

# HERITAGE RAILWAY ASSOCIATION

## GUIDANCE NOTE

### STEEL RIVETS & RIVETING

#### **Purpose**

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

#### **Endorsement**

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

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## **1. Introduction**

This Guidance Note is one of a series dealing with Locomotive Boilers that were produced by the "Steam Locomotive Boiler Codes of Practice" practitioners meetings.

Railway locomotive boilers are designed to create, store and distribute steam at high pressure. The working life of such a boiler can be considerably shortened if due care is not taken at all stages of inspection, repair, running maintenance and day-to-day running.

In the past there have been a series of accidents and explosions due to work being undertaken without having due regard to the inherent risks involved. It is with that in mind that H.M.R.I. and H.R.A. set up the series of meetings of boiler practitioners to discuss the issues; distil good practice and codify it into this series of Guidance Notes.

This guidance is written for the assistance of people competent to perform these tasks. In places the terminology used may be specific to such practitioners.

This guidance will also be useful to those in a supervisory or more general role, however no work should be undertaken unless the people concerned are deemed competent to do so.

Where managements decide to take actions that are not in agreement with these recommendations, following appropriate risk assessments or for other reasons, it is recommended that those decisions are reviewed by the senior management body of the organisation and a formal minute is recorded of both the reasons for and the decision reached.

## **2. Units**

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

## **3. Personal Protective Equipment**

Before undertaking any works a risk assessment must be conducted.

Protective equipment is to be supplied and used at work wherever there are risks to health and safety that cannot be adequately controlled in other ways.

The equipment must be

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

## **4. Inspection**

In the event of finding any rivet heads to be defective or suspect; seek guidance from the boiler Competent Person before proceeding with any replacement.

## **5. General**

Riveting, originally a crudely formed fastening, has become a highly finished mechanical part requiring great care in all its details of shape, material and formation. The rivets when completed should have a sufficient grip in the plates, should fill the holes and should have no sharp corners.

The rivet is the universal fastening of the boiler structure. It fulfils various functions:

- a) The rivets of longitudinal seams of the boiler shell have to hold the plates together by the grip of the heads of the rivets and also withstand the tensile force in the plates by the resistance of the rivets to shear.

- b) The rivets connecting the front shell angle of a Boiler barrel to the front tube plate have to grip the plates by the head and also to withstand the forces acting on the tube plates by tension in the rivet shank.

## **6. Materials**

Hot Forged Boiler Rivets should conform to BS1633:1958 and BS425:1943 these two standards have been withdrawn but none the less are still valid.

Many modern steels are cold worked, and although they may have the correct chemical composition, they will not comply with the mechanical properties. It may be worthwhile to consult with a metallurgist to find a modern steel to meet all the requirements below.

Current specifications for steel rivets for pressure vessels may be found in American code ASTM A31 - 04 (2009).

The Material should comply with the following.

- a) An ultimate tensile strength of 22/30 tons per square inch
- b) Yield strength; 50 per cent of the tensile strength
- c) The sulphur content; 0.050 per cent Maximum
- d) The phosphorus content; 0.050 per cent Maximum
- e) The manganese content; 0.30 to 0.7 Maximum
- f) The carbon content; 0.12 to 0.18 Maximum

For Example BS970: 1991/1996 EN32C or EN 3A,B,C , BS4360:1979 .40B , 080M15 , 080A15,070M20 , S235JR , S275JR or BS EN 10277:1999 C15 / C16. All of these types of mild steel will have suitable properties for rivet manufacture but may not comply with the above specification. It is a requirement when ordering from the manufacturer that a batch is selected from stock by specifying the criteria required, as material certificates will exist for each production run, it will be a matter of matching the most applicable grade from the supplier. Certain grades will only have mechanical or chemical analysis from the mill and the missing certification will be acquired from an accredited testing laboratory.

Materials Produced to other modern equivalent e.g. European or American specifications may be accepted by agreement with the competent person.

The Repairer shall be responsible for ensuring that all materials used are fit for the purpose and shall make these available for inspection as required. Copies of chemical and mechanical test/mill certificates shall be provided for the competent person and for the owners repair records.

The chemical test must be taken in conjunction with the physical tests; the first indicates the possibilities of the material and the latter is the actual capability.

Each batch of rivets shall be subject to bend and flattening testing.

For 'specifications for steel rivets and bars for rivets, pressure vessels' see ASME SA31

## **7. Testing of Rivets**

### **Cold Bend Test**

Rivets for cold bend testing shall be selected at the rate of at least two rivets per batch and shall have the shank doubled up until the inside surfaces meet without showing any signs of fracture (fig.1).

When ordering rivets consideration must be given to the rivet length for bend testing. If the rivet length is known to be too short for this test, four longer rivets must be manufactured from the same bar stock and tested.

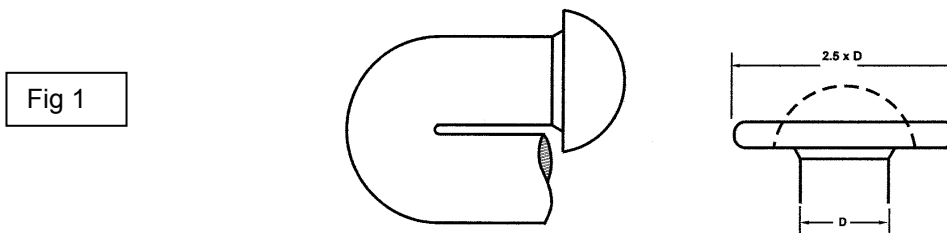
**Quench bend test**

Rivets for quench bend testing may be selected from the batch when requested by the competent person. The rivet should be heated to light cherry red (1200 degrees F) and quenched in water the temperature of which is between 80 and 90 degrees F.

A good quality of steel for rivets should bend flat on itself ,either cold or quenched, without any indication of cracking on the outside of the bend.

**Flattening Test**

Rivets for the flattening test shall be selected at the rate of at least two rivets per batch. Each tested rivet shall have the head flattened while hot until the final diameter is equal to 2 ½ times the nominal diameter of the shank. The flattened head shall not show any cracks.



**Retests**

In the event of a test rivet failing to comply with the specified requirements ,two further test rivets from the same batch may be selected and the test re carried out, should both re-tests prove to be satisfactory the rivets represented shall be accepted, but should one or both fail they must be rejected.

**8. Comparison of boiler and frame rivets / holes**

It should be noted that there is a difference between boiler quality rivets and rivets used for general work such as frame and tank fabrications.

Figure 2 shows a typical boiler rivet with a chamfer under the snap head and the hole preparation to suit.

