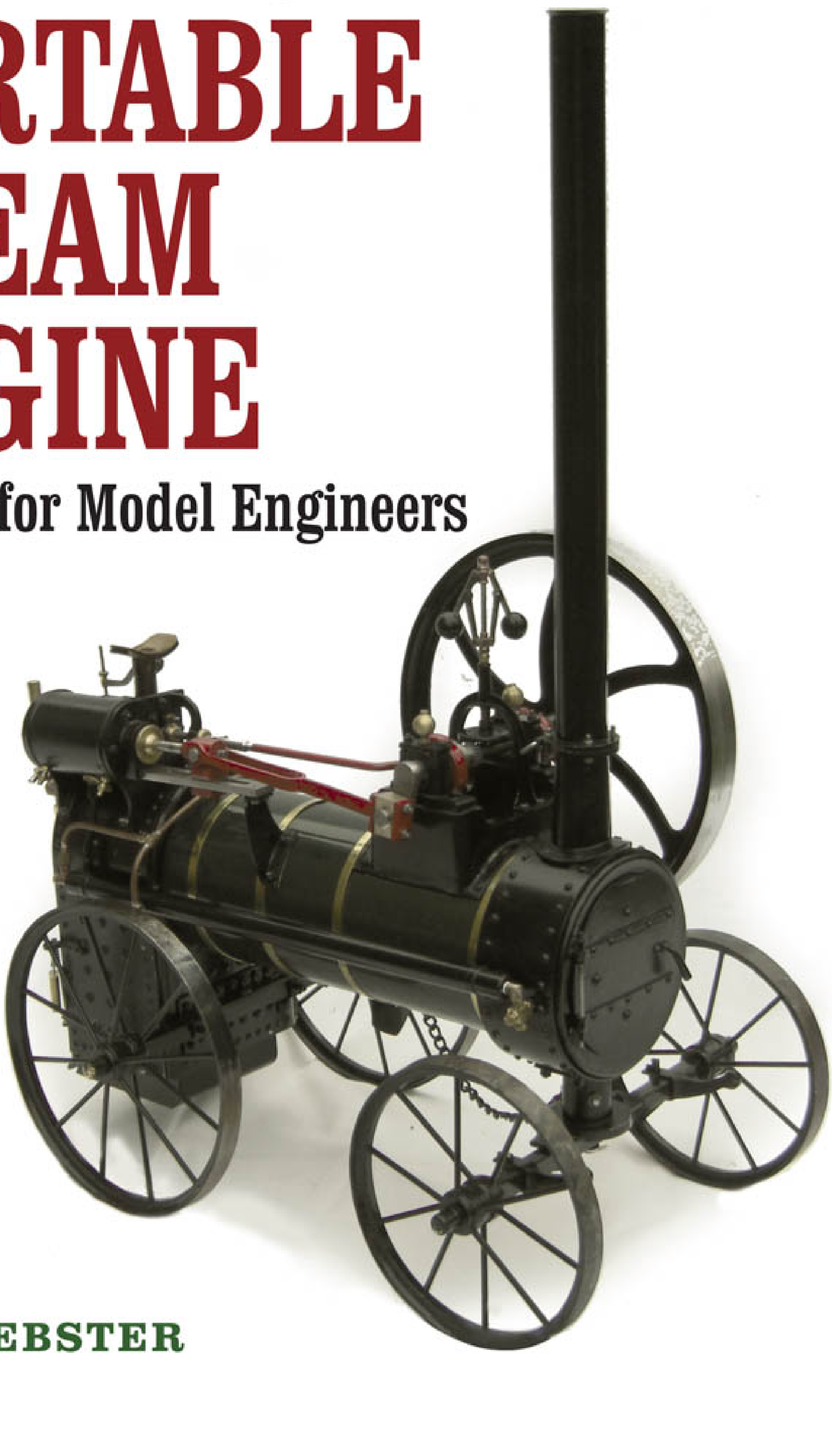
