with an external, unguarded trigger, it is recommended that a second isolating valve be fitted on the gun so that the operator can turn the air off when the gun is not in use. This obviates accidental discharge if the trigger is bumped or the gun mishandled.

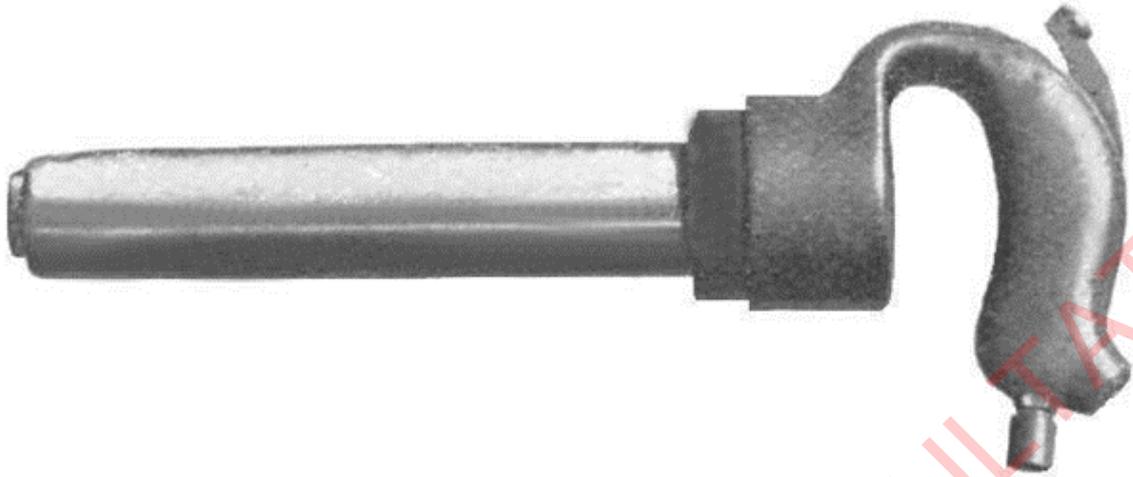
When holding the gun between operations, the thumb should be inserted between the handle and the trigger to minimize the risk of accidental triggering.

Whenever the rivet gun is not in the operator's hands, the bullet and snap should be removed to prevent accidental discharge.

The following information has been reproduced from old text and has not been edited for content. It may contain work practices and procedures that are no longer considered appropriate today.

It has been included to provide extra information, which is general in nature and should not be considered the only training required to attempt hot riveting. Guidance should be sought from experienced personnel and practice undertaken before the inexperienced attempt boiler riveting.

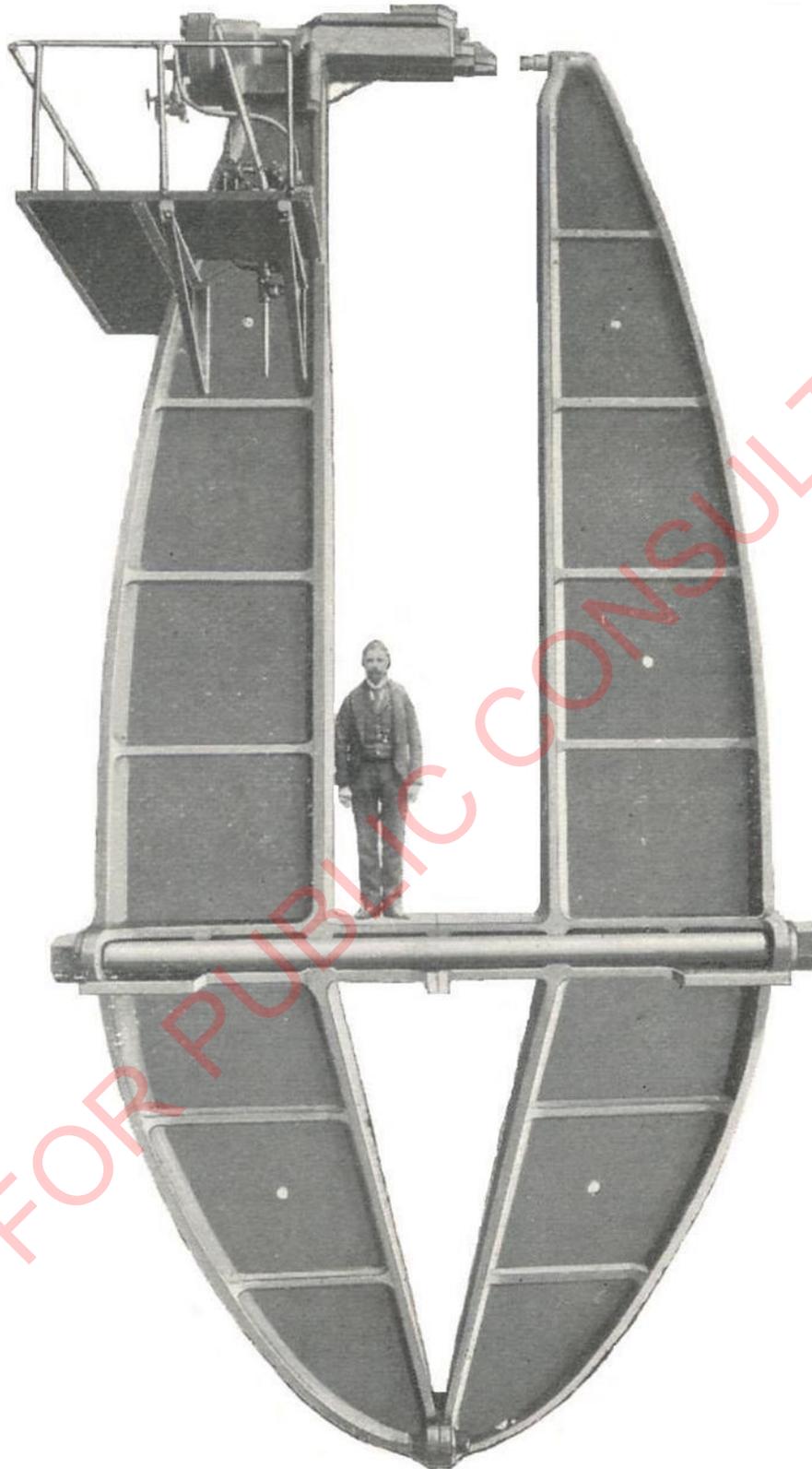
B.9 Examples of pneumatic riveting hammers



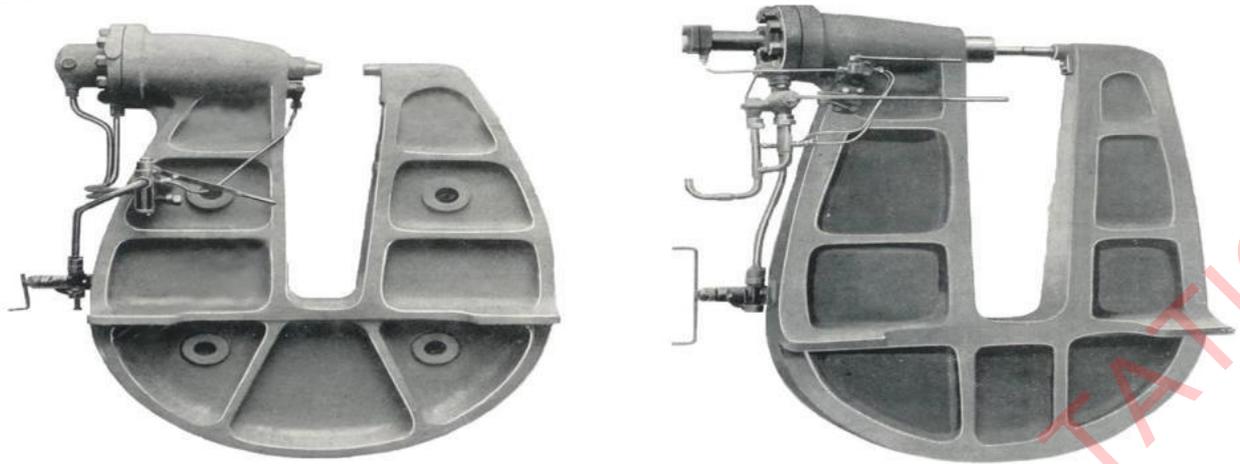
Appendix Figure B-1 Long stroke riveting hammer



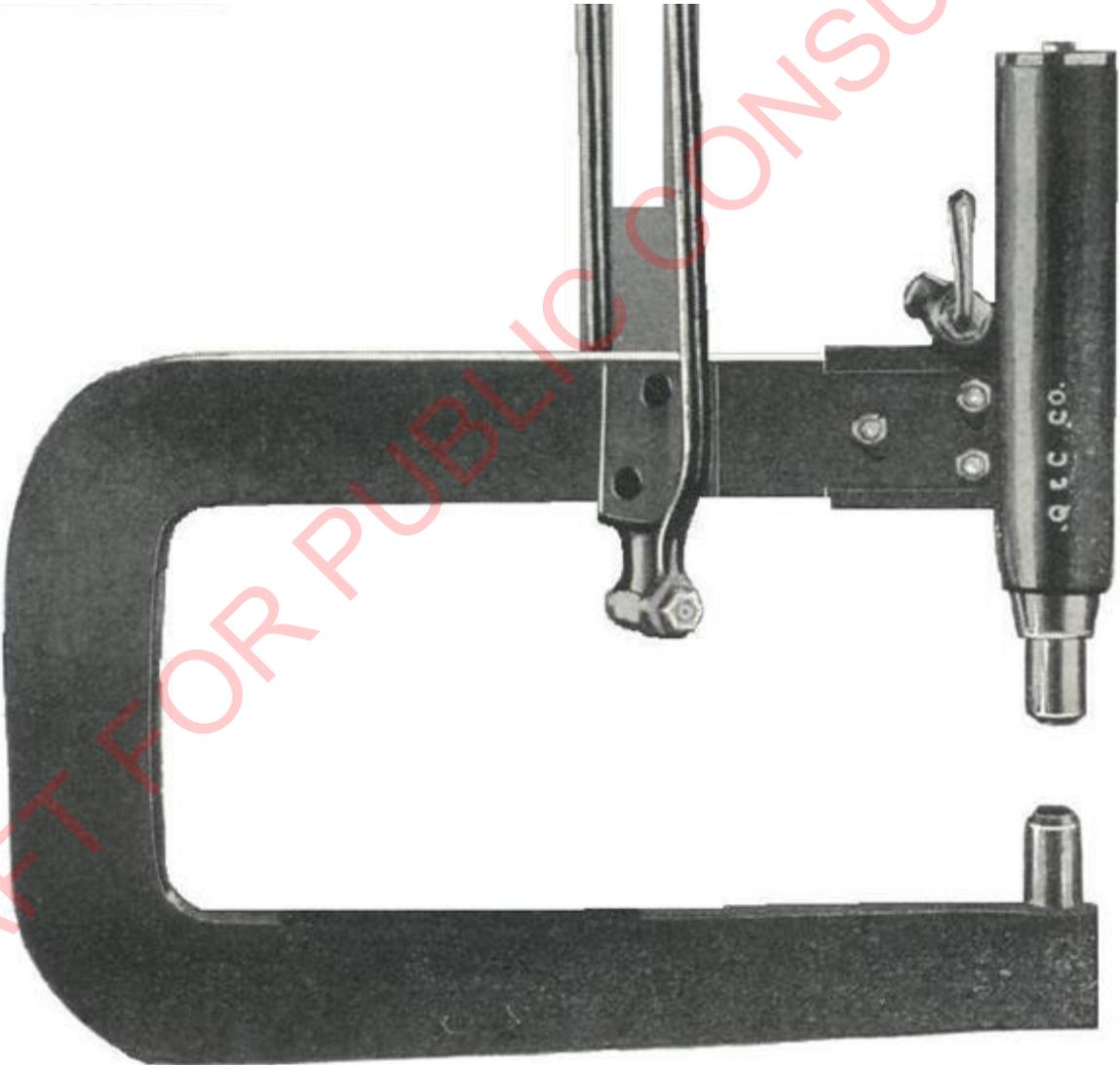
Appendix Figure B-2 Short stroke riveting hammer



Appendix Figure B-3 Fixed gap riveter



Appendix Figure B-4 Stationary gap riveter



Appendix Figure B-5 Portable gap riveter

B.10 Pneumatic riveting

B.10.1 Classes

The use of compressed air for operating riveting devices has led to the development of several different types of pneumatic riveting machines, which can be grouped broadly into two classes:

- (a) air or pneumatic riveting hammers; and
- (b) yoke or gap riveters.

Riveting hammers are built for both light and heavy work.

Hammers for light work weigh from 10 pounds to 12 pounds and the stroke of the piston varies from 2" to 4" which are capable of forming heads of rivets ranging from 5/16" to 9/16" in diameter.

Hammers for heavy work weigh from 16 pounds to 22 pounds, the stroke of the piston varies from 4" to 9", depending on the size of the hammer.

Pneumatic riveting hammers are classified as short stroke and long stroke hammers. Short stroke hammers are especially suitable for driving rivets 5/8" in diameter or smaller and long stroke hammers for driving rivets larger than 5/8" in diameter:

- (c) Heavy riveting hammers having a stroke of 4" are used for heading rivets from 5/8" to 3/4" in diameter.
- (d) Hammers with a 5-inch stroke can drive rivets 7/8" in diameter and smaller.
- (e) Hammers with a 6-inch stroke can drive rivets from 1" to 1 1/8" in diameter and smaller.
- (f) Hammers with an 8-inch stroke are used to drive 1 1/4" rivets; and
- (g) hammers with a 9-inch stroke are used to drive rivets 1 3/8" in diameter and smaller.

The yoke or gap riveter is built in two styles, known as the compression and hammer riveter.

The compression riveter gradually forms the rivet head by the great pressure exerted by the slow closing of the jaws of the machine.

The hammer type drives the rivets by a series of blows from a piston or plunger arranged in the jaws of the machine.

B.10.2 Pneumatic riveting hammer

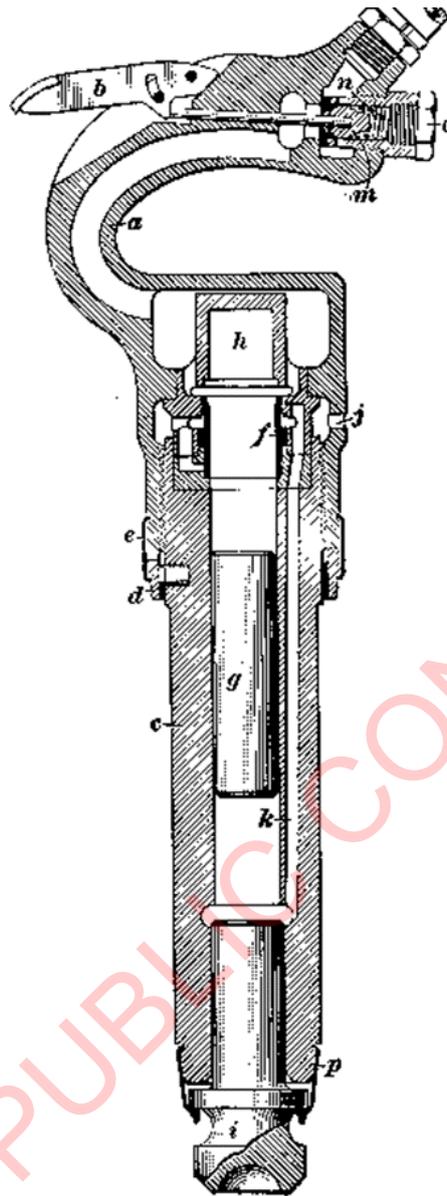
A sectional view of one form of pneumatic riveting hammer is shown in Appendix Figure B-6

The handle *a* is a steel drop forging and is open, although it may be made of the closed type. The latch (*b*) that controls the admission of air to the hammer is on the outside of the handle but in some forms, it is placed on the inside.

To obtain a rigid construction, the handle (*a*) and the cylinder are screwed together and then locked with a locking ring (*d*) and a locking spring *e*.

A valve block (*f*) is placed in the handle of the hammer to distribute the air in the operation of the piston or plunger (*g*).

An air pocket or chamber (*h*) is formed back of the valve block to act as a cushion against which the plunger strikes on its return stroke preventing it from injuring the air valve mechanism.



Appendix Figure B-6 Sectional view of a pneumatic riveting hammer

The plunger (*g*) passes through the valve block into the cushion chamber (*h*) on the return stroke on the outward stroke it is driven by air pressure to the outer end of the cylinder (*c*), where it delivers a sharp blow against the rivet set (*i*).

After the plunger (*g*) has been driven forwards in the cylinder, the valve (*f*) shifts and cuts off the admission of compressed air behind the plunger.

This valve movement at the same time uncovers the exhaust passage and allows the air behind the plunger to escape by way of the port (*j*).

Also, it admits air to the port (*k*) leading to the end of the cylinder and puts pressure on the front end of the plunger (*g*).

The plunger is then driven back into the cushion chamber (*h*).

The valve then shifts again, admitting air behind the plunger, another blow is delivered, and the sequence of actions is repeated.

Air enters the hammer from a hose through the connection *l* and its admission to the working barrel is controlled by the valve (*m*), the stem of which is in contact with the trigger, or latch (*b*). The valve is closed by the pressure of the spring (*n*) beneath the removable cap (*o*).

The rivet set (*i*) is held to the end of the hammer barrel by a spring clip (*p*).

B.10.3 Yoke riveters

One form of portable compression yoke riveter is shown in Appendix Figure B-7 (a) and (b). It is suspended from a crane and is readily moved to the work.

A frame *a* of cast steel forms the yoke of the machine and carries the operating mechanism. The distance (*b*) from the centre line of the rivet dies to the inside of the throat is called the reach of the riveter, and the depth (*c*) between the jaws is called the gap.

The lower rivet die (*d*) is held in a die holder (*e*) in the stationary lower jaw of the yoke.

The upper die (*f*) is held in a die holder *g* that is threaded and adjustable vertically in the plunger *h*.

The plunger slides up and down inside a sleeve (*i*) held in the upper jaw of the yoke which is lubricated through the oil holes *j*.

The adjustable feature of the upper die enables the riveter to be set to accommodate rivets of different lengths.

The rivet is driven, in the case of the machine shown in Appendix Figure B-7 (a) and Appendix Figure B-7 (b), by the descent of the upper die (*f*), the pressure being transmitted to the plunger (*h*) through a system of levers from the air cylinder (*k*).

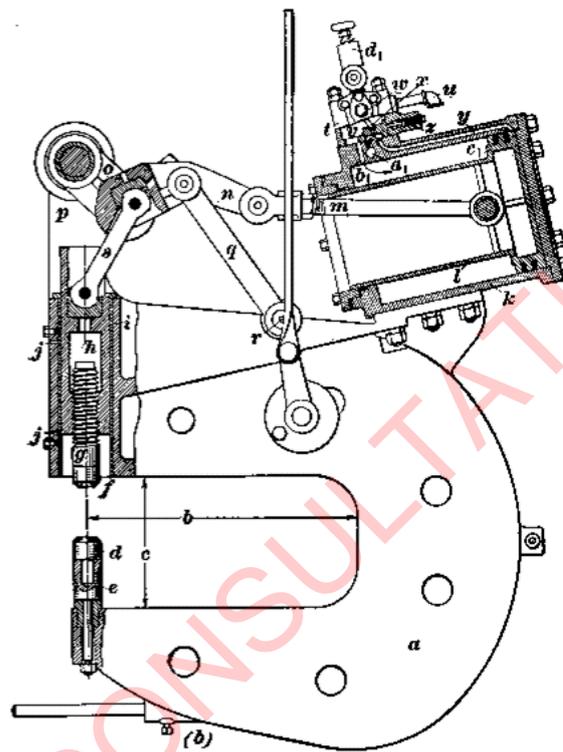
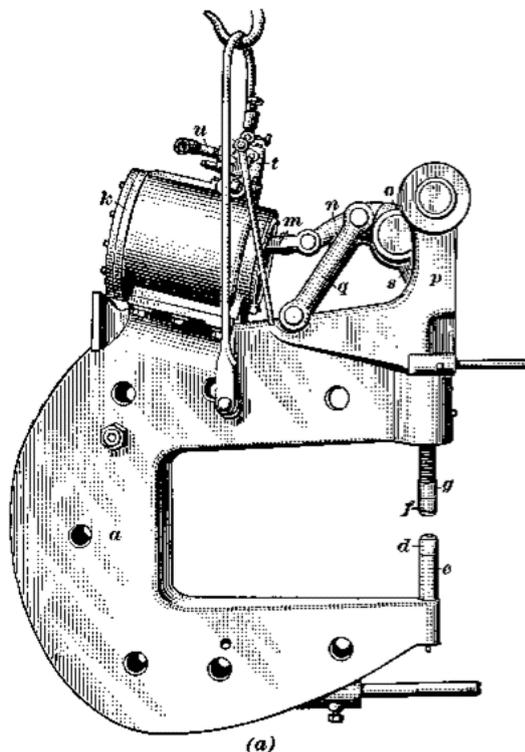
This cylinder contains a piston (*l*) that is connected by a rod into one end of a bent lever (*n*). The other end being pinned to the toggle (*o*) that swings on a pin in the bracket (*p*) on the upper jaw of the yoke.

At its middle the lever (*n*) is pinned to a swinging arm (*q*) that is pinned to the yoke at (*r*). A rod (*s*) is connected to the plunger (*h*) and the outer end of the bent lever (*n*).

Air under pressure is conveyed to the chest (*t*) through the pipe (*u*) which is admitted to the cylinder (*k*) by the slide valve (*v*).

A squared stem (*w*) at its inner end arm at (*x*) that fits in a groove in the back of the slide valve.

By turning the handle fitted on the squared stem, the valve is moved to the left, uncovering the port *y* and admitting air behind the piston (*l*), causing it to move outwards.



Appendix Figure B-7 (a) Pneumatic riveting hammer

Appendix Figure B-7 (b) Sectional view

The outward movement of the piston (*l*), Appendix Figure B-7 (b), carries the rod (*m*) outwards and forces the bent lever (*n*) to move outwards but at the same time, the rod (*q*) compels it to swing downwards with the result that its large end is forced to the left.

This movement causes both the levers (*o*) and (*s*) to turn and by a toggle joint action brings them into approximately the same vertical line, as shown in Appendix Figure B-8 (a).

As the pin at the upper end of the lever (*o*) is fixed in its bracket (*p*), the lower end of the lever (*s*) is forced down, carrying with it the plunger (*h*) and the upper die (*f*).

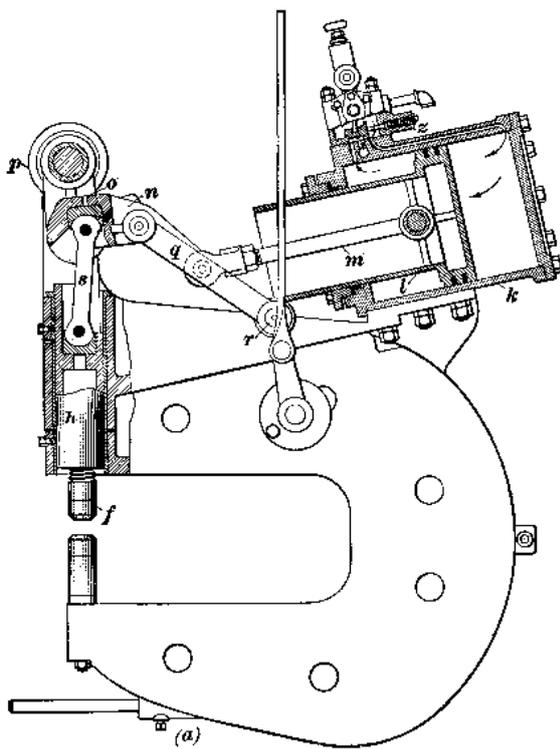
The pressure extreme pressure exerted by the die upsets the rivet shank, partly forming the head, as shown in Appendix Figure B-21.

When the mechanism has reached the position shown in Appendix Figure B-8 (a), the piston has completed half of its stroke.

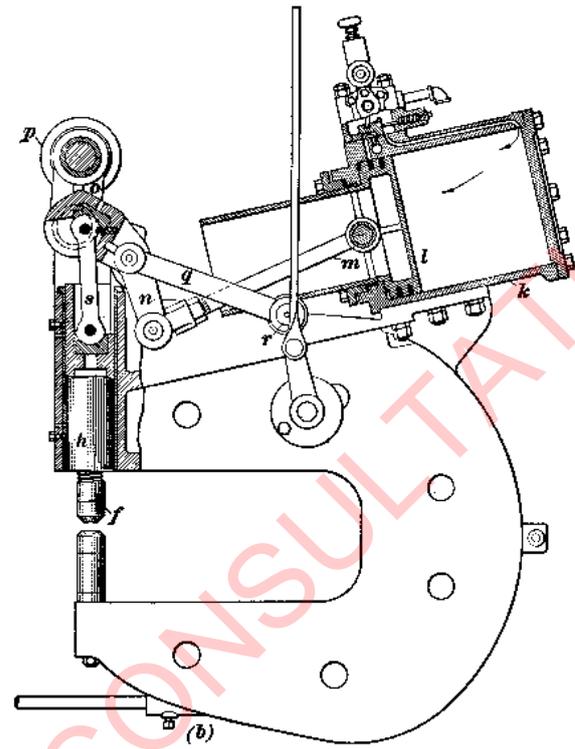
Further movement of the piston brings the parts to the positions shown in Appendix Figure B-8 (b).

The inner end of the bent lever (*n*) is forced down and out, giving a further slight downward movement of the rod (*s*) and the plunger (*h*), exerting a still greater pressure on the rivet.

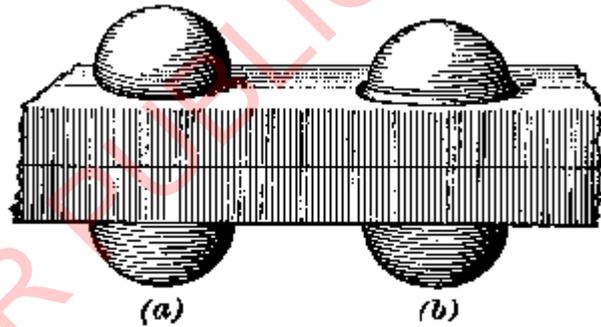
This final stage of the movement forces the plates together tightly and forms the finished rivet head, as shown in Appendix Figure B-9



Appendix Figure B-8 (a) Part compression



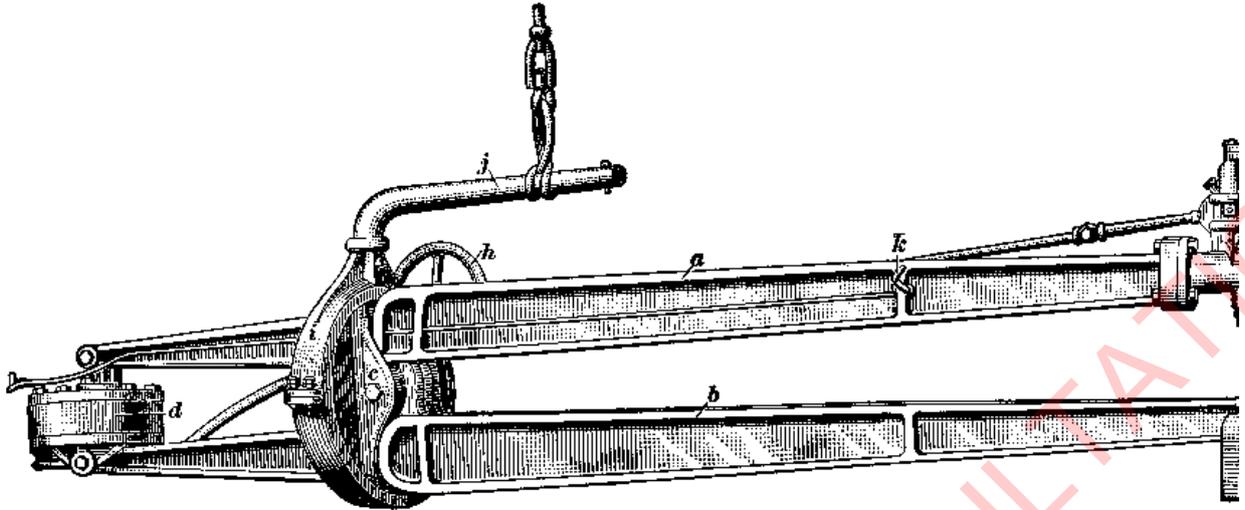
Appendix Figure B-8 (b) Full compression



Appendix Figure B-9 Finished rivet heads

The holes drilled in the yoke are located to the centre of gravity of the machine to allow it to be suspended as shown, with the rivet dies horizontal, or even inverted, with the operating cylinder k below instead of above, to suit different kinds of work.

A portable yoke riveter of the hammer type is illustrated in Appendix Figure B.10. The two arms, or jaws, (a) and (b) are fulcrumed on a pin in the disk (c).



Appendix Figure B-10 Hammer type yoke riveter

Between the short ends of the arms is located an air cylinder (*d*) containing a piston, and when air under pressure is admitted to the cylinder, the short ends of the arms are forced apart, turning the arms about their fulcrum and closing the rivet dies (*e*) and (*f*) on the work between the longer ends of the arms.

The cylinder *g* contains a piston that is driven by compressed air and that strikes the shank of the die (*f*).

The blows of this piston, in rapid succession, cause the die (*f*) to form the rivet head, the die (*e*) being cupped to receive the rivet.

The disk (*c*) carries at its outer edge a worm wheel that engages with a worm on the same shaft as the hand wheel (*h*).

By turning the hand wheel, the disk and the arms may be rotated inside the supporting ring *i* and the dies may be brought to correct alignment with the work.

The riveter is suspended by the arm (*j*) from a chain attached to a crane.

This type of riveter is built with a reach of between 48 inches to 108 inches and of such capacity as to drive rivets up to and including 1¼" in diameter.

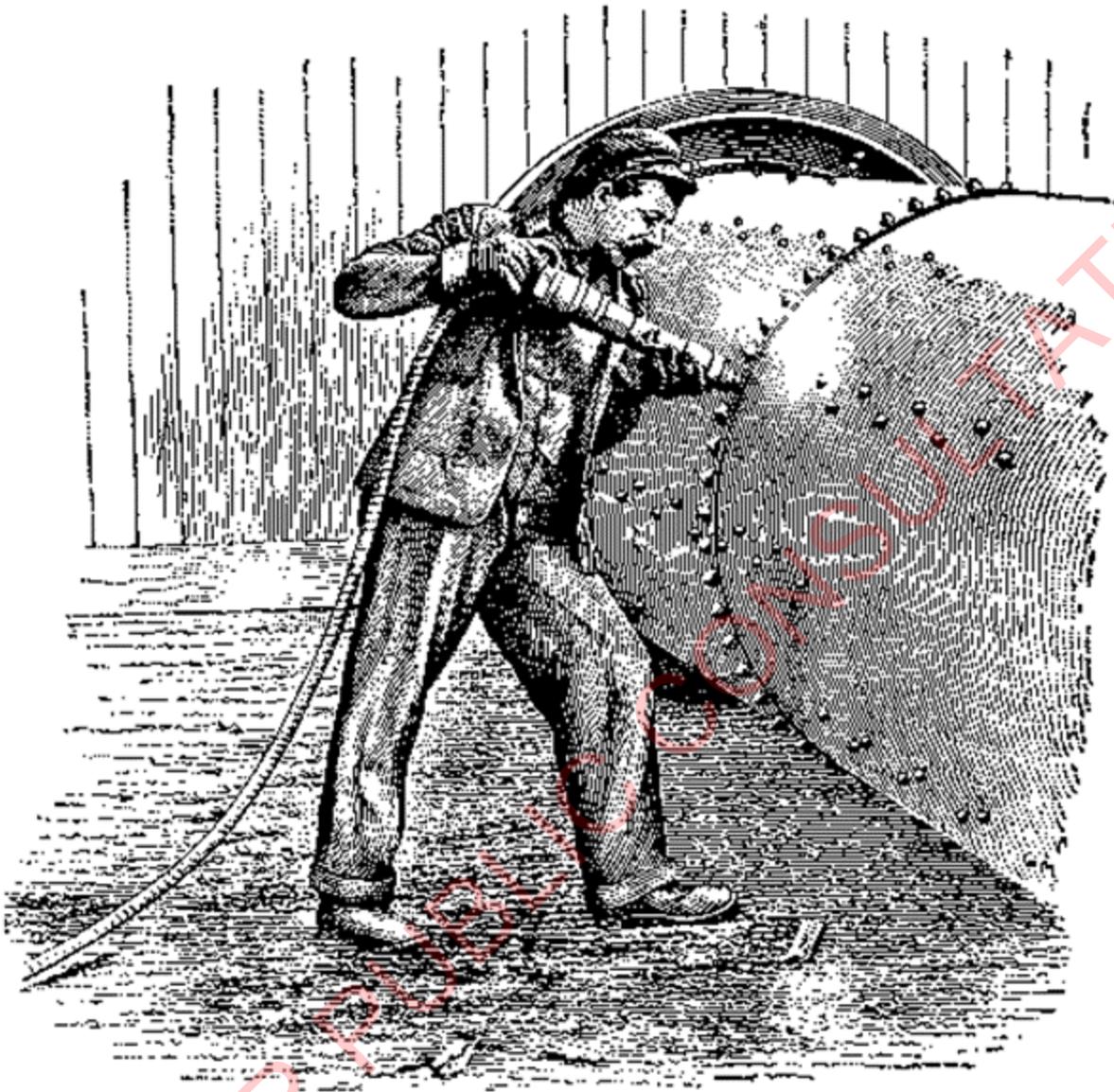
B.10.4 Use of pneumatic riveters

When a rivet is being driven, the air hammer should be held directly in line with the axis of the rivet (see Appendix Figure B.11), and with the rivet set held firmly against the end of the shank.

The hammer should be started slowly, so that the rivet will first be upset enough in the hole to prevent it from being forced back.

The full air pressure may then be allowed to act on the hammer and form the rivet head.

After the head is completed the handle end of the hammer may be lowered slightly to work down the edge of the rivet head. The rivet should be completely driven before it has lost its red heat.



Appendix Figure B-11

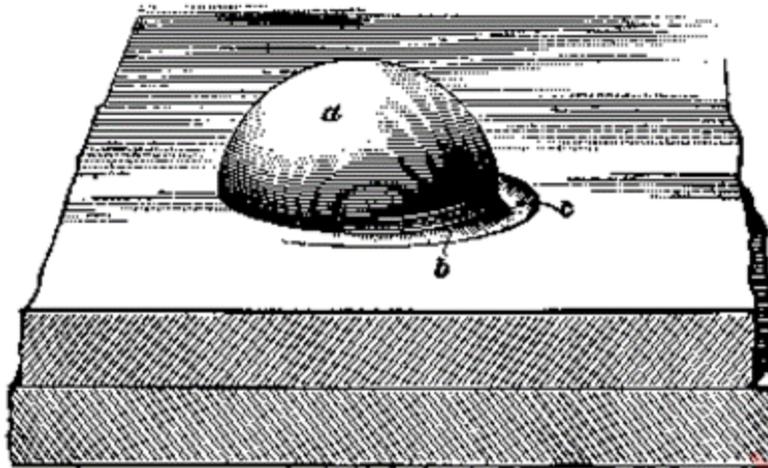
Continued hammering on rivets that have cooled injures the metal, often causing crystallization resulting in the head being knocked off by a blow, as if from a hammer.

Another bad practice in riveting is rolling the hammer, which consists in swinging the handle of the hammer in a large circle.

This causes the die or rivet snap of the hammer to strike the rivet head, causing the rivet to be off centre as per Appendix Figure B-12.

A groove (*b*) is formed in the rivet head, and the edge of the rivet die may even cut the boiler plate, forming a recess (*c*). When the rivet set becomes heated from continuous driving, it may be cooled by being dipped in a bucket of water.

In order that a pneumatic hammer may work to the best advantage, it shall receive a sufficient volume of air at a pressure of about 100 psi at the hammer. When the hammer is used at a distance of 50 ft or more from the nearest compressed air connection a $\frac{3}{4}$ " armoured hose should be used to supply air to the hammer.



Appendix Figure B-12 Off centre rivet

This size is somewhat large, but it ensures a good supply of air at the hammer.

Because the stiffness of the armoured hose, it is customary to use from 5 ft to 10 ft of flexible $\frac{1}{2}$ " hose between the hammer and the armoured hose.

The flexibility of the short hose enables the riveter to handle the air hammer with greater ease. Before the hammer is attached to the air connection, it is customary to blow out the air piping by opening the air valve.

This is done to remove water that condenses and collects in the piping.

Water affects the operation of the hammer, blocking the air ports and often causing the valve to stick by freezing the moisture.

B.10.5 Changing weight of plunger

Pneumatic tools receive hard usage, as a general rule, and are often abused because of unauthorised changes made by repairmen.

One unauthorised change being the substitution of the regular piston or plunger of the air hammer for a shorter lighter one, the idea behind this change increases the rapidity of the blows.

A short plunger is liable to disintegrate and break probably destroying the barrel in doing so.

Furthermore, it is probable that a short plunger will not be cushioned properly at the end of its rearward stroke, additional damage results in breaking the hammer handle.

If barrels, plungers, handles, or rivet dies of air hammers are broken frequently while in use, it should be ascertained whether short plungers have been substituted for the standard plunger.

Care should be exercised to see that the handles on the riveting and chipping hammers are always kept tight. Practically all these tools have a suitable locking device for securing the handle when it is screwed borne. In case of trouble this is one of the first areas to receive attention.

B.10.6 Lubricating pneumatic hammers

All pneumatic tools, when in use, should be oiled through the inlet valve hourly with a good quality of light mineral oil.

Pneumatic tool manufacturers, as a rule, supply suitable high-grade oil at very reasonable prices. Heavy oil should never be used.

The expansion of the air in passing through the tool causes low grade oil to become thick and gummy; this interferes with the free movement of the parts, besides closing the small air ports.

B.10.7 Use of air strainer

As a protection for pneumatic tools, the manufacturers recommend an air strainer, which should be applied to the compressed air line at the hose connection for removing foreign matter that may have accumulated into the airline.

The dirt passes through the compressor and out through the compressed air lines.

If no strainer is used foreign matter may enter the tools, preventing them from operating properly.

If strainers are fitted, the dirt accumulates in them, they can be removed at intervals and cleaned. A clean air supply reduces failures with air tools.