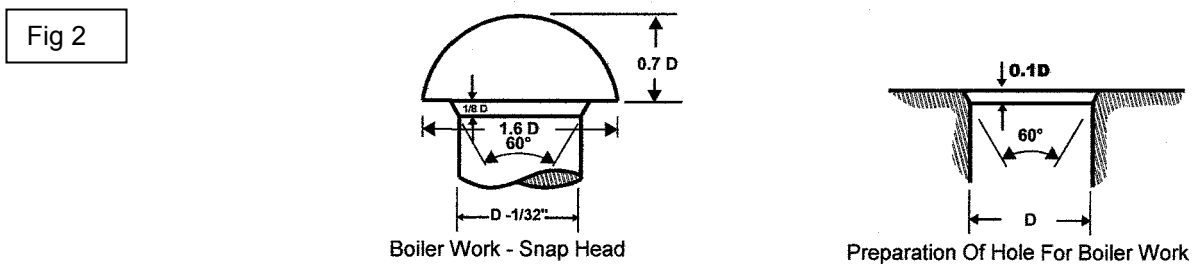
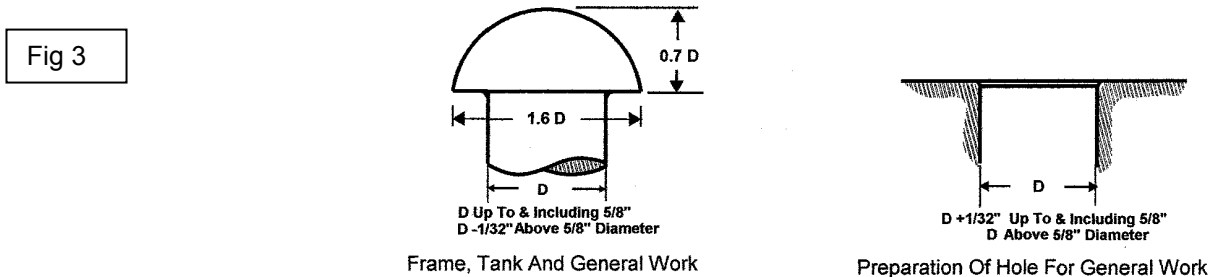


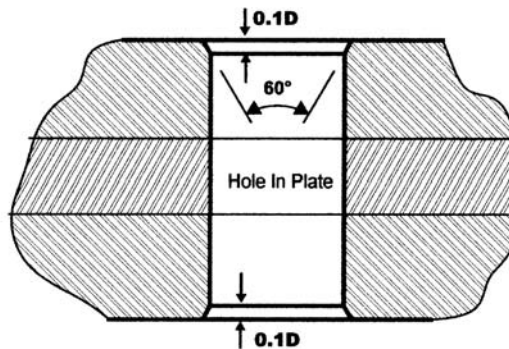
Figure 3 shows a general fabrication rivet with a small radius below the head and the reduced hole preparation required.



**9. Rivet Holes**

Figure 4 below shows the shape of the hole for boiler rivets. The object of the countersunk portion is to facilitate the flow of metal to the parallel shank and enable the hole to be tightly filled. The conical part of the shank not only facilitates the above action but helps to reduce the stress at the junction of the shank and the head.

Fig 4



All rivet holes should be drilled from the solid plate after the plates have been bent to form and are fixed together in the position they will occupy when finally riveted up.

After this drilling through the solid has been done the plates should be taken apart, and the rough edges, formed in drilling the holes, taken off with a countersinking tool, so that the edge of each hole is left with a slight countersink, and no burr remains such as might lie between the plates and prevent a tight joint being made.

When holes are punched in heavy steel plate there is considerable loss of strength (up to 30% in  $\frac{3}{4}$ " plate) unless the holes are enlarged between  $\frac{1}{16}$ " and  $\frac{1}{8}$ " by reaming after punching. The reaming process removes the inferior metal from around the punched hole.

**10. Sizes of Rivets: Finished Sizes**

When the rivet is put into the rivet hole it is a little less in diameter than the hole. The rivet is then squeezed by a hydraulic riveting machine or pneumatic hammer so that it increases in diameter and fills the hole. The diameter of the rivet, therefore, when finished is the same as that of the rivet hole, and it is this diameter "finished size" which is referred to in all the Tables and Figures which follow.

**11. Rivet Heads**

The heads of rivets should be well and truly formed, central on the shank, free from lip and well closed. The length of the rivet should be sufficient after completely filling the rivet hole to form a head at least equal in strength to the body of the rivet.

The strength of the head is particularly necessary where rivets are in tension, as in the case of rivets connecting gusset angles to the end plates, shell angles to end plates and connecting fitting blocks and stand pipes and manhole mouthpieces to the shell and in similar positions.

**Snap /Cup Heads**

Where space allows the cup head is generally adopted. The rivet dimensions should not be less than indicated in figure 5 below.

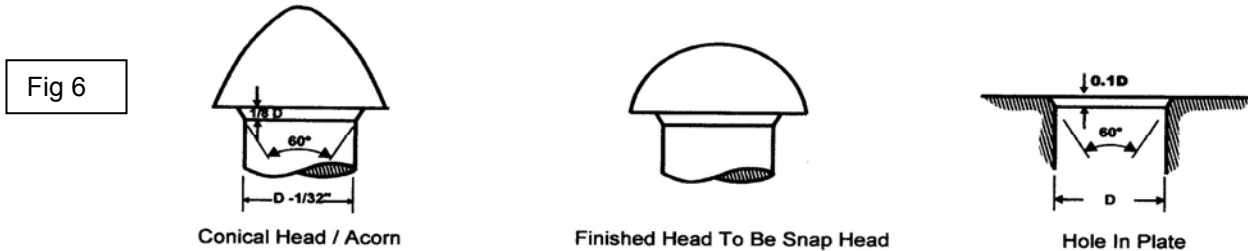
Fig 5



Oversized rivet heads may be used on the fire side of the foundation ring or in the smokebox for extra corrosion resistance providing space is available.

**Conical Head / Acorn**

Where a cup head is required with a better hole filling ability a conical head should be used, see figure 6 below. This type of head is well suited for foundation ring work or multiple plates and is usually inserted by hydraulic riveting equipment; it may also be inserted by pneumatic hammering holder up and pneumatic rivet hammer.



**Ellipsoidal Head**

Ellipsoidal head and pan head rivets as in figures 7 and 8 are less common in locomotive boiler construction, but may be used where previous designs require them or where space is limited for a snap headed rivet



**Pan Head**



**Countersunk Heads**

Countersunk heads are adopted in the construction of new boilers and in repair work, more particularly where hand work is necessary or where the projecting cup head would not give sufficient clearance.

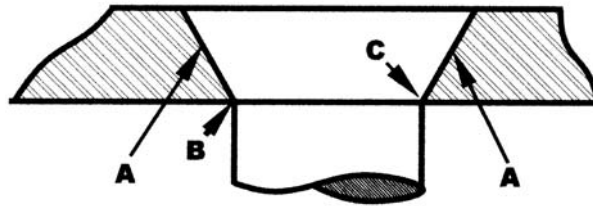
Where, however, it is practicable and especially where the rivets are in tension, cup heads should be used.

The countersunk form of head has its own disadvantage as compared with the regular cup head. There is a greater weakening effect to the plate as more material is removed, and the relatively thin oblique form of the face of the head does not grip the plates so well.

The best form of countersunk head requires careful consideration. Generally the countersink should penetrate about half through the plate and not more than three quarters in any form of countersink head.

In figure 9, the countersink is shown right through the plate and there is a sharp edge left at point C, Instead of the rivet holding by compression on the inclined portions AA. it may be holding merely on the corner B and thus have little binding power on the plate it is intended to connect while the concentration of strain at C. may tend to initiate fracture.