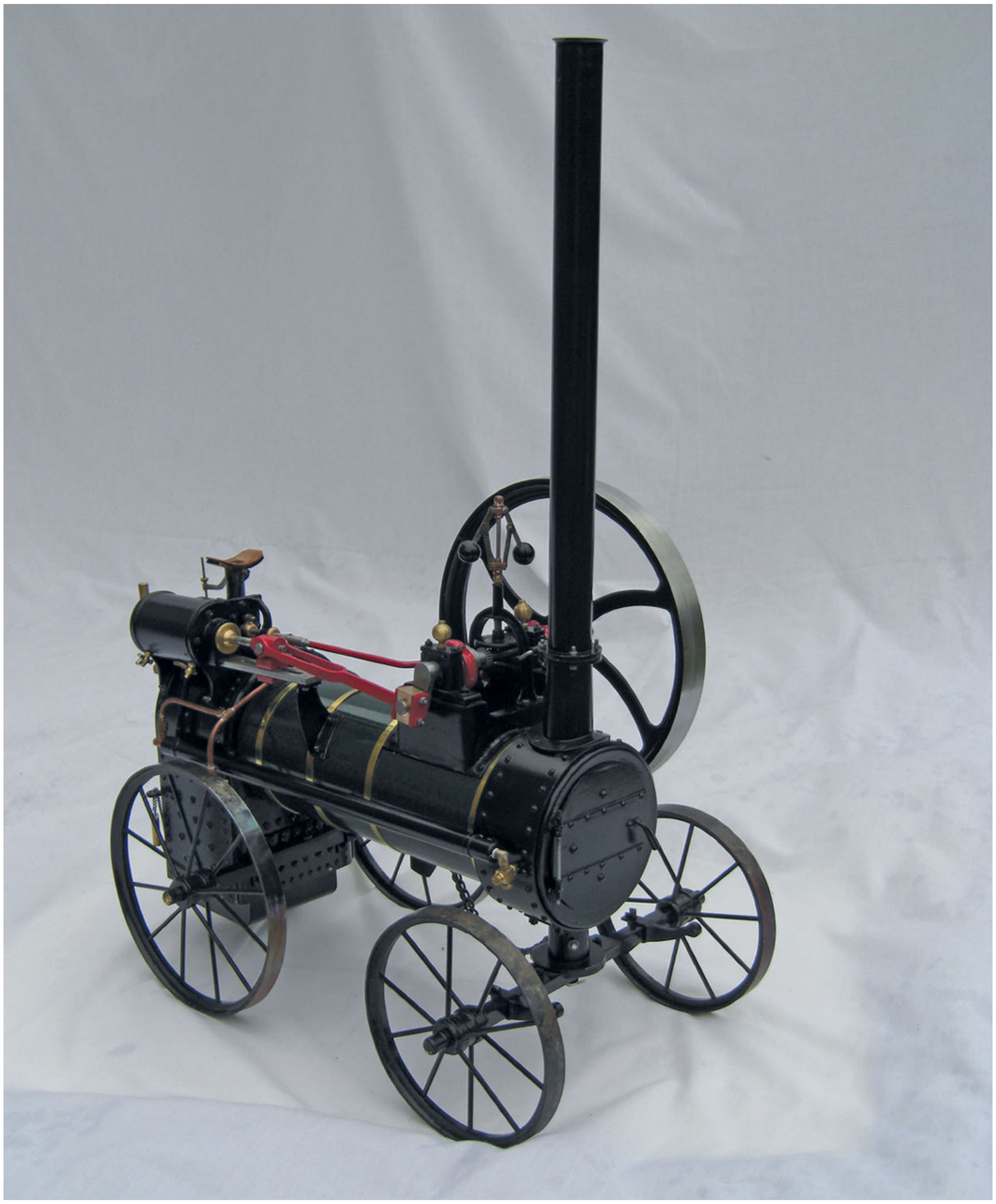
# BUILDING A PORTABLE STEAM ENGINE