A decrease in air tool efficiency while a strainer is used indicates the strainer should be examined immediately, as it may be found to be clogged with foreign matter.

B.10.8 Cleaning pneumatic hammers

Attention should be paid to the systematic cleaning of pneumatic tools.

When the hammers are returned to the tool room, they should be suspended in a bath of benzine or petrol, where they should remain overnight.

In the morning before the tools are received by the workmen they should be connected to an air hose and thoroughly blown out, after which a sufficient quantity of proper lubricating oil should be injected into the handle hose connection, and blown through, allowing oil to find its way into the tool. Where automatic oilers are not in use, the operator should be provided with a small oil can so that the hammer may be lubricated at hourly intervals.

The use of kerosene for cleaning an air hammer is inadvisable, as it is difficult to blow it entirely out of the hammer.

When there is a slight trace of kerosene left the light lubricating, oil will not adhere to the parts but is carried off by the exhaust. Before the operator realizes what is taking place, the hammer becomes dry, the parts expand, and the tool refuses to operate.

Great care should be exercised always to see that the ports are free from dirt. In some designs of hammers there are small ports that are easily clogged by any accumulation of dust in the oil used for lubricating purposes.

B.11 Hydraulic riveting

B.11.1 Procedure

In hydraulic riveting, the upsetting of the shank of the rivet and the forming of the rivet head are done by a squeezing process.

Heavy water pressure is applied to the movable rivet die.

The water used for this purpose is pumped into a storage cylinder containing a piston or plunger loaded with a very heavy weight.

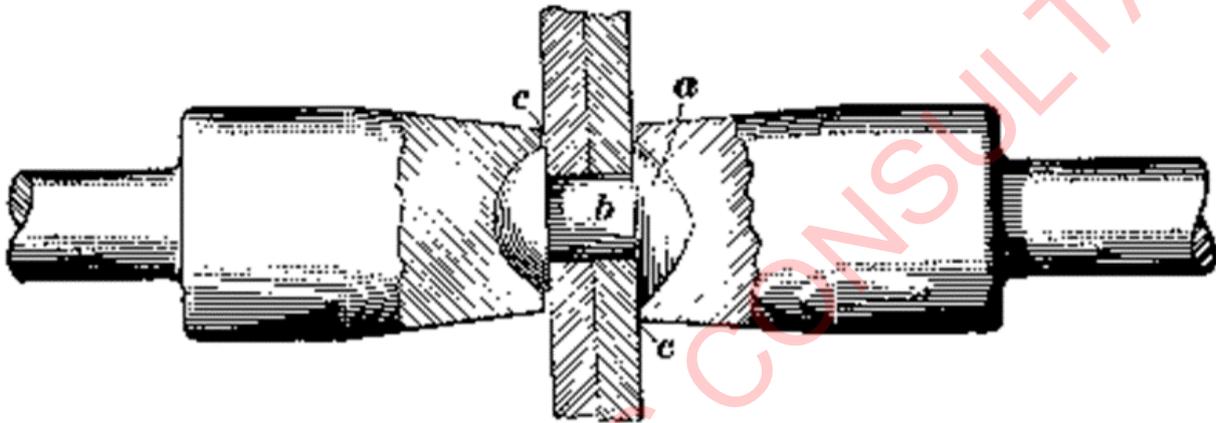
Pressure is maintained on the water that is led through pipes to the riveter.

Hydraulic riveting, known in the shop as bull riveting, is superior to all other methods of riveting, because it produces a better quality of work and a greater quantity in a given time. The general practice in hydraulic riveting is to use the cone-head type of rivet, applied from the outside of the boiler, and to form the second head of the rivet on the inside of the boiler.

The cone head on the outside is converted into either a button head or a conoid head during the driving of the rivet, the shank being upset from both ends.

In this, as in other methods of riveting, the dies should be at right angles to the surfaces of the plates and their centre lines should coincide with the axis of the rivet.

If they are not, as shown in Appendix Figure B-13 the rivet head *a* will be formed to one side of the shank, or eccentric to it.



Appendix Figure B-13 Rivet head formed eccentric to the shank

In such a case, the shank is not upset properly, and the rivet will leak, necessitating its removal and the driving of another rivet.

Also, there is danger that the edges (*c*) of the dies will cut into the plate, as shown at (*c*), Appendix Figure B-13.

B.11.2 Tonnage required

The pressure in tons, required for hydraulic riveting is approximately 100 tons per square inch of rivet section. The required pressure for commercial sizes of rivets (driven size) is given in Appendix Table B-14.

The pressure gauges on hydraulic riveters are usually graduated to indicate the total pressure, or tonnage, on the ram, in order that the riveter will not have to make calculations.

TABLE I
TONNAGE FOR HYDRAULIC RIVETING

Diameter of Rivet Driven Size Inch	Pressure Required Tons	Diameter of Rivet Driven Size Inches	Pressure Required Tons	Diameter of Rivet Driven Size Inches	Pressure Required Tons
$\frac{1}{2}$	30	$1\frac{5}{8}$	80	$1\frac{5}{8}$	150
$\frac{3}{8}$	30	1	80	$1\frac{3}{8}$	150
$\frac{1}{4}$	30	$1\frac{1}{8}$	90	$1\frac{7}{8}$	160
$\frac{3}{16}$	40	$1\frac{1}{8}$	100	$1\frac{1}{2}$	170
$\frac{1}{8}$	60	$1\frac{3}{8}$	125	$1\frac{3}{8}$	180
$\frac{1}{16}$	70	$1\frac{1}{4}$	125	$1\frac{1}{8}$	180

Appendix Figure B-14 Tonnages for hydraulic riveting

B.11.3 The arrangement of boiler

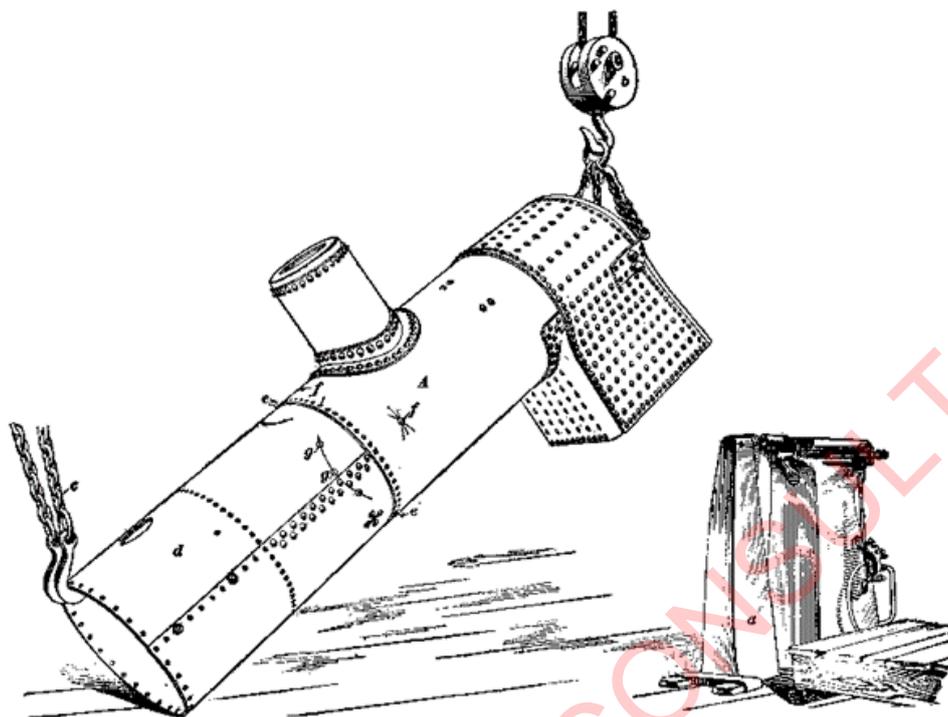
The arrangement of the work before and during the riveting is very important.

In Appendix Figure B-15 is shown a small locomotive type boiler A being raised so as to be placed over the stake a of the hydraulic riveter.

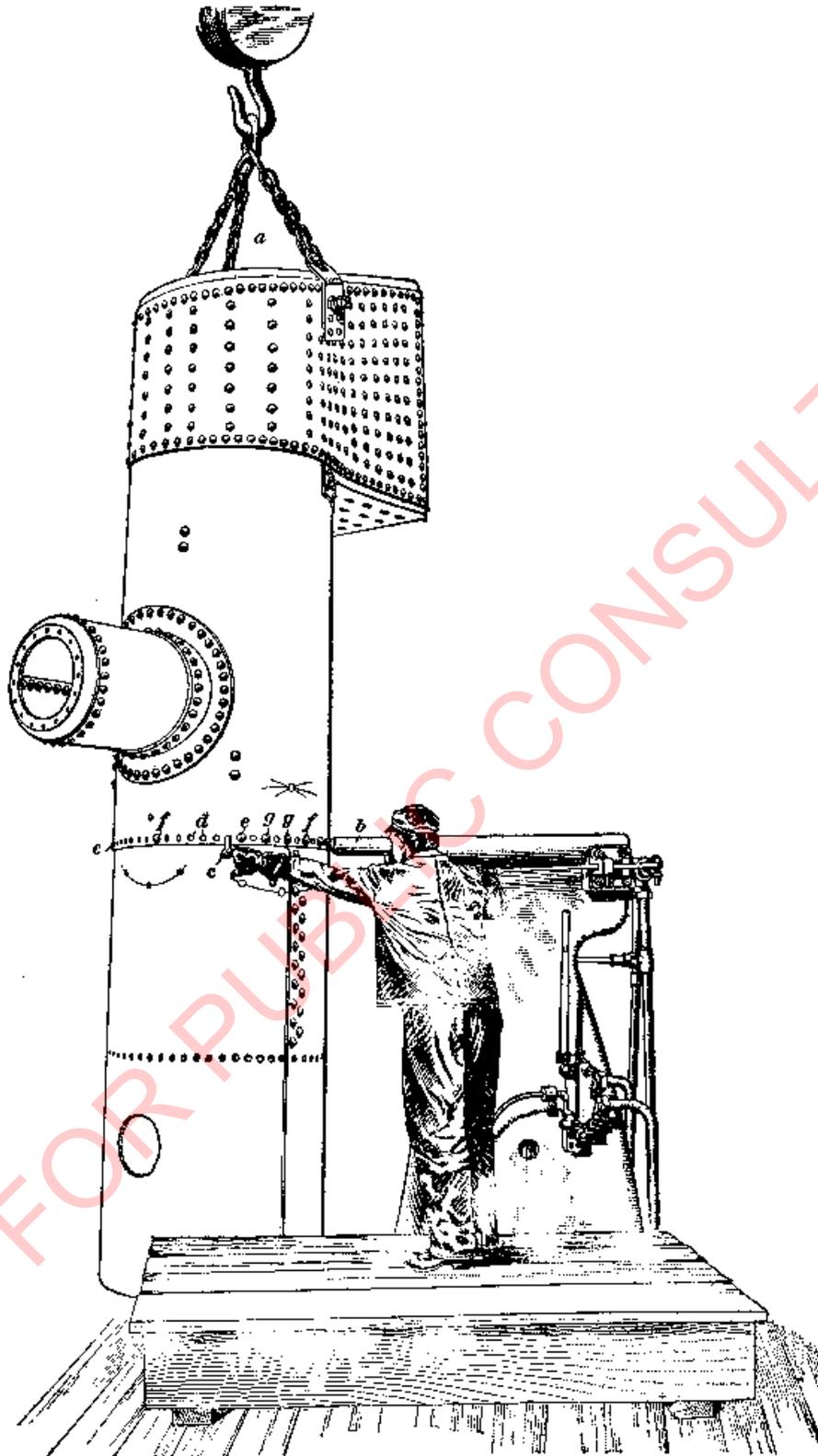
The boiler is raised by the hoist (b) aided by hoist (c).

The latter hoist is used to raise the boiler to a sufficient height so that the first course (d) will not drag on the floor when the firebox end is raised by the hoist (b).

The illustration shows the course (d) just after being connected to the boiler A by the drift pins (e), which hold the course in place until the boiler is raised to a vertical position, as shown in Appendix Figure B-15.



Appendix Figure B-15 Lifting boiler for hydraulic riveting



Appendix Figure B-16 Vertical boiler position for hydraulic riveting

Then the first course is lined up, the lining up being accomplished by trying the tram marks on all quarters and making the distances between the centres Appendix Figure B-16 (f) and (g) equal.

After the boiler has been lined up, the first course is bolted to the boiler.

The connecting of a course to the boiler at the hydraulic riveter is performed by the workmen, and becomes necessary, either when the depth of the gap is insufficient to permit driving of all rivets of the completely assembled boiler, or when the location and shape of the parts necessitate this practice.

After it has been lowered by means of chains (*a*), Appendix Figure B-16, so that the centre of the plunger (*b*) coincides, as near as practicable, with the centre line of the rivet to be driven.

The overhead crane from which the boiler is suspended permits the boiler to be swung about, and its movement is governed by the operator and a helper, who stick bars at (*c*), into the rivet holes and move the boiler until the right position is approximately reached.

The pressure is then applied, and the rivet driven; great care should be taken that the newly formed head on the inside of the boiler is concentric with the rivet shank.

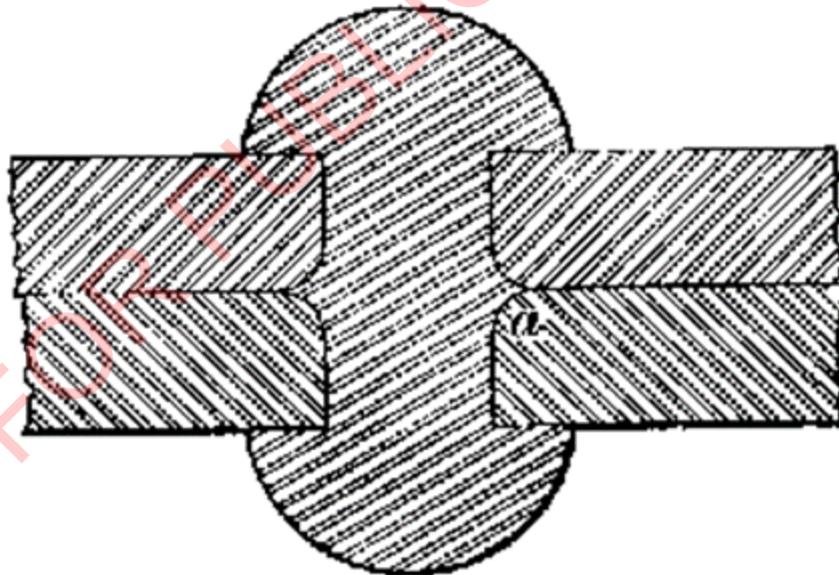
The riveting can be done better and quicker if the boiler is first tacked; that is, after the course is bolted, the circumferential seam (*d*), Appendix Figure B-16, should first have a rivet (*e*) driven on each quarter; the rivets are then driven about midway between the rivets *e*, after which the rivets (*g*) should be driven in every other hole.

The bolts that were placed in some of the holes when assembling the parts, that are not shown in the illustration, are then removed and the remainder of the rivets driven.

This procedure obviates the danger of throwing the courses out of line when riveting.

If plates are not tightly bolted together before riveting, the body of the rivet may swell between the sheets, forming a washer (*a*) as shown in Appendix Figure B-17.

The washer tends to separate the plates, making a poor joint that cannot be made steam tight by caulking.



Appendix Figure B-17 Swelling of rivet

Driving three (3) or four (4) rivets rapidly in adjacent holes is poor practice and invariably results in loose and leaky rivets as the heavy pressure used in driving the third or fourth rivet will tend to spring the plate; the first rivet driven will still be hot and pliable and it will be almost certain to stretch a little because of the spring of the plate.

After the formation of the rivet head, the pressure should be retained on the rivet for at least 15 seconds and rivets adjacent to it should not be driven until it has cooled so much that the springing of the plate will not stretch it.

It is not good practice to have several heated rivets in holes at one time.

Even if the operator drives them as fast as he can, the time consumed in changing the machine from one rivet to another will be such that the rivets will be driven at a different temperature; furthermore, the rivets may so heat adjacent portions of the plate as to cause blue heat, cracking the sheet when the rivet is driven.

The A.S.M.E. Boiler Code gives the following conditions governing machine riveting:

- (a) Rivets shall be machine driven wherever possible, with sufficient pressure to fill the rivet holes, and shall be allowed to cool and shrink under pressure.
- (b) Barrel pins (drift pins) fitting the holes and tack bolts to hold the plates firmly together shall be used. A rivet shall be driven at each side of each tack bolt before removing the tack bolt.

B.12 Hand riveting

B.12.1 Hand riveting hammers

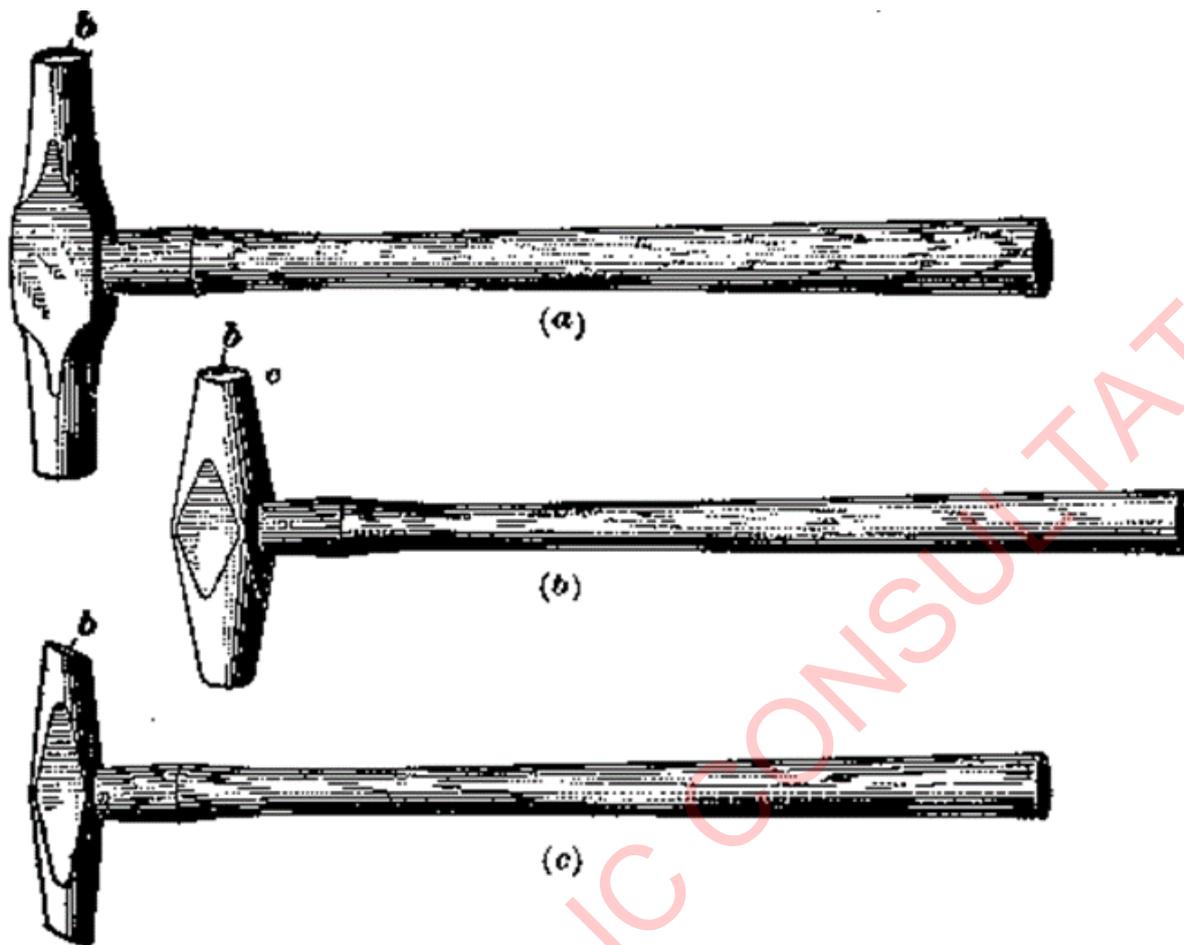
Three hammers used in hand riveting are shown in Appendix Figure B-18.

The hammer illustrated in (a) is called a plugging hammer and is used to plug, or knock down, a rivet. The faces (b) on the ends are slightly rounded.

The hammer illustrated in (b) is known as a finishing hammer and is used to finish the rivet after the rivet has been knocked down with the plugging hammer. The faces (b) at the ends are flat, with rather sharp edges (c).

The hammer illustrated in (c) is known as a bevel faced hammer and is used in special cases where it is difficult to use the regular tools.

The angle of the bevelled ends (b) is usually about 20°, although other angles are employed, according to the views of the riveter and the varying conditions affecting the work.

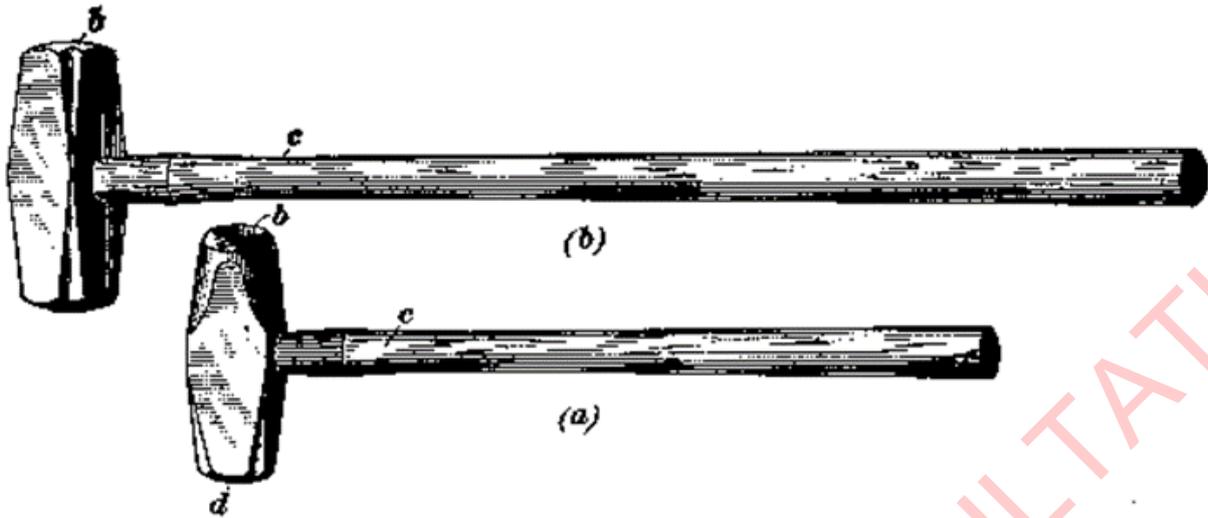


Appendix Figure B-17 Hand riveting hammers

The rivet set, or snap, shown in Appendix Figure B-18 (a), is used in hand riveting for finishing the head after it has been roughly formed by the hammers.

The end (b) is tapered and recessed, like the end of a rivet die, except that the bridge is very small and rounded on the outer edge.

The handle (c) enables the riveter to hold the set on the rivet while a number of blows are struck on the head (d) forming the rivet head to the shape of the recess. Only the tapering recessed end (b) is hardened.

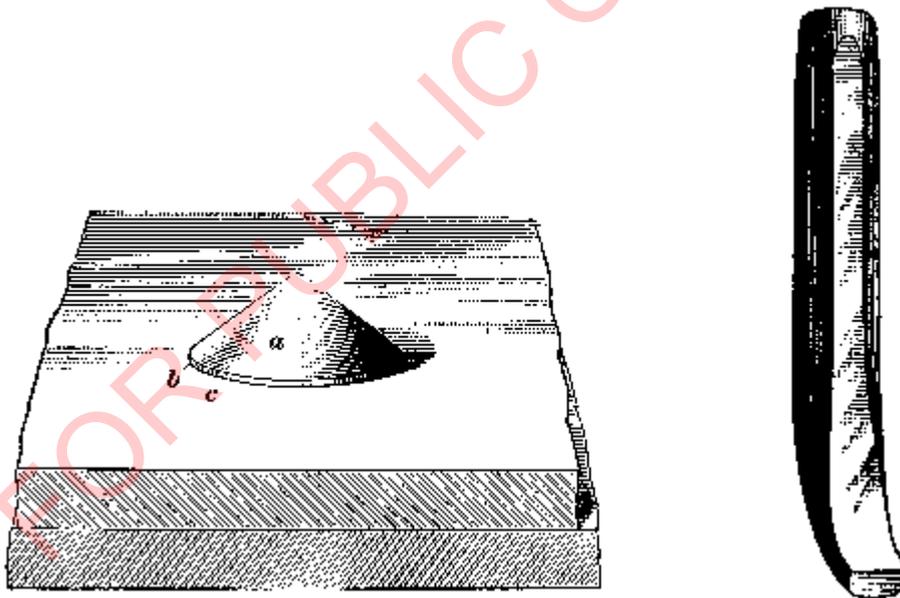


Appendix Figure B-18 (a) and (b) Rivet set

The double-faced maul shown in (b) is used for knocking down, that is, upsetting, the rivet, and also for striking the rivet set illustrated in (a).

It is termed double-faced because it has a face (b) on each end.

Mauls used for striking the rivet set weigh about eight (8) pounds and have a handle (c) about 36" long.



Appendix Figure B-19 Steeple head and thumb tool

B.12.2 Driving riveting by hand

In the early days of boiler making all rivets were knocked down and then finished with light hammers, forming a rivet head (a), Appendix Figure B-19, called a steeple head.

This method of riveting is known as hand riveting.

The older and more experienced boilermakers usually finished the head with a finishing hammer, but others caulked, or as it is otherwise termed, worked down, or cut in, the edge (b) of the steeple head to the sheet (c) by the use of a thumb tool, Appendix Figure B-19, commonly called a Frenchman.

The secret of driving hand rivets tightly lies not only in the proper heating of the rivets preparatory to driving them and in having the sheets well fitted and closely laid together, but also to a large degree in the ability of the riveter to drive the rivets so as to fill the rivet holes; this involves striking heavy blows quickly and squarely on the shank of the rivet.

The rivet holes should be countersunk, a narrow and deep countersunk hole being preferable to a wide and shallow countersunk hole.

When a shallow and broad countersink is used there is more chance that the rivets head will fly off than when a narrow and deep countersink is employed.

B.12.3 Snap riveting

The method of knocking down the rivet with steel mauls and finishing it by striking blows on a rivet set, is called snap riveting.

Following the introduction of heavier plates and larger rivets required by the demand for an increase in the working pressure of boilers, snap riveting supplanted hand riveting to a great extent.

In order to upset the heads of the large rivets used for the heavy plates while the rivets are in the holes, it is necessary that the heads receive the force of very heavy blows; hence, there arose the use of heavy mauls instead of light plugging hammers for knocking down the rivet.

The formation of the head by use of the rivet snap has an advantage over the hand method of forming the head.

The heavy blows struck on the rivet set during the formation of the rivet head tend to force more metal into the body of the rivet, thereby filling the rivet hole.

In hand riveting this is not the case, for after the rivet is plugged down with the plugging hammer a light finishing hammer is used merely to proportion and finish the rivet head.

The light hammers are not employed when the rivet is hot, as they do not upset the rivet in the hole; in fact, their use tends to loosen the rivet, and if the outer edge of the hand driven rivet were not cut in, or caulked, to the shell, most hand driven rivets, especially those in heavy plates, would leak.

In snap riveting, the rivet should be driven straight down in the hole until the projection above the sheet is about equal to the depth of the recess in the rivet set.

Then the rivet set is applied directly in line with the rivet and is driven until its edges are nearly in contact with the sheet.

To work down the edge of the newly formed rivet head, the rivet set is raised about $\frac{1}{4}$ " and pulled over to bear hard against one side of the rivet head; the rivet set is then driven, thereby forcing parts of the edge of the rivet head down on the sheet.

The rivet set is then raised again and shifted part way around the rivet head and another portion of the edge of the rivet head is worked down.

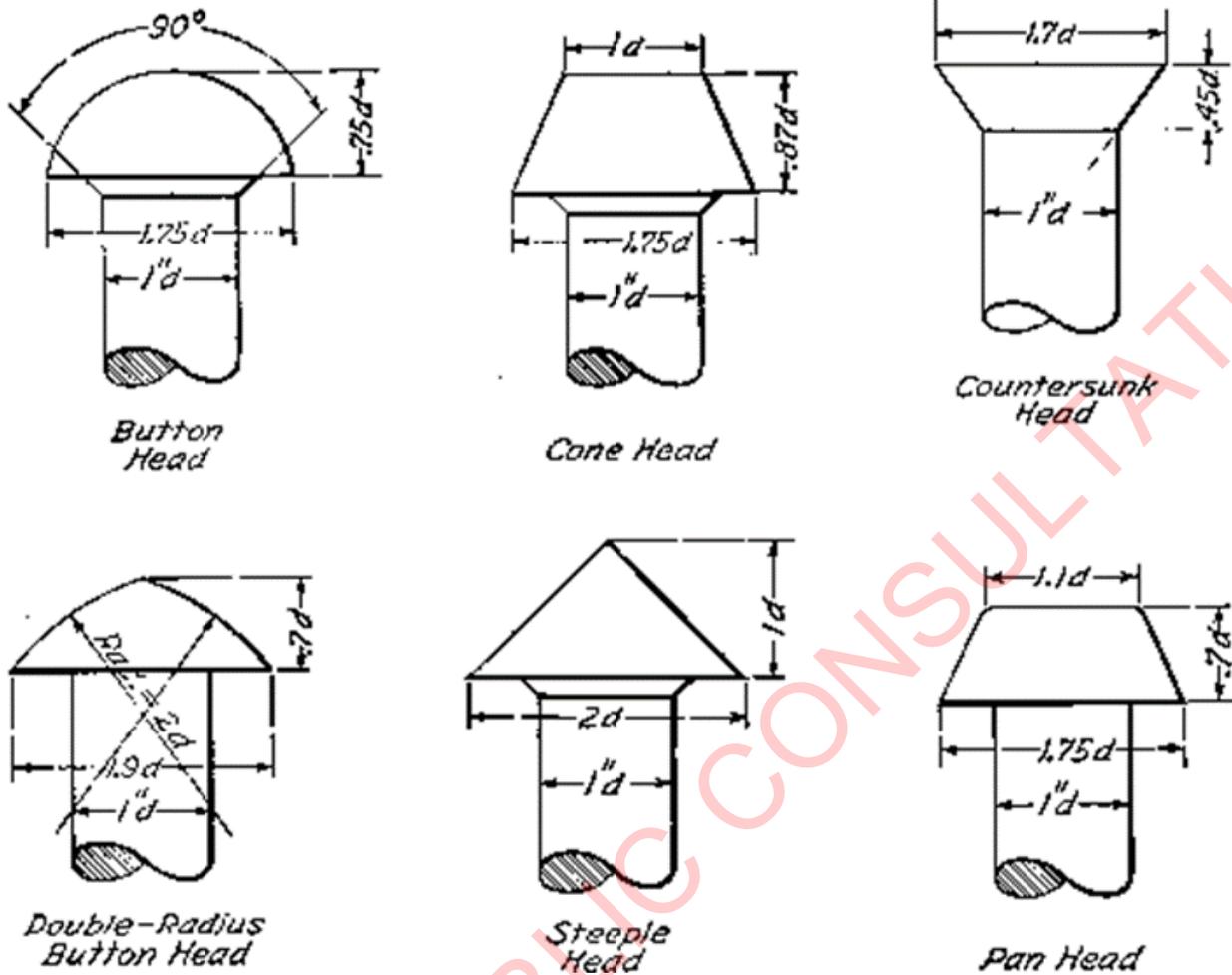
This process is continued until the rivet head edge has been forced down all around the rivet head.

B.13 Rivets and rivet dies

B.13.1 Types

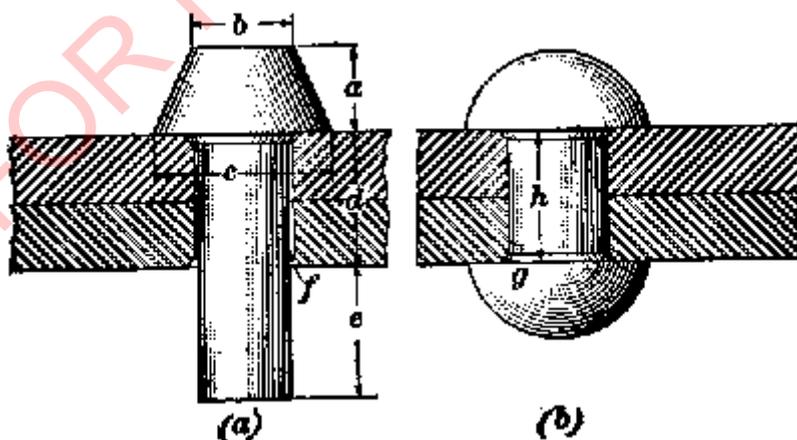
For the various kinds of boiler connections requiring riveted seams it has been found that certain forms of rivet heads give the best results.

The ones generally used are shown in Appendix Figure B-20, and of these types, the button head, cone head and countersunk head are employed the most.



Appendix Figure B-20 Rivet head forms

The cone head is sometimes upset and formed into a button head, as shown in Appendix Figure B-21. The practice has proved satisfactory in producing tight joints



Appendix Figure B-21 Button head rivet forms

The rivet hole is usually lightly countersunk, which assists in making tight rivets, as the head of the rivet is upset into the enlarged section of the rivet hole.

The countersunk rivet is used in plate connections where overlapping plates or other structural parts could not be fitted together if the rivet heads projected above the surface of the plate.

B.13.2 Dimensions

The plates that form steam boilers are fastened together by rivets.

A rivet is a piece of soft iron or steel rod with a head formed at one end.

The cylindrical part of the rivet is called the shank; it is inserted into a hole drilled or punched through the plates to be joined, and its end is then hammered or pressed to form a second head, the plates being gripped and held firmly between the heads.

From these dimensions it is easy to calculate the proportions of a rivet head of any type for any diameter of rivet shank.

For example, suppose that the dimensions of the head shown in (a) are required for a rivet whose shank is $\frac{3}{4}$ " in diameter.

As $(d) = \frac{3}{4}$ ", the height of the head is 0.75 ", $(d) = 0.75" \times 0.75" = 0.5625"$, and the diameter of the head is $1.75d = 1.75 \times 0.75 = 15/16"$.

The dimensions of rivets shown in Appendix Figure B-22 are in accordance with the A.S.M.E. Boiler Code, but a variation of 10% is permissible; that is, any dimension may be as much as one-tenth larger or smaller than that indicated.

In boiler, plate, and tank work, various forms of rivets are used, and their names are derived from the shapes of their heads.

Of the several forms shown in Appendix Figure B-22, those in (b), (c), (d), (e) and (g) are most commonly used in boiler construction.

The cone head rivet is slightly tapered under the head, the depth (a) of the tapered part being $1/32$ " for rivets from $1/2$ " to 1 " in diameter and $1/16$ " for rivets greater than 1 " in diameter.

The outer edge of the rivet hole is correspondingly bevelled, or chamfered, when this form of rivet is used, as shown in Appendix Figure B-23 (a), removing the sharp corner around the hole and making a good seat for the rivet head.

Frequently this form of rivet is driven, or headed, using tools that forms button heads on one end only as shown in (b) has proved to be a very good form to obtain a steam tight joint.

The double radius, button head rivet, shown as (e) in Appendix Figure B-22, and known also as the conoid head rivet, is another very good form.

It is, generally believed to be superior to the button head type, as it is easily made tight in the plate and remains so.

The countersunk rivet, shown in (g), is used in riveted joints when it is undesirable to have rivet heads project above the surface, where they might interfere with the placing of plates or other parts in their correct positions.

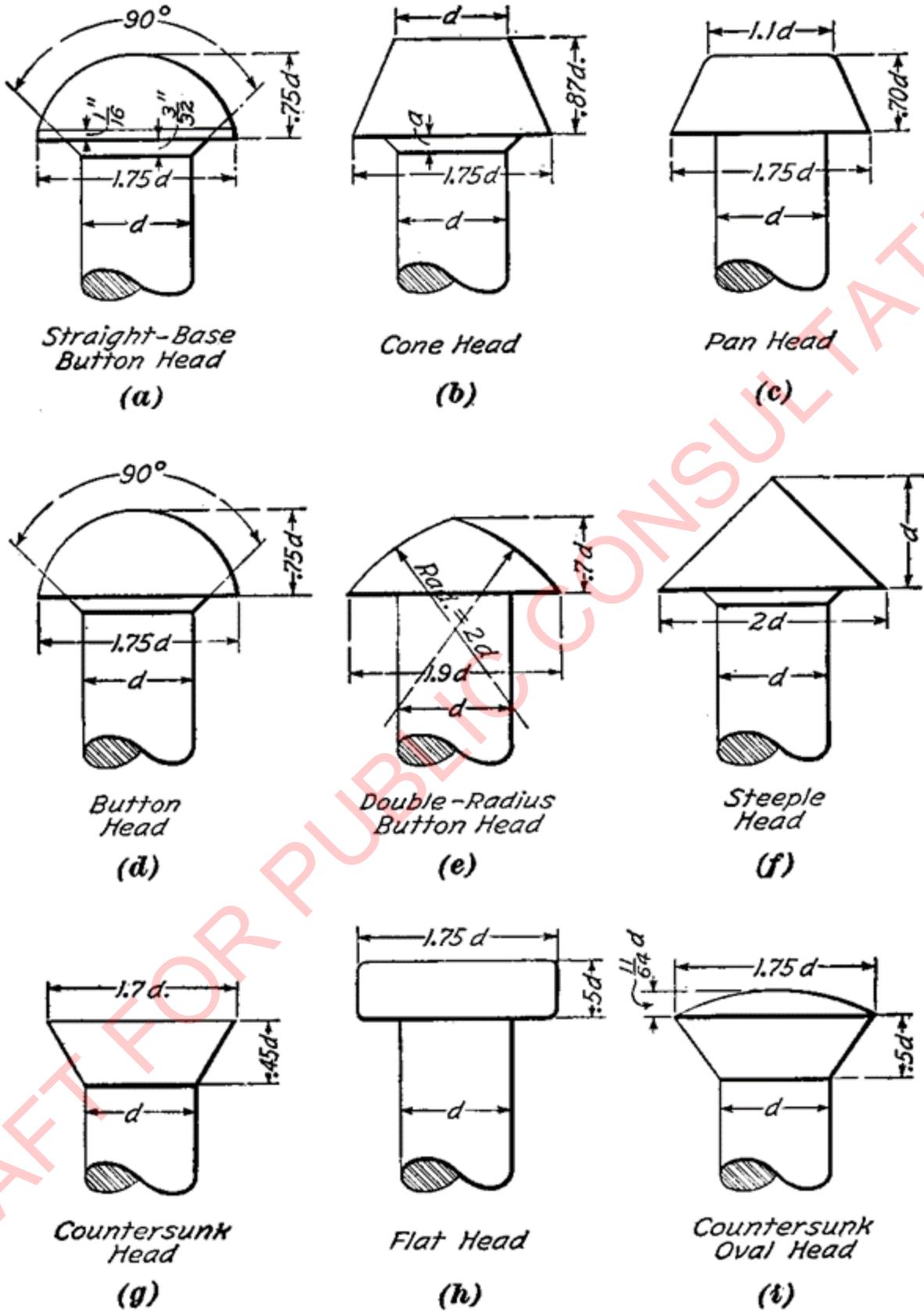
The flat-head rivet, shown in (h), is also used for some connections of the same kind, but is more extensively employed in lighter metal work, such as etchings, stacks, and boiler casings.