Fig 9



There are many variations in the forms of countersink heads adopted but experience indicates the type of head used generally in railway boiler work is the shallow countersunk snap head, see figure 10, or the rounded countersunk head, see figure 11, as these give the most satisfactory results. This form gives a substantial head with usually satisfactory grip and takes up the contraction after cooling more effectively than a head without any lip. Where, however, there are special reasons for truly flat heads the proportions shown on figure 12 are recommended.

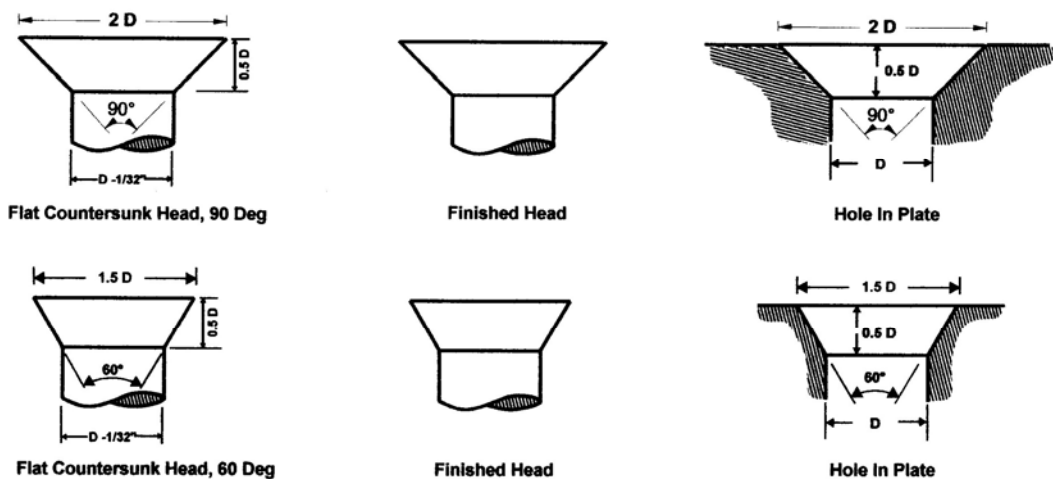
Fig 10



Fig 11



Fig 12



In obtaining the percentage of the plate remaining, for calculating the strength of a joint in which countersunk rivets are used, account should always be taken of the material removed in forming the countersunk portion.



## 12. Rivet length

Charts for rivet length are available from the rivet manufacturer or can be calculated by one of the following methods.

Estimated lengths are for rivet holes  $1/32$ " greater in diameter than the rivet, for rivets up to and including  $7/8$ " diameter: and for rivets over  $7/8$ " diameter the rivet hole is  $1/16$ " greater in diameter than the rivet.

In order to form the head and fill the clearance space in the rivet hole the rivet should have a length in excess of the thickness of the plate approximately  $3/4$  times the diameter for countersunk and  $1\frac{1}{2}$  times the diameter for ordinary riveting.

This method is only a starting measurement and some experimentation may be required to reach the ideal length.

### Allowance for rivet heads by calculation

D = Diameter of rivet in inches

T = Total length of rivet shank before closing

d = Diameter of hole in inches ( $=D + 1/32$ "

t = Thickness of plates through which the rivet passes

l = Additional allowance for material to fill the hole ( $=0.06 \times D$  per inch thickness of plate)

L = Length of rivet required to form a snap head  $= 0.9(d+3/32) = \mathbf{0.9(D+1/8)}$ "

C = Length of rivet shank to form counter sink (where depth of s/sink =  $0.45d$ ) =  $\mathbf{0.16(D+1/8)}$ "

For snapped rivets  $T = L + l + t = 0.9(D+1/8) + (0.06 \times t / D) + t$

For countersunk rivets  $T = C + l + t = 0.16(D+1/8) + (0.06 \times t / D) + t$

Length of bar for making rivets = T + L for snap and T + C for countersunk head.

If the difference of D and d is greater than  $1/32$  inch these lengths will be insufficient.

Hand-riveting requires shorter rivets than machine riveting.

Example: Snapped Rivet  $3/4$ " diameter rivet through two  $3/4$ " plates

$$T = 0.9(\frac{3}{4} + \frac{1}{8}) + (0.06/0.75 \times 1\frac{1}{2}) + 1\frac{1}{2} = 0.7875 + 0.12 + 1.5 = 2.4075 \approx \mathbf{2.41}$$

## 13. Tacking Holes

All tacking holes should be drilled.

The riveting can be done better and quicker if the boiler is first tacked; that is, after the course is bolted, for example on a circumferential seam on a boiler barrel it should first have a rivet driven on each quarter; the rivets are then driven about midway between the rivets, after which the rivets should be driven in every other hole. The bolts are then removed one at a time 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 figure 13. The washer tends to separate the plates, making a poor joint that cannot be made steam tight by caulking.

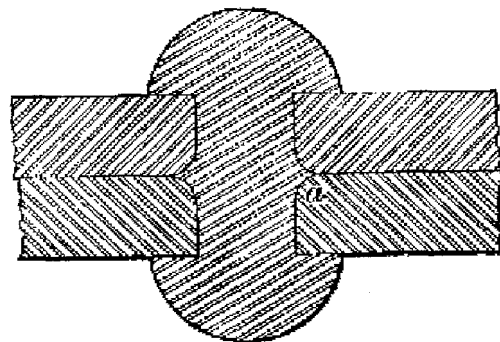


Fig 13

Driving three or four 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.

### **The A.S.M.E. Boiler Code gives the following conditions governing riveting:**

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."

## **14. 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 must 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 or gas 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 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 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 must be removed, the removal requiring considerable time and labor.

The proper rivet temperature for the various methods of driving rivets is about as follows:

Rivets driven by hand and pneumatic hammer, especially if they are long, should be white hot, which corresponds to a temperature of about 2,300 degrees F (1260 degrees C).

For hydraulic riveting, the rivets should be heated to a dull cherry red that corresponds to a temperature of about 1,500 degrees F (815 degrees 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 have all been successfully used.

For an open fire, such as is usually employed for heating the rivets for hand, snap, and pneumatic riveting, coke or gas is preferable; and for hydraulic or similar methods of riveting, coal, gas and oil furnaces and electric heaters are largely used.

## **15. Defective Heads**

If the riveting cup is a little smaller than the rivet head a slight lip is formed all round; if this lip is concentric it is satisfactory. If the head is strongly lipped it indicates that too long a rivet has been used. On the other hand, it is to be noted that the attempt to ensure the absence of the slightest lipping often results in too small a head and the cup indenting the plates, which is more objectionable than lipping. The rivet heads should be central on shank, and not eccentric.

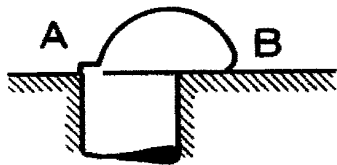


Fig 14

Figure 14 shows a badly eccentric head, which is lipped at A, but has not quite filled the cup at B and shows a small crack at B. Such heads indicate that the cup forming the head has not been central with the point of the rivet when the pressure was applied. This may be caused by the holes not being fair, causing the rivet to be inserted at an angle, the surfaces of the plates not being at right angles to the machine, or the cups not being quite opposite to each other owing to the machine not being in order.