## A Guide for Model Engineers



TONY WEBSTER



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THE CROWOOD PRESS

First published in 2014 by
The Crowood Press Ltd
Ramsbury, Marlborough
Wiltshire SN8 2HR

**www.crowood.com**

This e-book first published in 2015



**British Library Cataloguing-in-Publication Data**
A catalogue record for this book is available from the British Library.

ISBN 978 1 84797 866 0

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# *Foreword*

Tony Webster is well qualified to write this book on the Lampitt engine. Having known him for many years, I have always been impressed by his ability to root out the unusual prototypes and to adapt simple techniques and materials to do the job. His own collection of models is a testament to his ability and ingenuity. His workshop, housed in the garage of his house, is quite simple and does not contain elaborate machine tools; rather it displays the good solid evidence of hand work and simple fixtures.

If you are a beginner, expect to be instructed in the basic methods rather than sophisticated ones. Although a portable engine is not a complicated affair, there are some tricky techniques to be mastered, but Tony will guide you through them. There is also advice about materials and tools that you should not treat lightly. I have seen not only the model develop from its early stage on the drawing board, but also the original survivor at its home in the East Midlands, not many miles from where we both live. There is nothing ordinary about the prototype; it is a survivor, a representative of a bygone age in which traction engines and portables were built in small numbers by so many little businesses in the agricultural areas of the country. Each has its own unique features, but only the fittest of them survived well into the second quarter of the twentieth century.

I know that some modern techniques are included for the taking. I would urge you to take notice of them, as they will save time and effort and enable you to produce a good result. The boiler is something that must be taken seriously. Making even a simple example demands considerable patience and painstaking work. Above all do not hesitate to get help in this matter. Most experienced model engineers are only too pleased to help a beginner in the hobby.

Now start to enjoy this account of a journey that, I can promise you, will take much longer to complete than you would ever have thought.

D. A. G. Brown, C. Eng.

# *Introduction*

This book details the construction of a portable steam engine and is written for the complete newcomer to model engineering. The making of each part will be described in detail, with hints on sourcing material and buying tools to establish your own workshop. When finished, you will have a complete steam engine that may be used to drive machinery. It will also be worthy of being shown at model-engineering exhibitions where you may receive recognition for the skills you have demonstrated. You will have gained many metalworking skills and completed an engineering apprenticeship of which you can be proud. Along the way you will have met many knowledgeable people and have perhaps joined a new group of like-minded friends.

# *Acknowledgements*

I wish to thank my daughter, Susan, for her help with editing and the layout, and Derek Brown for help with the boiler and proof-reading.

This book is dedicated to my wife, Barbara.

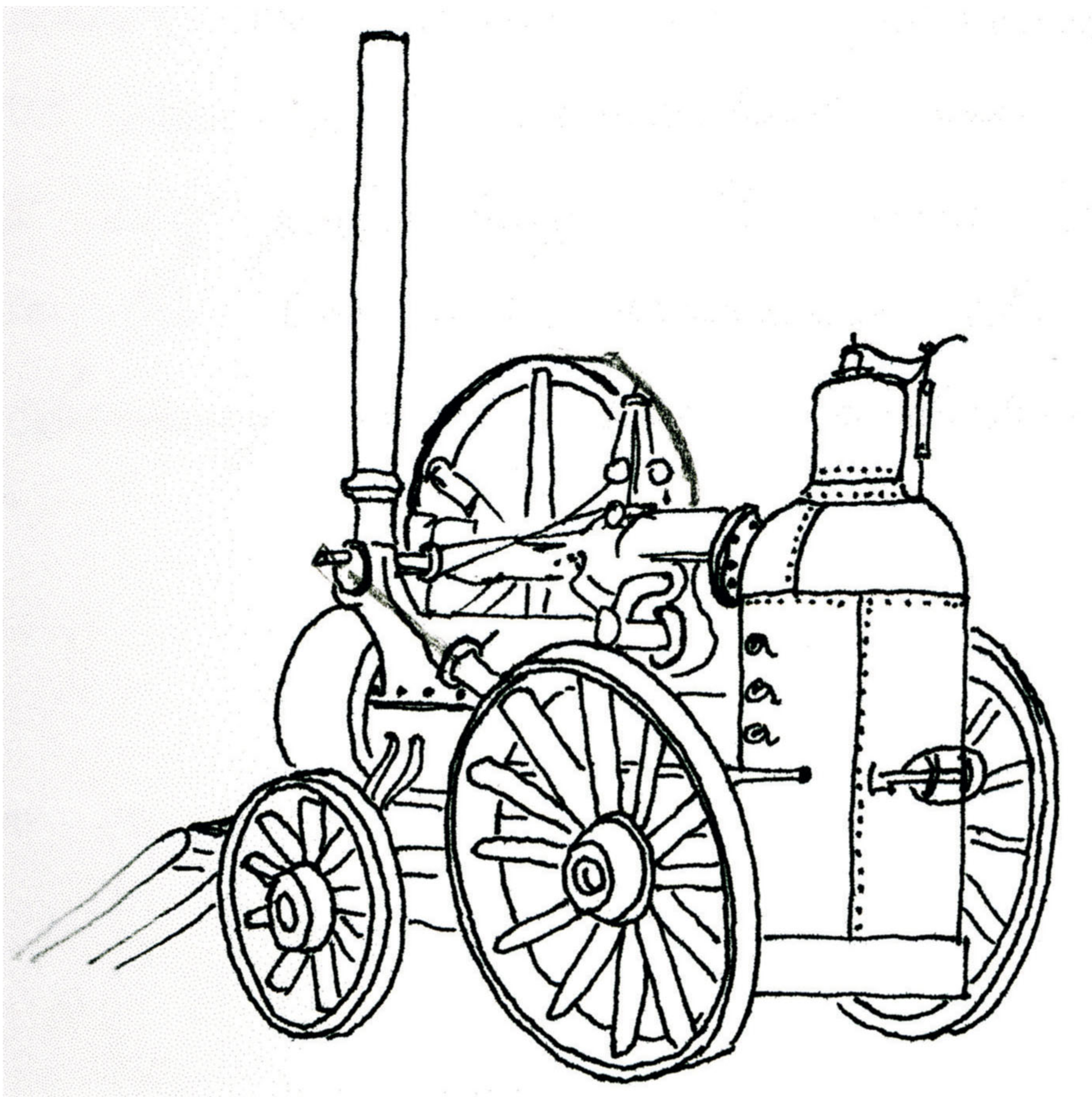
# 1 The Background History and Development of Portable Engines