The rivet holes in plates are bored or punched from $1/32$ " to $1/16$ " larger in diameter than the rivet shank so that the rivet may be inserted readily.

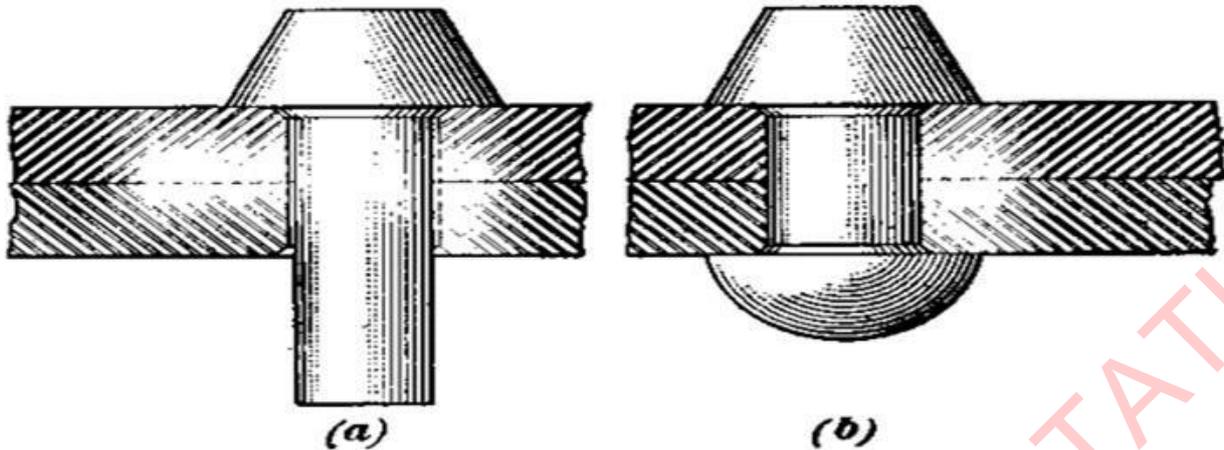
Drilled or punched holes have sharp corners at the top and bottom of the hole; the sharp edges were removed with a ragging tool.

The purpose of removing these sharp corners is they form a sharp corner in the neck of the rivet just under the head that may cause the rivet head to shear off during service conditions.

Sharp edges may also prevent close contact of the plates.



Appendix Figure B-22 Rivet head dimensions



Appendix Figure B-23 Cone head rivet bevel and rounding

The rivets previously described are manufactured by forging different forms of heads on the ends rods and then shearing off the rods to the desired length, high pressure rivets are first machined to a form a few thousandths an inch larger than the finished size, after which the shanks finished by grinding to the correct dimension, which shall not vary more than 0.002 inches from the size specified.

This is as a tolerance and refers to an allowable error or variation from specified dimensions in the process of manufacture of an article.

These rivets have a finely polished surface and were ground to fit in the holes drilled for them so that when driven they will produce a metal to metal fit.

To allow for the expansion of the rivet shank when heated, the rivet holes are drilled $1/32''$ larger than the shank, through both members of the joint held together by clamps or bolts, after which the holes are reamed to a very smooth finish.

The heating of high pressure rivets is done in an electric furnace the temperature of which is controlled by a thermostat so that each rivet will be driven at exactly the same heat.

Air is carefully excluded from the heating chamber of the furnace in order to prevent oxidation and scaling of the finished shank surface of the rivets.

All these precautions shall be observed in the manufacture of high pressure rivets in order that they may fit accurately in their holes and produce a joint that will not leak.

When the boiler is designed to operate at a pressure of 650 psi or higher, riveted joints are no longer satisfactory and seamless boiler drums are employed with the ends closed by welding.

B.13.3 Proportions

The acceptable forms of rivet heads in accordance with the A.S.M.E. Boiler Code are indicated in Appendix Figure B-24. The proportions are based on a shank diameter of 1".

For any other diameter, the dimensions are proportional.

A cone-head rivet $3/4''$ in diameter, Appendix Figure B-25, has the head dimensions where the depth is $0.87 \times 3/4'' = 0.65''$, the top diameter (b) is $1 \times 3/4'' = 3/4''$, and the base diameter (c) is $1.75 \times 3/4'' = 1.31 =$ inches.

The dimensions of the rivets may be one-tenth larger or smaller than the dimensions found in accordance with the A.S.M.E. Boiler Code.

Fillets under the head may be used but are not required.

The length of rivet required for riveting depends on the plate thickness, method of riveting, diameter of rivet hole, and diameter of rivet hole.

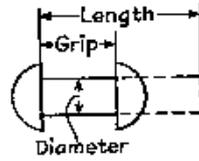
For average conditions, where the clearance between the rivet and the rivet hole is $1/16''$, the amount to allow for upsetting the rivet in the rivet hole and for the formation of the rivet head is determined as follows:

To the length d , which is the sum of the plate thicknesses, a sufficient length of shank material (e) shall be added so that, when the rivet is upset, the clearance space (f) all around the rivet will be filled, and so that the head g will be properly formed.

The net distance (h) after the rivet is driven is called the grip.

The distance (e) for hydraulic riveting is from 1.75 to two (2) times the diameter of the rivet hole.

TABLE II
LENGTHS OF BUTTON-HEAD RIVETS FOR VARIOUS GRIPS

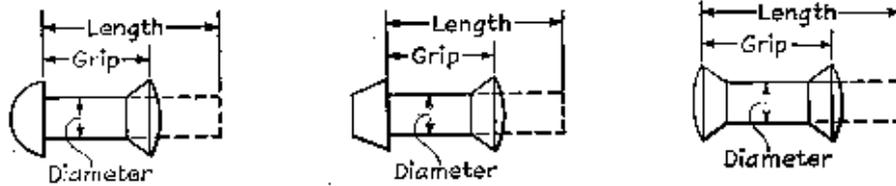


Grip Inches	Diameter of Rivet, in Inches								
	$\frac{1}{4}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	1	$1\frac{1}{8}$	$1\frac{1}{4}$
	Length of Rivet, in Inches								
$\frac{1}{4}$	$1\frac{1}{8}$	$1\frac{1}{4}$	$1\frac{7}{8}$	$1\frac{3}{4}$	$1\frac{3}{4}$	2	$2\frac{1}{8}$		
$\frac{3}{8}$	$1\frac{3}{8}$	$1\frac{1}{2}$	$1\frac{7}{8}$	$1\frac{7}{8}$	$2\frac{1}{8}$	$2\frac{1}{8}$	$2\frac{1}{8}$		
1	$1\frac{5}{8}$	$1\frac{3}{4}$	$1\frac{7}{8}$	$2\frac{1}{8}$	$2\frac{3}{8}$	$2\frac{3}{8}$	$2\frac{3}{8}$	$2\frac{7}{8}$	
$1\frac{1}{4}$	$1\frac{7}{8}$	2	$2\frac{1}{8}$	$2\frac{3}{8}$	$2\frac{3}{8}$	$2\frac{3}{8}$	3	$3\frac{1}{8}$	
$1\frac{1}{2}$	$2\frac{1}{8}$	$2\frac{1}{4}$	$2\frac{1}{4}$	$2\frac{1}{4}$	$2\frac{1}{4}$	$3\frac{1}{8}$	$3\frac{1}{8}$	$3\frac{1}{8}$	$3\frac{1}{4}$
$1\frac{3}{4}$	$2\frac{3}{8}$	$2\frac{1}{2}$	$2\frac{3}{4}$	3	$3\frac{1}{4}$	$3\frac{3}{8}$	$3\frac{3}{8}$	$3\frac{3}{8}$	4
2	$2\frac{5}{8}$	$2\frac{3}{4}$	$3\frac{1}{8}$	$3\frac{1}{4}$	$3\frac{1}{2}$	$3\frac{1}{2}$	$3\frac{3}{8}$	4	$4\frac{1}{4}$
$2\frac{1}{4}$	$2\frac{7}{8}$	3	$3\frac{3}{8}$	$3\frac{3}{4}$	$3\frac{3}{4}$	4	$4\frac{1}{8}$	$4\frac{1}{4}$	$4\frac{1}{2}$
$2\frac{1}{2}$	$3\frac{1}{8}$	$3\frac{1}{4}$	$3\frac{3}{8}$	$3\frac{3}{4}$	4	$4\frac{1}{4}$	$4\frac{1}{4}$	$4\frac{1}{8}$	$4\frac{3}{4}$
$2\frac{3}{4}$	$3\frac{3}{8}$	$3\frac{1}{2}$	$3\frac{3}{8}$	4	$4\frac{1}{8}$	$4\frac{1}{2}$	$4\frac{1}{8}$	$4\frac{7}{8}$	$5\frac{1}{8}$
3	$3\frac{5}{8}$	$3\frac{3}{4}$	$4\frac{1}{8}$	4	$4\frac{1}{8}$	$4\frac{1}{2}$	$5\frac{1}{8}$	$5\frac{1}{4}$	$5\frac{1}{8}$
$3\frac{1}{4}$			$4\frac{1}{4}$	$4\frac{3}{8}$	$4\frac{3}{8}$	5	$5\frac{1}{8}$	$5\frac{1}{8}$	$5\frac{3}{8}$
$3\frac{1}{2}$			$4\frac{3}{4}$	$4\frac{3}{4}$	$5\frac{1}{4}$	$5\frac{1}{4}$	$5\frac{3}{8}$	$5\frac{3}{4}$	$5\frac{7}{8}$
$3\frac{3}{4}$			5	$5\frac{1}{4}$	$5\frac{3}{8}$	$5\frac{3}{8}$	$6\frac{1}{8}$	$6\frac{1}{8}$	$6\frac{1}{4}$
4			$5\frac{1}{8}$	$5\frac{1}{4}$	$5\frac{3}{8}$	$5\frac{3}{8}$	$6\frac{1}{8}$	$6\frac{1}{8}$	$6\frac{1}{8}$
$4\frac{1}{4}$			$5\frac{3}{8}$	$5\frac{3}{4}$	$5\frac{3}{4}$	$6\frac{1}{8}$	$6\frac{3}{8}$	$6\frac{3}{8}$	$6\frac{3}{4}$
$4\frac{1}{2}$			$5\frac{5}{8}$	6	$6\frac{1}{8}$	$6\frac{1}{8}$	$6\frac{3}{4}$	$6\frac{3}{4}$	7
$4\frac{3}{4}$			6	6	$6\frac{1}{4}$	$6\frac{3}{8}$	7	$7\frac{1}{8}$	$7\frac{1}{4}$
5			$6\frac{1}{8}$	$6\frac{1}{4}$	$6\frac{3}{8}$	$6\frac{3}{8}$	$7\frac{1}{8}$	$7\frac{1}{8}$	$7\frac{1}{8}$
$5\frac{1}{4}$			6	6	7	$7\frac{1}{8}$	$7\frac{3}{8}$	$7\frac{3}{8}$	$7\frac{3}{8}$
$5\frac{1}{2}$			7	$7\frac{1}{8}$	$7\frac{1}{8}$	$7\frac{3}{8}$	$8\frac{1}{8}$	$8\frac{1}{8}$	8
$5\frac{3}{4}$			$7\frac{1}{4}$	$7\frac{3}{8}$	$7\frac{3}{8}$	$7\frac{3}{4}$	$8\frac{3}{8}$	$8\frac{3}{8}$	$8\frac{3}{8}$
6			$7\frac{3}{8}$	$7\frac{3}{4}$	$7\frac{3}{4}$	8	$8\frac{3}{8}$	$8\frac{3}{8}$	$8\frac{3}{4}$

NOTE.—Estimated lengths are for rivet holes $\frac{1}{16}$ inch greater in diameter than the rivet, for rivets up to and including $\frac{3}{4}$ inch in diameter; and for rivets over $\frac{3}{4}$ inch in diameter the rivet hole is $\frac{1}{8}$ inch greater in diameter than the rivet.

Appendix Figure B-24 Button head rivet lengths

TABLE III
LENGTHS OF COUNTERSUNK RIVETS FOR VARIOUS GRIPS



Grip Inches	Diameter of Rivet, in Inches									
	$\frac{1}{4}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	1	$1\frac{1}{8}$	$1\frac{1}{4}$	
	Length of Rivet, in Inches									
$\frac{1}{2}$	$\frac{7}{8}$	1	$1\frac{1}{8}$	$1\frac{1}{8}$	$1\frac{1}{8}$	$1\frac{1}{8}$	$1\frac{1}{8}$	$1\frac{1}{8}$		
$\frac{3}{4}$	$1\frac{1}{8}$	$1\frac{1}{4}$	$1\frac{1}{8}$	$1\frac{1}{8}$	$1\frac{1}{8}$	$1\frac{1}{8}$	$1\frac{1}{8}$	$1\frac{1}{8}$		
1	$1\frac{1}{8}$	$1\frac{1}{2}$	$1\frac{1}{8}$	$1\frac{1}{8}$	$1\frac{1}{8}$	$1\frac{1}{8}$	$1\frac{1}{8}$	$1\frac{1}{8}$	2	
$1\frac{1}{4}$	$1\frac{1}{8}$	$1\frac{3}{4}$	$1\frac{1}{8}$	$1\frac{1}{8}$	2	$2\frac{1}{8}$	$2\frac{1}{8}$	$2\frac{1}{8}$	$2\frac{1}{8}$	$2\frac{1}{8}$
$1\frac{1}{2}$	$1\frac{1}{8}$	2	$2\frac{1}{8}$							
$1\frac{3}{4}$	$2\frac{1}{8}$	$2\frac{1}{4}$	$2\frac{1}{8}$							
2	$2\frac{1}{8}$	$2\frac{1}{2}$	$2\frac{1}{8}$	$2\frac{1}{8}$	$2\frac{1}{8}$	$2\frac{1}{8}$	$2\frac{1}{8}$	3	$3\frac{1}{8}$	$3\frac{1}{8}$
$2\frac{1}{4}$	$2\frac{1}{8}$	$2\frac{3}{4}$	3	3	$3\frac{1}{8}$	$3\frac{1}{8}$	$3\frac{1}{8}$	$3\frac{1}{8}$	$3\frac{1}{8}$	$3\frac{1}{8}$
$2\frac{1}{2}$	$2\frac{1}{8}$	3	$3\frac{1}{4}$	$3\frac{1}{8}$						
$2\frac{3}{4}$	$3\frac{1}{8}$	$3\frac{1}{4}$	$3\frac{1}{2}$	$3\frac{1}{8}$	$3\frac{1}{8}$	$3\frac{1}{8}$	$3\frac{1}{8}$	$3\frac{1}{8}$	4	4
3	$3\frac{1}{8}$	$3\frac{1}{2}$	$3\frac{3}{8}$	$3\frac{1}{8}$	$3\frac{1}{8}$	$3\frac{1}{8}$	4	$4\frac{1}{8}$	$4\frac{1}{8}$	$4\frac{1}{8}$
$3\frac{1}{4}$			$4\frac{1}{8}$							
$3\frac{1}{2}$			$4\frac{1}{8}$							
$3\frac{3}{4}$			$4\frac{1}{8}$							
4			$4\frac{1}{8}$	5	5	5	$5\frac{1}{8}$	$5\frac{1}{8}$	$5\frac{1}{8}$	$5\frac{1}{8}$
$4\frac{1}{4}$			$5\frac{1}{8}$							
$4\frac{1}{2}$			$5\frac{1}{8}$	$5\frac{1}{8}$	$5\frac{1}{8}$	$5\frac{1}{8}$	$5\frac{1}{8}$	6	6	$6\frac{1}{8}$
$4\frac{3}{4}$			$5\frac{1}{8}$	$5\frac{1}{8}$	$5\frac{1}{8}$	$5\frac{1}{8}$	$5\frac{1}{8}$	$6\frac{1}{8}$	$6\frac{1}{8}$	$6\frac{1}{8}$
5			$6\frac{1}{8}$							
$5\frac{1}{4}$			$6\frac{1}{8}$							
$5\frac{1}{2}$			$6\frac{1}{8}$							
$5\frac{3}{4}$			$6\frac{1}{8}$	$6\frac{1}{8}$	7	7	$7\frac{1}{8}$	$7\frac{1}{8}$	$7\frac{1}{8}$	$7\frac{1}{8}$
6			$7\frac{1}{8}$							

NOTE.—Estimated lengths are for rivet holes $\frac{1}{8}$ inch greater in diameter than the rivet, for rivets up to and including $\frac{3}{4}$ inch in diameter; and for rivets over $\frac{3}{4}$ inch in diameter the rivet hole is $\frac{1}{16}$ inch greater in diameter than the rivet.

Appendix Figure B-25 Countersunk head rivet lengths

For pneumatic riveting, from $1\frac{1}{2}$ to $1\frac{5}{8}$ times the diameter of rivet hole; and for hand riveting, from $1\frac{3}{8}$ to $1\frac{1}{2}$ times the diameter of the rivet hole.

The lengths of button head and countersunk rivets of various diameters for different grips, are given in Appendix Figure B-24 and Appendix Figure B-25.

Suppose that a button-head rivet one (1) inch in diameter is to have a grip of three (3) inches when driven and that the required length is to be found. In such a case, Appendix Figure B-25 is used.

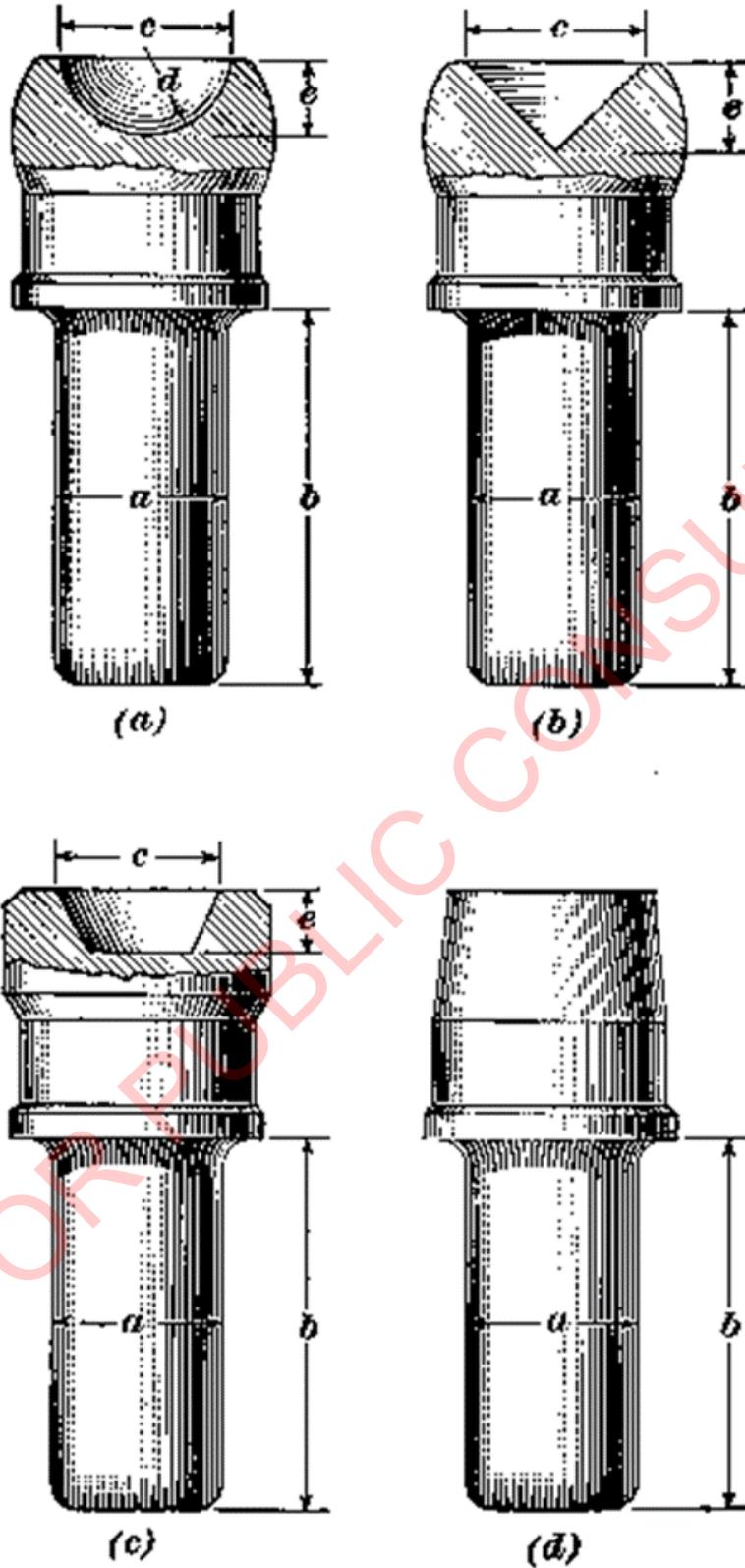
The value three (3) is in the first column, representing the grip, and the horizontal line is followed to the right until the column headed 1 is reached, where the value $5\frac{5}{8}$ is found. Then, the rivet required shall have a length of $5\frac{5}{8}$ ".

If the length of a countersunk rivet $\frac{3}{4}$ " in diameter, with a grip of $2\frac{1}{2}$ ", is to be found, Table III is used. The horizontal line having $2\frac{1}{2}$ in the first column is followed to the right to the column headed $\frac{3}{4}$ where the value $3\frac{3}{8}$ is found, indicating that the length of rivet should be $3\frac{3}{8}$ ".

B.14 Pneumatic riveting sets

For upsetting rivets and forming rivet heads by the pneumatic riveting process, specially shaped riveting sets are used.

The principal forms, shown in Appendix Figure B-26, are identified according to the shapes of rivet heads they produce. A button head set is shown in (a), a steeple-head set in (b), a pan head set in (c), and a flush set in (d).



Appendix Figure B-26 Pneumatic riveting forms

The shank diameter (a) and the length (b) depend on the type and make of air riveting hammer. The head dimensions (c), (d) and (e) are proportioned in accordance with the A.S.M.E. requirements for rivet heads.

The rivet set in (d) is employed in driving flush rivet heads, the plate being countersunk. The rivets are plugged down practically flush with the plate.

As rivet sets are subjected to both heat and blows during the riveting process, the tool steel of which they are made shall be of high grade.

Special heat treatments for hardening and tempering the steel are given to the finished rivet sets.

B.15 Hydraulic riveting dies

Rivet dies for hydraulic riveting are similar to pneumatic riveting sets, but they are larger and heavier so as to withstand the heavy pressure exerted on them.

The button head rivet die (a), Appendix Figure B-27, is constructed with a tapered end (b), so that it can form a head on a rivet without coming in contact with an adjacent rivet head already formed.

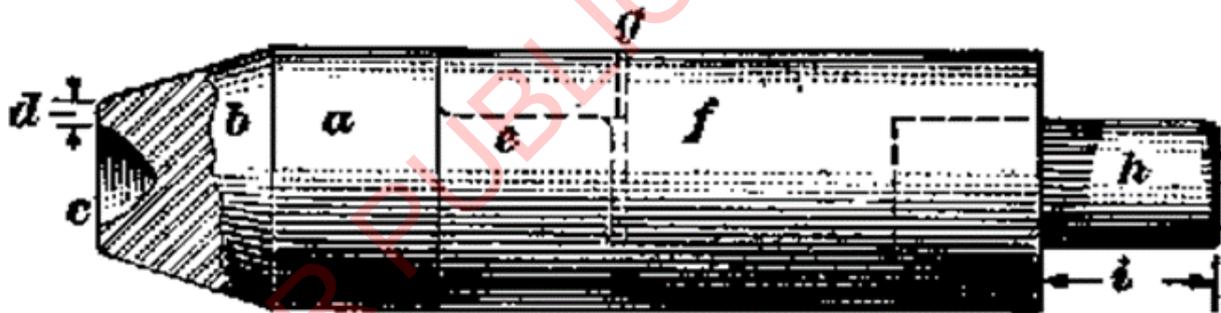
The recess (c) shapes the rivet head; the bridge (d), which is about ¼" wide, gives strength to the end of the rivet die.

By means of the stem (e) the die may be attached to the plunger directly, or in some cases indirectly by means of the die holder.

The die holder (f) is usually constructed with a vent hole g so that the stem (e) of the rivet die can readily be inserted.

The stem h of the die holder serves the same purpose as the stem (e) of the rivet die; as a rule, it is not turned down from the body of the die holder, but is a round pin, shrunk into the die holder.

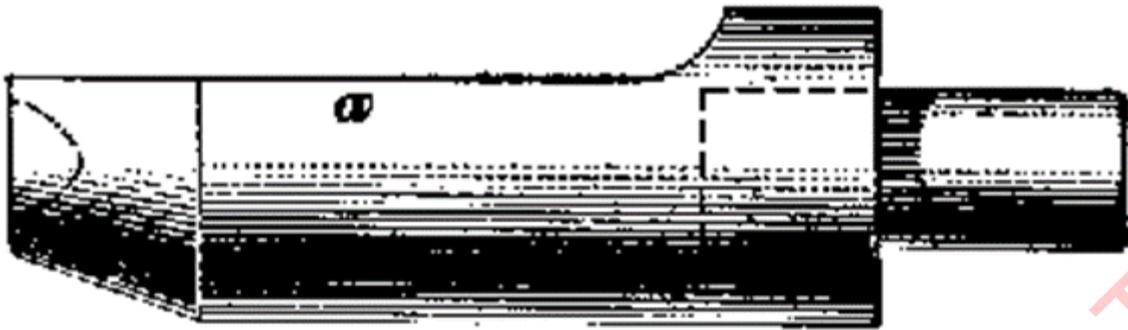
The length (i) of the stem (h) should be as great as possible, usually not less than 2",



Appendix Figure B-27 Pneumatic riveting forms

Frequently, in order to drive certain rivets, it is necessary to make dies of a special shape. For instance, the rivet die (a) in Appendix Figure B-28 is cut away, as shown, so that it can clear an obstruction near a rivet.

It would often be impossible for a die shaped like that shown in Appendix Figure B-27 to reach a rivet because of some adjacent obstruction.



Appendix Figure B-28 Cut away of modified die

B.16 Rivet heating

B.16.1 Rivet forges

For heating rivets to the required temperature necessary for hand, pneumatic, and hydraulic riveting, rivet forges are employed.

The earlier type of rivet forge, employed before the advent of pneumatic and hydraulic riveters, burned coal or coke as fuel and was of the type shown in Appendix Figure B-29.

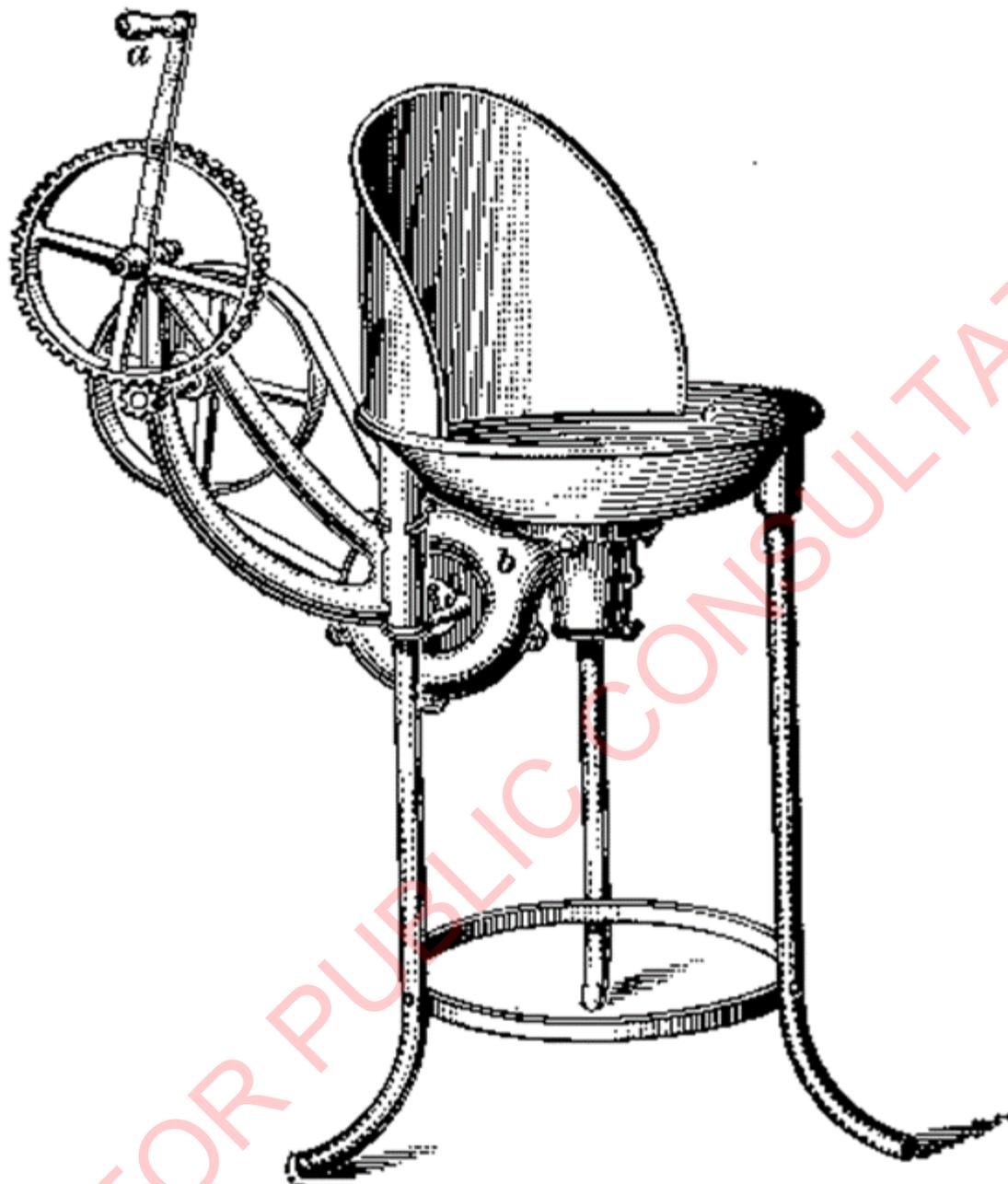
The air blast is produced by turning crank *a* that, through the gears and belt drive shown, rotates a fan inside the casing *(b)* and forces air up through the base of the fire pot *(c)*.

The coal is placed in the fire pot and so laid that the centre of the fuel bed burns, the fuel surrounding the fire being kept moistened to confine the fire to the centre.

The rivets to be heated are embedded in the hot coals, a number being inserted at one time. As each hot rivet is taken from the fire, a cold one is added.

Difficulty arises in heating rivets when the fire spreads; For that reason, the fire area should be maintained as small as possible.

Considerable attention is required to keep the fuel bed in proper condition, and at the same time shift the rivets and operate the air blast.



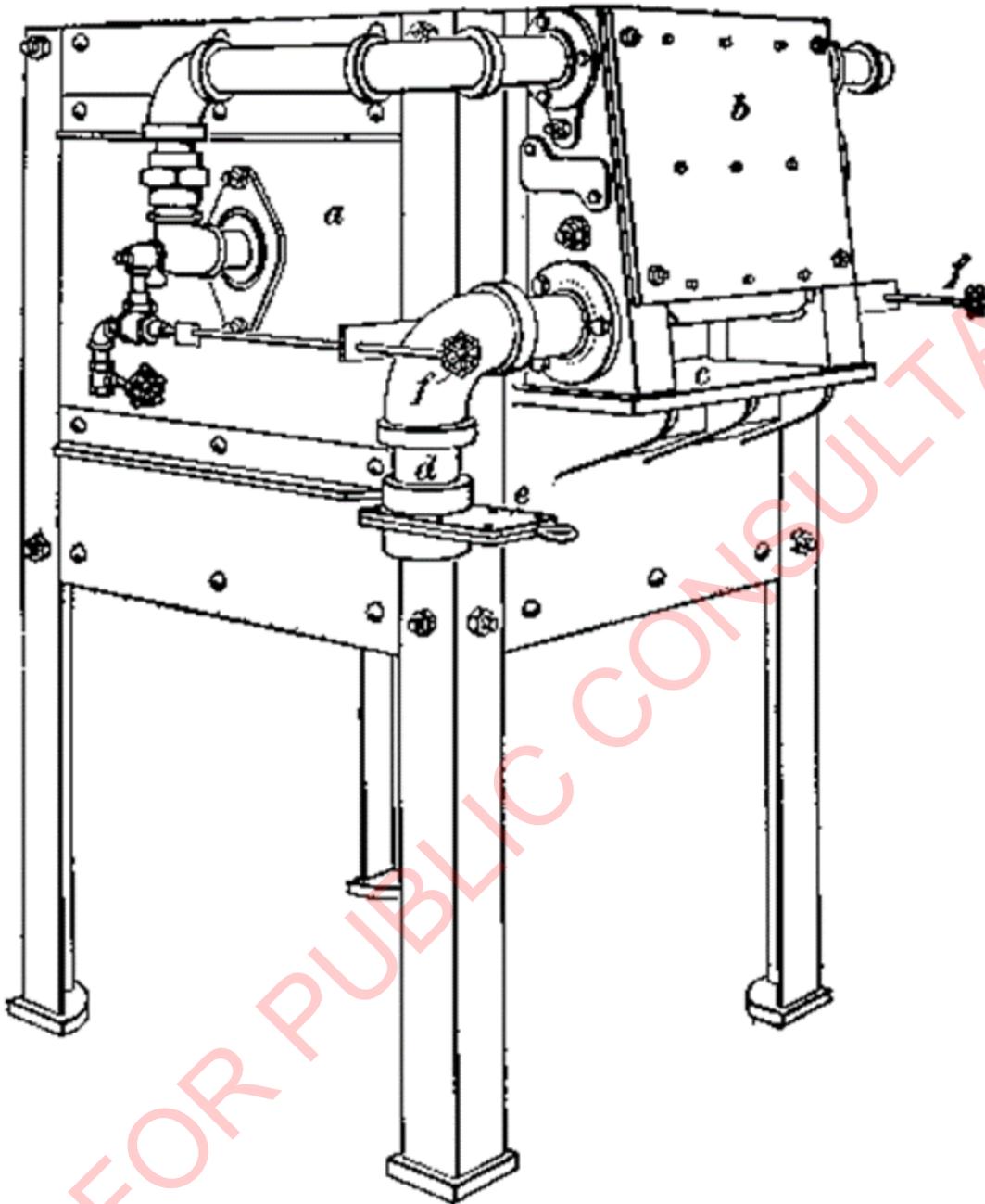
Appendix Figure B-29 Coal-fired rivet heater

The modern method of heating rivets is by the use of oil or gas as fuel or by the use of electricity.

The use of oil fuel in a properly constructed rivet forge ensures better heat regulation than is obtainable with the coal burning forge, and so it is possible to obtain a more nearly uniform heating of the rivets, with less danger of burning them.

The rivet heating furnace shown in Appendix Figure B-30 is designed for burning oil fuel. The steel casing enclosing the heating chamber is lined with firebrick.

To protect the rivet heater from the intense heat and allow him to work close to the furnace and handle the work to better advantage, an air-cooled shield (*b*) is placed over the working opening (*c*).



Appendix Figure B-30 Oil-fired rivet heater

A blast of compressed air is left flowing continually across the opening (c) and forms a protection for the operator against the escaping heat.

The air for this purpose is conveyed to the furnace through the pipe (d) and the intensity of the blast may be regulated by the shutter (c).

The regulation of the fuel supply to the furnace is controlled by the valves (f), so that the operator does not need to move about the furnace or take his attention from the rivet heating

When oil is used the air blast should have a pressure from eight (8) ounces to 2 psi.

Any uniform pressure above 5 psi is sufficient for supplying the fuel to the burners.

The consumption of oil varies according to the intensity of the heat desired, but ordinarily it ranges from two (2) to five (5) gallons per hour.

The oil is pumped from a supply tank and the air pressure is supplied by either a fan or an air compressor.