Fig 15

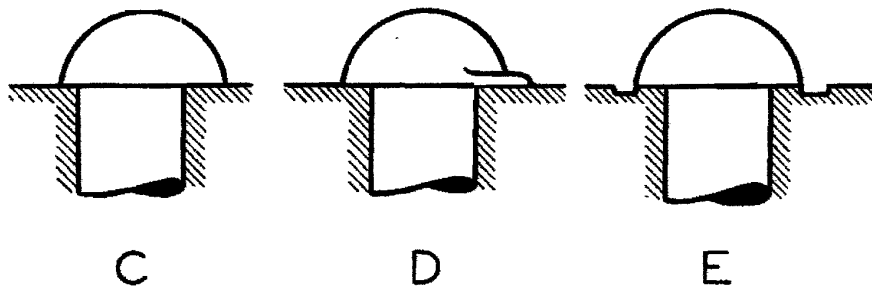


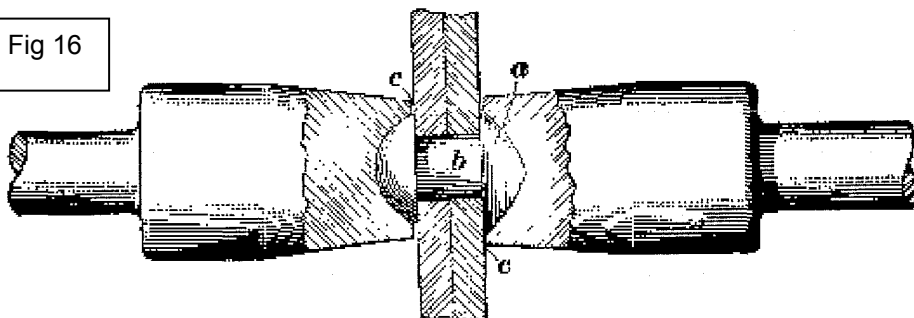
Figure 15 shows a head which is eccentric (C), otherwise satisfactory. (D) shows a head which is fairly centrally made but heavily lipped on one side; this is probably due to a little excess of material in the rivet, and if not excessive is not a serious defect. (E) shows a head round which the die of the riveting machine has indented the shell plate. Probably the rivet when inserted in the hole has been rather too short, and consequently there was not sufficient material to properly fill the die, leading to some indentation of the shell plate which is poor practice.

## 16. Hydraulic Riveting

### Procedure for Hydraulic Riveting

In hydraulic riveting, the upsetting of the shank of the rivet and the forming of the rivet head are done by a squeezing process. Hydraulic pressure is applied to the movable rivet die. Pressure is maintained on the oil/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 great 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 an ellipsoidal 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.

Fig 16

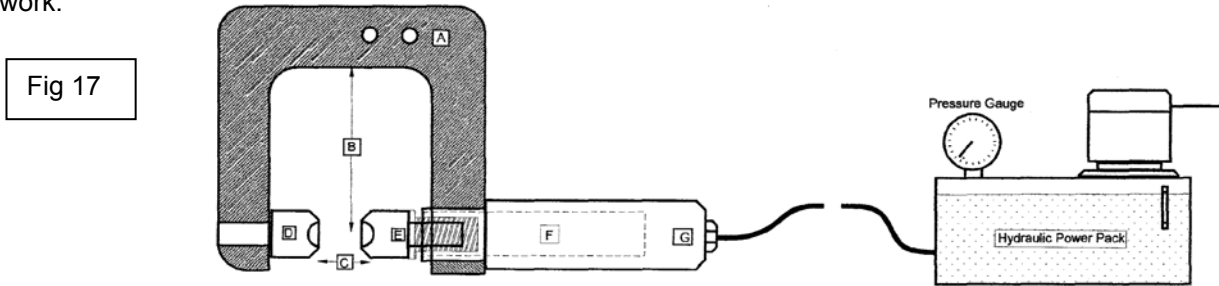


If they are not, as shown in figure 16, the rivet head will be formed to one side of the shank, or eccentric to it.

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 a danger that the edges of the dies will cut into the plate, as shown at (c) of figure 16.

**Yoke Riveters**

A compression yoke riveter is shown in figure 17. 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 in the stationary lower jaw of the yoke. The upper die (E) is held in a die holder that is threaded and adjustable vertically in the plunger (F). The plunger slides up and down inside a ram (G) held in the upper jaw of the yoke. The adjustable feature of the upper die enables the riveter to be set so as to accommodate rivets of different lengths.

The rivet is driven, by a hydraulic power pack with a gauge to show the pressure applied.

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 below instead of above, to suit different kinds of work.

**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.

**Tonnage Required for Hydraulic Riveting**

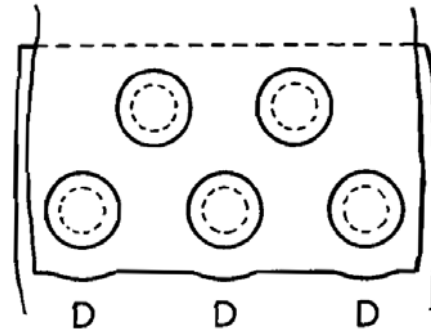
Table 1, below, gives the standard closing pressures which must be observed when using hydraulic riveting machines. The pressure gauges on hydraulic riveters are usually graduated to indicate the total pressure, or tonnage, on the ram, in order that the riveter will not have to make calculations.

Type of work and size of rivets	Material	Load per rivet Tons	Duration Seconds
Low Alloy High Tensile Steel boilers 7/8" diameter #	Steel to Steel	65	10 to 12
Ordinary M.S. boilers 3/4", 7/8" & 1" diameter #	Steel to Steel	33, 45 & 60	8 to 10
Foundation rings etc 3/4" to 7/8"	Copper to steel	32 to 35	5 to 6
Copper Fire boxes 3/4" to 7/8"	Copper to Copper	Pneumatic Hammer	--
Sundry steam tight work 5/8" diameter #	Steel to Steel	23 to 25	8 to 10
1-1/16" diameter	Steel to Steel	100	10 to 12
Expansion angles	Steel to Steel	40	8 to 10

# It is assumed that the rivet passes through only two thicknesses of plate having a maximum total thickness not much in excess of the rivet diameter. As the total plate thickness increases beyond the rivet diameter, the riveting pressure increases approximately in proportion to the square root of thickness. Thus, if the total thickness of the plate is four times the rivet diameter, twice the riveting pressure given in the table would be required.

The pressure used in the riveting machine should be sufficient to close the rivets properly and securely without causing undue stress in the plate. Sometimes, where too high a pressure is employed, the edges of the lap are bulged, owing to the excessive pressure round the rivet, as indicated on figure 18.

Fig 18



The bulging takes effect not only at the edge of the plates, but also between the rivet holes; and in the case of longitudinal seams, as the plate cannot extend in the longitudinal direction, it tends to arch between the rivet holes.

When this bulging occurs at the ring seams it stretches the plates between the rivet holes and thereby increases the circumference and at the same time the diameter of the shell at the seam; this increased diameter can be seen by applying a straight edge along the shell plate.

### Maintenance of Riveting Pressure

When the rivet heads are being formed by the riveting or machine the pressure should be kept on by the machine for a short period. The pressure should be kept on sufficiently long for the rivet to cool down a little, so as to acquire strength to withstand the spring of the plates and to retain them in close contact.