Portable engines, the forerunner of the traction engine, were made in large numbers in almost every county in the country from the 1830s right through to the 1930s, extending beyond the eclipse of traction engine manufacture. Most of the well-known manufacturers of traction engines produced examples, but many were made by blacksmiths and foundries that are now obscure and forgotten.

The early portables had horizontal or vertical boilers with a self-contained engine, often mounted on a frame or chassis, and the whole was supported by four wheels. By the 1850s they had developed into using a locomotive type boiler with the engine mounted on the top, indeed using the boiler as part of the structure of the engine. Two large wheels supported the heavy firebox end of the boiler and under the smokebox would be the turntable and two smaller wheels. These would be steered and hauled by a pair of horses in shafts, which would have been necessary to pull the 2 tons of engine over the rough roads of the time. Wrought iron wheels, mounted on a cast iron hub, would have been made in the foundry, or a local wheelwright would have supplied wooden wheels.

A locomotive boiler, as used on railway locomotives, has a large horizontal cylindrical part containing the fire-tubes, with the smokebox and chimney at the front, and a vertical square part containing the firebox at the rear. The steam cylinder was mounted machine, which would have needed another on top of the firebox and the crankshaft over two horses to pull it from farm to farm. Four the cylindrical part at the chimney end. horses might have been needed on wet and

The main use for such engines was to provide 'rotative power' for driving a thrashing machine, which would have needed another two horses to pull it from farm to farm. Four horses might have been needed on wet and muddy winter roads. An 'outfit' comprising a thrashing (or threshing) machine – known as a mill in Scotland – and an engine was often owned and run by thrashing contractors who travelled from farm to farm all winter, thrashing the farmers' corn on the way.



*Hornsby's first prize engine of 1848.*

*A threshing machine, driven by a portable engine, in use in a Northamptonshire village in about 1900.* *BYFIELD PHOTOGRAPH MUSEUM; COURTESY OF POLLY HARRIS-WATSON*

*A portable engine driving a circular saw at the village sawmill.* *BYFIELD PHOTOGRAPH MUSEUM; COURTESY OF KEVIN PERRY*

The combine harvester is a modern version of a threshing machine with a cutter-bar on the front and made to be self-moving.

Many sawmills were driven by portable engines that were given a permanent, static home in makeshift sheds made from surplus timber to protect the saw, engine and workers from inclement weather. Sawmill off-cuts provided a readily available supply of fuel for the fire.

By the 1860s some of these portables had been made or converted into self-moving engines by placing a chain around sprockets on the crankshaft and a rear wheel, but a horse was still needed in the shafts to steer the engine. In the 1870s the traction engine, as we now know it, developed from the portable engine by reversing the positions of the cylinder and crankshaft. This made the drive to the rear wheels within the reach of a train of gears. A cross-shaft and chain arrangement to steer the front axle brought the steersman and driver together on the man-stand at the rear. Traction engines changed little in the next fifty years or so. Portable engines, however, continued to be made throughout this period.