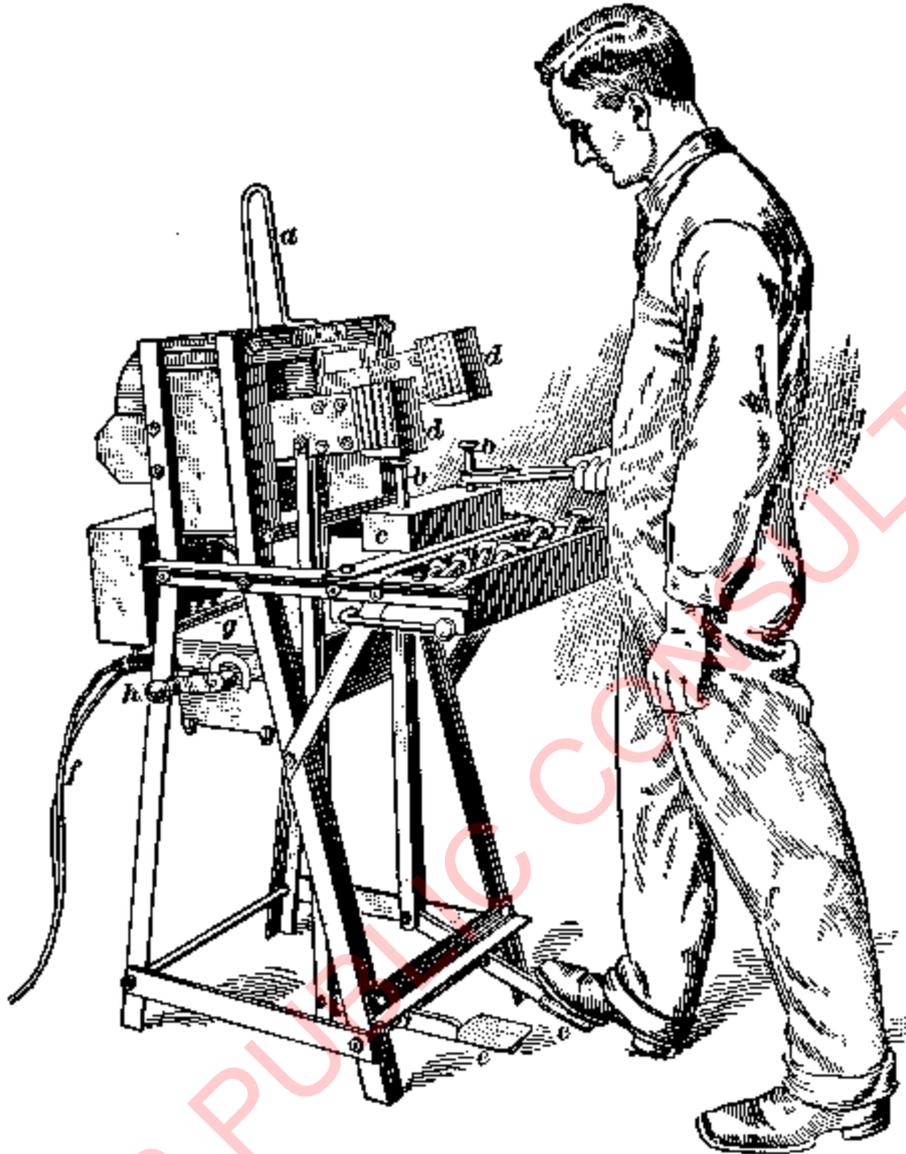
In addition to rivet heating, the furnace is adapted for handling the heating of other material, such as stays, tubes, or small tools that are to be worked over and tempered.

B.16.2 Electric rivet heater

One form of portable rivet heater using electricity as the heating medium is shown in Appendix Figure B-31. The loop or hanger *a* enables the device to be picked up by a crane and carried to the place where the riveting is to be done, but sometimes wheels are fitted to the bottom of the frame so that the heater may be readily moved about the shop.

The rivet (*b*) is set on the stationary copper block *c*, and the movable block (*d*) is lowered on it by releasing the pedal *e*.

Electric current supplied through the cables (*f*) flows from the block (*d*) through the rivet to the block (*c*) and in so doing heats the rivet.



Appendix Figure B-31 Electric rivet heater

The current may be regulated so that six (6) different heats are obtainable as required for the heating of rivets of different sizes.

For this purpose, the controller g is installed, with the regulating handle h within easy reach of the operator.

During the heating process the rivets are in plain view of the operator, which is an advantage in obtaining rivets of the proper size; Also, they do not radiate so much heat.

B.16.3 Precautions in heating rivets

The material used in rivets is made according to rigid specifications to obtain certain characteristics, so that when the rivets are properly heated and driven they will withstand heavy and continued stresses without breakage.

Rivet heating plays an important part in the construction of boilers.

To obtain hot rivets without burning requires a well-constructed rivet forge, proper temperature regulation, and close attention to the rivet furnace and rivets.

When coal or coke is used as fuel, a deep, clean fire without clinkers is necessary and a sufficient amount of live coal shall be between the air blast and the rivets so that the air blast does not strike directly into the space occupied by the rivets.

With the use of the oil furnace, the hot blast should not play directly on the rivets, as oxidizing and burning of the outside of the metal results without heating the interior uniformly.

A baffle wall of fire-resisting material is usually placed in the furnace to direct the blast away from the rivets.

Sparks from the rivet indicate that the temperature is too great and that the rivet is burning. Too many rivets should not be placed in the furnace fire at one time, as it is very difficult to handle a large number without burning some of them.

Allowing the rivet to remain in the fire for a long time is called soaking the rivet.

This practice is detrimental to the rivet material, as it causes the metal to waste away reducing the diameter of the rivet shank, and results in the formation of scale.

When such a rivet is driven, it does not fill the rivet hole completely, and the scale wedges in between the plate and the rivet.

This condition causes leakage around the rivet head, which cannot be made tight by caulking, and the strength of the rivet is considerably reduced.

Rivets so driven shall be removed, the removal requiring considerable time and labour.

The proper rivet temperature for the various methods of driving rivets is about as follows: Rivets driven by hand, especially if they are long, should be white hot, which corresponds to a temperature of about 2,300°F (1,260°C).

Rivets driven by pneumatic hammer should be heated to a bright cherry red, that corresponds to a temperature of about 1,700°F (926°C).

For hydraulic riveting, the rivets should be heated to a dull cherry red that corresponds to a temperature of about 1,500° F (815°C).

The reason why hand and pneumatic riveting require hotter rivets than the hydraulic system is that less time is required for upsetting rivets by the hydraulic system.

The particular type of fuel and the kind of forge used for heating rivets depend entirely on the shop. Coal, coke, gas, and oil are successfully used in various parts of the country.

For an open fire, such as is usually employed for heating the rivets for hand, snap, and pneumatic riveting, coke is preferable; and for hydraulic or similar methods of riveting coal, gas, and oil furnaces and electric heaters are largely used.

B.16.4 Rivet tongs

In Appendix Figure B-32 is illustrated a pair of rivet tongs are used for extracting the heated rivet from the rivet fire or heater.



Appendix Figure B-32 Rivet tongs

They are made with two jaws (*a*) and two handles (*b*), hinged together as shown, the jaws being curved so as to enable the rivet shank to be gripped easily and securely.

B.17 Holding on devices

B.17.1 Holding on

Holding on, or bucking up, of the rivet during hand and pneumatic riveting is accomplished by, holding a heavy bar of suitable shape, called a dolly bar, firmly against the rivet head.

The purpose of holding on is to force the rivet into place and hold it there while the upsetting and heading of the shank are being done.

Holding on is fully as important as the heating and driving of the rivet.

The holding on bar is employed for laying up overlapping plates by holding the bar along the joint while the riveter strikes the plate several blows with a light sledge hammer

Holding on bars, designed to suit different riveting conditions.

One type of straight dolly bar, weighing from 16 pounds to 20 pounds, is shown in Appendix Figure B-33.

It consists of an iron body (*a*). A removable rivet die (*b*) that can be replaced by other dies of different sizes to suit the sizes of rivet beads.

The dolly bar should be heavy enough to absorb the blow from the hammer without rebounding from the rivet.

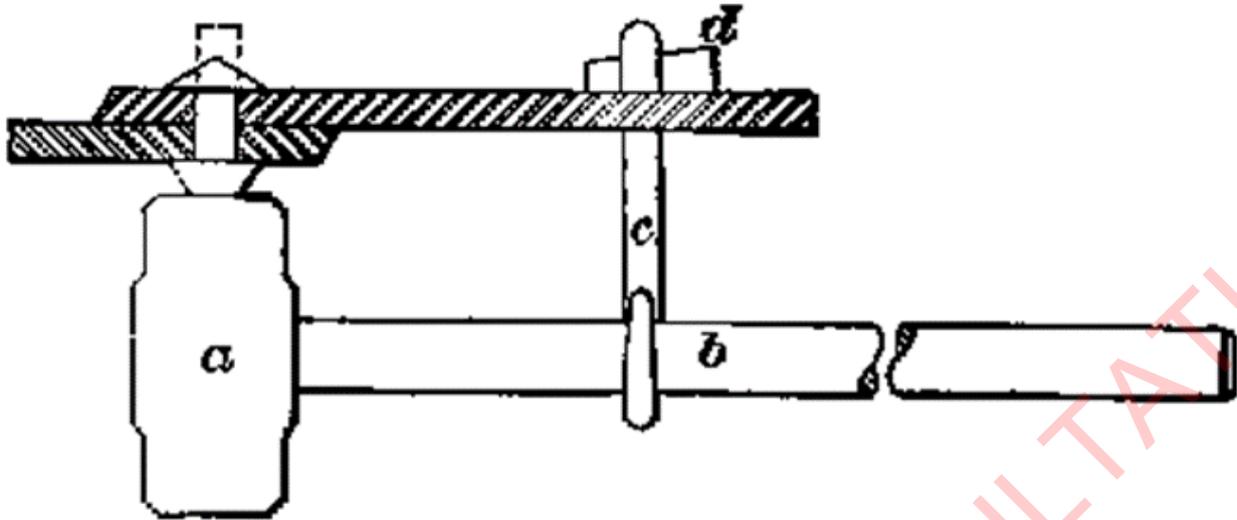
A bar that continually jumps from the rivet head causes crystallization of the rivet shank under the head.



Appendix Figure B-33 Dolly bar

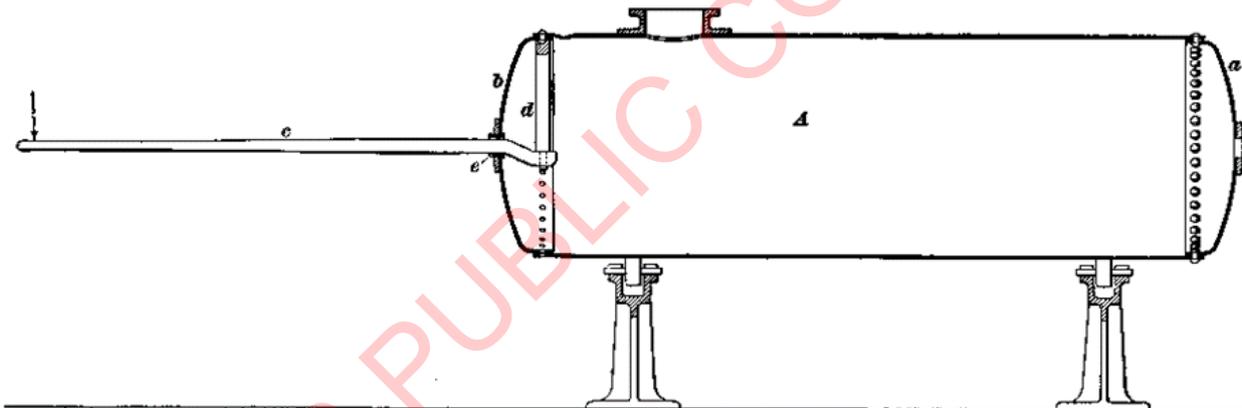
The pry dolly shown in Appendix Figure B-34 resembles a large sledge and is used where the seam can easily be reached. The operator forces the head (*a*) against the rivet by bearing down on the handle (*b*).

A hook (*c*) is used for holding the bar, and by means of the key (*d*) the position of the bar can be quickly shifted.



Appendix Figure B-34 Pry dolly type 1

Another form of pry dolly is illustrated in Appendix Figure B-35. It is used with a tank or a drum that is closed with flanged heads (a) and (b), leaving no opening of sufficient size to permit the entrance of a man for holding on purposes.



Appendix Figure B-35 Pry dolly type 2

The riveting of such a vessel is accomplished by first riveting either head, in each case there is an opening in each head large enough for handling a pry dolly; if not, the head without such an opening is riveted first.

In the case shown, the head a is riveted by either pneumatic or hydraulic machine, but the rivets in the other head (b) shall be driven by hand or pneumatic riveting, the rivets being held on by the use of a special form of pry dolly.

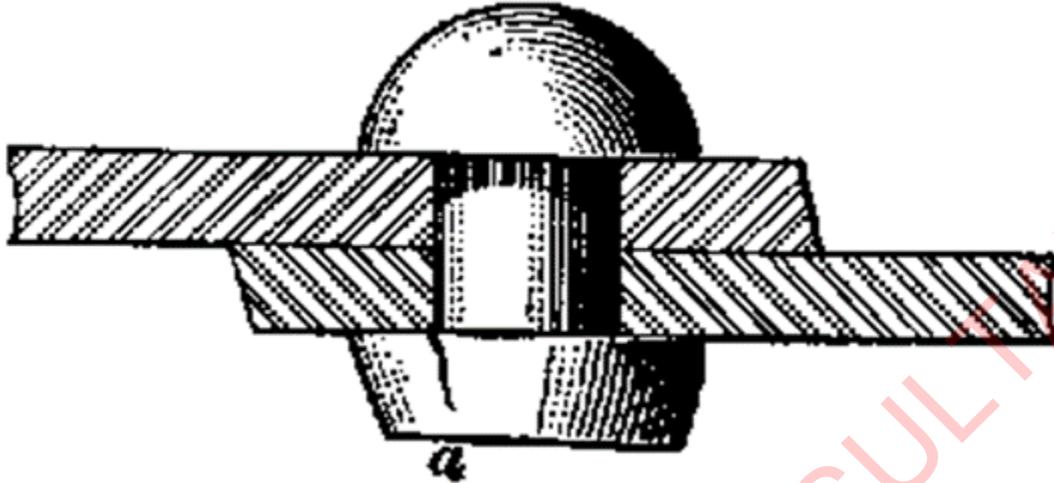
The pry dolly consists of a long handle (c) carrying an upright bar (d) recessed at the outer end to fit the rivet head.

The inner end of bar (d) has a stem that passes through a hole in the lever (c).

By bearing down on the lever in the direction of the arrow the (b) and (d) is held against the rivet. The hole in the head (b) is protected from damage by liner (e).

In hand riveting the face of the dolly bar may be flat, but in snap and pneumatic riveting, it is better to have a recess in the bar to correspond with the shape of the rivet head. In heavy riveting, when a flat

faced bar is used for bucking up, the rivet head flattens out and frequently cracks as shown at (a) in Appendix Figure B-36.

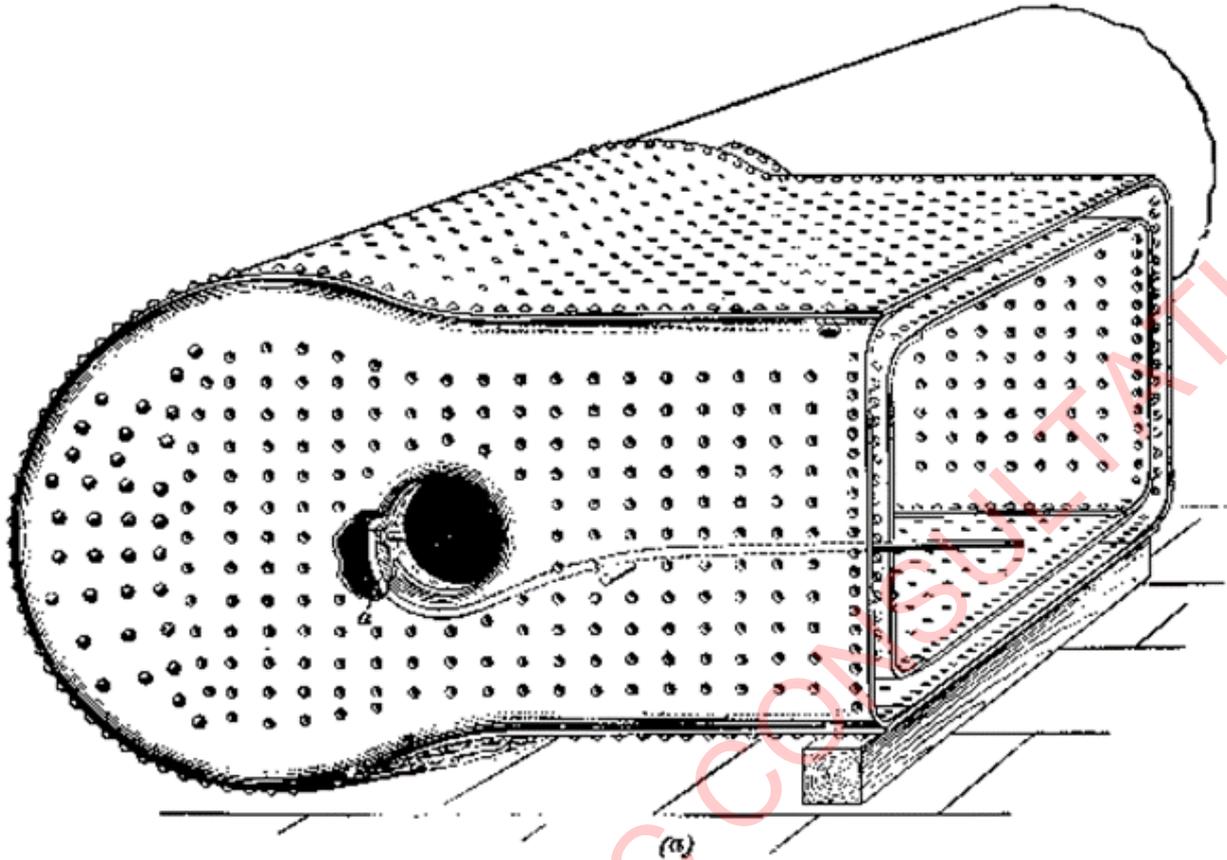


Appendix Figure B-36 Crack forming in rivet

B.17.2 Holding on rivets around door holes

Owing to the shape of locomotive fireboxes, and the riveted flange connections of door holes, holding on bars of special shapes are used.

One method of driving the rivets of a flanged door hole is shown in Appendix Figure B-37 and Appendix Figure B-38.

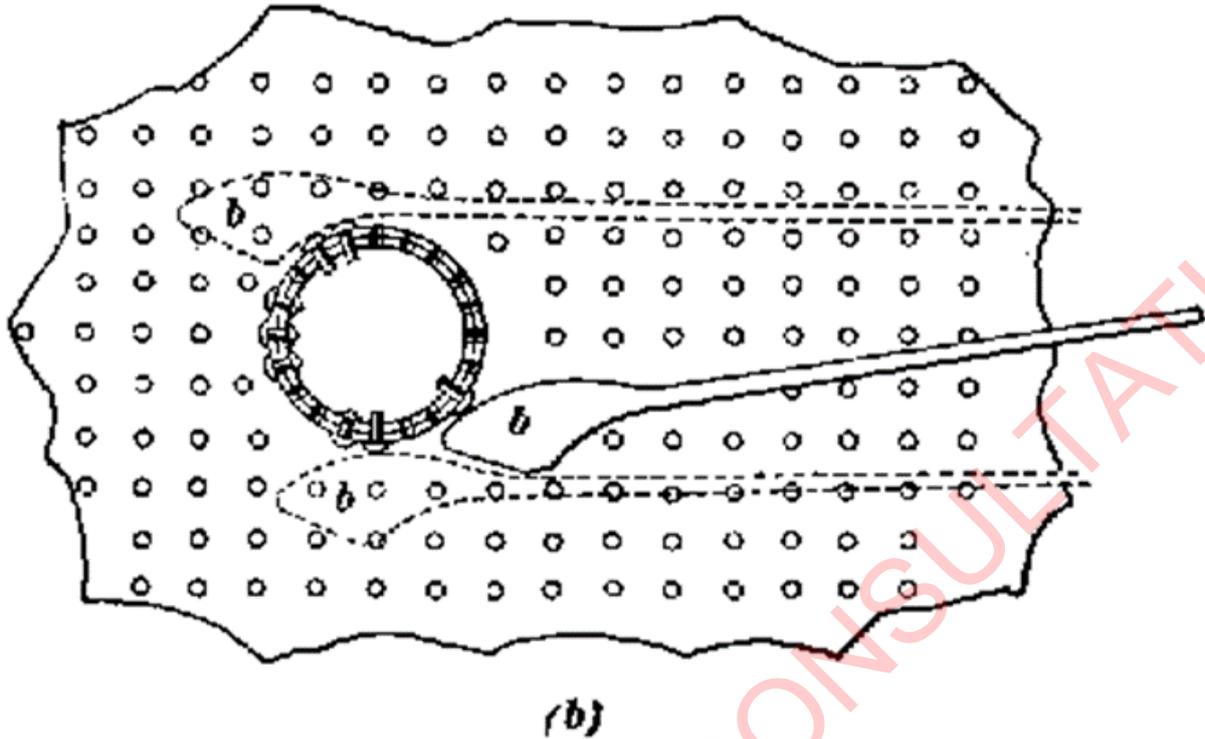


Appendix Figure B-37 Riveting using a flanged door hole

The top rivets are held on, as shown in (a), by a bent bar a of suitable shape to fit around the door flanges. The bar is supported near the middle by a pin, and by bearing down on the bar, pressure is exerted on the rivet.

In (b) are illustrated the positions of a holding on bar (b) for riveting the remainder of the rivets. The bar is so shaped that either edge can be used for holding on purposes.

Considerable shifting of the bar is needed to determine the easiest method of handling riveting of this kind.



Appendix Figure B-38 Riveting using a flanged door hole (detail)

B.17.3 Pneumatic holder on

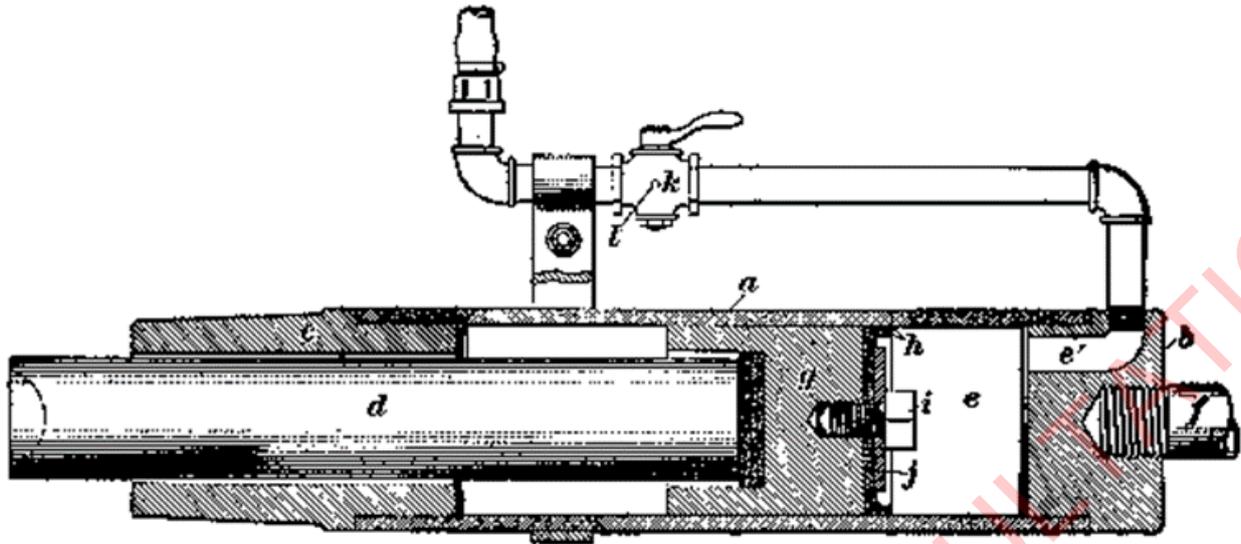
In Appendix Figure B-39 is shown a longitudinal section of a pneumatic holder on, commonly called an air dolly.

It is used in driving rivets by the air hammer or in hand riveting for holding the rivet head solid against the inside of the plate so that the second head can be formed on the outside.

The pneumatic holder on consists of a brass or steel cylinder *a*, about 3" in diameter and 12" in length, and threaded at both ends, into which are screwed the heads *(b)* and *c*.

The front head *(c)* acts as a guide for the holding on bar *(d)* the hole in the head is sufficiently large to allow free movement of the bar.

The holding on bar is generally about 2" in diameter and is recessed at the holding on end, to a cup shape, to suit the shape of the rivet head.



Appendix Figure B-39 Pneumatic holder on (air dolly)

The rear head (b), Appendix Figure B-39, closes the air chamber (e), air being admitted into the chamber through the air passage (e) which is about $\frac{5}{8}$ " in diameter.

In the outer end of the rear head there is a hole about 1" in diameter into which is screwed a piece of pipe (f) of the length required by the diameter of the boiler.

Since the bar (d) has a stroke of about 6", no change in the length of the pipe (f) is necessary for a difference of an inch or so in the diameter of the boiler.

The piston (g) is machined from a wrought iron bar or from a steel casting.

It is made a sliding fit and is recessed as shown to form a scat for the holding on bar (d).

To the piston is applied a leather packing ring (h), which is held firmly to the piston by the cap screw (i) and washer (j) preventing the air from passing to the opposite side of the piston.



Appendix Figure B-40 Using a pneumatic holder

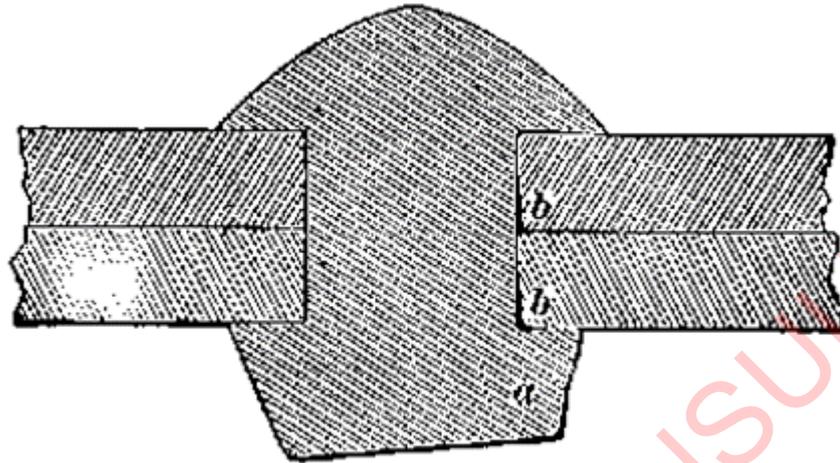
The method of operating the pneumatic holder on is as follows:

A pipe (*f*), Appendix Figure B-39 of proper length having been inserted, the holder on is placed in the boiler or tank with the end of the pipe diametrically opposite the rivet to be driven, as shown at (*a*), Appendix Figure B-39, and the compressed air is admitted into the chamber (*e*), Appendix Figure B-39, by turning the stop cock (*k*). The air pressure forces the holding on bar (*d*) against the head of the rivet that is to be driven, holding it securely against the plate.

After the rivet has been driven, the air pressure is cut off by closing the stop cock *k*, which opens communication of the air in the chamber (*e*) with the atmosphere through the exhaust hole *l*, which is from $\frac{1}{8}$ " to $\frac{3}{16}$ " in diameter.

The air pressure in the chamber (*e*) then escapes rapidly and the holding on bar (*d*) can be pushed back into the barrel, when the holder on is moved to the next rivet.

The pneumatic holder on requires an air pressure of about 100 psi, and can be operated in any position. If the holding on bar is allowed to bear unfairly against the rivet, the rivet head will be deformed, as at a, Appendix Figure B-42, and the shank will not be entirely upset, leaving gaps (*b*) between the rivet and the rivet hole on the deformed side of the rivet head.



Appendix Figure B-41 Deformed rivet head

B.17.4 Combination holder on and jam riveter

There are a number of types of combination holder on and jam riveter, but Appendix Figure B-43 illustrates the general construction.

By opening the throttle valve in the handle *a* to a certain position, compressed air is admitted into the chamber (*b*) against the head of the cylinder *c*.

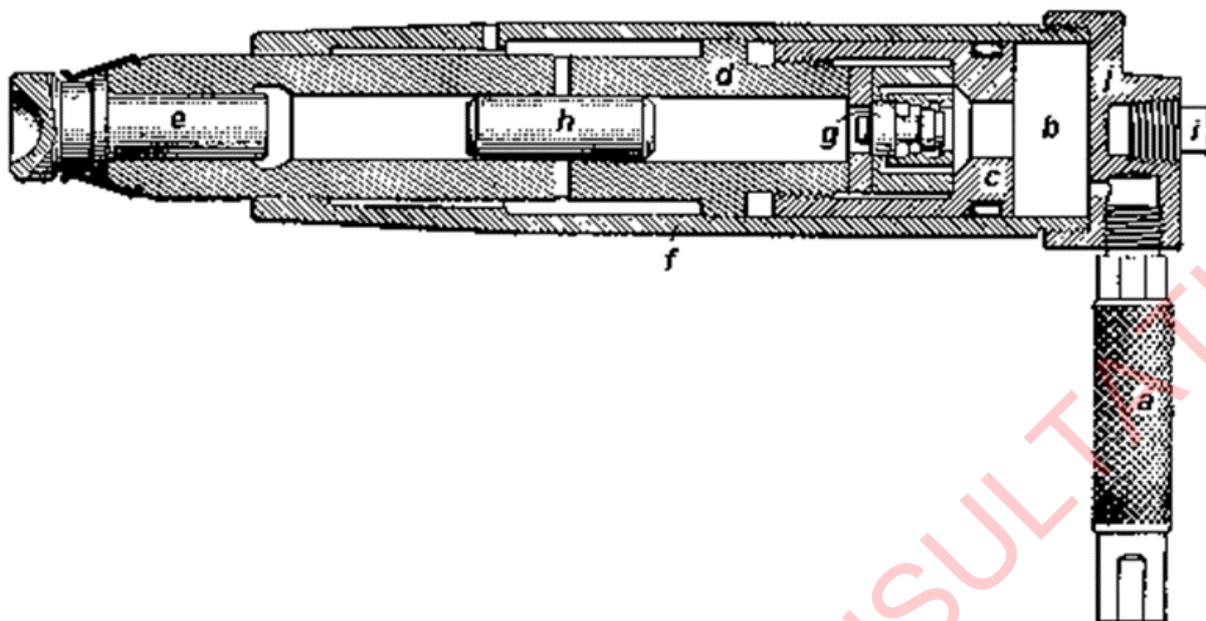
This cylinder is screwed to a barrel (*d*) that forms an air hammer and that carries the rivet set *e*. The pressure of the air pushes the barrel (*d*) and the rivet set forwards in the casing (*f*) and forces the rivet set firmly against the rivet.

On opening the throttle valve wider, air enters the cylinder (*c*) through the valve (*g*), causing the piston *h* to reciprocate and strike blows on the rivet set (*e*).

This counteracts the blows of the riveting hammer on the opposite end of the rivet driving the rivet from both ends.

This feature is of great value in driving rivets from both ends obtaining tightness.

The throttle valve can be so regulated that only the holding on action may be used, if desired. For centring the device, a casing cap (*i*) is screwed into the head (*j*).



Appendix Figure B-42 Jam riveter

B.18 Repairs to riveted joints (leaking riveted seams)

B.18.1 Caulking leaky rivets

All riveted seams, in boilers that have been in use for some time, are affected by expansion and contraction resulting from the changes of temperature that occur during the operation of the boiler.

The repeated stresses set up cause rivets to leak and very often loosen some rivets in their holes.

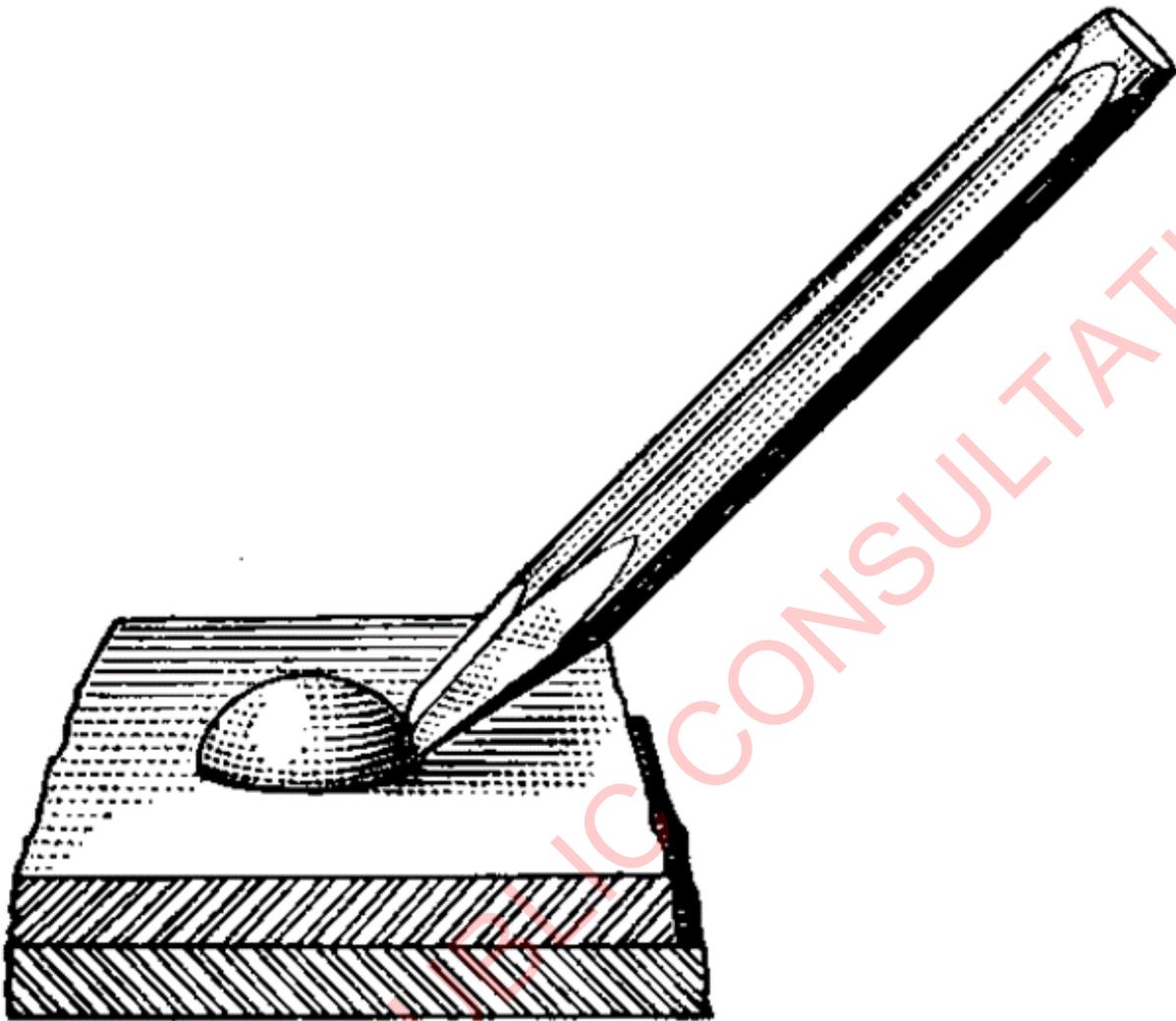
The latter trouble is usually caused by defective material or workmanship at the time the boiler was built.

When a rivet is driven so that the body or shank does not fill the hole completely, the rivet will be loose in the hole.

In hand riveting this occurs from improper holding on of the rivet while forming the rivet head; in machine riveting, to the improper application of the power riveter or to forming of the rivet head; off centre with respect to the axis of the rivet

A leaky rivet has a discoloration around the head and on the surrounding plate.

When a leaky rivet is tight in the rivet hole it can be made steam tight by caulking the edge of the head with a tool of the form shown in Appendix Figure B-43.



Appendix Figure B-43 Caulking tool

The caulking tool should be held so that the rivet material along the outer edge is driven down on the plate; for, if the caulking tool is at too great an inclination, the metal will be raised away from the plate making the leak worse.

The test for tightness of a rivet consists in striking the rivet head lightly with a hand hammer.

A tight rivet when struck gives a clear metallic sound and the hammer rebounds from the blow; in the case of a loose rivet the sound is dull and the hammer does not rebound

All loose rivets should be cut out and replaced, as they cannot made steam tight and kept so for any great length of time.

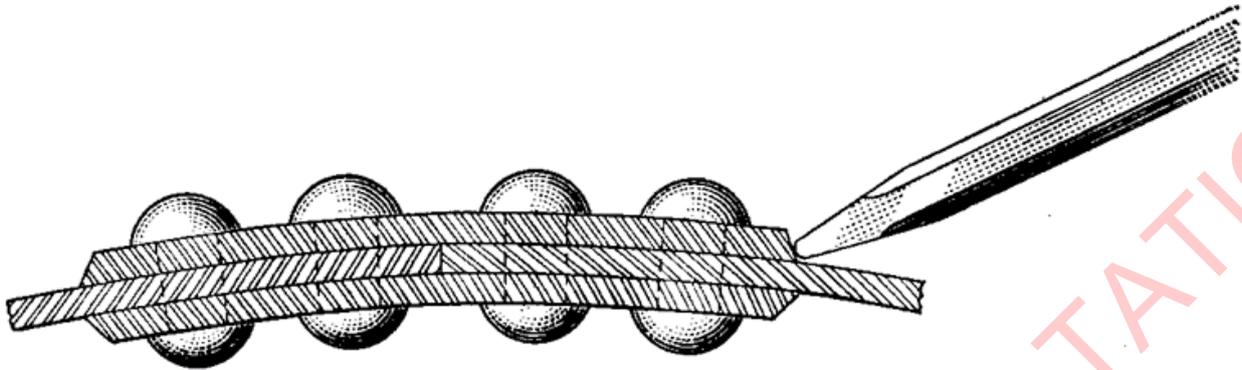
B.18.2 Caulking leaky riveted joints

In addition to the leaks that develop around rivets, the seams of overlapping plates leak after continued operation of the boiler.

Usually, if the rivets in the joint are tight, and if the plates that overlap are laid up metal to metal, the seam can be made steam tight by caulking.

In such work the caulking tool should have a round nose or caulking face so that when it is struck, the plate will be upset a trifle filling in the crevice or opening through which steam and water escape.

The caulking tool should be held at right angles to the caulking edge, in the manner shown in Appendix Figure B-45, so that the metal will be forced down against the underlying plate.



Appendix Figure B-44 Caulking tool angle

If the caulking tool is held at too great an angle to the caulking face is too sharp, it will act as a wedge and force the overlapping plates apart making the conditions worse.

A leaky seam should never be caulked while there is either steam pressure or water pressure on the boiler, as doing so will seldom be effectual, and usually cause more harm than good, because new leaks will be started at other places.

B.18.3 Renewing damaged calking edges

The edge of a plate that has been caulked several times to stop leaks will spring away so far from the other plate that further caulking will fail to make a tight joint.

When this is found to be the case, the caulking edge of the plate may be chipped away for a depth that should not exceed $\frac{1}{8}$ ".

A sharp chipping chisel should be used for this operation, and the edge should be chipped to about the same bevel as when the boiler was built.

This operation, however, cannot be repeated very often, because it will soon reduce the lap of the plate, and therefore its strength, to a dangerous extent.

The caulking edges of seams of internally fired boilers may be built up, or reinforced, by the electric, oxy acetylene, or other methods of welding.