## 17. Pneumatic Riveting

### SAFETY NOTES

Hot riveting is possibly the most hazardous activity that occurs during boiler repairs, and is therefore worthy of special safety note.

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. 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, and rivet guns shall not be pointed at any person, nor used for practical jokes. 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 shall 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.

## Classes of Pneumatic Riveters

The use of compressed air for operating riveting has led to the development of a number of different types of pneumatic riveting machines; Riveting hammers are built for both light and heavy work.

Hammers for light work weight from 10 to 12 pounds and the stroke of the piston varies from 2 to 3 inches, which are capable of forming heads of rivets ranging from 5/16" to 9/16" in diameter. Hammers for heavy work weight from 16 to 22 pounds, the stroke of the piston varies from 4 to 9 inches, 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 up to 5/8 inch in diameter and long stroke hammers for driving rivets larger than 5/8 inch in diameter.

Heavy riveting hammers having a stroke of 4 inches are used for heading rivets from 5/8 to 3/4 inch in diameter.

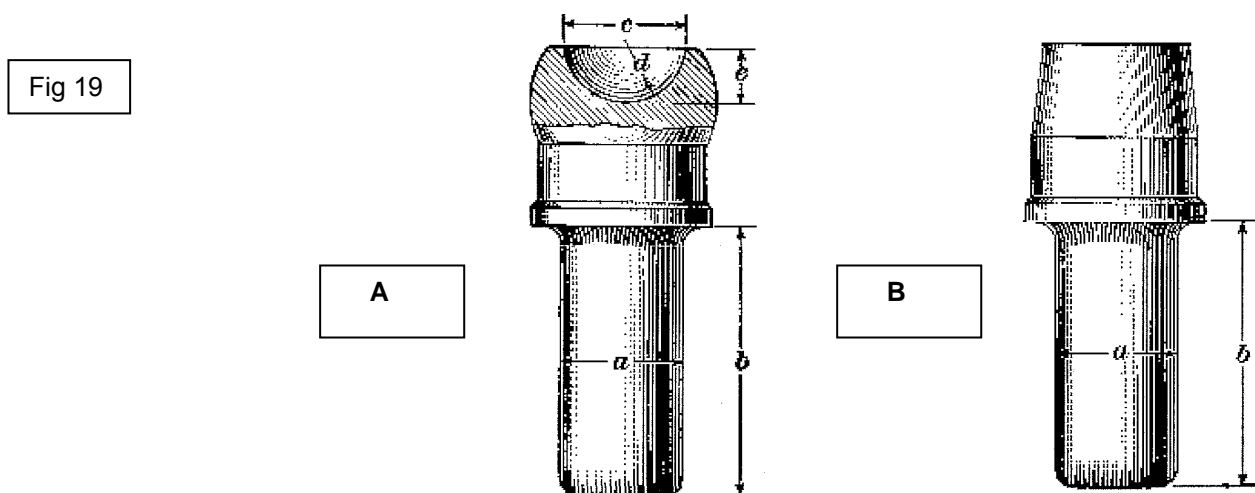
Hammers with a 5 inch stroke can drive rivets 7/8 inch in diameter and smaller.

Hammers with a 6 inch stroke can drive rivets from 1 inch to 1 1/8 inches in diameter and smaller.

Hammers with an 8 inch stroke are used to drive 1 1/4 inch rivets; and those hammers with a 9 inch stroke are used to drive rivets 1 3/8 inches in diameter.

### Pneumatic riveting sets

For upsetting rivets and forming rivet heads by the pneumatic riveting process, specially shaped riveting tools are used. The principal forms, shown below, are identified according to the shapes of rivet heads they produce.



A snap head set is shown in (A) and a flush set in (B).

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 requirements for the rivet heads.

The rivet set in (B) is employed in driving flush rivet heads, the plate being countersunk. The rivets are plugged down practically flush with the plate. As rivet heads are subjected to both heat and blows during the riveting process, the tool steel of which they are made must be of high grade.

Special heat treatments for hardening and tempering the steel are given to the finished rivet sets.

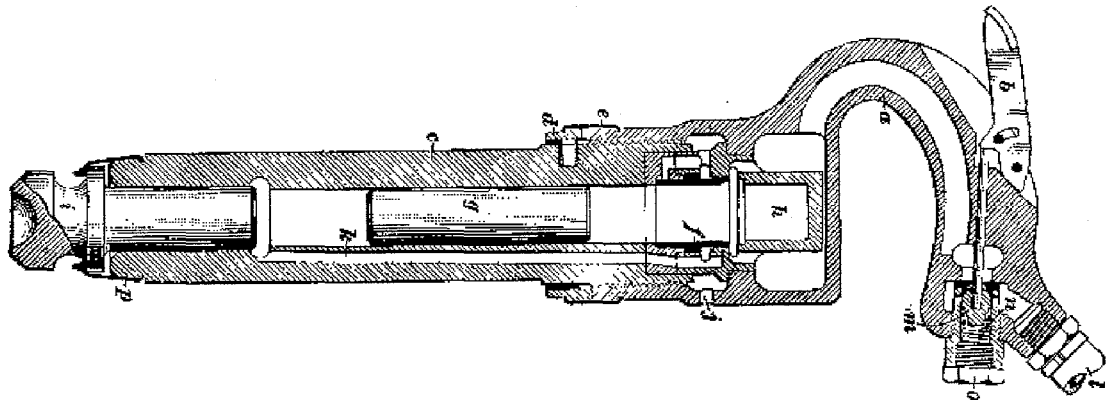
## Pneumatic Riveting Hammer

A sectional view of one form of pneumatic riveting hammer is showing in figure 20. 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 (c) 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.

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).

Fig 20



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).

## Use of Pneumatic Hammers

In driving rivets with a pneumatic hammer, the air hammer should be held directly in line with the axis of the rivet, and with the rivet set held firmly against the end of the shank. The head of the rivet should be 'plugged' squarely into the hole, care being taken not to bend over the point of the rivet but to upset it, filling the hole its entire length. The hammer should be started lightly until the rivet has settled into the hole somewhat, to prevent bending to one side. In driving any type of rivets held or backed up by a dolly-bar or hand hammer, the riveter should run the hammer slowly until enough head is formed to hold the rivet in the hole, as otherwise the holder-on will have difficulty in keeping the hammer or dolly-bar on the rivet, 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.

Continued hammering on rivets that have cooled is bad practice.

In order that a pneumatic hammer may work to the best advantage, it must receive a sufficient volume of air at a pressure of about 100 pounds per square inch at the hammer. When the hammer is used at a distance of 50 feet or more from the nearest compressed air connection a  $\frac{3}{4}$  inch armoured hose should be used to supply air to the hammer.

This size is somewhat large, but it ensures a good supply of air at the hammer. On account of the stiffness of the armoured hose, it is customary to use from 5 to 10 feet of flexible ½ inch 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 collected in the piping. Water effects the operation of the hammer, blocking air ports and often causing the valve to stick by freezing the moisture.

### Lubricating Pneumatic Hammers

All pneumatic tools, when in use, should be oiled through the inlet valve as necessary with a good quality of light mineral oil. Pneumatic tool manufacturers, as a rule, supply suitable high grade oil. Heavy oil should never be used. The expansion of the air 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 smaller air ports.