## THE PROTOTYPE

The word ‘prototype’, in the context of model making, does not mean the first trial assembly of a new design, but the full-size example, which may or may not exist. In our case this is a portable engine, which we are going to replicate in model size.

The original full-size engine is a portable steam engine originally made by Lampitt & Co. of Banbury, Oxfordshire. An example from this period of engine construction has been deliberately chosen for its simplicity of construction, particularly the cylinder, which can be made from a piece of round gunmetal, or cast iron, bar. No castings will be used in its construction, except possibly for the flywheel, which could use an existing casting. However, a fabricated flywheel will also be detailed.

There seems to have been two Lampitts in Banbury: John Lampitt of the Vulcan Foundry, Neithrop (Banbury), millwright, iron founder and engineer; and Charles Lampitt of the Christ Church Works, Banbury, engineers, millwrights, brass founders and tower bell-hangers. It is unclear whether the company moved to larger premises, or whether John and Charles were of different generations.

C. Lampitt, Vulcan Foundry, Banbury, exhibited a horse-drawn seed dribbler at the Great Exhibition of 1851 at the Crystal Palace, London, but there is no mention of steam engines at that time.

John Lampitt made threshing machines in the 1860s (number 555 was made in 1861), but Lampitts built a combined total of only about twelve portable and traction engines.

## SCALE

The question of scale needs to be discussed. The makers of model locomotives relate everything to the track width or gauge and the scale is determined by how much the prototype gauge of 4ft 8½ in has to be reduced to model engineering gauges of 3½ in, 5in or 7¼ in. Thus scales of

¾ in to the foot, just over 1in to the foot or 1½ in to the foot are used to scale the sizes down. Narrow gauge locomotives come out much bigger.

Traction engines, portables, stationary and marine engines are scaled at so many inches to the foot. There are some very popular traction engine models in a scale of 1in to the foot and also 1½in to the foot (onetwelfth and one-eighth). These make very good mantelpiece models but are generally not big enough to do much work. Two inch scale (12 [inches in a foot] divided by 2 = 6, therefore one-sixth of full size) makes a more viable engine;3in (¼ full-size) is a good size for rallying. Four inch and 4½ in scale (1/3 and 3/8) and 6in, or half size, make problems in manufacture and transportation because of their bulk and weight. You will now see why every scale is abbreviated to '2in' and so on: 'to the foot' is assumed.

We are going to work to a scale of 2in to the foot, which will give us a model of about 18in in length; all dimensions will be in inches. The imperial system is the traditional measuring system for model engineers, mainly because the prototypes were made using this system. It may also be that, having bought our imperial drills and threading equipment, we are reluctant to change. Many school leavers have to learn the imperial system before they can start work in an established factory. However, there are many places where it may sometimes be an advantage to use metric-sized material where it is more readily available. These alternative sizes will be shown in parentheses after the imperial sizes, where appropriate.

## Boiler

The usual starting point for the construction of a portable or traction engine is the boiler, which is there to make the steam and provide part of the structure of the whole engine. As you are just starting out in model engineering and do not yet have the tools and resources necessary to make anything in metal, the description of the boiler's construction will be left until much later when you have gained some metalworking skills. However, the drawing for the boiler is included at an early stage to enable you to obtain a boiler from a professional boilermaker. There is no shame in buying your boiler: many experienced model engineers always obtain their boilers from a professional maker.

# *2 Workspace, Tools and Materials*

The subjects listed in this chapter are in the same order in which they are introduced in the succeeding chapters.

## SAFETY

Do not forget that most of the time you will be working alone. There will be no-one to help or switch off a machine if something goes wrong.

Always use a vice or clamp when drilling.

Only measure the workpiece when machinery is stationary.

Do not have any loose clothing, such as ties or cuffs, when using machinery.

Wear safety glasses.

## TOOLS

The tools and materials that will be required to make this engine will be discussed below, together with their source of supply and their safe use. They should all appear in the order of their first mention in the text.