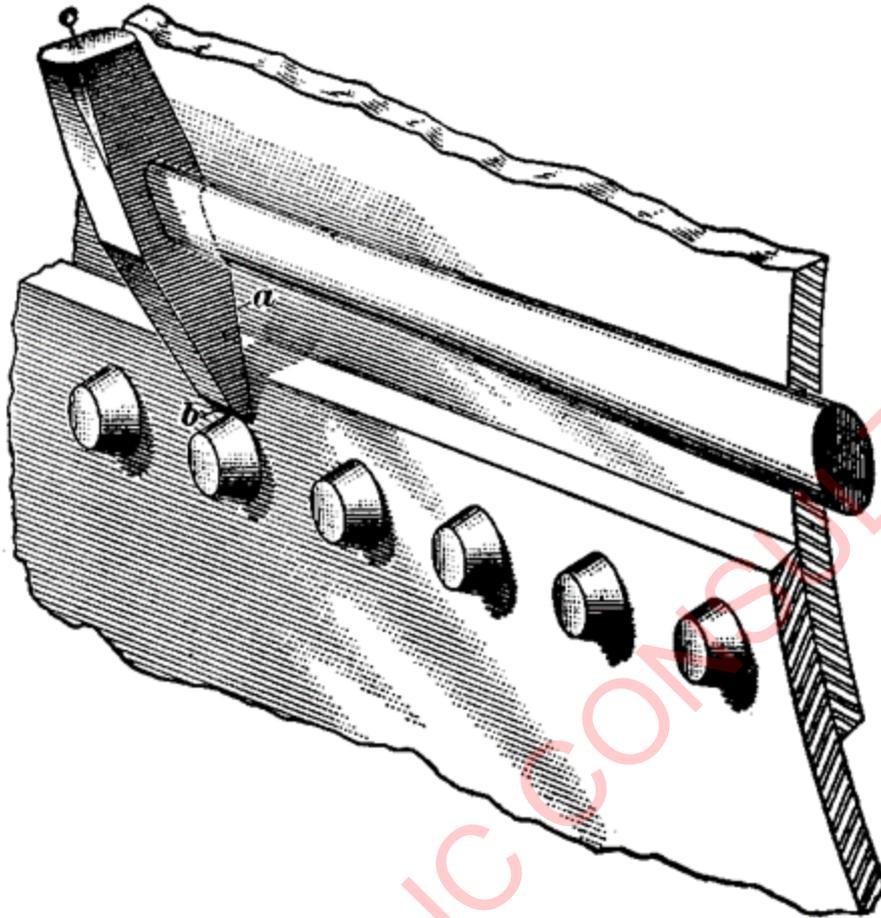
Caulking edges of shells above the fire line of externally fired boilers may also be built up by welding.

These recommendations are in accordance with the requirements of the United States Steamboat Inspection Service and are approved by the A.S.M.E. Boiler Code for stationary boilers.

B.19 Removing rivets

B.19.1 Cutting off rivet heads

The heads of rivets $\frac{7}{16}$ " in diameter and smaller can be cut off by using an ordinary cold chisel and a hand hammer, and a drift pin may be used for backing out the rivet shank after the head is removed. For cutting off larger rivets, heavier tools are needed, such as sledge and a side set, shown in Appendix Figure B-45.

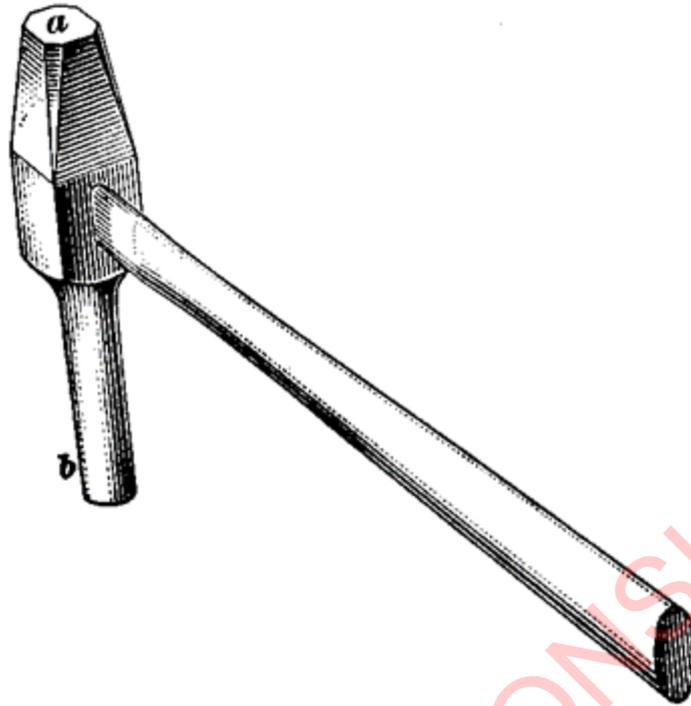


Appendix Figure B-45 Removing rivets

The side set is placed with its flat face *a* against the plate and the cutting edge *b* at the point where the rivet head meets the plate.

The end *c* is then struck with the sledge. After the rivet head is moved, the shank of the rivet is backed out by using the punch shown in Appendix Figure B-46, called a backing out punch.

The end *a* is struck with a sledge while the end *b* is held against the rivet shank.

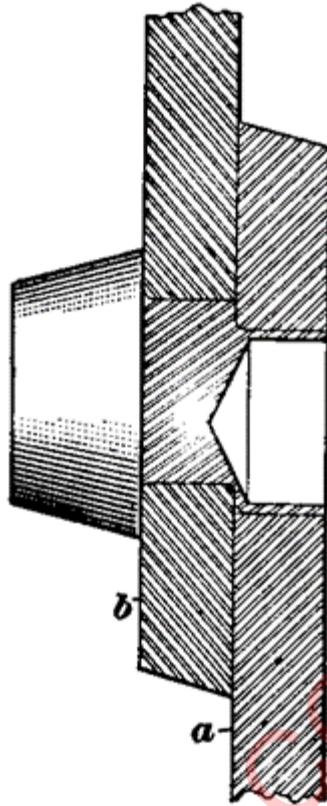


Appendix Figure B-46 Backing out punch

Another effective tool for cutting off rivet heads may be made by equipping a heavy type of pneumatic riveting hammer with a bushing to hold a long cold chisel. It is better to cut off rivet heads than to break them off in repair work, as less damage is done to the plates.

When a rivet is to be backed out from a light plate, that is, a plate less than $\frac{3}{8}$ " in thickness, it is the practice to place a dolly bar or sledge against the plate on the side opposite that from which the rivet is being driven out.

The bar or sledge should be held against the plate, close to the rivet, to back up the plate, preventing bulging of the plate and aiding in the removal of the rivet.



Appendix Figure B-47 Rivet head requiring to be drilled out

When a rivet has been driven in rivet holes that are not in proper alignment, or offset, it is difficult to back out the rivet shank.

In such a case, after the head has been removed, the rivet shank should be drilled out, as shown Appendix Figure B-47.

On the end from which the rivet head has been cut off, a centre punch mark is made as near the centre of the shank as can be judged.

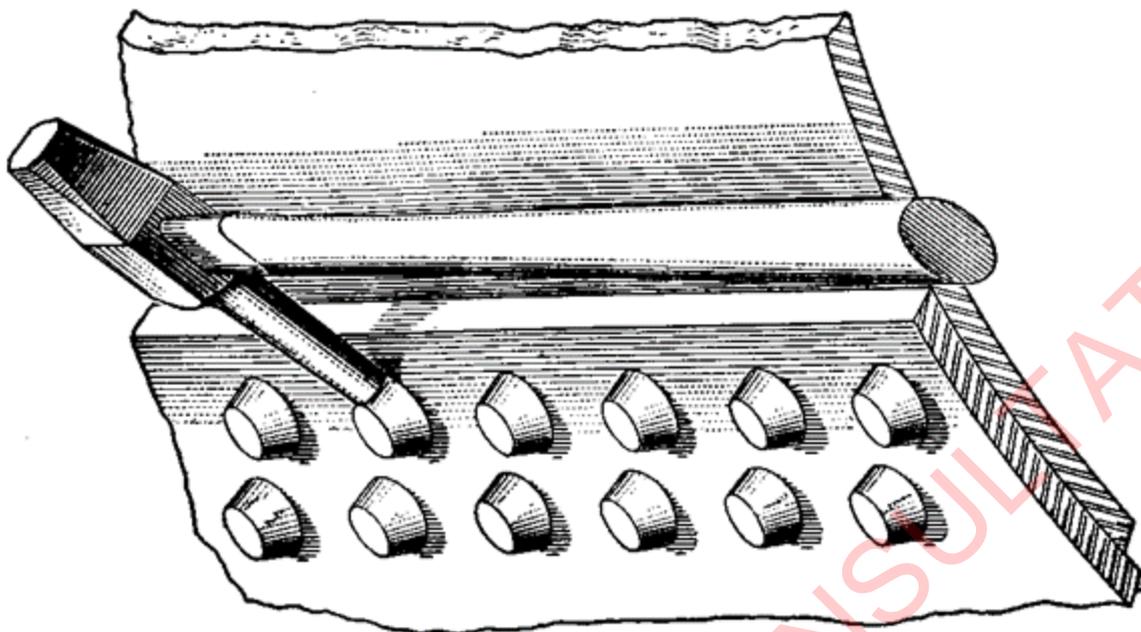
Then, with a drill $1/16$ th to $1/8$ '' smaller than the diameter of the rivet hole, the part of the shank in plate a is drilled out.

It will then be easy to back out the part remaining in the plate (b).

The holes should then be reamed out to a larger diameter to obtain as nearly a true hole as possible, after which an oversize rivet, heated very hot, should be driven in as rapidly as possible, so as to fill the hole

B.19.2 Breaking off rivet heads

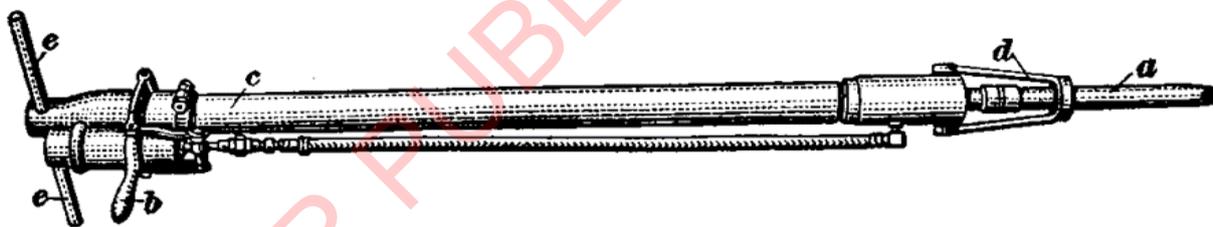
There are two methods of knocking off rivet heads, or breaking them off, either of which may be used if the boiler plate is to be renewed; or if the plate is of sufficient thickness to withstand injury from hammering the head of the rivet.



Appendix Figure B-48 Hand method of breaking off rivet heads

The hand method involves the use of the backing out punch, which is placed against the rivet head, as shown in Appendix Figure B-48, and struck with a heavy sledge until the head of the rivet is broken off.

The time required to knock off a rivet head may be reduced to a few seconds by the use of the device shown in Appendix Figure B-49.



Appendix Figure B-49 Rivet head breaking tool

It is operated by compressed air and is commonly called the iron mule, because it delivers a terrific blow against the rivet head.

The end of the driving tool *a* is set against the rivet head and the air control lever (*b*) is moved back and forth. The air admitted to the cylinder (*c*) of the device drives a piston that delivers a heavy blow on the tool *a*.

Usually, from six to eight blows are sufficient to break the head off a rivet 1" in diameter.

The clip (*d*) keeps the tool *a* in place and the handles (*c*) enable the operator to hold the machine in position on the work.

B.19.3 Removal of countersunk rivets

A countersunk rivet with one countersunk head can sometimes be removed by cutting or knocking off the head opposite the countersunk end and then punching it out from the side from which the head was removed.

When this cannot be done, the countersunk head is drilled or chipped out.

The drilling may be done, with tools available, an ordinary ratchet, or a pneumatic drilling machine, or an electric drill.

In drilling out the countersunk head, the rivet head is first centre punched heavily enough to start the drill, and centrally, so that the drill will not strike the plate.

The drilling should not be carried to a greater depth than that of the countersink in the plate.

Cutting out of the countersunk head may be done with a round nosed chisel and a hammer, but this method involves considerable work and time.

If both heads of the rivet are countersunk, it may be necessary to remove both heads in order to back out the shank.

B.20 Redriving rivets

B.20.1 Riveting in repair work

When, in boiler repair work, old rivet holes from which the rivets have been removed are found to be in bad shape, either from corrosion or from bad workmanship, it is advisable to ream the holes for a rivet one size larger than the old one before inserting a new rivet.

When rivet holes are out of arm's reach, either long handled rivet tongs or three-pronged spring tongs shown in Appendix Figure B-50 are employed.

The latter consists of two jaws a welded on the end of a handle and a flat piece of spring steel (*b*) riveted or otherwise fastened to the handle.

To insert a rivet, the jaws (*a*) are slipped over the rivet shank, the spring piece (*b*) resting on top of the rivet head, holding the rivet in the tongs.



Appendix Figure B-50 Long handled rivet tongs

When the rivet shank has been inserted in the hole, the tongs are removed by a pull at right angles to the rivet.

As a general rule, machine riveting is not feasible in boiler repair work, except in rare instances.

Nearly always the rivets shall be driven by hand, although it is often possible to use a pneumatic hammer for the purpose.

Owing to the time usually required to get a rivet into place in repair work, it is seldom possible to drive rivets red hot.

More force is required to drive rivets while cold than while hot; Therefore, special attention shall be paid to proper holding on against the rivet in order that, after they have been driven, their shanks may fill the holes properly and their heads grip the plates tightly.

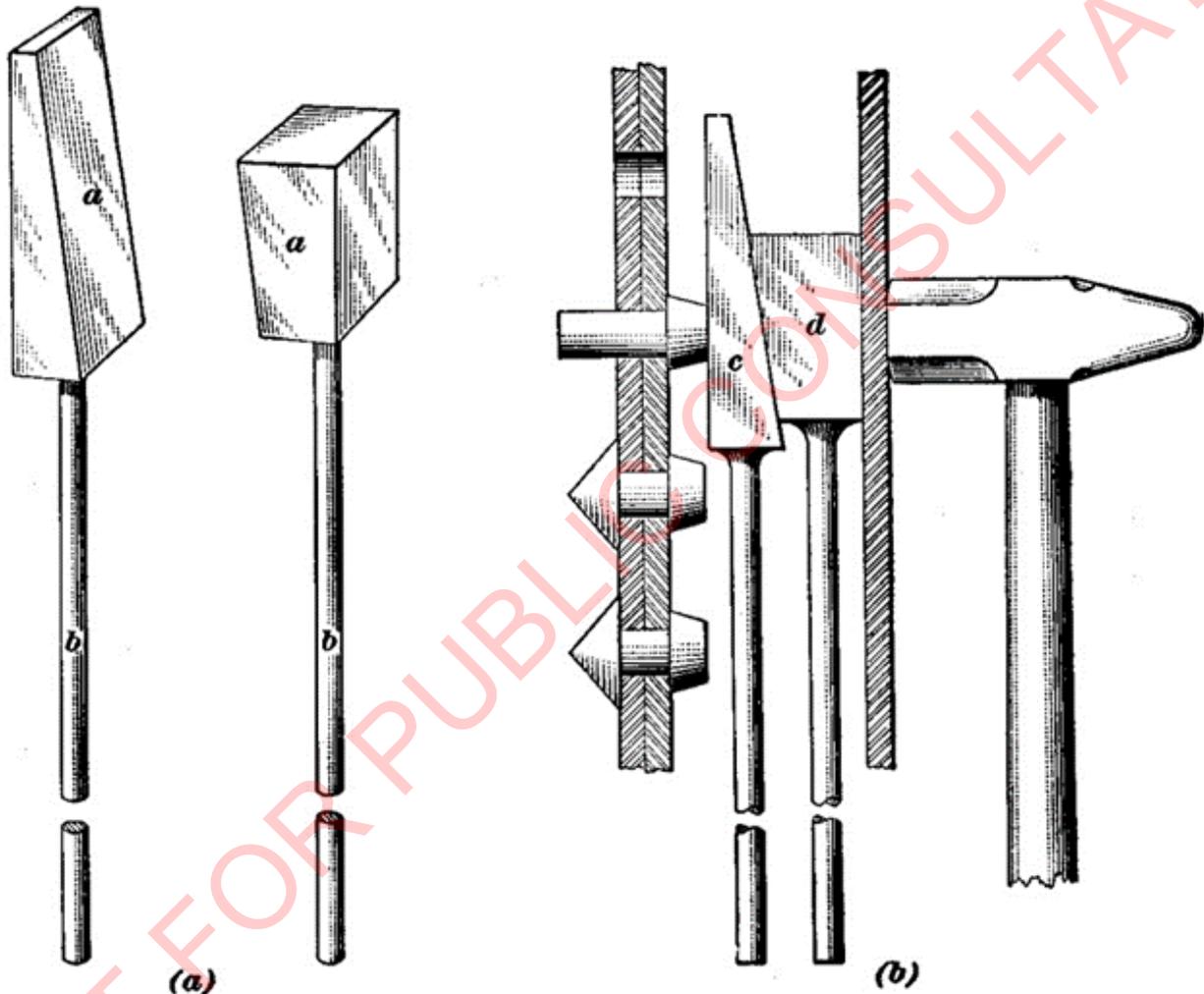
On account of the restricted space in some repair work, due to location of stays, tubes, and connecting plates, it is necessary to employ holding on bars and wedges of special shapes.

B.20.2 Use of wedge bars

When rivets have to be backed up from the water side of plates forming water legs of a boiler, as, for instance, the firebox and outside sheets of a locomotive type boiler, a pair of wedge bars may be used for holding on.

Two such bars, used in conjunction with each other, are shown in Appendix Figure B-51 (a); Their application is illustrated in (b).

As shown in Appendix Figure B-52, each bar has a wedge-shaped head forged from steel (a), to which is fastened a round handle of suitable length (b).



Appendix Figure B-51 Wedge bars

In one wedge bar the handle is fastened to the small end of the head, and in the other bar the handle is fastened to the large end of the head.

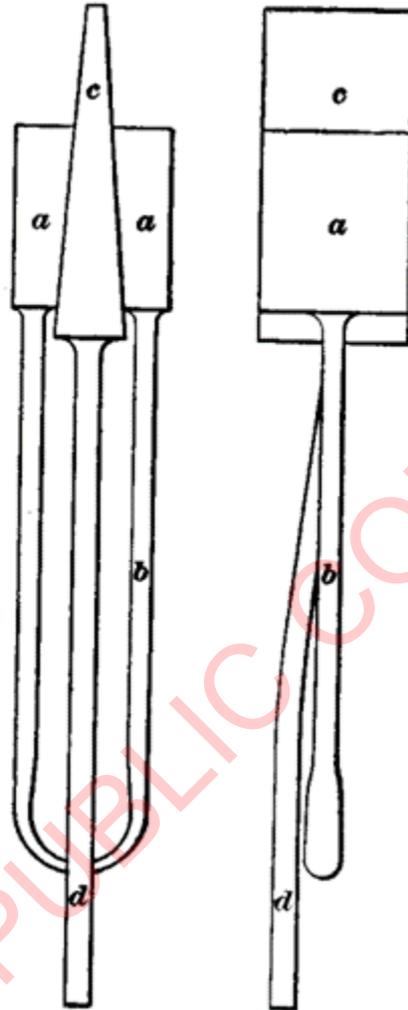
When the rivet blank has been inserted in the hole in the plates, the two wedge bars are placed against the head of the rivet blank and the opposite plate, as shown in (b), are wedged in tightly by tapping the handle of the wedge bar (c). At the same time the wedge bar (d) is held from slipping

During riveting, it is advisable further to back up the rivet by holding a sledgehammer or other heavy object in line with the wedge bars, as shown.

The spring block wedge bars shown in Appendix Figure B-52 are another form used in backing up rivets in narrow water leg spaces.

They consist of two tapered forged steel heads (*a*) and a U-shaped spring handle *b*, with a central wedge (*c*) having a tapered head and an offset handle (*d*) to clear the spring handle of the other wedge bars.

In the use of these wedge bars, the bars *a* are inserted first and then the central wedge (*c*) is driven into place.

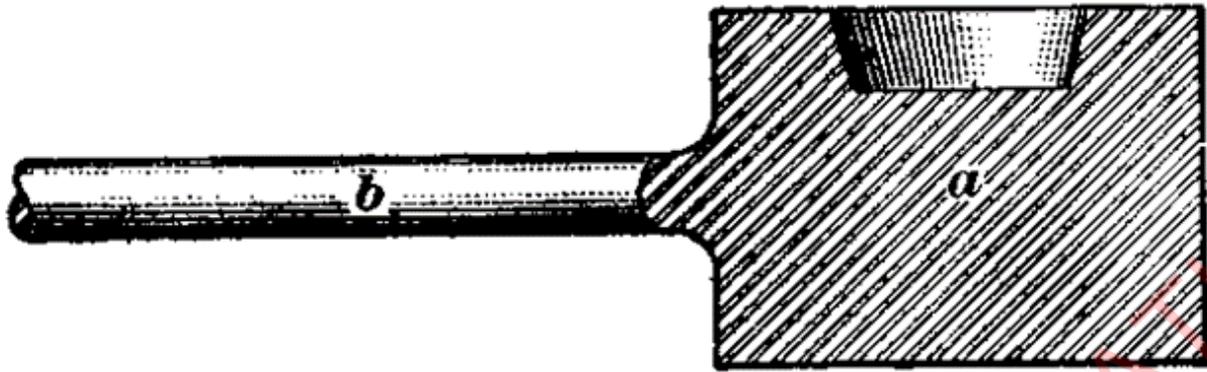


Appendix Figure B-52 Spring block wedge bars

B.20.3 Holding on bars

An objection to straight wedge bars is that they flatten the rivet heads; furthermore, considerable care shall be taken in handling the bars to keep them central with the rivet shank. For these reasons a cup bar in connection with wedge bars is often used.

A cup bar is shown in Appendix Figure B-53.



Appendix Figure B-53 Cup bar

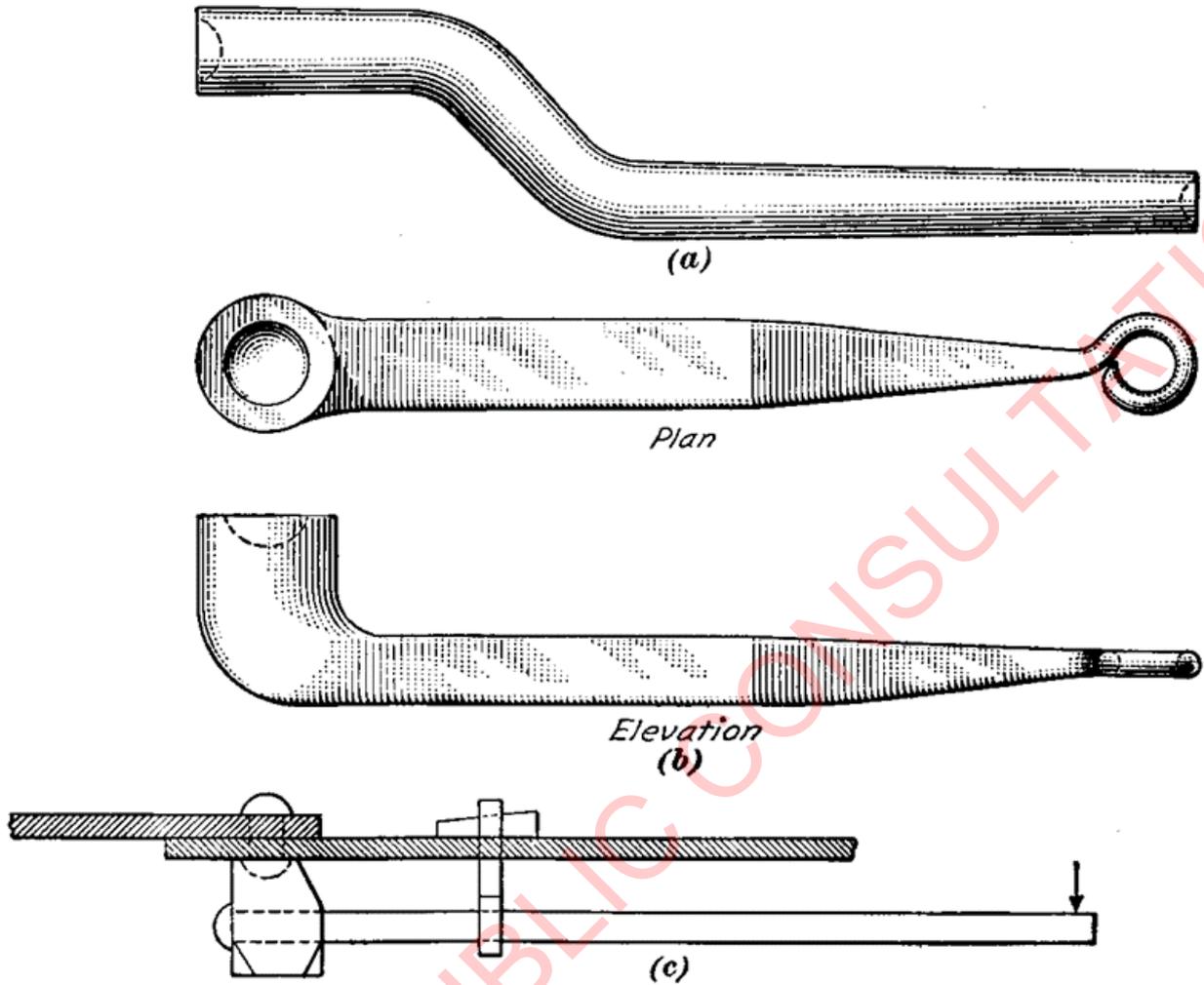
It has a recessed head *a* to fit the rivet head, and a long handle (*b*). The head *a* is placed over the rivet head and backed up by one or two wedge bars.

In places where there is room for backing up a rivet, cylindrical dolly bars may be used. The offset dolly bar, recessed at both ends, as shown in Appendix Figure B-54 (*a*), to fit the rivet head, is a convenient form to hold against the rivet while the other head is riveted over.

When conditions permit, pry dollies may be used.

The gooseneck dolly shown in (*b*) and the straight pry dolly shown in (*c*) are holding on devices ordinarily employed.

These tools may be modified in any suitable way to meet unusual conditions in riveting work.



Appendix Figure B-54 Cylindrical dolly bars

B.21 Application of patches

B.21.1 Use of patch bolts

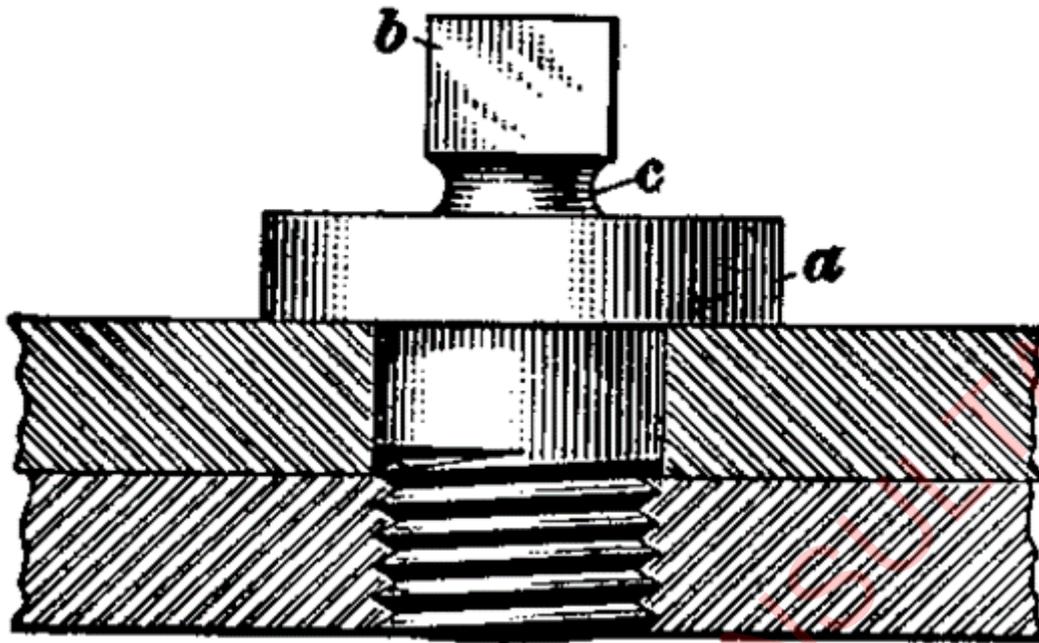
In boiler repair work, it often occurs that rivets removed for a reason cannot be replaced by new ones, because of their location. It is impossible to back up new rivets for driving.

Likewise, in applying patches to boiler plates, it frequently is not feasible to fit rivets in one or more of the holes used for attaching the patch.

In such cases, patch bolts of suitable form and size may be used; but care shall be taken to see that they not only draw the two plates together but also properly fill the holes.

B.21.2 Types of patch bolts

A patch bolt and its method of application are shown in Appendix Figure B-55.



Appendix Figure B-55 Patch bolts

The bolt is usually turned from a round bar of iron, so as to form a circular flat cap *a*, and the shank of the bolt is generally threaded 12 threads per inch, United States standard.

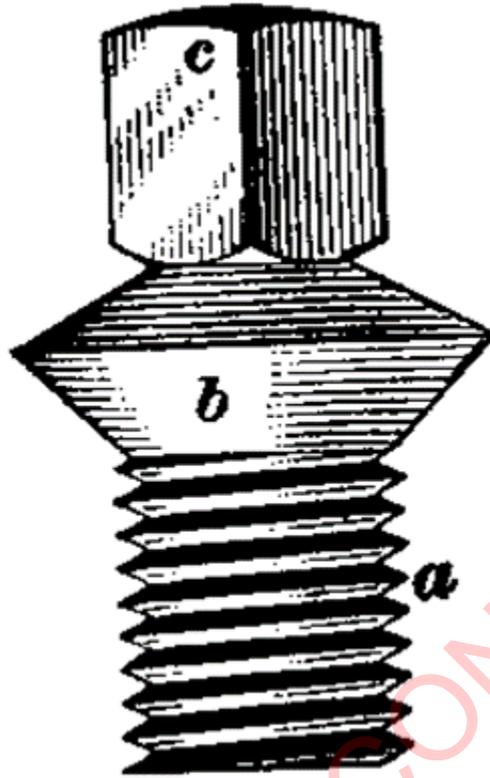
The threaded part is made slightly longer than the thickness of the plate into which it is screwed. The head is formed with a square end (*b*) so that a wrench can be applied to screw the bolt into place.

After the bolt is screwed home the head (*b*) is cut off with a hack saw or is twisted off.

Neck (*c*) may be nicked with a cold chisel and the head (*b*) broken off by a blow from a hammer. But a much better way of removing surplus material is to use a cutting torch, as this obviates hammering, which may disturb the joint.

B.21.3 Method of applying patch bolts

In the installation of either the flat head patch bolt, Appendix Figure B-57, or the countersunk patch bolt it is necessary that the hole in the plate on which the head of the patch bolt is seated be reamed so that the holes are in proper alignment.



Appendix Figure B-56 Flat head patch bolt

Correct alignment of the holes may be obtained as follows:

Both of the connecting plates are lined up and bolted together to hold them in place, and a patch bolt tap is run through

The threads in the plate on which the holes (*b*) head of the bolt is to rest are reamed out by the use of the self-aligning reamer shown in Appendix Figure B-57.



Appendix Figure B-57 Self-aligning reamer

This reamer is made with a threaded end *a* to fit the tapped holes in the plate and can be obtained in sizes from ½" in diameter upwards, varying by sixteenths of an inch.

The reamer is fluted at *(b)* with from four (4) to seven (7) cutting edges, depending on its size. The shank *(c)* is made with a square end, allowing the tool can be rotated with a spanner.

Countersunk patch bolts are seated in countersunk seats formed in the boiler plate.

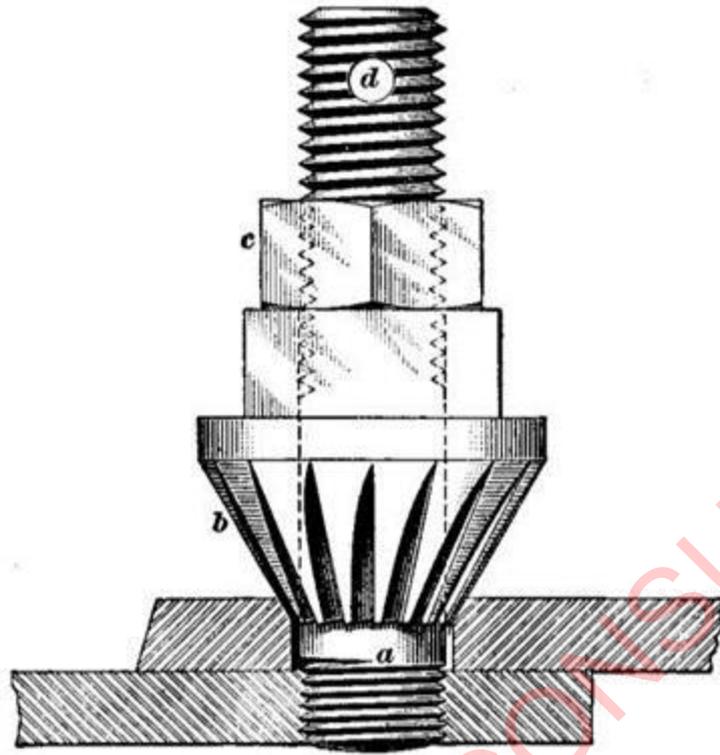
To obtain perfect alignment with the threaded hole, a self-aligning countersink, Appendix Figure B-58, is used. It consists of a threaded stud *(a)*, a fluted countersink *b*, and a feed nut *c*.

The threads in the plate in which the countersunk patch bolt is to be seated are removed as explained in Art. Then the countersinking tool is screwed into position in the threaded hole in the lower plate.

By turning the cutting head *(b)* and screwing down the feed nut *(c)*, the hole in the plate is countersunk uniformly in line with the tapped hole.

The stud *a* may be screwed in or out by inserting a bar in the hole *(d)*.

Another form of this tool uses a square head on the outer end of the stud, instead of a hole, to enable it to be turned.



Appendix Figure B-58 Self-aligning countersink

B.22 Forms of riveted joints

B.22.1 Terms used in riveted work

If a joint is formed by having the edges of two plates overlapped and joined by one or more rows of rivets, it is called a lap joint.

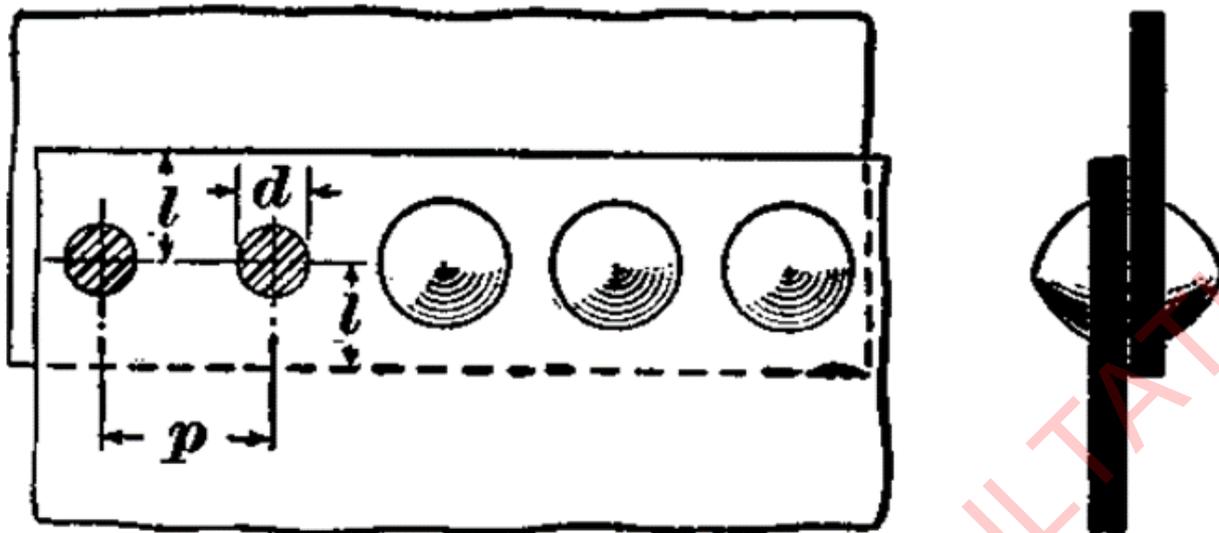
If the plates are placed edge to edge and the junction or seam is covered with a narrow strip of boiler plate, called a strap, on either one or both sides of the plate, and the whole is riveted together, the joint is called a butt joint,

The strap is also known as a cover plate, a welt, or a butt strap.

The terms seam and joint mean the same when applied to riveted connections.

Riveted joints are also classified, according to the number of rows of rivets in the seam, as single-riveted, double-riveted, triple riveted, and quadruple-riveted joints, and from the arrangement of the rivets in the joint as staggered riveted and chain riveted joints.

A single-riveted lap joint is shown in Appendix Figure B-59.



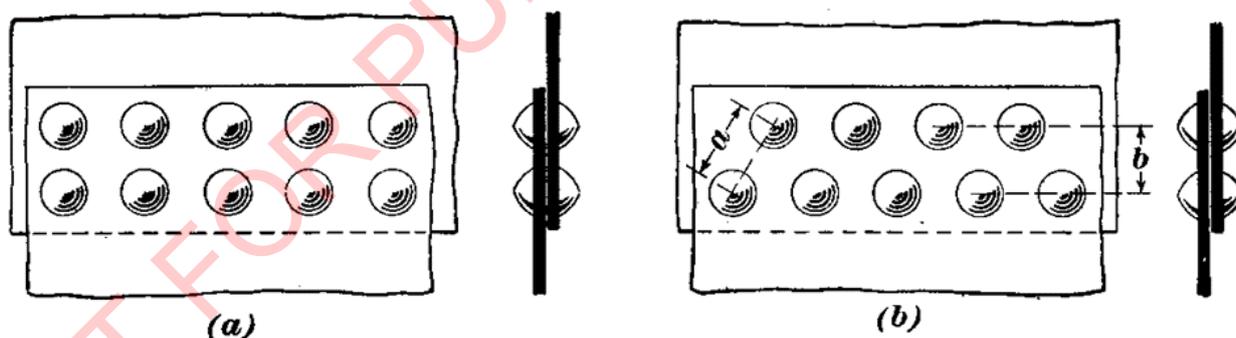
Appendix Figure B-59 Single riveted lap joint

The distance between rivet centres, measured in the direction of the length of the seam, is the pitch of the rivets, and the lap is the distance l from the centre of the rivet hole to the edge of the plate, although the distance (l) is also sometimes referred to as the lap.