### Use of the Air Strainer

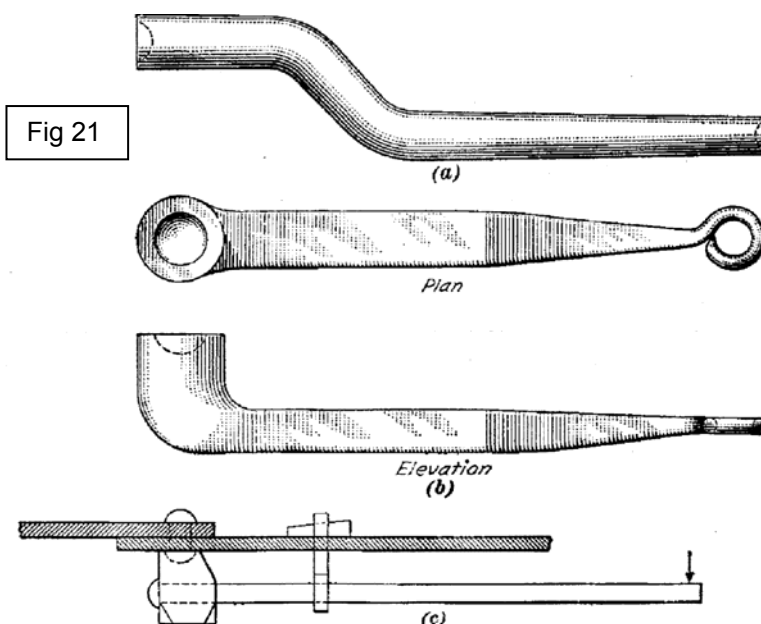
As a protection for pneumatic tools, the manufacturers recommend an air strainer, which should be applied to the compressed air line at the hose connection for the purpose of removing foreign matter that may have accumulated into the airline. The dirt passes through the compressor and out through the 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.

### Cleaning Pneumatic Hammers

Attention should be paid to the systematic cleaning of pneumatic tools.

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 at all times to see 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.

## 18. Holding up



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 figure 21 (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 as 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.



## Jam holder on

A common method of holding up a headed rivet is to use a 'jam back' it is a simple air powered cylinder usually with a piston of around 4 inches in diameter and has a stroke of about 5 inches. the piston holds the snap and the back of the cylinder has a threaded boss to enable a bar to be attached to wedge it between the rivet head and a suitable opposing surface.

## Combination Holder On and Jam Riveter

There are a number of types of combination holder on and jam riveter; figure 22 illustrates the general construction.

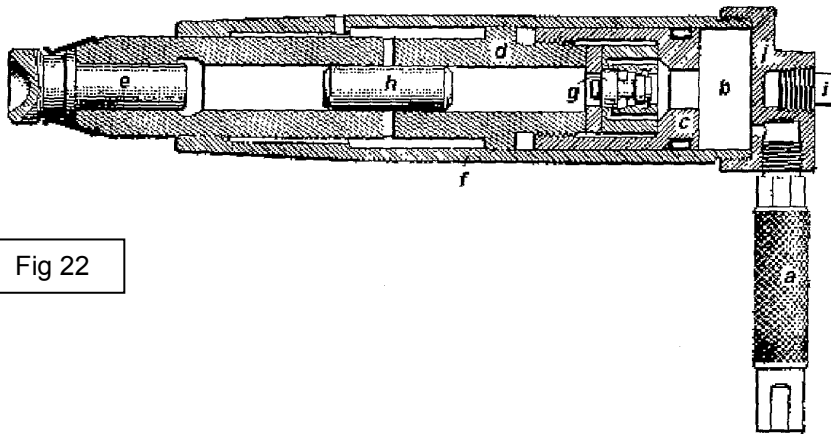


Fig 22

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 regulated so that only the holding on action may be used, if desired. For centering the device, a casing cap (i) is screwed into the head (j).

## 19. Wedge Riveting

This form of riveting occurs when an inner firebox and the outer shell cannot be riveted by a squeeze riveting machine or a jammer and or rivet hammers. Wedges come in various lengths from 1' 0" to 6' 0", and are used with many combinations of packing blocks and blocks made to go over rivets that are already fixed in opposite plates. The only time you cannot wedge rivet is if the water spaces are so narrow that you cannot get the rivets down the water spaces and into the holes, to produce a rivet head of acceptable size.

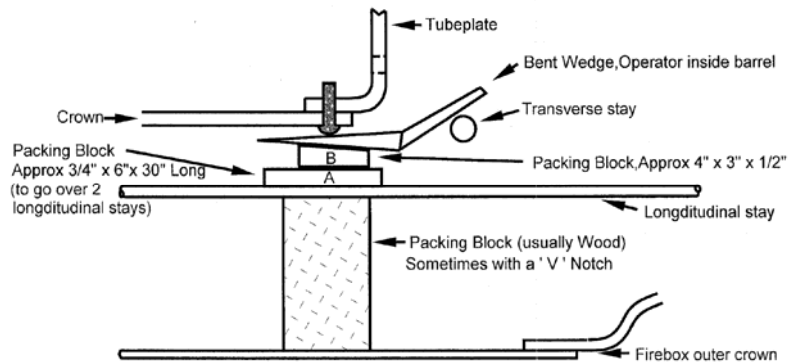
With any wedge riveting there are several golden rules to remember.

- a) The rivet must be white hot
- b) The holes should be reamed with 1/16" clearance
- c) The operation must be performed as quick as possible
- d) When the rivet is in place a slight bend is sometimes desirable to be put in the rivet by the person knocking down the rivet. (This helps to keep the new formed head central when knocking down).
- e) The plates must be closed prior to any riveting
- f) Free running bolts are used when riveting, to ensure speed of operation
- g) The wedge will need continual hitting with the hammer whilst riveting
- h) Avoid the wedge hitting any side or crown stays
- i) Minimum of three experienced people are needed in the team, warmer, wedger, riveter.

**Inner Firebox Crown Wedge Riveting**

To rivet the crown of an inner firebox, the operation is performed with the boiler upside down; the longitudinal stays are packed up with wood to keep the amount of deflection to a minimum, but still allowing room for the rivets to be inserted from the waterside up, see figure 23.

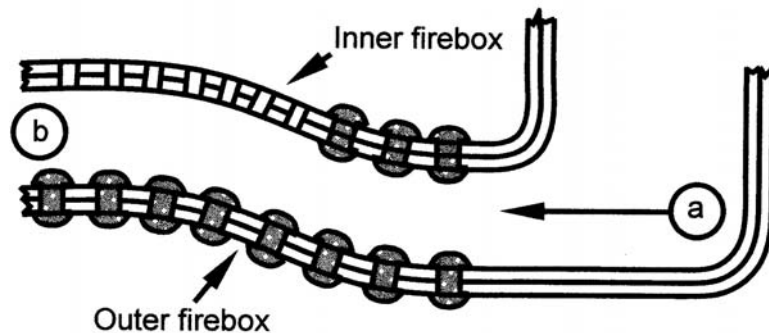
Fig 23



It is sometimes necessary to pull the packing blocks clear of the rivet hole to get the rivet in place, in any position (A & B).