B.22.2 Double and triple riveted lap joints

Two different forms of double-riveted lap joint are shown in Appendix Figure B-61, that in (a) being chain-riveted and that in (b) staggered-riveted.

In a joint having chain riveting, the rivets in one row are directly opposite those in the next row; but, if staggered riveting is used, the rivets in one row are opposite the centres of the spaces between the rivets in the adjacent row.



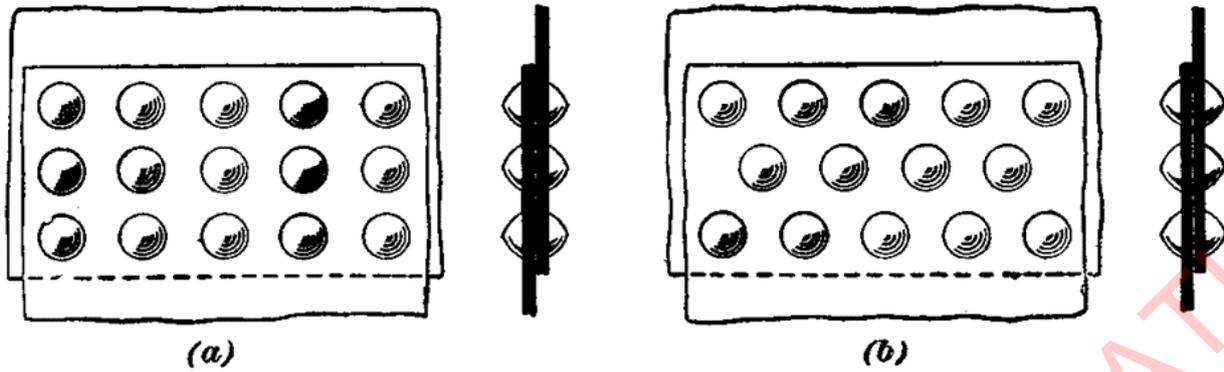
Appendix Figure B-60 Double-riveted lap joint

A joint with staggered riveting is often referred to as a zigzag-riveted joint.

The diagonal distance (a) from the centre of one rivet to the centre of the next rivet in the adjacent row is called the diagonal pitch.

The distance (b) between the centre lines of adjacent rows of rivets is the back pitch; It is measured at right angles to the direction of the seam.

Two types of triple-riveted lap joint are shown in Appendix Figure B-61, that in (a) having chain riveting and that in (b) staggered riveting.



Appendix Figure B-61 Triple-riveted lap joint

Quadruple riveted lap joints have four (4) rows of rivets and either chain or staggered riveting may be used. Triple riveted and quadruple riveted lap joints are now seldom used in boiler work.

Formerly such joints were used for longitudinal seams but owing to the offset produced by overlapping the plate, difficulty arose in obtaining a true cylindrical shell.

Another objection to such seams is that when the shell is under pressure, a bending action arises in the joint, which produces crystallisation of the metal between the rivets.

A correctly designed butt joint is superior to the lap joint in regard to strength and by its use the shell can be rolled to a true cylindrical form.

B.22.3 Single riveted single strap butt joint

A single riveted butt joint with a single cover plate (a) is illustrated in Appendix Figure B-62.

The ends of the boiler shell (b) are butted against each other, and in order to have the edges straight and parallel with each other they are machined on a plate planer.

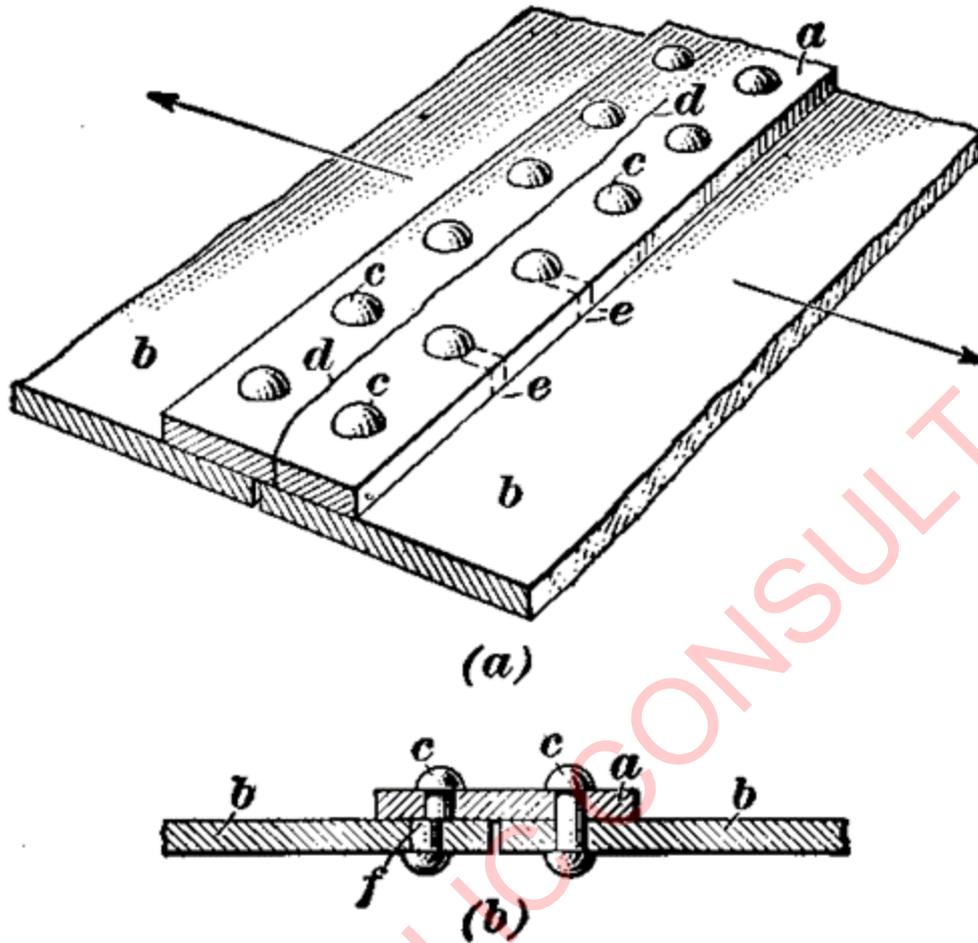
It will be seen that the joint has two (2) rows of rivets (c) and yet is called a singled riveted butt joint.

This follows the fact that the separation of one plate from the other is opposed by only one row of rivets. If the plate is stronger than the rivets, the plates (b) can be separated only by the shearing off the rivets.

The pull on the joint as shown by the arrows in a, tend to break or tear the butt strap along the line dd to crush or shear the metal in front of the rivets, as indicated by the dotted lines e, and to shear the rivets as shown at (f) in b.

Rivets driven through the plate and the butt strap and acted on pressure are in single shear, as the resistance of the rivet to shearing action is that of the sectional area of each rivet.

Butt joints with single butt straps may be double riveted, triple riveted etc. and the rivet arrangement may be chain or staggered



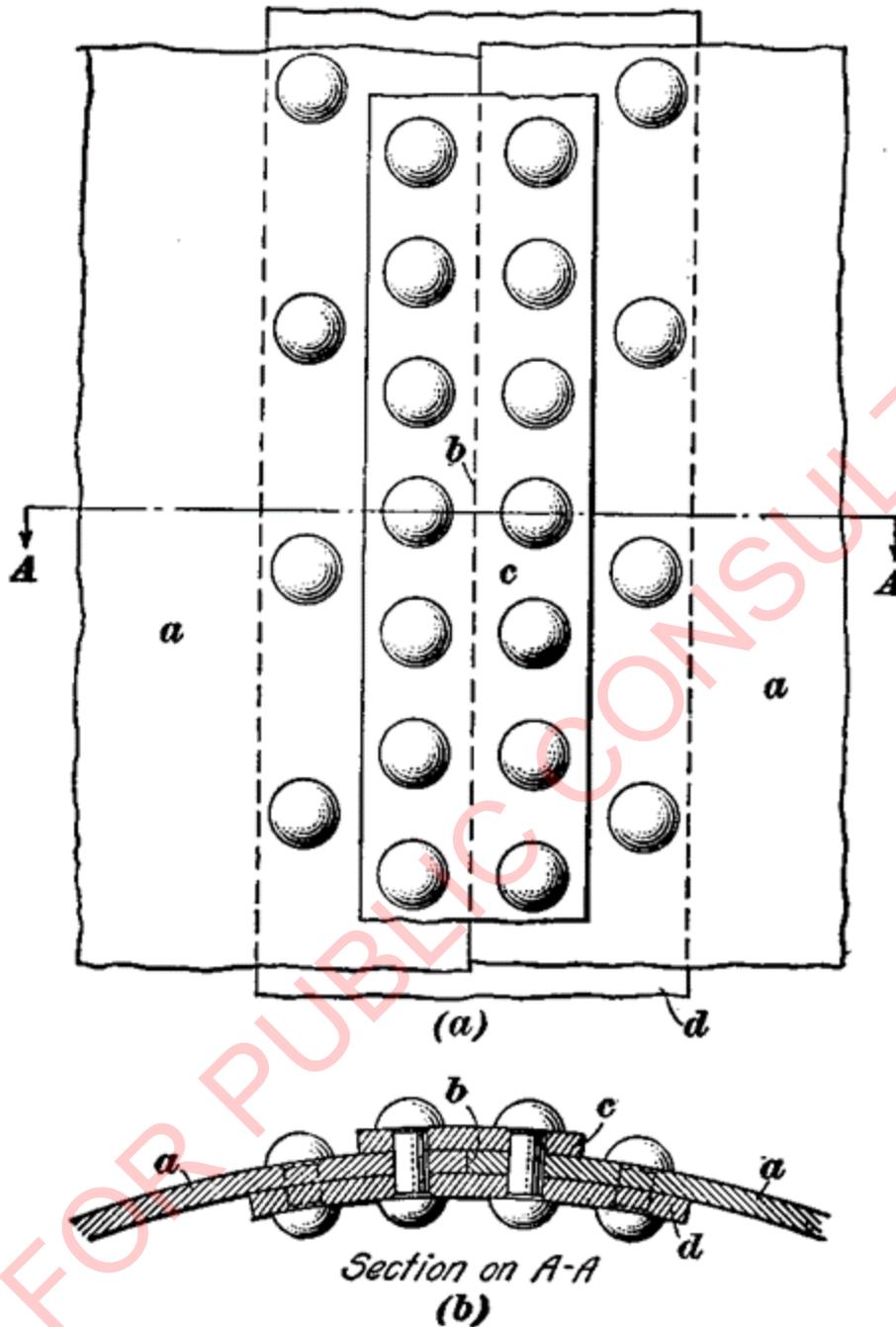
Appendix Figure B-62 Single riveted butt joint with a single cover plate

B.22.4 Double strap butt joints

The butt joint in Appendix Figure B-63 (a) consists of plates a that butt together at (b) and are joined by the use of two butt straps (c) and (d).

The outer strap (c) narrower than the inner strap (d).

It will be noticed in the sectional view (b) that the outer strap is riveted to the plates and the inner butt strap by two (2) rows of rivets and that the inner strap is riveted to the plates by four (4) rows of rivets, two (2) rows being on each side.

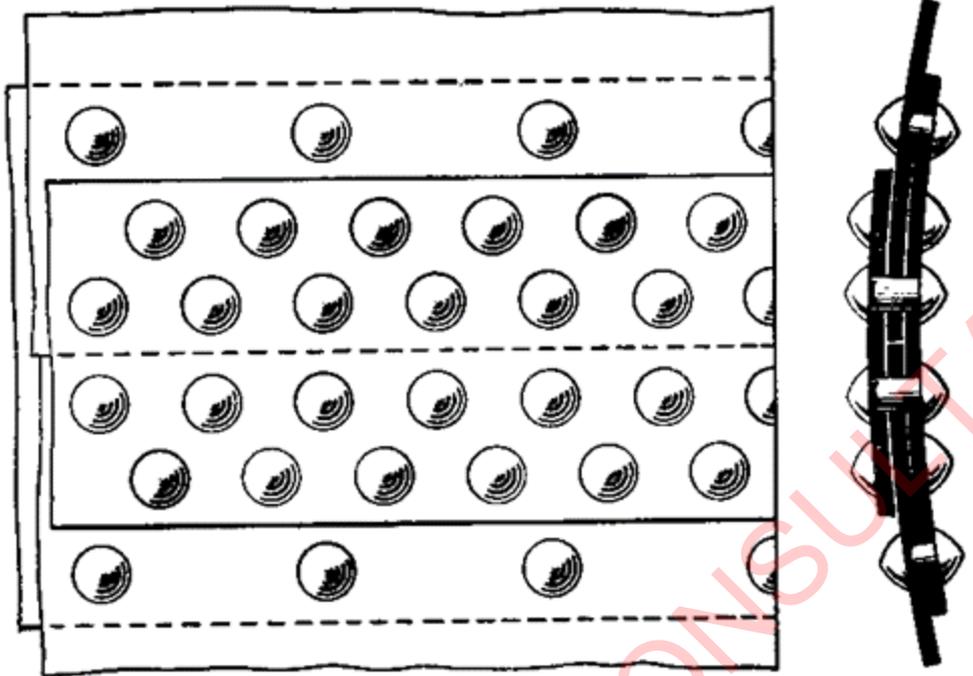


Appendix Figure B-63 Double strap butt joints

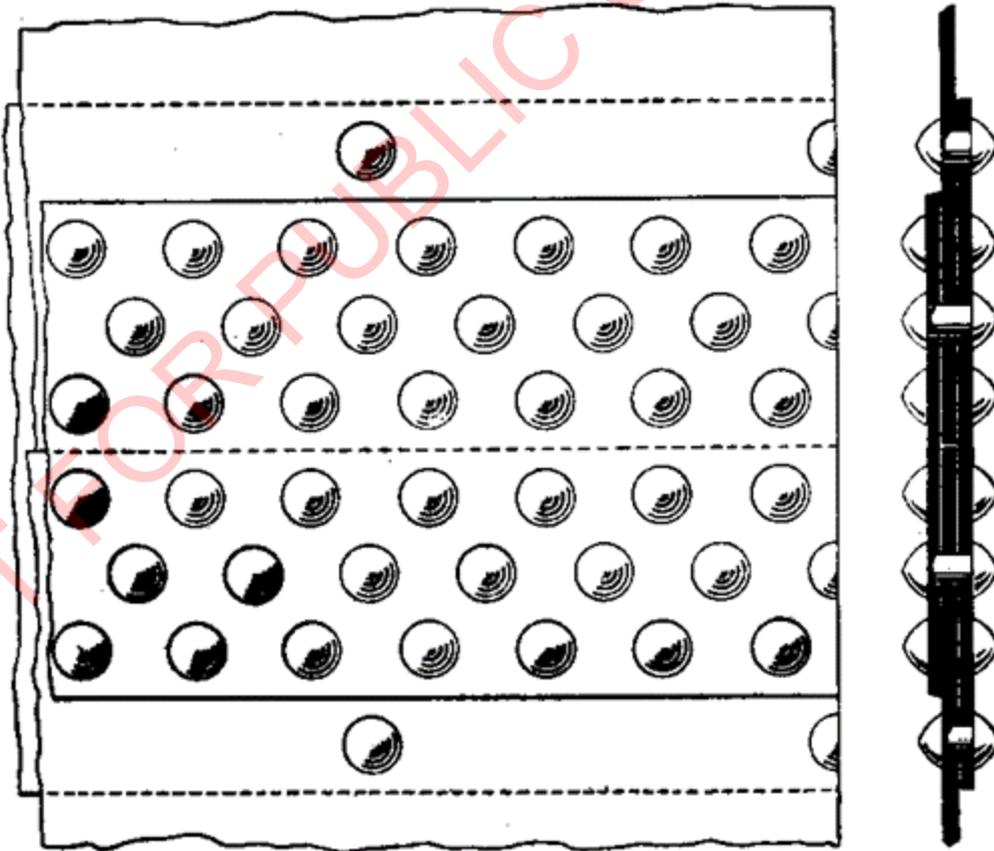
Butt joints may also be triple riveted, as shown in Appendix Figure B-64 (a), or quadruple-riveted as in (b), with the rivets arranged according to the staggered or the chain method.

The advantage of the double strap butt joint having the outer strap narrower than the inner strap is that it is designed to give a stronger form of joint than any other.

The rivets are usually staggered. The pitch of the rivets in the outer rows, which are in single shear, is double the pitch of the rivets in the inner rows.



(a)



(b)

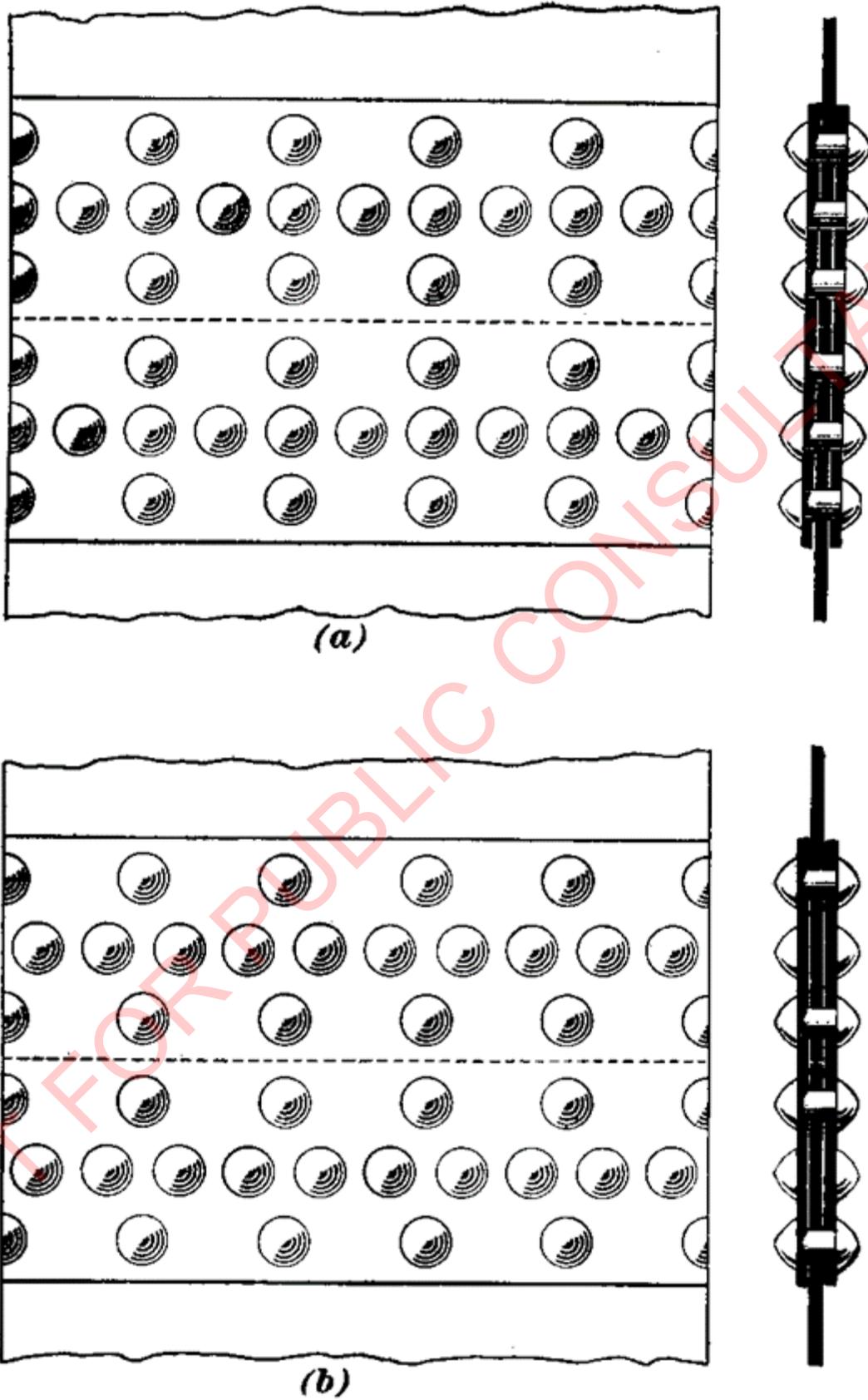
Appendix Figure B-64 Triple and quadruple riveted strap butt joints

B.22.5 Butt joints with straps of equal widths

A triple riveted double-strap butt joint with chain riveting is shown in Appendix Figure B-66 (a) and the same type of joint with staggered riveting in (b).

The inner and the outer butt straps are of the same width on each side of the centre line of the seam, indicated by the dotted line, there are three rows of rivets.

The rivets in the outer and the inner rows of these three have twice the pitch of the rivets in the centre row.



Appendix Figure B-65 Triple riveted double-strap butt joint with chain riveting

Another form of double strap butt joint, known as the saw tooth joint, is shown in Appendix Figure B-66. It is quadruple riveted, and the outer strap (*a*) is cut to the outline indicated, the joint taking its name from the shape same as that of inner strap of this strap.

The overall width of the strap *a* is the same as that of the inner strap (*b*).

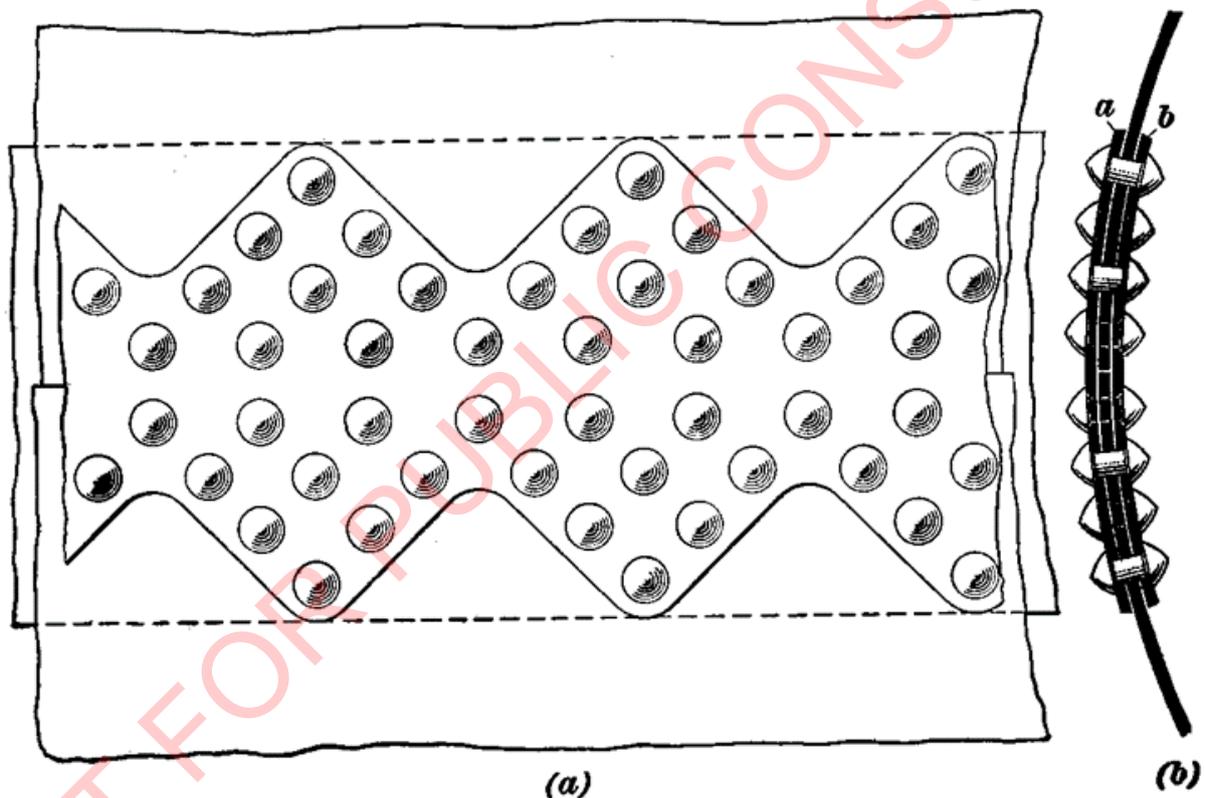
This form of joint is more expensive to make than an ordinary double strap butt joint and is seldom used in boiler practice, except for shells of Scotch boilers.

It enables better caulking to be done along the edges of the outer cover plate.

B.23 Arrangement of riveted joints

B.23.1 Location of longitudinal seams in shell boilers

Owing to the high furnace temperatures, the eroding action of the fuel gases, and the number of overlaps in the plates, it is customary to locate the longitudinal seams of shell boilers as far as possible from the fire.



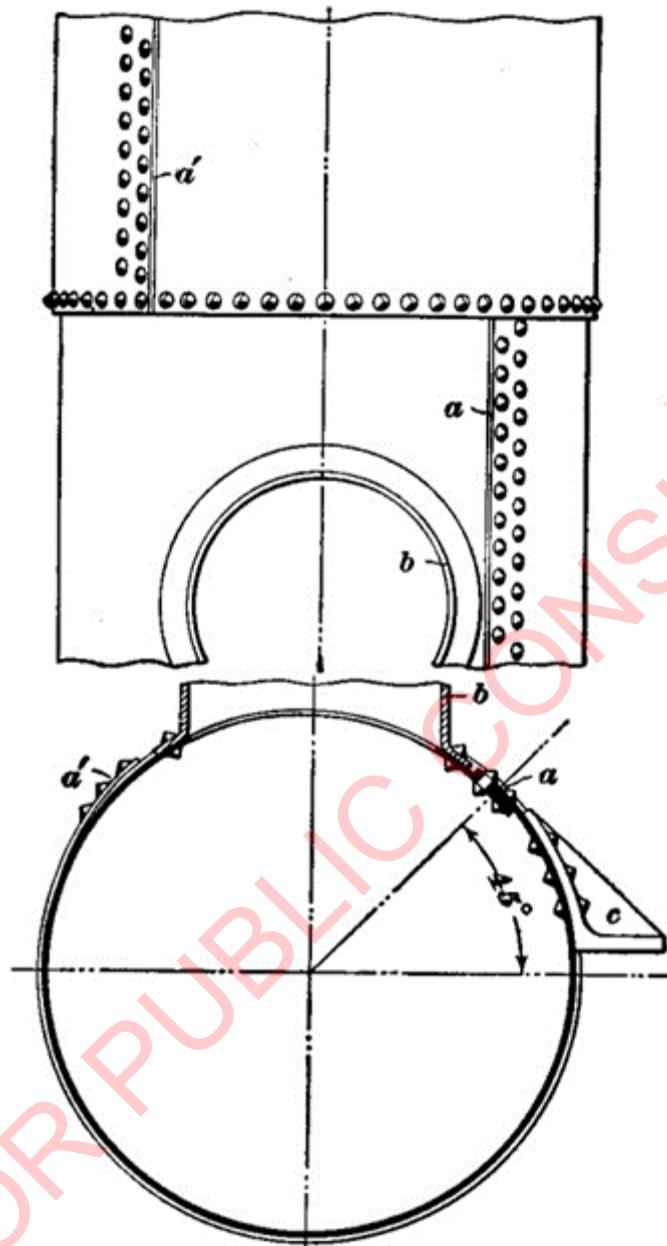
Appendix Figure B-66 Saw tooth joint on a double strap butt joint

Shell boilers of the horizontal return tube type usually have two or more sections, or courses with only one longitudinal seam to the course.

The longitudinal seams are so arranged that they break joints, or alternate, as shown at (*a*) and (*a'*), Appendix Figure B-67; that is, the longitudinal seams in adjacent courses are not in one line, but one seam is to the right and the other to the left of the centre.

Each seam is midway between the top and the side of the boiler.

This arrangement of the seams permits the dome (*b*) to be installed, if one is required, and also the brackets (*c*) without interfering with the joint construction.



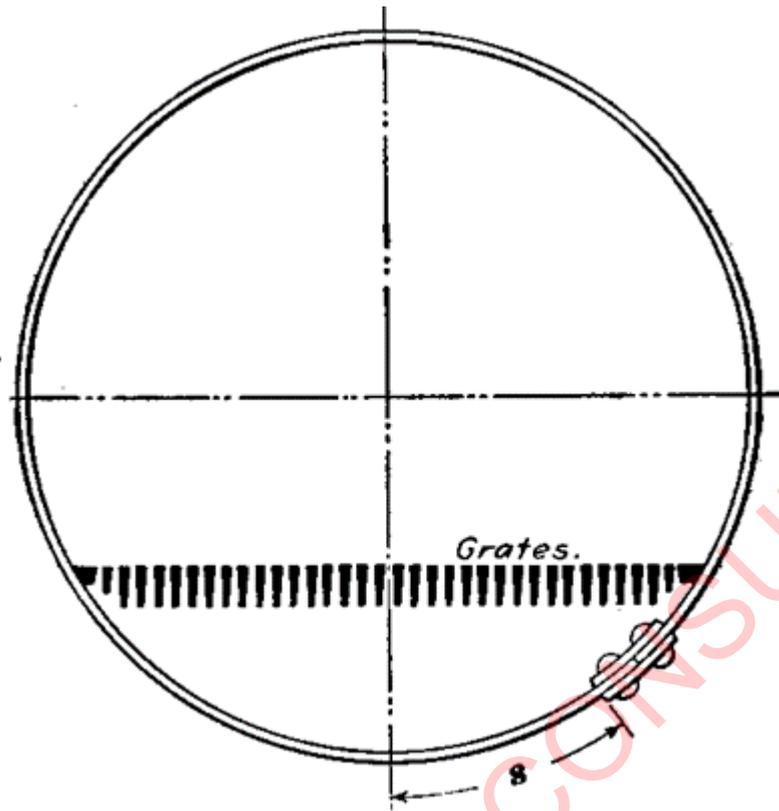
Appendix Figure B-67 Shell boilers of the horizontal return tube type

B.23.2 Location of longitudinal joints in internally fired furnaces

In plain cylindrical furnace flues of internally fired boilers the longitudinal joint, as shown Appendix Figure B-68, is generally located just below the grate, either to the right, as in the illustration, or to the left. The distance s is made as large as possible in order that the seam will not interfere with cleaning out the ashes.

In a vertical tubular boiler, the longitudinal (vertical) seam, if the boiler has only one course, may be located wherever convenient provided it is clear of the fire door opening

If the boiler has two or more courses, the longitudinal seams should break, or alternate.



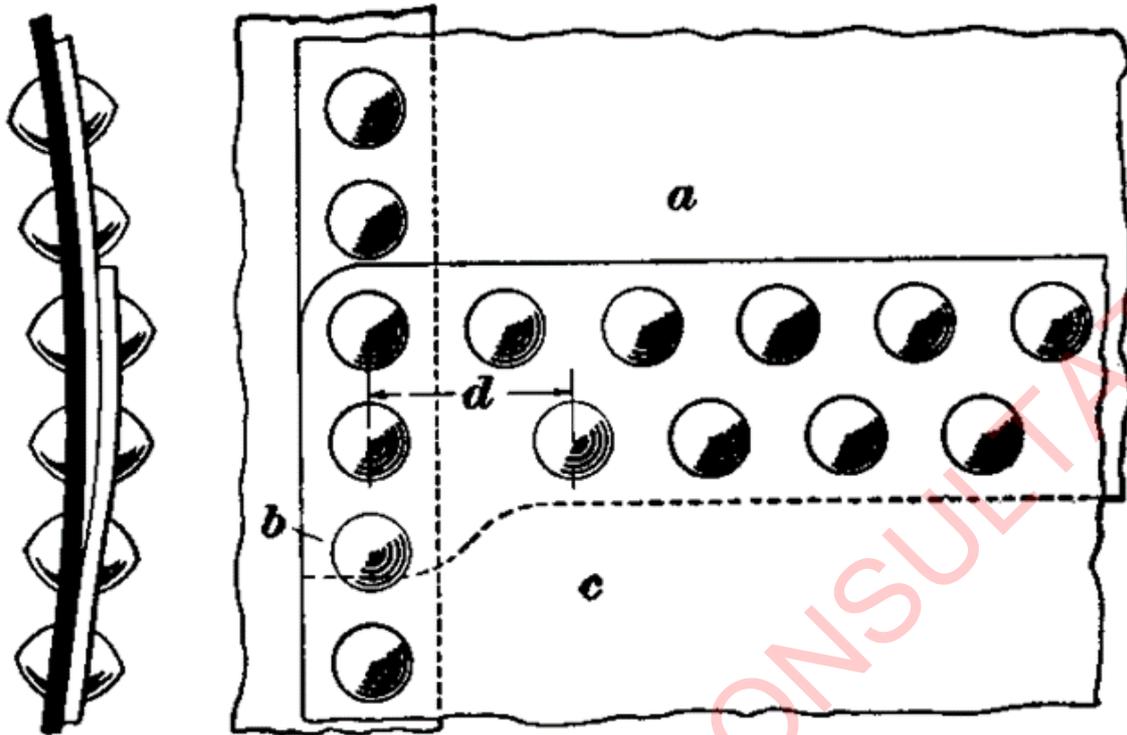
Appendix Figure B-68 Longitudinal joint in plain cylindrical furnace flues

B.23.3 Connecting longitudinal lap joints at girth seam

If plates lap together at the girth seams in boilers having longitudinal lap joints, the inner end (a), Appendix Figure B-69, of the plate shall be hammered out thin or scarfed, as it is commonly called, at the corner (b).

The outer end (c) of the plate is bent circular so as to fit the scarfed corner of (a).

If the lap joint is double zigzag riveted, as shown, it is customary to make the pitch of all the rivets in the outer row uniform, in the inner row, the distance (d) from the rivet in the girth seam to the first rivet of the longitudinal seam will then be equal to 1.5 times the pitch.



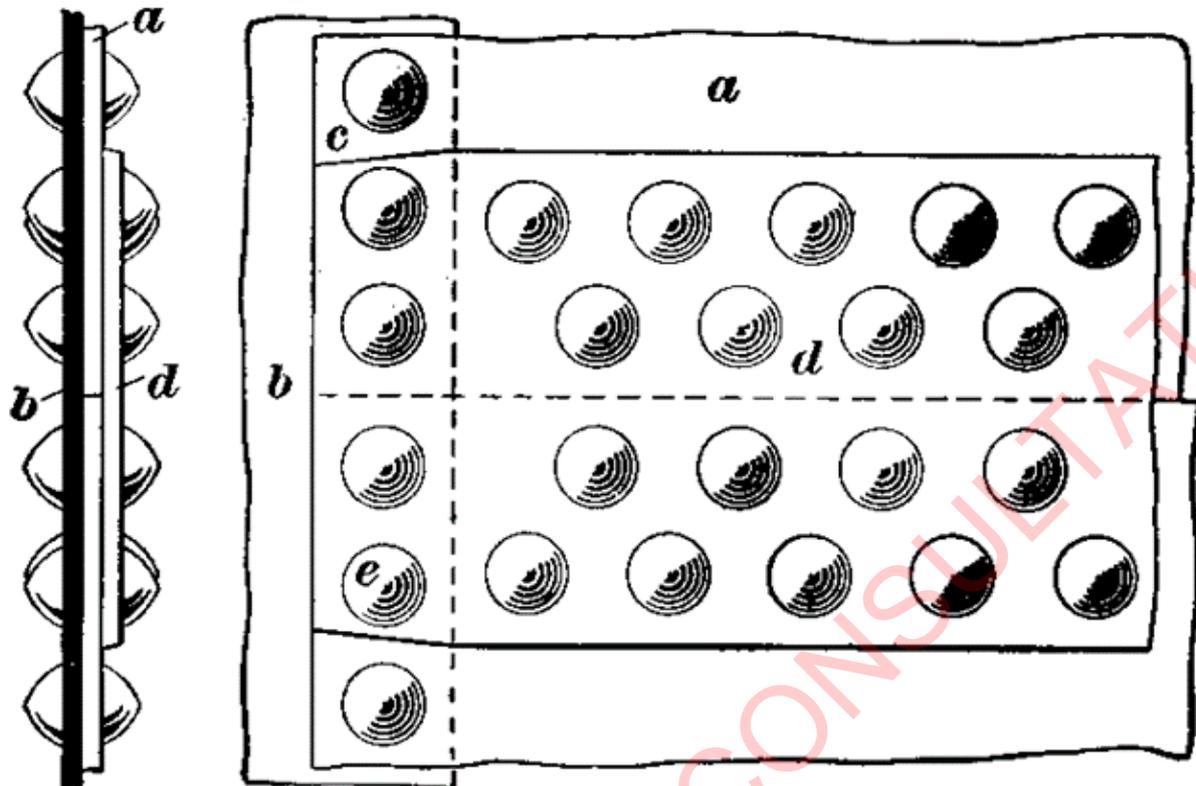
Appendix Figure B-69 Longitudinal lap joints at girth seam

B.23.4 Connecting single strap butt joint and girth seam

In the case of butt joints having single cover plates, the junction of the longitudinal seam and the girth seam is made as shown in Appendix Figure B-70.

The larger shell course (*a*) overlaps the smaller course (*b*), forming the girth seam (*c*).

The butt strap (*d*) extends to the outer overlapping edge of the larger course (*a*) and the rivets (*e*) of the girth seam pass through the shell plates (*a*) and (*b*) and the strap (*d*).