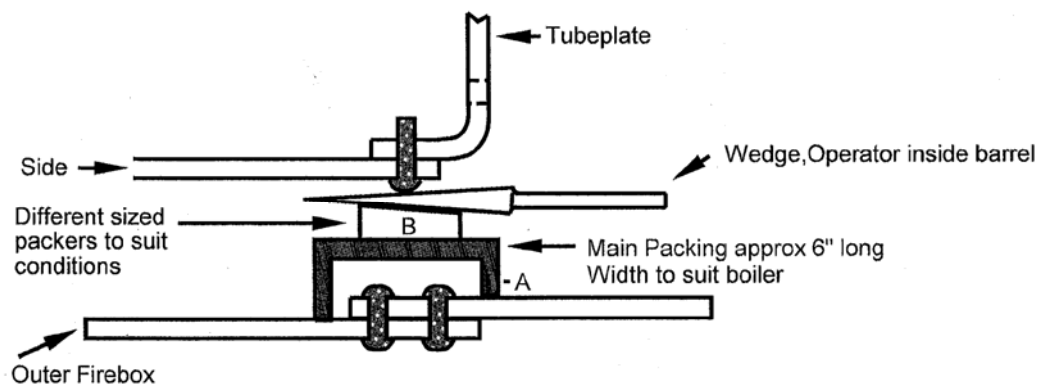
Start from one side and work to the opposite side one hole at a time until complete. From the corner of the firebox crown to where the box starts to go straight (i.e. the valley and legs) are riveted with the boiler on its sides (a) to (b), see figure 24.

Fig 24



This time a different main packing piece and differing thicknesses of secondary packing are used as the water space reduces; see figure 25 (A & B).

Fig 25

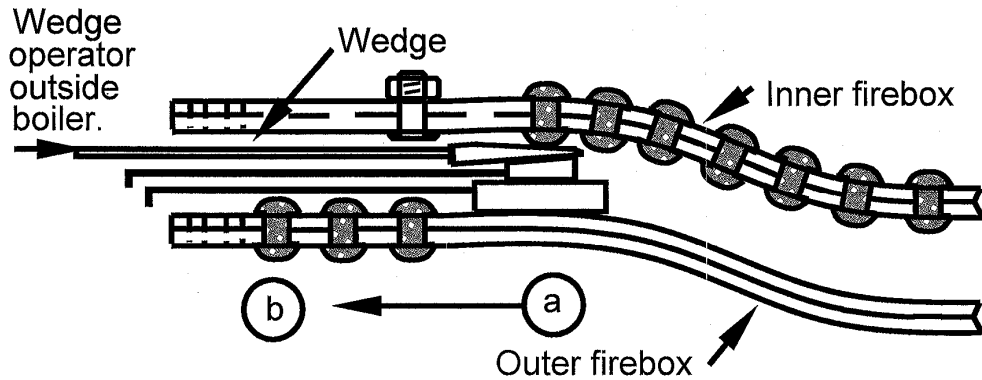


**Wedge riveting Fire Box Legs**

**Method 1 Foundation ring removed**

To rivet the legs with the foundation ring removed it is possible to rivet both the inner box and the outer wrapper plates through the foundation ring hole. Starting at (a) and working to (b), see Fig 26

Fig 26



This time the long wedge is used with packing blocks as before (A & B), but with a length of rod welded to them to get the rivets wedged at point (a), for this operation long tongs (spring or normal) are used to get the rivets down the water space into the hole. This method of riveting is performed with the boiler on its side.

**Method 2 Foundation ring fitted**

The second method of riveting the legs is with the boiler upright.

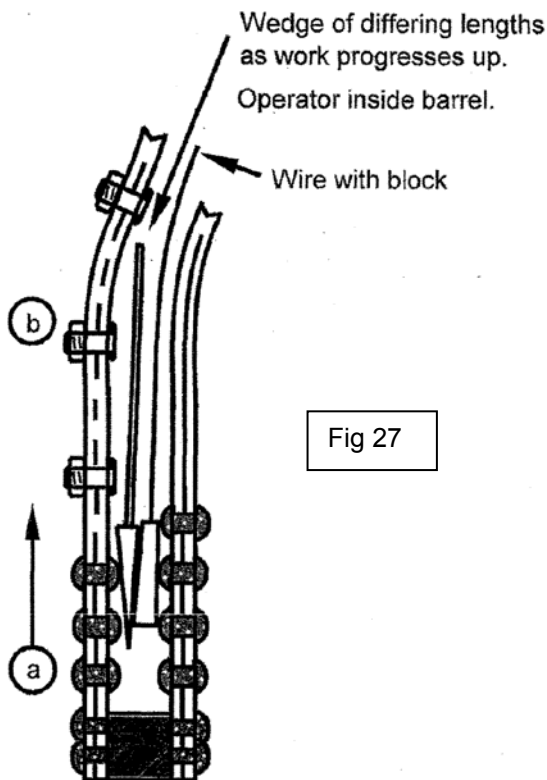


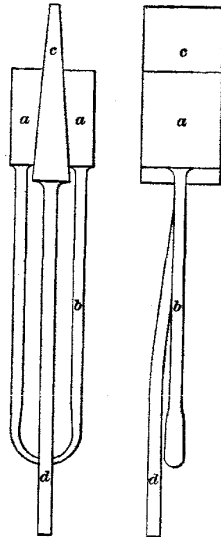
Fig 27

This time start at (a) and work to (b).

Only one block of thicker material is used and is suspended by a piece of wire to any available side stay, moved as required.

The wedger is working from inside the boiler barrel. Sometimes it is not possible to put a rivet in the bottom hole and a stud is fitted in its place. To do this by method 2 the packing block is made to go against the outer rivets not over them, sometimes this is not practical then a packing block is used as in method 1.

Fig 28



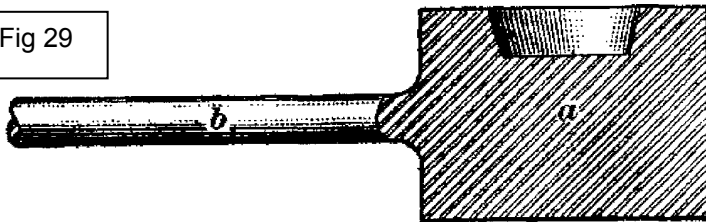
The spring block wedge bars shown in figure 28 are another form used in backing up rivets in narrow water leg spaces.

They consist of two tapered forged steel heads a and 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.

**Holding on bars**

An objection to straight wedge bars is that they flatten the rivet heads; furthermore, considerable care must 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 figure 29.

Fig 29



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.

**20. Rivet Tongs**

Figure 30 illustrates a pair of rivet tongs are used for extracting the heated rivet from the rivet fire or heater.

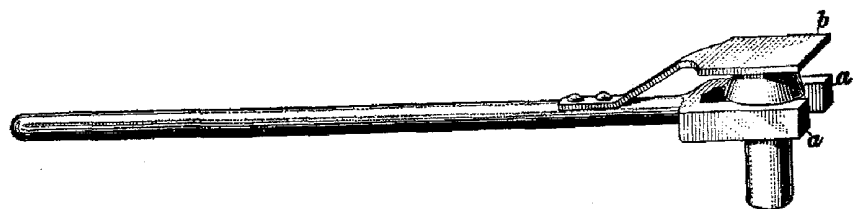
Fig 30



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.