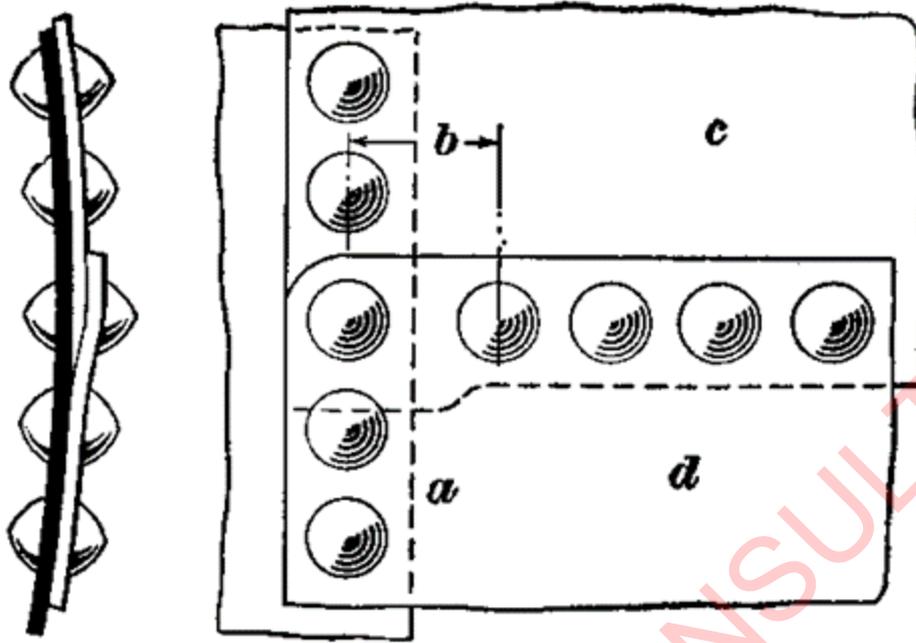


Appendix Figure B-70 Junction of the longitudinal seam and the girth seam

In staggered riveting, the rivets in the butt joint adjoining the girth seam are usually pitched as explained in the preceding article.

In single riveted longitudinal lap and butt joints it frequently is necessary, in order that the rivet die used on the inner head of the rivet may clear the inner edge (*a*), Appendix Figure B-71, of the girth seam, to make the pitch (*b*) greater than the pitch of the rivets in the longitudinal seam.

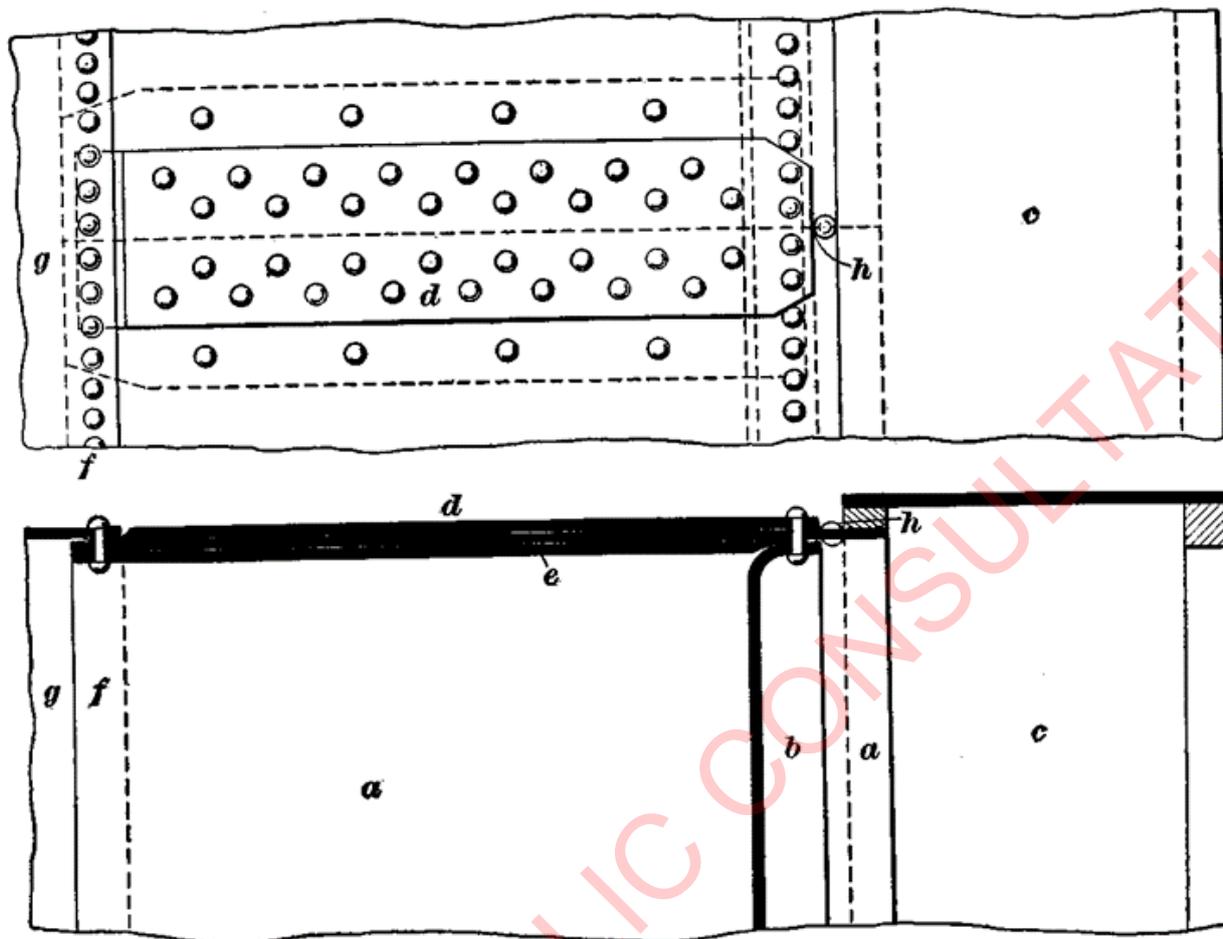
The inner end of the plate (*c*) is scarfed at the junction of the two courses, and the outer end of the plate (*d*) is bent to fit properly over the plate (*c*) and make a tight joint.



Appendix Figure B-71 Single riveted longitudinal lap and butt joints

B.23.5 Longitudinal seam at smoke box locomotive boiler

In boilers of the locomotive type having double-strap butt joints the joints at the smoke box end may be arranged as shown in Appendix Figure B-72.



Appendix Figure B-72 Longitudinal seam at smoke box

The end course a extends beyond the tube sheet (b) so that the smoke box course (c) can be riveted to it.

The tube sheet (b) is flanged outwards so that it can be riveted to the shell courses (a) and (c). From this arrangement of the tube sheet or head (b), it is said to be backed in.

The outer butt strap (d) at the smoke box end is flush with the outer edge of the flange of the head b, and the inner strap (e) is scarfed at the end to fit the curvature of the flange.

The rivets in the girth seam at the smoke box end pass through the shell a, the flange of the head b, and the butt strap (d).

The connection of the girth seam (f) and the longitudinal seam is made by extending the inner butt strap (e) to the edge of the course (a).

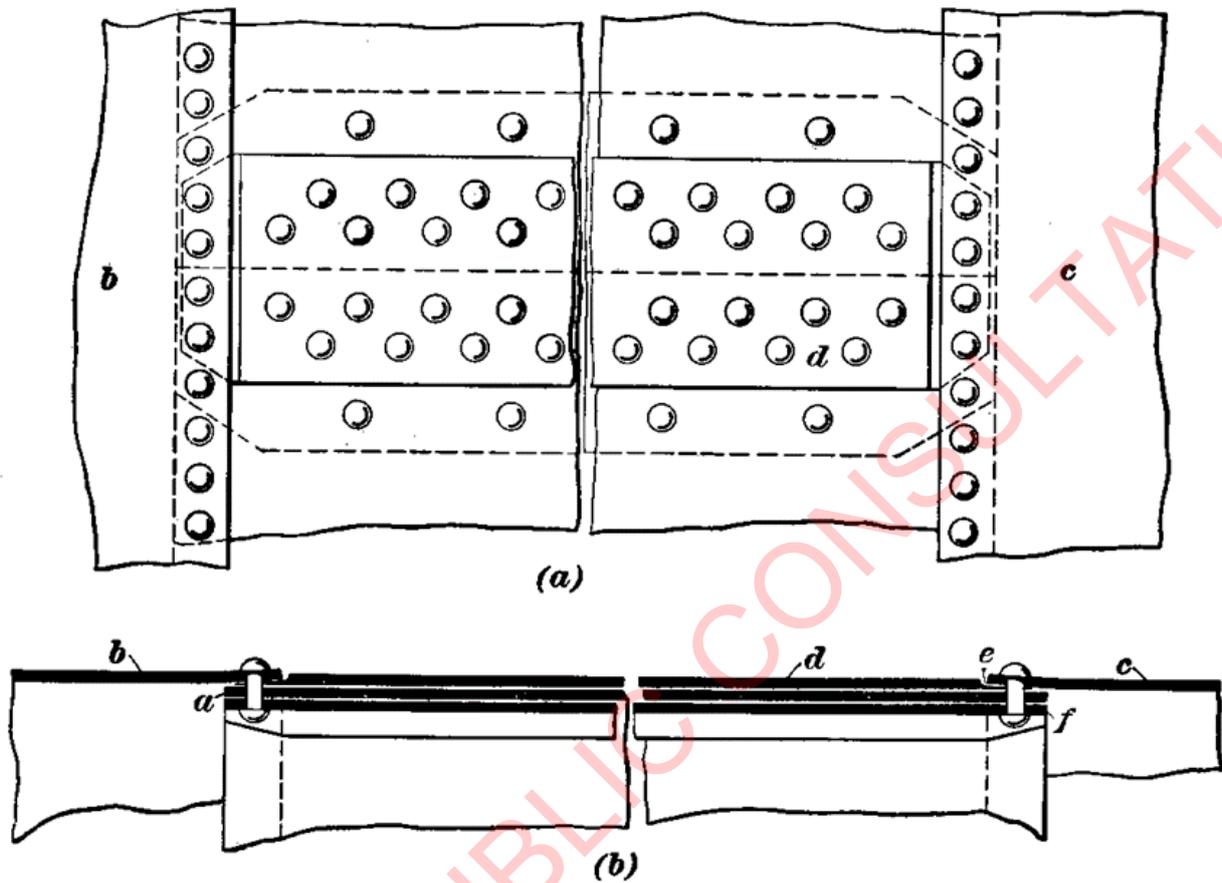
The external strap (d) is either made straight and butted against the plate g or else it is scarfed and placed under the larger course (g).

In the former case, sufficient space shall be allowed between the shell and the butt strap for caulking the seam. To prevent leakage at the junction of the butt joint and the smoke box, a stop rivet h is used.

It is usually a plug $\frac{3}{4}$ " or $\frac{7}{8}$ " in diameter, threaded and screwed tightly into the sheet a, after which both ends are formed into heads and the caulked.

B.23.6 Connecting double strap joint and girth seam

In a horizontal return tubular boiler having Three courses, in Appendix Figure B-73 (a) and (b), the middle course a is slightly small, in diameter and fits inside the two end courses (b) and (c).



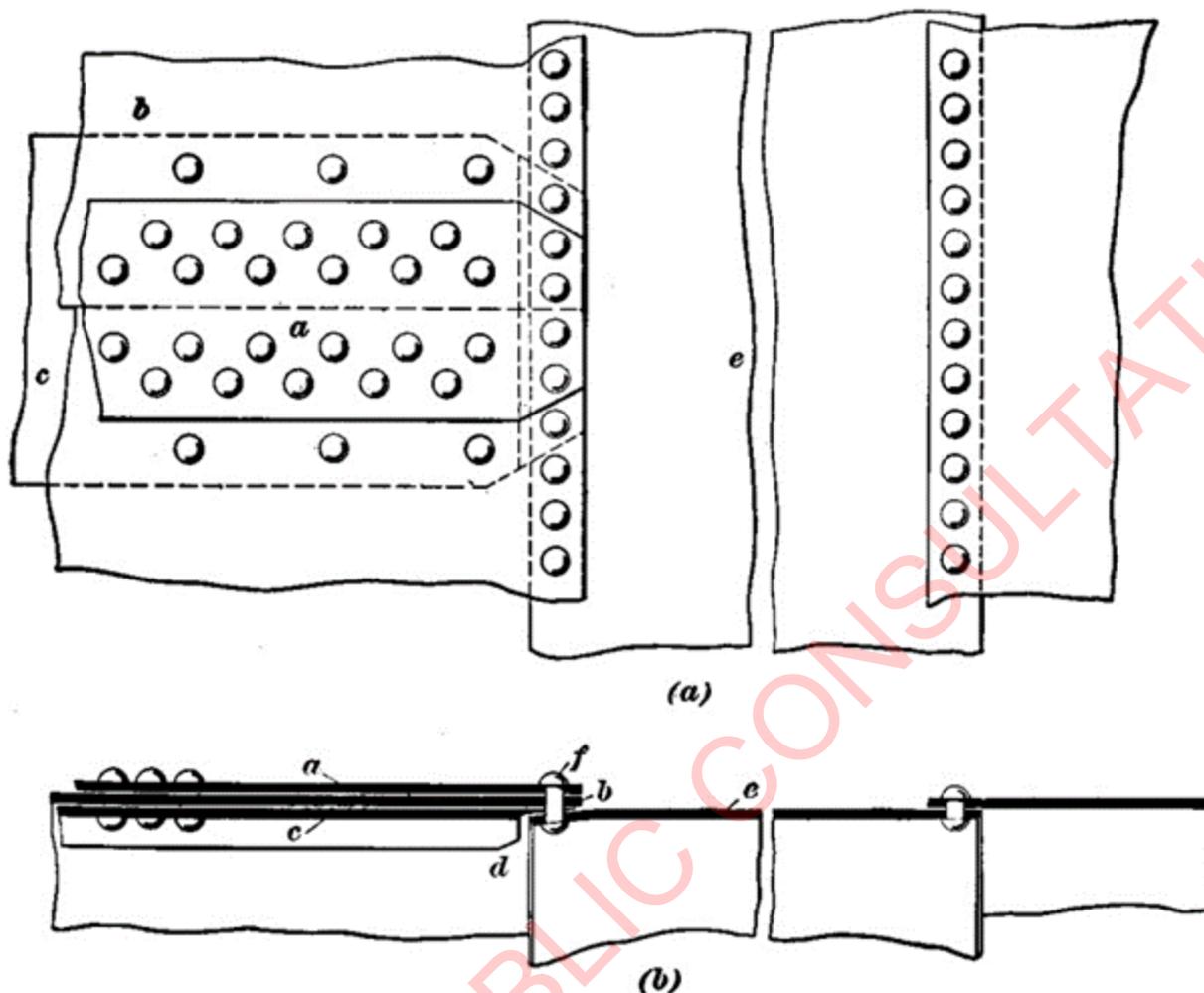
Appendix Figure B-73 Horizontal return tubular boiler with Three courses

The outer butt strap (d) of the longitudinal seam of the small course is scarfed at both ends and placed under the plate of the large courses (b) and (c) as shown at (e) in the sectional view (b). The inner butt strap (f) is not scarfed and extends the full-length (c) the middle course (a).

The arrangement of the girth seam and the longitudinal seam in the end courses is illustrated in Appendix Figure B-74.

The outer butt strap is made equal to the length of the end course. The inner butt strap (c) is usually scarfed at both ends, as indicated at (d).

At one end it is passed over the flange of the tube sheet and at the other end over the middle course (e) at the girth.



Appendix Figure B-74 Girth seam and the longitudinal seam in the end courses

B.23.7 Seam connections of shell of locomotive boilers

An approved arrangement of the circumferential and longitudinal seams of the first, second, and third courses of a locomotive boiler is shown in Appendix Figure B-75.

The circumferential seams are double riveted, and the longitudinal seams have double butt straps, with the inner strap wider than the outer one, alternate rivets being omitted in the outer row.

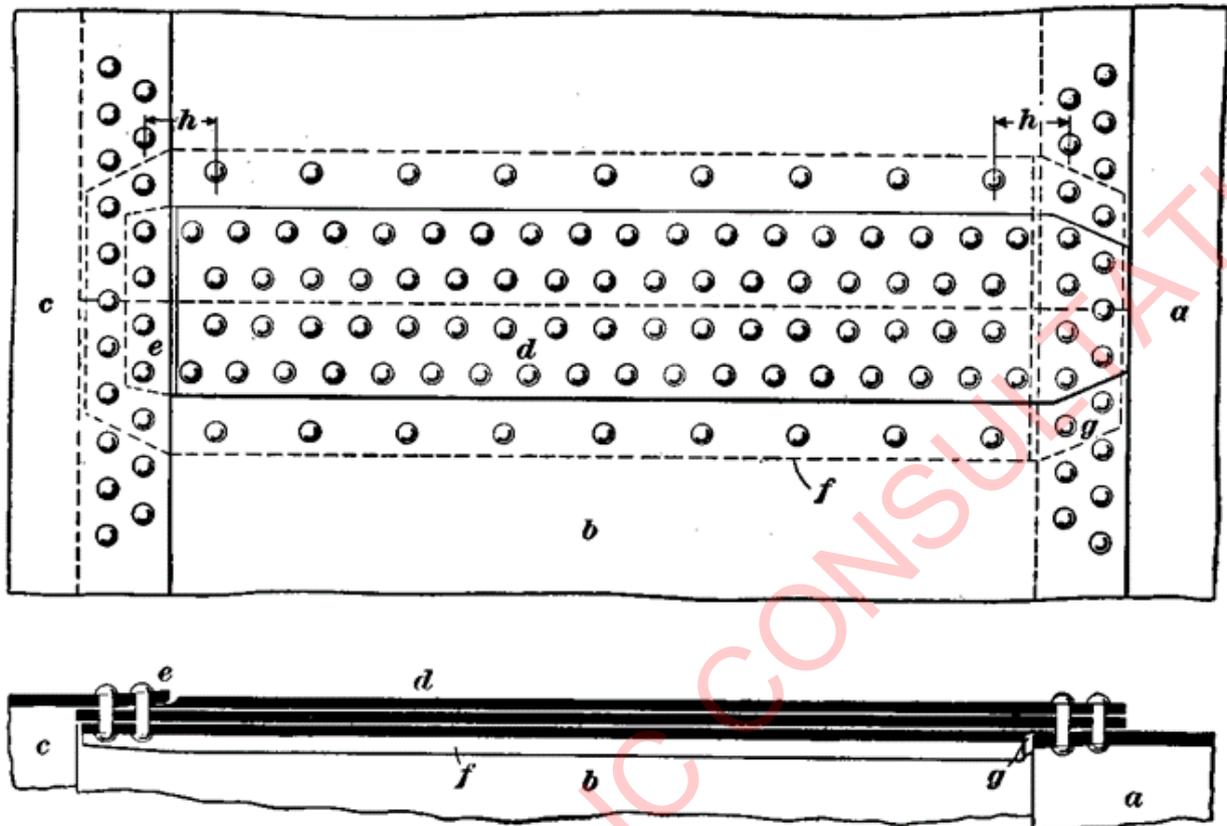
It is the usual practice (b) make the first course a, to which the smokebox tube plate is riveted, the smallest; the second course (b) fits outside of the course (a), and the third course (c) fits outside of the course b.

The outer butt strap (d) of the longitudinal joint of the second course (b) is of full thickness at the girth seam between the courses (a) and (b) but is scarfed sufficiently at the seam between the courses (b) and (c) to go under the first row of rivets, as shown at (e).

The plate of the course (c) is bent upwards slightly to give room for the scarfed end of the strap d. The inner butt strap is of full thickness at the girth seam between the courses (b) and (c) and extends far enough to take both rows of rivets.

At the girth seam between the courses a and b, the butt strap is scarfed, as shown at g, and lies on top of the first course, the plate a being bent downwards slightly to accommodate the scarfed end of the strap (f).

The distance h from the girth-seam rivets to the first rivet in the outer row of the longitudinal seam should be the same at both ends.



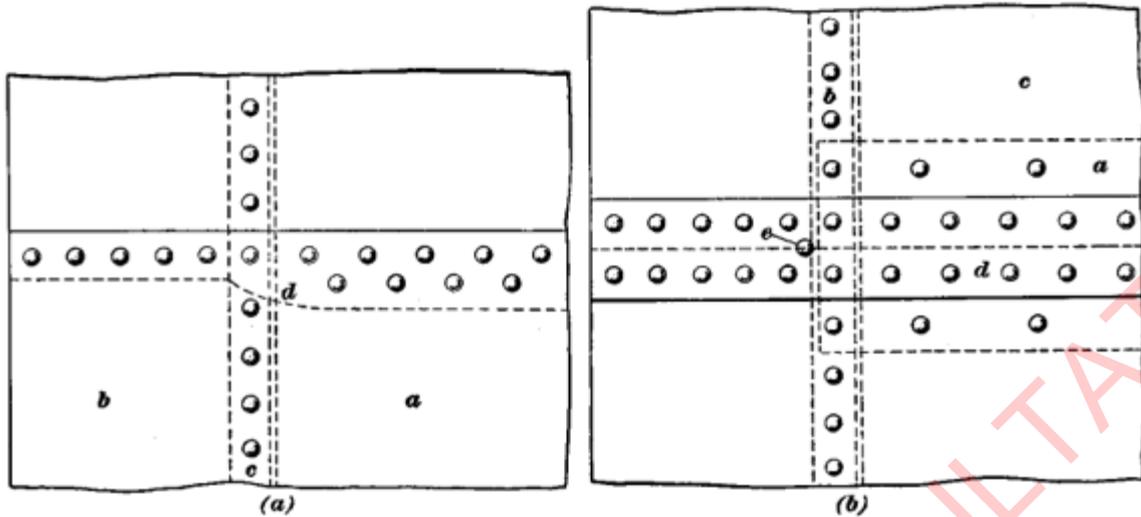
Appendix Figure B-75 Seam connections of shell of locomotive boilers

B.23.8 Arrangement of smoke box

In the locomotive type of boiler, which always has a smoke box, and in the horizontal return tubular boiler, which may have one, the smoke box may be a separate course, or the first course may be extended, serving both the smoke box and the first course.

The first mentioned construction is customary for large boilers, and the second one for small boilers.

In boilers having double riveted longitudinal lap joints, the first course and smoke box made of one sheet, there is no need of double riveting the longitudinal joint of the smoke box, as it is not subject to pressure.



Appendix Figure B-76 Seam arrangement for smoke box

The usual method of arranging the seams is shown in Appendix Figure B-76 (a)

In this illustration, part of the first course is shown at (a); The smoke box end of the sheet, at (b); And the front flue sheet, or round head, which is backed in, at (c).

Because the smoke box is single riveted while the shell sheet is double riveted, the shell sheet is cut away as shown.

The inside of the shell plate is scarfed at (d) in order that a tight joint can be made between it and the head (c).

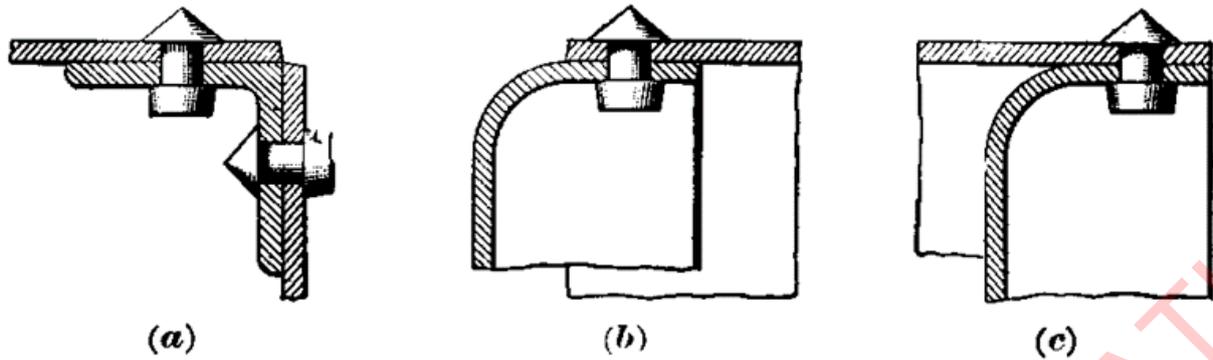
In a boiler having the first course and the smoke box made of one sheet and a longitudinal double riveted double strap butt joint, it is the usual practice to scarf the inner butt strap (a), Appendix Figure B-64 (b), and insert the scarfed end between the flanged head (b) and the shell sheet c

The outer butt strap (d) is made long enough to reach to the end of the smoke box and is single riveted, as shown.

A stop rivet (e) is placed at the edge of the flange of the front head.

B.23.9 Method of making angular connections

There are various ways of making angular connections in structural and boiler work. Some of the methods are illustrated in Appendix Figure B-77.



Appendix Figure B-77 Angular connections

For structural work, such as tanks, breechings, and bases for boilers, the plates can be readily joined by riveting them to an angle iron, as shown in (a).

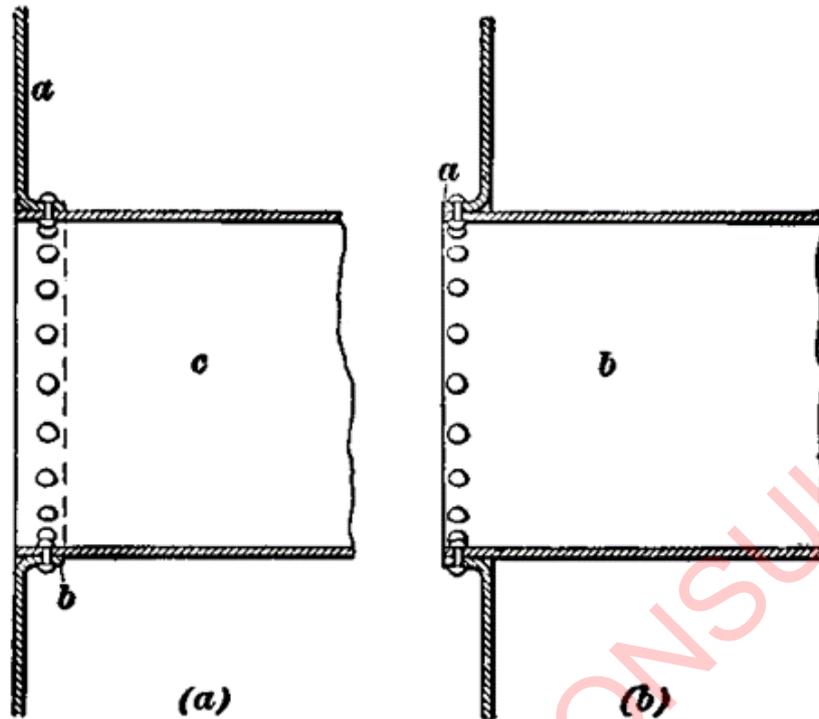
For boiler work, in which the ends of the shells are closed in, it is the usual practice to use flanged heads, as shown in (b) and (c).

The head in (b) is turned with the flanged inwards and in (c) it faces outwards.

Two ways of connecting an internal furnace to a tube sheet are shown in Appendix Figure B-78 (a) and (b). To make the connection shown in (a) the tube sheet shall have a flange (b) turned inwards.

The furnace (c) is then brought flush with the outer edge of the flange.

This method requires a longer shell (b), but it permits the riveting to be done on the outside.



Appendix Figure B-78 Connecting an internal furnace to a tube sheet

B.24 Arrangement of firebox joints

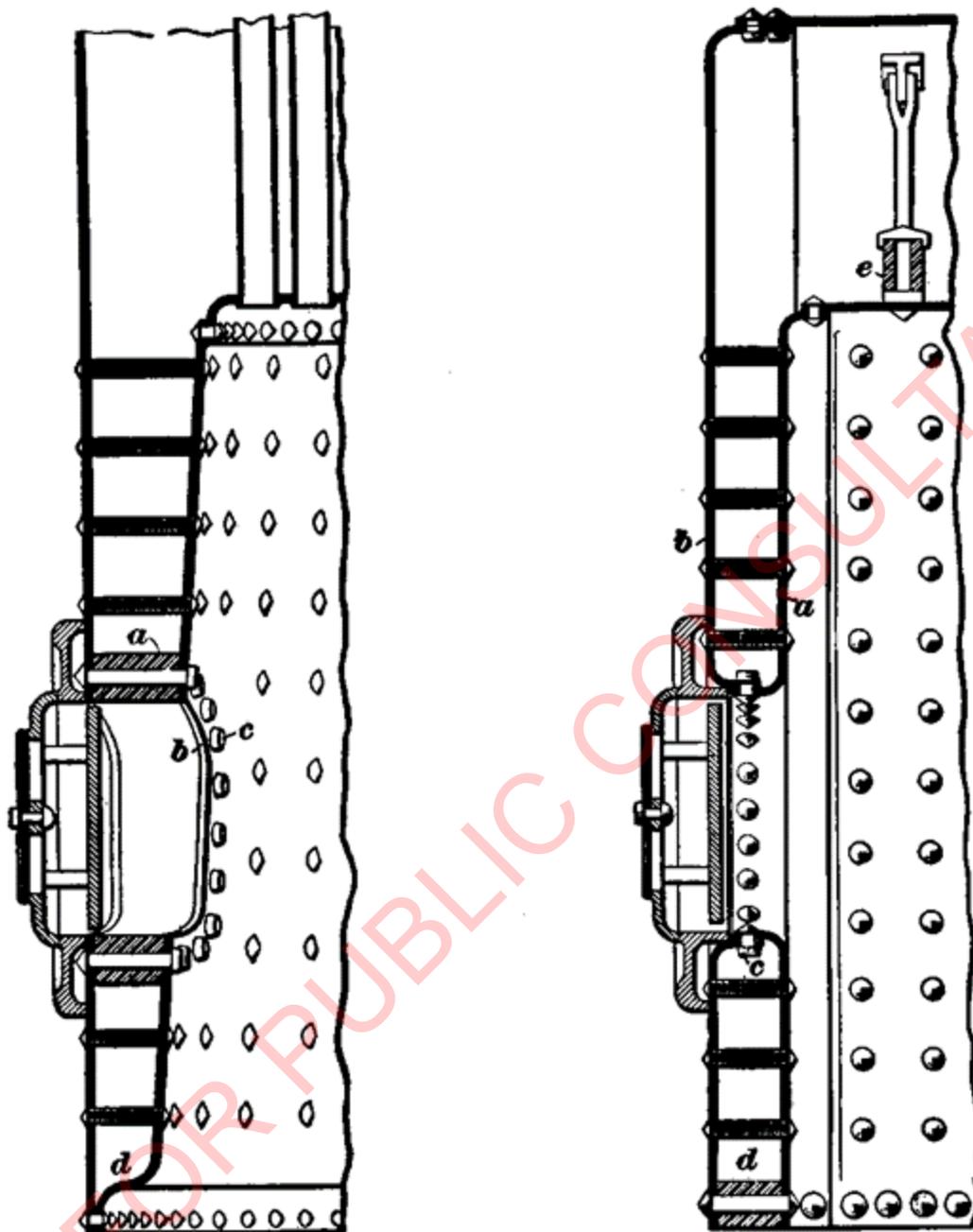
B.24.1 Fire door and mud ring connections

A method of forming the fire door hole for the furnace of a vertical boiler is shown in Appendix Figure B-79, the same method is also used to some extent with the smaller types of locomotive boilers used for stationary purposes

The door ring (*a*) is usually a steel casting or a wrought iron ring placed between the shell plate and the furnace plate and riveted with a single row of rivets.

An objection to placing the door ring in this way is that it is rigid which prevents free expansion of the furnace plate, this causes leaks within a short time along the caulking edge (*b*) and at the inner rivet heads (*c*).

The bottom of the water space may be closed by forming an ogee flange (*d*) on the furnace sheet and then riveting it to the shell.



Appendix Figure B-79 Forming a fire hole door for a vertical (left) and locomotive (right) boiler

This construction, however, is not adopted when the furnace plate is relatively thin or the water space at the bottom very large, because the thickness of the sheet will be reduced considerably by the operation of flanging

In locomotive type boilers, the fire door hole is usually constructed as shown in Appendix Figure B-80.

The door sheet *a*, of the furnace is flanged outwards and the back head (*b*) is flanged inwards, the two flanges being united by a row of rivets (*c*).

The bottom of the water leg shall not be closed by flanging the furnace sheets, as this would prevent the holding on and driving of the rivets (*c*).

It is closed by placing a mud ring (*d*) between the furnace sheets and the outer plates and securing the ring to the sheets with rivets.

The mud ring is usually made of wrought iron, although cast steel rings are extensively used.

Experience has shown that in fire door holes constructed as shown in Appendix Figure B-80 (right) the inner sheet will sooner or later crack from the caulking edge to the rivet holes c, and a in the curved part of the flange.

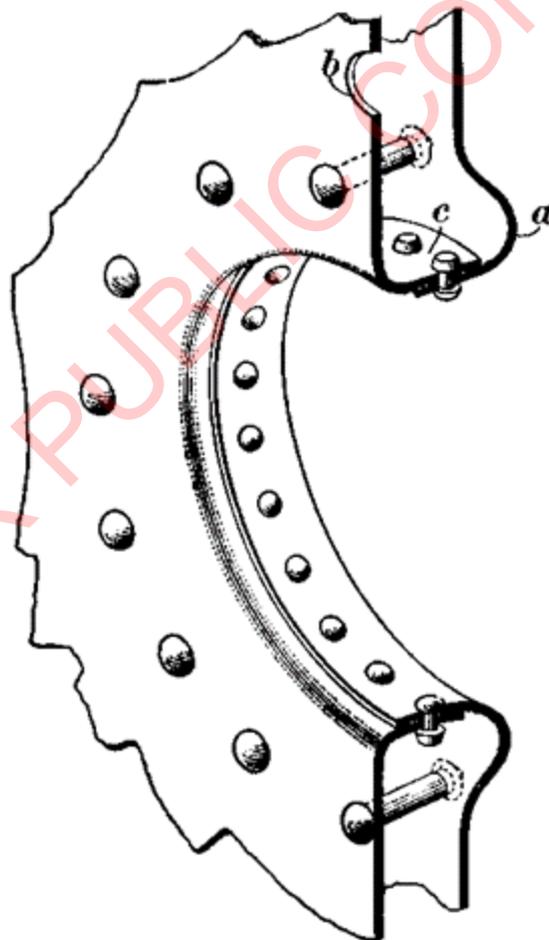
The inner, or furnace, sheet (a) is highly heated when the boiler is in use, but owing to the rigidity of the flange and the joint at the fire door hole, aided by the adjoining stay bolts, the flanged part of the fire door of the furnace sheet cannot expand as freely as the other parts of the sheet and stresses are set up in this part.

Every time the fire door is opened the stresses are intensified by the inrush of cold air that cools the joint and causes contraction.

The repeated bending of the material under these stresses will ultimately cause rupture at one or more places.

A collection of sediment on top of the fire door hole leads to overheating and increases the danger of cracking the plates.

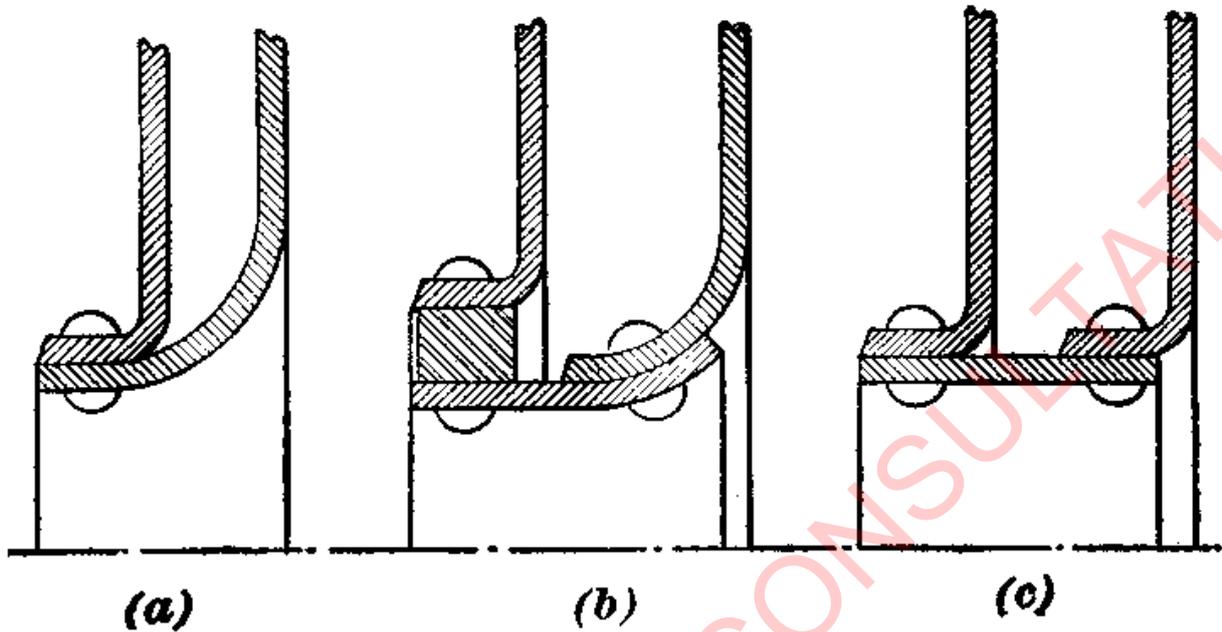
To lessen the danger of cracking at the fire door holes, the construction illustrated in Appendix Figure B-81 has been devised.



Appendix Figure B-80 Fire door hole

The end sheet of the furnace is flanged to the form of an ogee curve as shown at a; for this reason, the furnace sheet is rendered rather flexible at the fire door hole.

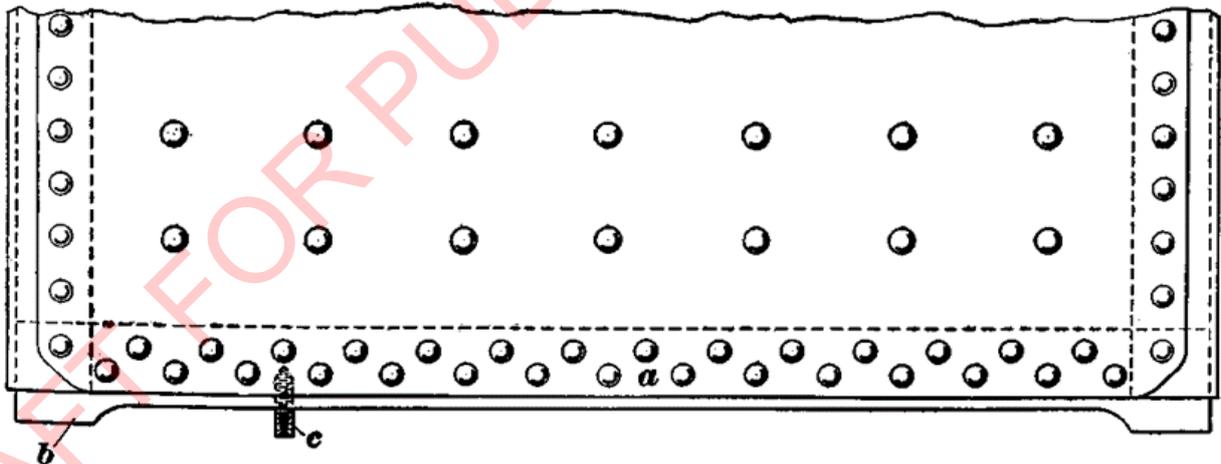
A good-sized washout hole (*b*) placed directly over the fire door permits the ready removal of foreign matter that collects around the top of the door flanges at *c*. In Appendix Figure B-81 (*a*) to (*c*) are shown several other forms of construction for door hole openings.



Appendix Figure B-81 Various fire door hole constructions

B.24.2 Connecting sheets to mud rings

In large locomotive type boilers, the bottom of the water leg is closed by a wrought iron or steel mud ring.



Appendix Figure B-82 Mud ring

In modern practice, the ring is made of sufficient depth to project about $\frac{1}{2}$ " below the lower edge (*a*), Appendix Figure B-83, of the furnace and water leg sheets permitting the edges to be caulked from the sides.

If the mud ring does not project below the lower edges of the sheets, leaky caulking edges are caulked with great difficulty, especially if the boiler is standing on a frame or foundation.

To prevent the mud ring from cracking at the corners, it is good practice to provide a boss (*b*) at each corner. The extra metal in the boss will counteract the weakening effect of the holes drilled for the corner bolts, which are bolts used to fasten the sheets to the mud ring at the corners.

Mud rings for boilers carrying medium pressures are generally single riveted; for high pressure boilers, double zig zag riveting is considered good practice.

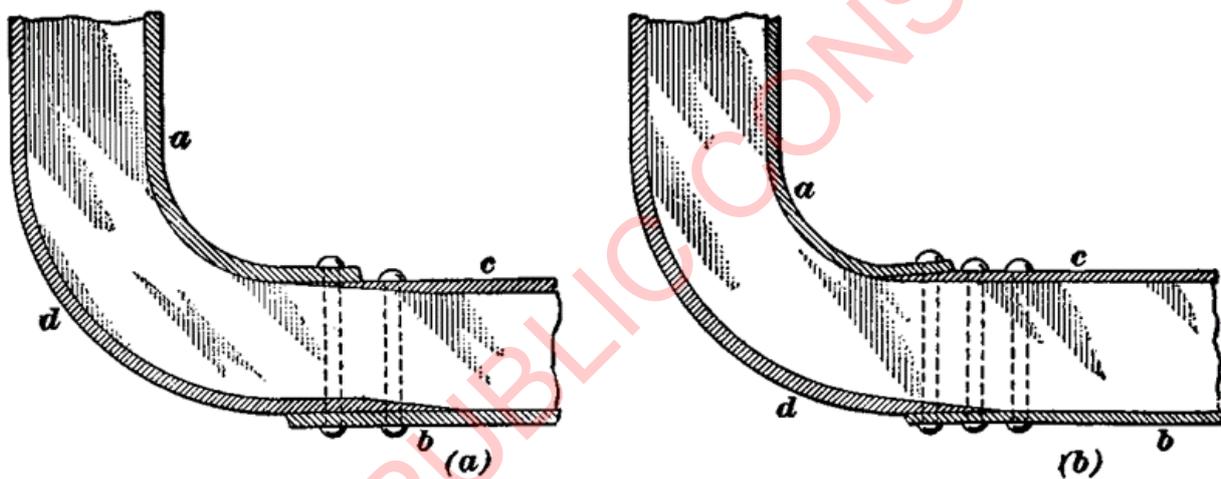
When studs are to be screwed into mud rings for attaching an ash pan or for a similar purpose, the studs shall be so located as to clear the rivets.

In a single riveted mud ring, the studs should be placed midway between rivets; in a double riveted mud ring, they should be placed directly beneath a rivet of the upper row, as shown at (*c*), Appendix Figure B-83.

In modern practice, mud rings are machined both inside and outside eliminating the expensive and difficult work required to make the sheets fit metal to metal over an unfinished or rough mud ring.

The corners of mud rings should be shaped as illustrated in the plan view, Appendix Figure B-83 (*a*).

This construction makes the flange of the furnace sheet (*a*) and the outside firebox sheet (*b*) lie flat.



Appendix Figure B-83 Mud ring corners

The furnace side sheet (*c*) and the boiler head (*d*) are scarfed to go under the sheets *a* and *b*.

If the corners of the mud ring are shaped as shown in Appendix Figure B-84 (*b*) the flanged furnace sheet *a* will have to be bent inwards to go over the scarfing of the furnace side sheet (*c*) and the outer firebox sheet (*b*) will have to be bent outwards to go over the scarfing of the boiler head (*d*).

Such construction is not only expensive and unsightly, but it also requires three (3) lengths of rivets at the joints, whereas only two (2) lengths of rivets will be required if the corner is laid out as shown in (*a*).

The outside sheets of firebox boilers are fastened to the corners of the mud rings by threaded corner bolts, the number and arrangement at each corner depending on the radius of the corner and whether the sheets are single riveted or double riveted to the mud ring.

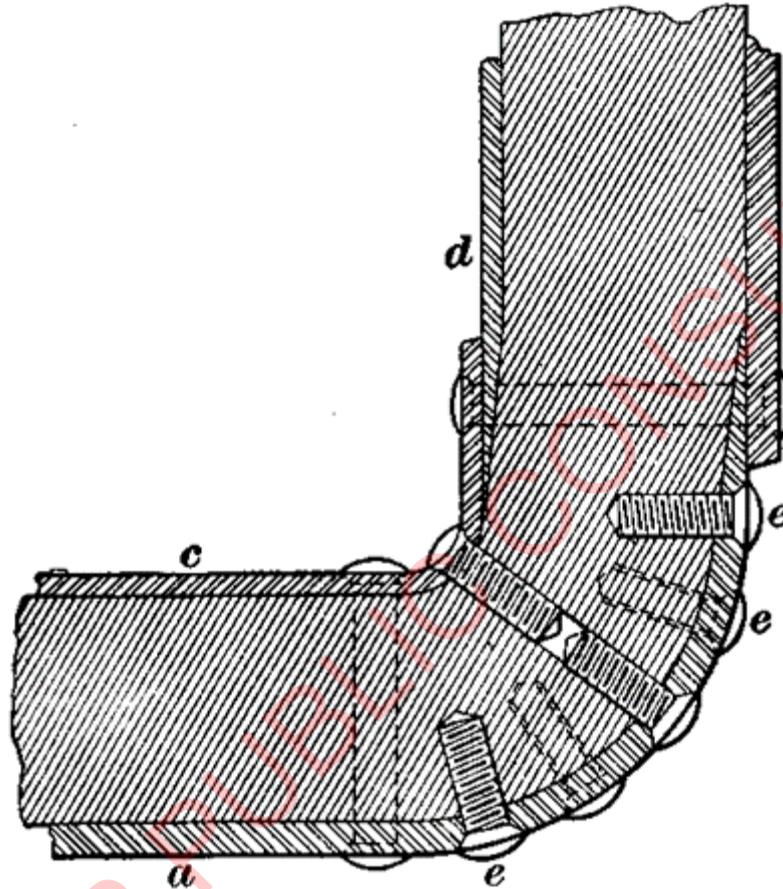
A usual arrangement of corner bolts is shown in Appendix Figure B-85, in which the boiler head is shown at (*a*), the outer firebox sheet at (*b*), the flanged furnace sheet at (*c*), and the furnace side sheet at (*d*). The sheets (*a*) and (*c*) are first laid against the mud ring, after which the holes for the corner bolts (*e*) are drilled through the sheets (*a*) and (*c*) into the mud ring.

The holes are then tapped and enlarged or countersunk in the plates (*a*) and (*c*), so that the heads of the corner bolts will be similar to oval countersunk rivet heads.

Instead of using corner bolts with oval heads, some mechanics thread a rod and screw it into the mud ring.

This rod is then cut off, sufficient material being left to form a head, and the projecting ends are riveted over filling the countersunk holes in the plates (a) and (c).

The edges of the bolt heads are always caulked down to the sheet. In the illustration, corner bolts are used at the corner, but very often rivets are used at this point.



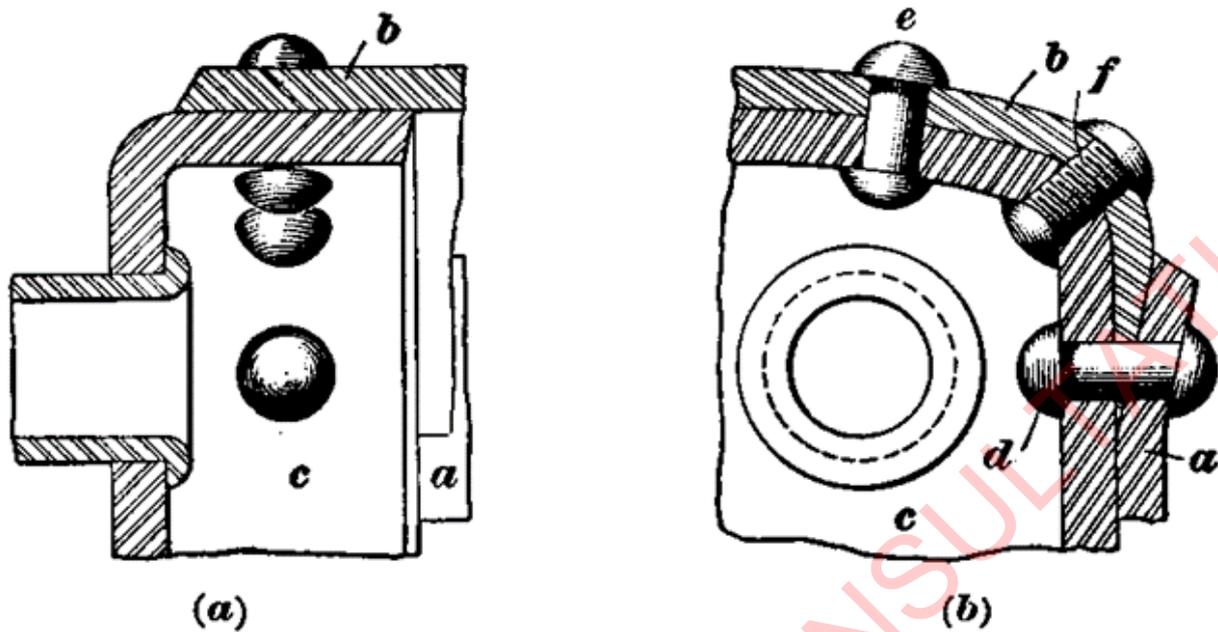
Appendix Figure B-84 Corner bolt arrangement

In Appendix Figure B-86 is illustrated a longitudinal section and in (b) a cross section of a firebox corner, showing the connection between the side sheet (a), the crown sheet (b), and the tube sheet (c).

If the tube sheet is flanged to a very small radius in the corner, it is very difficult to drive a rivet properly midway between the rivets (d) and (e) in (b), that is, directly in the corner.

The usual practice is to drill and tap a hole at this point, generally using a tap $\frac{3}{4}$ " in diameter and having twelve threads per inch.

A plug is then screwed tightly into the tapped hole and its ends are riveted over and caulked.



Appendix Figure B-85 Fire box corner bolt arrangement

B.24.3 Fire cracks in joints

It has been found by experience that in firebox boilers the furnace side of the furnace sheets is liable to crack at the joints from the rivet holes outwards toward the edge of the plate (*e*) such cracks being termed fire cracks.

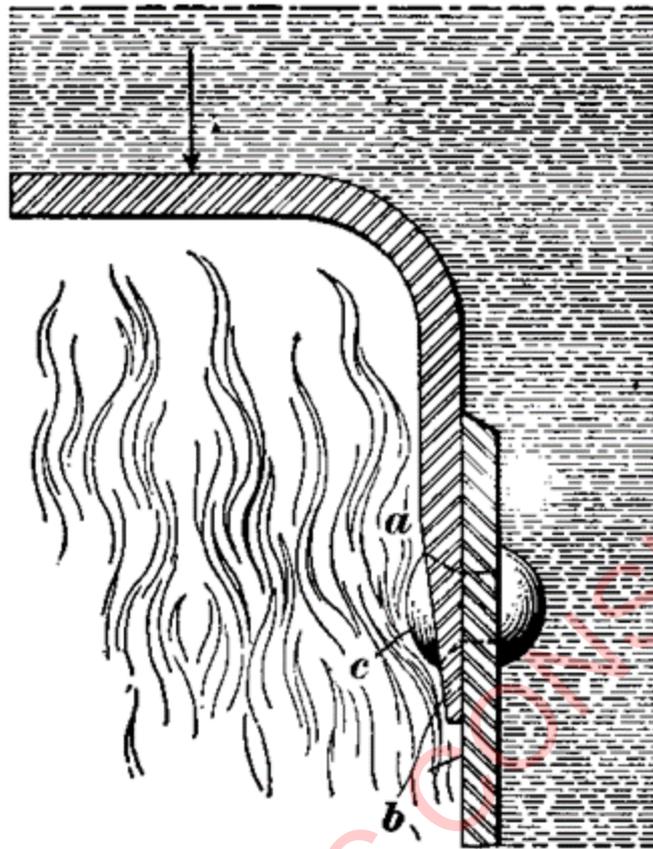
The lap joints are kept relatively cool on the water side, but the fire side of the lap, especially with thick plates, becomes so hot as to set up stresses that ultimately result in cracks.

To reduce the liability that fire cracks will occur, it is the practice to bevel the furnace side of the lap from (*a*), Appendix Figure B-87, to the edge (*b*), countersink the rivet holes, and drive (*b*), oval countersunk rivets (*c*).

The thinning of the material assists the water on the water side in keeping the furnace side of the lap cool, and does not reduce the strength of the joint, as the pressure tending to rupture the joint acts in the direction of the arrow.

In an externally fired boiler of the horizontal return tubular or flue type, part of the girth seam is exposed to the flames and fire cracks may occur on the fireside of the seam.

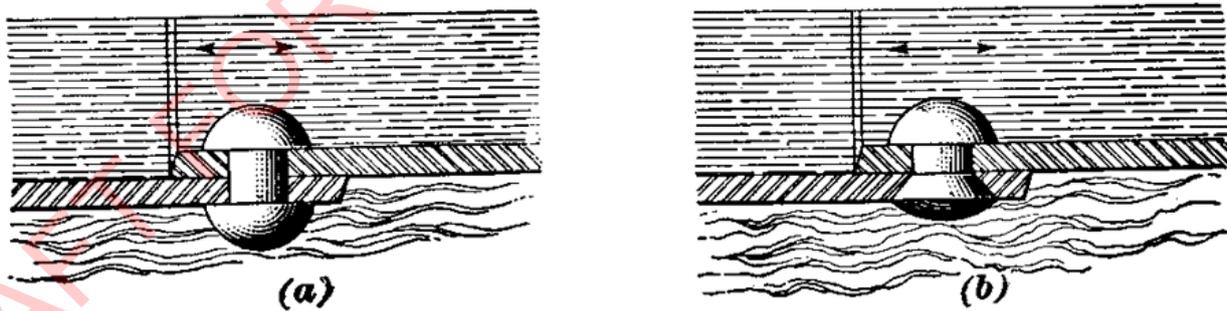
As the internal pressure, indicated by the arrows in Appendix Figure B-86 (*a*) and Appendix Figure B-86 (*b*) tends to pull the lap apart and to crush or shear out the metal between the rivet holes and the edge of the plate, the lap should not be bevelled as shown in Appendix Figure B-87, because this would materially weaken the joint.



Appendix Figure B-86 Bevel locations

A common construction at the girth seams is shown in Appendix Figure B-87 (a), the rivet having an oval head on the fire side.

If however, the rivet is made with a countersunk head on the fire side, as shown in (b), there will be less material at the joint without greatly weakening the plate; consequently, the water will tend to maintain a more nearly uniform temperature at the lap, thereby reducing the liability of the occurrence of fire cracks.



Appendix Figure B-87 Girth seams

Appendix C Boiler History File (Normative)

C.1 General

This appendix gives requirements and recommendations on some of the documentation for the boiler history file. As the file is added to, a detailed history of the boiler will be established. This file shall be referenced during inspection and maintenance and updated during these times.

An example form is provided in AS 3788:2024, Appendix D.

These are minimum requirements only and should be adapted to suit the requirements of the individual operator.

C.2 Documentation

Documentation shall be maintained in accordance with the *ONRSR Rail Locomotive Boilers Guideline*.

The boiler history file should include any supporting documentation that may be relevant to the boiler. Legible copies should be kept on site to facilitate easy access during inspection and maintenance.

C.3 Examples of documents to be maintained

C.3.1 Inspection reports

The details provided in Clause C.3.2 and Clause C.3.3 are the essential requirements to conduct a comprehensive inspection of a locomotive boiler as laid out in this document.

C.3.2 Initial Inspection

The initial inspection is one that shall be carried out when a boiler is either new or second hand, is unknown or unfamiliar. It is intended to capture a base line of critical information that will be part of the future inspection and maintenance plans. I.e. determination of remaining life (refer to AS 3788:2024, Appendix B.4). If original documentation is not available the boiler shall be recertified in accordance with AS 3788:2024, Section 4. All original construction drawings should be attached to this form.

It is incumbent on the RSO to understand the construction particular to boiler type and to include all relevant information.

Suggested inclusions in this form are as follows:

- (a) General information.
 - (i) Owner.
 - (ii) Builder.
 - (iii) Boiler ID number.
 - (iv) Location of boiler ID number.
 - (v) Boiler registered number.
 - (vi) Weld certifications.
 - (vii) Welder qualifications.
 - (viii) Location of boiler registered number.
 - (ix) Locomotive boiler fitted to.
 - (x) Build date.
 - (xi) Build location.

- (xii) Type of boiler (locomotive, water tube, fire tube etc).
 - (xiii) Material of boiler shell sheets.
 - (xiv) Material of rivets.
 - (xv) Grate area.
 - (xvi) Type of grate (fixed, rocking, rosebud, Waugh).
 - (xvii) Gauge column measurements (distance between crown sheet and water and steam passages, distance between water and steam passages, whether water passages are above or below crown sheet, distance between crown sheet and test cocks).
 - (xviii) Safety valves (number, make, style, general condition).
 - (xix) Steam turret (location, type – cast, pipe – general condition including mounting holes).
 - (xx) Feedwater non-return valves (location, type, general condition).
 - (xxi) Injectors (location, type, general condition) .
- (b) Boiler barrel condition:
- (i) Front tubeplate (thickness, presence of cracks, wastage, condition of rivets, general condition).
 - (ii) Fire tube (smoke tube) measurements (number, diameter, thickness, general condition).
 - (iii) Flue tube measurements (number, diameter, length, thickness, general condition).
 - (iv) Superheater elements (number, passes, thickness, general condition).
 - (v) 1st strake (outside diameter, thickness, presence of cracks, wastage, rivet condition, general condition).
 - (vi) 2nd strake (outside diameter, thickness, presence of cracks, wastage, rivet condition, general condition).
 - (vii) 3rd Strake (outside diameter, thickness, presence of cracks, wastage, rivet condition, general condition).
 - (viii) Stays (number, position, diameter, type – palm, longitudinal etc – general condition).
 - (ix) Main steam pipe (length, diameter, general condition) .
- (c) Inner firebox:
- (i) Side sheets (thickness, presence of cracks, wastage, rivet condition, general condition).
 - (ii) Firebox wall stays (head condition).
 - (iii) Crown sheet (thickness, presence of cracks, wastage, rivet condition, general condition).
 - (iv) Crown stays (head condition).
 - (v) Tubeplate (thickness, presence of cracks, wastage, rivet condition, general condition).
 - (vi) Arch tube measurements (number, diameter, length, thickness, general condition).
 - (vii) Thermic siphon measurements (number, diameter, length, thickness, general condition).
 - (viii) Fire hole ring (diameter, rivet condition, general condition).

- (ix) Inside throat (if tube sheet is in two pieces).
- (d) Outer wrapper:
 - (i) Side sheets (thickness, presence of cracks, wastage, rivet condition, general condition).
 - (ii) Firebox wall stays (number, pitch, diameter, type – rigid or flexible and their locations – general condition including head condition and cap and cup condition on flexible wall stays).
 - (iii) Crown sheet (thickness, presence of cracks, wastage, rivet condition, general condition).
 - (iv) Crown stays (number, pitch, diameter, type – rigid, flexible, parallel, tapered – general condition, including nut condition and cap and cup condition on flexible crown stays).
 - (v) Mounting pads (including position, thickness, rivet condition, general condition).
 - (vi) Foundation ring (water space at front, sides and back, rivet condition, general condition).
 - (vii) References available (including original drawings, material specifications, design specifications, test samples, NDE reports, boiler history file).
 - (viii) Name of responsible person and date.

C.3.3 Annual Inspection

The items listed below are recommended components of an annual inspection report.

Suggested inclusions for this form are:

- (a) Owners name
- (b) Owners address Location of boiler
- (c) If boiler is situated on a railway, the name and address of the responsible person on that railway
- (d) Boiler ID number
- (e) Location of boiler ID number
- (f) Date of inspection
- (g) Number or name of locomotive that boiler is fitted to
- (h) Method of firing
- (i) Maximum allowable working pressure
- (j) Those parts of seams and components subject to steam pressure that are covered by lagging or otherwise inaccessible for examination and the date of the last exposure of such parts for examination
- (k) Those parts concealed by the locomotive frame and the date of last removal from the locomotive frame for an examination of the parts listed above
- (l) All examination and tests that were made including NDE carried out (with reports attached), the removal of any insulation, cladding or components

External and internal condition of boiler, including any defects that materially affect the maximum permissible working pressure, including:

- (m) Boiler barrel condition:

- (i) Front tubeplate (thickness, presence of cracks, wastage, condition of rivets, general condition).
- (ii) Fire tube (smoke tube) measurements (number, diameter, thickness, general condition).
- (iii) Flue tube measurements (thickness, general condition).
- (iv) Superheater elements (thickness, general condition).
- (v) 1st strake (thickness, presence of cracks, wastage, rivet condition, general condition).
- (vi) 2nd strake (thickness, presence of cracks, wastage, rivet condition, general condition).
- (vii) 3rd strake (thickness, presence of cracks, wastage, rivet condition, general condition).
- (viii) Stays (type – palm, longitudinal etc – general condition).
- (ix) Main steam pipe (general condition).
- (n) Inner Firebox:
 - (i) Side sheets (thickness, presence of cracks, wastage, rivet condition, general condition).
 - (ii) Firebox wall stays (head condition).
 - (iii) Crown sheet (thickness, presence of cracks, wastage, rivet condition, general condition).
 - (iv) Crown stays (head condition).
 - (v) Tubeplate (thickness, presence of cracks, wastage, rivet condition, general condition).
 - (vi) Arch tube measurements (thickness, general condition).
 - (vii) Thermic siphon measurements (thickness, general condition).
 - (viii) Fire hole ring (rivet condition, general condition).
 - (ix) Inside throat (if tube sheet is in two pieces).
- (o) Outer wrapper:
 - (i) Side sheets (thickness, presence of cracks, wastage, rivet condition, general condition).
 - (ii) Firebox wall stays (general condition including head condition and cap and cup condition on flexible wall stays).
 - (iii) Crown sheet (thickness, presence of cracks, wastage, rivet condition, general condition).
 - (iv) Crown stays (general condition, including nut condition and cap and cup condition on flexible crown stays).
 - (v) Mounting pads (thickness, rivet condition, general condition).
 - (vi) Foundation ring (rivet condition, general condition).

C.3.4 Fit-for-service declaration

This form identifies the parties involved with the re-certification process. As a declaration, it requires all parties to state that all work was carried out in accordance with AS 3788:2024

The declaration shall meet the requirements of the *ONRSR Rail Locomotive Boilers Guideline*.

C.3.5 Boiler of locomotive on loan declaration

This form is an on-loan declaration to third parties operating a locomotive boiler. This will assist with interface coordination plans as required by rail safety regulator.

C.3.6 Open and dry storage checklist

This form is a check list that gives guidance regarding storage of in-service boilers.

C.3.7 Inspection and maintenance plan

This gives guidance to what should be considered as part of the annual maintenance plan.

C.3.8 Daily operational log

The log should include hours that boiler has been in steam or kilometres travelled, any faults or defects noted, noted by whom, rectifications carried out and by whom and dated.

Commentary CC.3.8

The time boiler the has been in steam can be calculated as being from commencement of light up to dropping of the fire.

This log should include the specific inspection requirements for each boiler, and give guidance in looking for items such as:

- (a) leakage or signs of leakage;
- (b) bulges;
- (c) blowing joints;
- (d) broken stays;
- (e) fusible plug condition;
- (f) brick arch condition;
- (g) safety valve operation;
- (h) operation of injectors;
- (i) operation of gauge columns;
- (j) condition of spark arrestor;
- (k) integrity of the ashpan; and
- (l) any other defects that affect safety or operation of the boiler.

C.3.9 Stay and tube replacement log

The stay and tube replacement log should include diagrams of tube sheets, firebox sheets, and show the locations of any replacements.

Appendix D Boiler Wash Out (Normative)

D.1 General

This appendix provides requirements and recommendations on boiler washouts.

D.2 Scope

This appendix shall be adhered to unless it can be proven that another process is equal to or better than the practices and materials laid down in this document.

D.3 Introduction

After many hours of steaming, a boiler evaporates a considerable amount of water, leaving behind scale and residue, which settle internal surfaces of the boiler. These form an insulating coating over the heating surfaces, and the presence of this coating seriously affects the heat transfer, and consequently the efficiency of the boiler, besides causing loosening of flues, tubes and wall stays and overheating and burning of the plates and seams.

Dissolved solids cause scale formation (which may lead to overheating) and are a main cause of priming. Suspended solids cause mud and sludge to form in the boiler and are a main cause of foaming and priming.

Dissolved gases (such as oxygen) cause pitting corrosion and reduce the life of the boiler (see Section 18, Boiler water treatment).

A washout is a process of removing the scale and residue that accumulates in the boiler due to operational conditions.

D.4 General

The boiler may be at ambient temperature prior to draining the water in preparation for wash out. Alternatively, the boiler may be drained whilst warm as this could assist with drying the boiler for storage.

The RSO shall assess and manage the risk of thermal shock/boiler stresses when draining boilers and conducting wash outs to prevent damage to the boiler.

The washout shall occur as soon as possible after draining the boiler otherwise any remaining sediment could set hard inside the boiler.

The RSO shall provide a procedure for the washing out of locomotive boilers. The procedure should include:

- (a) preparation, including a list of correct equipment and tools, ensuring adequate water pressure and volume; and
- (b) removal of mud-hole, hand-holes and/or washout plugs.

The order of washing out can be summarised as from top to bottom, front to back.

To enable a visual inspection of internal surfaces, particular attention shall be paid to areas where scale and sludge tend to accumulate, such as:

- (c) foundation ring;
- (d) fire hole ring;
- (e) blow down valve strainers (where fitted);
- (f) bottom of the boiler barrel;

- (g) combustion chamber plates and stays (where fitted);
- (h) arch tubes (see Section 16);
- (i) thermic siphons (see Section 9 and the end of this Appendix).

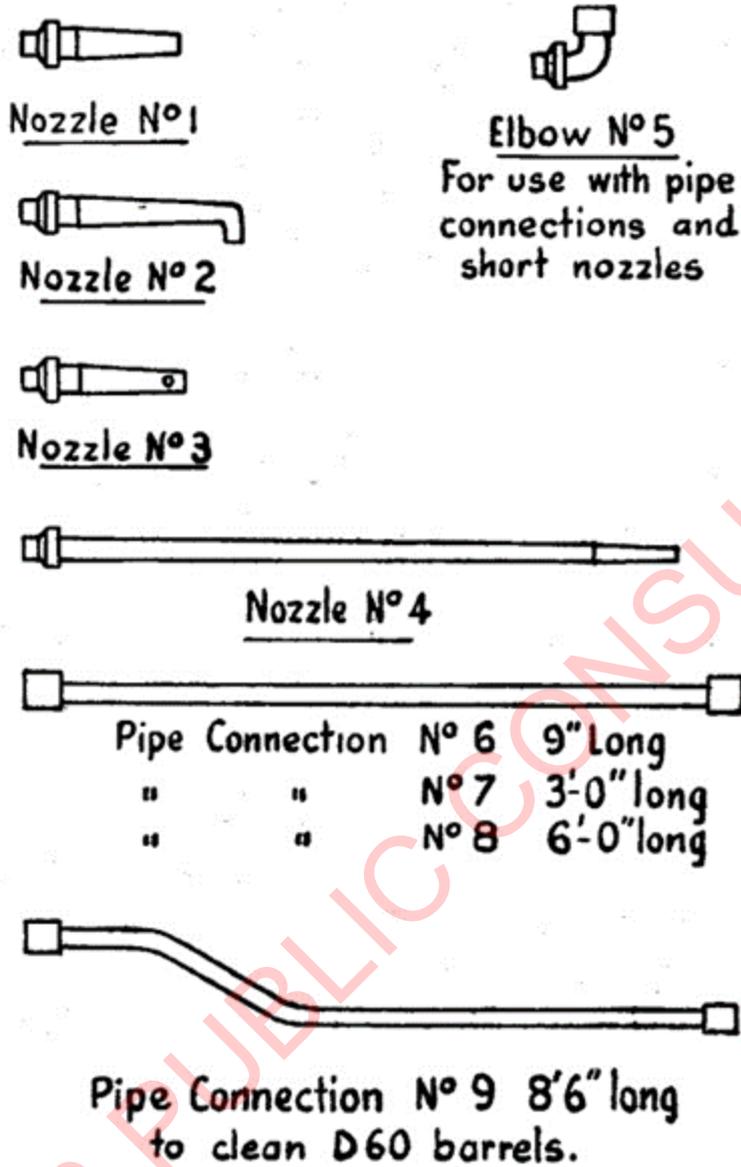
Visual inspection of internal surfaces by a competent person, paying particular attention to areas of known degradation and including signs of:

- (j) grooving;
- (k) wastage (stays, plates, rivet heads etc);
- (l) cracking;
- (m) blistering;
- (n) adhering scale.

Once the washout is completed the following activities shall be carried out:

- (o) Boxing up the boiler (i.e. Replacement of washout plugs, hand holes and mud holes);
- (p) Refilling with treated water: and
- (q) Record of washout (recorded in the boiler history file).

Examples of wash out nozzles are provided in Appendix Figure D-1. These types of nozzles are made from soft copper to protect the threads in washout holes etc.



Appendix Figure D-1 Examples of washout nozzles

D.5 Cleaning thermic siphons and arch tubes

Siphons fitted to locomotive boilers require close attention to ensure that all mud, scale and other deposits are removed during washouts. This is essential to maintain them in a safe and satisfactory condition and to prolong their lives. See also Section 9 and 15.

Appendix E Fusible Plug Inspection Report (Informative)

Below is an example of a fusible plug inspection form.

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Fusible Plug – Removal Form

Note: Use two sheets per plug; one for removal, one for insertion

LOCOMOTIVE DATE / /

PLUG LOCATION FRONT CENTRE REAR CENTRE
CENTRE REAR LEFT REAR RIGHT

INSPECTION PRIOR TO REMOVAL

	YES	NO
LEAKAGE PAST THREAD	<input type="checkbox"/>	<input type="checkbox"/>
LEAKAGE PAST LEAD	<input type="checkbox"/>	<input type="checkbox"/>
EASE OF REMOVAL		
VERY HARD	<input type="checkbox"/>	<input type="checkbox"/>
HARD	<input type="checkbox"/>	<input type="checkbox"/>
FIRM	<input type="checkbox"/>	<input type="checkbox"/>
EASY (LOOSE)	<input type="checkbox"/>	<input type="checkbox"/>

INSPECTION AFTER REMOVAL

	YES	NO
PLUG BODY / DRIVE SQUARE OR SOCKET		
CRACKED	<input type="checkbox"/>	<input type="checkbox"/>
DISTORTED	<input type="checkbox"/>	<input type="checkbox"/>
WASTED	<input type="checkbox"/>	<input type="checkbox"/>
THREADS		
CRACKS	<input type="checkbox"/>	<input type="checkbox"/>
NICKS/BRUISES	<input type="checkbox"/>	<input type="checkbox"/>
WASTED	<input type="checkbox"/>	<input type="checkbox"/>
ROUNDED FORM	<input type="checkbox"/>	<input type="checkbox"/>
REDUCED DEPTH	<input type="checkbox"/>	<input type="checkbox"/>
LEAD CORE		
WATER LEAKAGE	<input type="checkbox"/>	<input type="checkbox"/>
MELTED	<input type="checkbox"/>	<input type="checkbox"/>
LEAD DOME		
SLUMPED	<input type="checkbox"/>	<input type="checkbox"/>
COPPER PLATING		
SCABBING	<input type="checkbox"/>	<input type="checkbox"/>
SHOWING LEAD	<input type="checkbox"/>	<input type="checkbox"/>
LIFTING FROM LEAD	<input type="checkbox"/>	<input type="checkbox"/>
CORRODED	<input type="checkbox"/>	<input type="checkbox"/>

PLUG FUTURE USE OK TO RE-USE SCRAP RECONDITION

THREADED HOLE IN BOILER

CLEANED WITH TAP	<input type="checkbox"/>	<input type="checkbox"/>
No. OF FULL THREADS		
THREAD CONDITION		
ROUNDED FORM	<input type="checkbox"/>	<input type="checkbox"/>
REDUCED DEPTH	<input type="checkbox"/>	<input type="checkbox"/>
CRACKS	<input type="checkbox"/>	<input type="checkbox"/>
NICKS/BRUISES	<input type="checkbox"/>	<input type="checkbox"/>
WASTED	<input type="checkbox"/>	<input type="checkbox"/>

DETAILS OF ANY WORK TO BE DONE ON THREADED HOLE

PLUG REMOVED BY	NAME	SIGN	DATE / /
PLUG INSPECTED BY	NAME	SIGN	DATE / /

Fusible Plug – Insertion Form

LOCOMOTIVE DATE / /

PLUG LOCATION CENTRE FRONT CENTRE REAR CENTRE
REAR LEFT REAR RIGHT

INSPECTION PRIOR TO INSERTION		YES	NO
PLUG BODY / DRIVE SQUARE OR SOCKET	CRACKED	<input type="checkbox"/>	<input type="checkbox"/>
	DISTORTED	<input type="checkbox"/>	<input type="checkbox"/>
THREADS	WASTED	<input type="checkbox"/>	<input type="checkbox"/>
	CRACKS	<input type="checkbox"/>	<input type="checkbox"/>
	NICKS/BRUISES	<input type="checkbox"/>	<input type="checkbox"/>
	WASTED	<input type="checkbox"/>	<input type="checkbox"/>
LEAD CORE	ROUNDED FORM	<input type="checkbox"/>	<input type="checkbox"/>
	REDUCED DEPTH	<input type="checkbox"/>	<input type="checkbox"/>
	WATER LEAKAGE	<input type="checkbox"/>	<input type="checkbox"/>
	MELTED	<input type="checkbox"/>	<input type="checkbox"/>
LEAD DOME	SLUMPED	<input type="checkbox"/>	<input type="checkbox"/>
	SCABBING	<input type="checkbox"/>	<input type="checkbox"/>
	SHOWING LEAD	<input type="checkbox"/>	<input type="checkbox"/>
	LIFTING FROM LEAD	<input type="checkbox"/>	<input type="checkbox"/>
COPPER PLATING	CORRODED	<input type="checkbox"/>	<input type="checkbox"/>

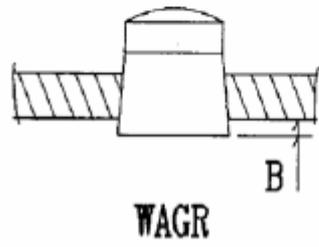
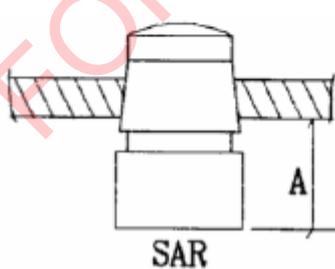
PLUG FUTURE USE OK TO RE-USE SCRAP RECONDITION

PLUG INSERTION
SAR/CR TYPE HAND TIGHTENED
NIPPED UP WITH TOOL
No. OF THREADS VISIBLE < 1 OR > 3 = REJECT _____
ALTERNATIVELY: DIMENSION 'A' < 1" OR > 1 1/8" = REJECT _____

WAGR TYPE HAND TIGHTENED
NIPPED UP WITH TOOL
DIMENSION 'B' < 2.5 OR > 3.5 mm = REJECT _____

DETAILS OF ANY WORK TO BE DONE ON THREADED HOLE

PLUG INSPECTED BY NAME SIGN DATE / /
PLUG INSERTED BY NAME SIGN DATE / /



NOTE:

Form supplied by Pichi Richi Railway Preservation Society.

Bibliography (Informative)

The following referenced documents are cited in this Standard for information only:

- AS 1548, Steel plates for boilers and pressure vessels
- AS 4041:2006, Pressure piping
- AS 4458:1997, Pressure equipment - Manufacture
- AS 4343:2014, Pressure equipment - Hazard levels
- AS 3992:2020, Pressure equipment - Welding and brazing qualification
- BS 2486:1997, Recommendation for treatment of water for land boilers. Heritage Railway Association Guidance Note Ref No. HGO-B9118 Boiler Water Treatment
- ASME Boiler and Pressure Vessel Code
- Boiler Door Joint Failures – J E Gander April 1978
- Heritage Railway Association HGR-B9009 – Washout Plugs
- Heritage Rail Association, Technical Library Index, <http://athra.asm.au>.
- Maintenance of Locomotive Boilers, Heritage Railway Association, Ian Allan Publishing, 1999.
- NACE Recommended Practice 01 98: Corrosion Under Insulation
- National Board Inspection Code, National Board of Boiler and Pressure Vessel Inspectors 2007.
- SAR CME 205 TAPER THREADS SQUARE TO AXIS OF SCREW
- SAR drawing for plugs and taps. Drg Number 5-DT-5
- Current Instructions, Procedures & Drawings applicable to the particular locomotive type, e.g. Pichi Richi Railway, Don River Railway, Puffing Billy, QR Heritage, all former and government railways.
- Current Instructions, Procedures & Drawings applicable to the particular locomotive type and fusible plugs, e.g. Pichi Richi Railway, Don River Railway, Puffing Billy, QR Heritage, all former and government railways. (Note, these will typically include all or part of the original Railway reference documents)
- Original Engineering Drawings (the most recent version) applicable to the locomotive type and fusible plugs, e.g. Government Railway Drawings from NSWGR, SAR, VR, and former government railways.
- Original Railway Instructions & Procedures applicable to the locomotive type and Fusible Plugs, e.g. Government Railway Documents from NSWGR, SAR, VR, and former government railways.