When rivet holes are out of arm's reach, either long handled rivet tongs or three pronged spring tongs shown in figure 31 are employed.

Fig 31



The latter consist 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.

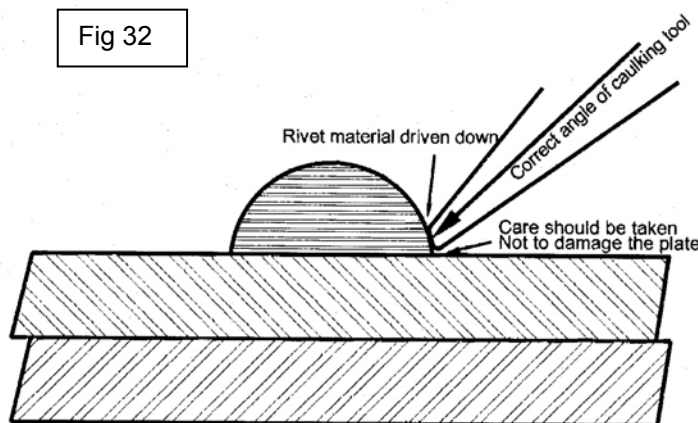
When the rivet shank has been inserted in the hole, the tongs are removed by a pull at right angles to the rivet.

## 21. Caulking 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 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 as shown in figure 32.



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 be made steam tight and kept so for any great length of time.

## 22. Removal of Rivets

There are several methods of Rivet removal, with variations depending on the tools and skills available.

### Removal of headed rivets

The first method involves an Oxy acetylene cutting torch or gouging nozzle. This process must only be used where either the plate around the rivets being removed is also being replaced or if the operator of the equipment has the required skills to remove the head without any damage to the surrounding plate work or hole. If minor damage occurs it may be welded up by qualified a welder but if the damage is severe the plate work must be replaced. Care must be taken not to overheat the surrounding plate work during rivet removal and cause distortion.

If only a few rivets require removal a second method may be carried out using a grinder to remove the head and then the rivet may be punched out or drilled. The drilling may be done, with tools available, an ordinary ratchet, or a pneumatic drilling machine, or an electric drill.

## 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, 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.

## 23. Riveting in repair work

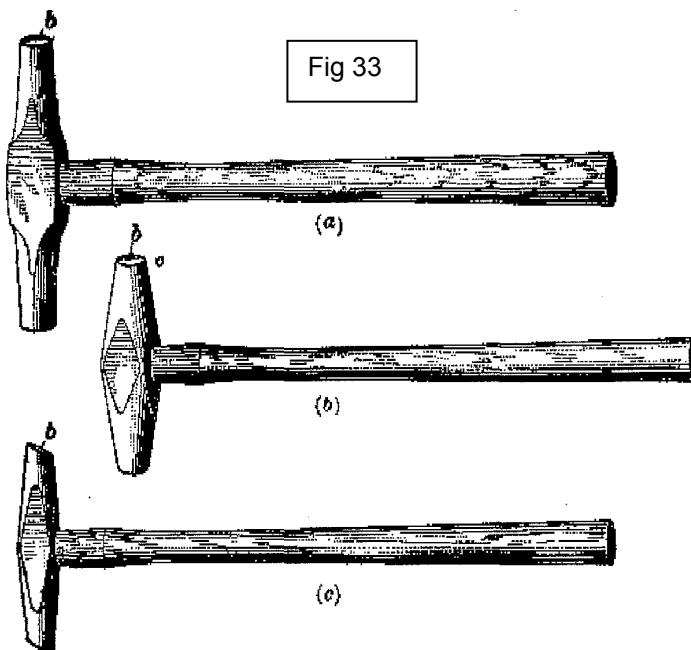
When, in boiler repair work, old rivet holes from which the rivets have been removed are found to be in bad shape, either from corrosion or from bad workmanship, it is advisable to ream the holes for a rivet one size larger than the old one before inserting a new rivet.

As a general rule, machine riveting is not feasible in boiler repair work, except in rare circumstances. Nearly always the rivets must be driven by hand, although it is often possible to use a pneumatic hammer for the purpose.

## 24. Use of patch screws

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 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 must be taken to see that they not only draw the two plates together, but also properly fill the holes.

## 25. Hand Riveting Hammers



Three hammers used in hand riveting are shown in figure 33.

The first hammer illustrated 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 second hammer illustrated 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 third hammer illustrated is known as a bevel faced hammer, and is used in special cases (for example patch bolt edges on a firebox tube plate) where it is difficult to use the regular tools. The angle of the bevelled ends (b) is usually about 20 degrees, although other angles are employed, according to the views of the riveter and the varying conditions affecting the work.

## 26. Design of Riveting

Whenever possible the original boiler drawings and design work must be followed or as in the case of repairing the rivets replaced like for like. Where there are special reasons for a change from design for example a patch or repair is required the following notes are provided to assist in the selection of an appropriate construction; further useful information can be found in British standards for example BS931. The competent person must be consulted before commencement of work and a written approval obtained.

The design of riveting must be such as not to subject any part to unduly high stress and also must be arranged so as to give a tight joint and to permit satisfactory work in the riveting.

### Pitch of Riveting

Too wide a pitch of rivets allows the plates to spring up between the rivets, and prevents proper fullering and caulking. On the other hand when rivets are spaced too closely together the net plate section is unduly reduced, and the squeezing by the machine sometimes distorts the plate and renders a seam leaky which would be tight with a wider pitch. When large rivets are close together the plate between them becomes unduly heated in riveting, which also tends to leakage. Having regard to the foregoing, the rivets should not be pitched more closely together than is given in Table 2.

RIVETING Size of Rivet Hole	MINIMUM PITCH	
	Single Riveting	Double Riveting
3/4 inch	1 3/4 inch	2 inch
13/16 inch	2 inch	2 1/4 inch
7/8 inch	2 1/8 inch	2 1/2 inch
15/16 inch	2 1/4 inch	2 3/4 inch

### Size of Rivet in relation to thickness of Plates

In deciding on the diameters of rivets care must be taken to keep the diameters up in relation to the thickness of the plates to be riveted together. If the rivet is unduly long in proportion to its diameter, no amount of squeezing on the ends would suffice to fill the hole towards the centre part of it. In the practical carrying out of riveting there must always be sufficient material in the ends which are squeezed together to flow up the shank and fill the hole. Generally the diameter of the rivets should be fixed according to the thickness of plates which are to be riveted together, and should be somewhat as given in Table 3. (The rivet in no case should be less in diameter than the thickness of the plate.)

Thickness of Plate	Diameter of Rivet Holes & Finished size of Rivet
3/8 inch	3/4 inch
7/16 inch	13/16 inch
1/2 inch	13/16 inch
9/16 inch	13/16 inch
5/8 inch	7/8 inch
11/16 inch	7/8 inch
3/4 inch	15/16 inch
13/16 inch	1 inch
7/8 inch	1 inch
15/16 inch	1 1/16 inch
1 inch	1 1/16 inch

### Lap of Plate

The lap of the plate, that is the distance from the centre of the rivet hole to the nearest edge of the plate, should not be less than one and a half times the diameter of the rivet hole.

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