*Before mounting your vice, check that a vertical bar is clear of the bench front.*

## WORKSPACE

The place where you carry out your model engineering activities needs careful thought. Will it be the garage, shed, kitchen or bedroom? A bedroom, although warm and dry, would be unsuitable for a machine shop or for hammering, especially if you live in a terrace or a semi-detached house, or anywhere with a hollow wooden floor. The use of the kitchen will have to come second to the needs of domestic life, especially when you are in the middle of something tricky. There is nothing better than a dedicated workspace, be it a garden shed or the end of the garage, where you can leave your tools on the bench and know that they will be there the next time you go in. It is most frustrating to have to set up your workspace every time you want to spend a few hours in the workshop, but many people work in these conditions and make wonderful models. In either case it is necessary to add some heat insulation in the form of fibreglass between the roof joists; a shed will need some more, or expanded polystyrene, in the walls. This will not only keep you warm in winter, but also cool in summer when the sun is beating down and you want to complete the present component.

For heating, use an electric convector or fan heater. Do not use a paraffin or gas-burning heater as the products of combustion include water vapour, which will make all your steel stock and your tools go rusty, and that is to be avoided at all cost. Also you will find that rock wool insulation falls apart when pushed up between the roof joists. Fibreglass holds together much better and stays put while you nail up some sheets of hardboard or even double-wall corrugated cardboard. White emulsion paint will help to brighten the interior and reflect the light from two or three five-foot fluorescent lights strategically placed over the bench and machine areas.

The bench is another area that needs some thought. A folding Workmate-style bench can be useful if you need the garage for the car as well, but some of the later models of bench lack diagonal bracing and therefore rigidity. A welded-angle steel bench, as big as you can accommodate, is ideal. The top should be 1¼in (40mm) thick and a lower shelf loaded with your metal and casting stock will help to keep it in place and aid rigidity. Screwing it to the wall also helps. The bench must stay in place when a file or hacksaw is used energetically.

A vice is essential to hold the workpiece and should be securely bolted to the bench top close to a leg – preferably the right leg if you are right-handed – not in the middle where the bench frame and top will flex and vibrate. An engineer’s vice of 3 or 4in width is ideal, but get one as big as funds will allow up to 4in wide. When installing a vice, ensure that a long straight bar can be held vertically between the vice jaws and clear (just) of the bench front edge. Don’t forget the bolt in the middle at the back.

## THREE-JAW CHUCKS

These are supplied with two sets of jaws: one set for small diameters and one for large. The inside, or small, set is usually fitted and the large set supplied loose. Each jaw is stamped with numbers (1, 2, 3) and the slots in the front face of the chuck body are similarly stamped. It is important that the jaws are only ever fitted to their own slot. Start by removing the unwanted jaws by turning the chuck key anticlockwise in one of the keyholes. Keep going until the jaws stop moving and they can be removed by hand. All three will move out simultaneously, hence the term ‘self centring’.

Looking into the slots you will notice a disc with a spiral groove that appears to move inwards or outwards when the chuck key is turned. Now examine the jaws. Keep the two sets separate and observe the curved grooves that engage with the grooves on the disc or scroll. Keeping all the groove curves the same way round, you should find that the steps on the other set are opposite.

You will need the set with the largest step at the top. Identify the number of each jaw and place them ready, in order, with no. 1 at the top. Find the slot marked ‘1’ and turn the chuck key clockwise, turning the scroll anticlockwise, until the outer end of the scroll groove is just about to emerge in slot no. 1. If it emerges you will have to back it off. Slide the no. 1 jaw into the no. 1 slot until it engages with the scroll. Turn the chuck key clockwise and the jaw should be drawn inwards. Do not let the groove pass the no. 2 slot. Back off, if necessary, and slide jaw no. 2 into slot 2 and so on with no. 3. You will find it easier to turn the chuck around a bit between fitting jaws. Wind the jaws into the middle of the chuck where they should all arrive together. If they do not, you will have to repeat the whole process.

*Three-jaw chuck with inside jaws fitted. The outside jaws are supplied loose.*

## DRAW FILING

Using the soft jaws, grip the workpiece in the vice, near to the end, with half the width above the jaws. Using a 6in or 8in smooth file, grip the handle with the right hand. With the left hand holding the end of the file (like when holding straight cycle handlebars), and with your left hip against the bench, push the exposed part of the file along the edge of the workpiece, keeping the file horizontal side to side. The file is travelling and cutting sideways for a distance of 5 or 6in. Repeat until the edge of the workpiece is smooth. The workpiece is then moved along in the vice and the next part cleaned up, blending the end of the stroke in with the last position. This is a very useful technique for smoothing the edge of a piece of metal. Deburr the edges of the workpiece.


*Second tap, split button die and die nut for final sizing.*

## TAPS AND DIES

Model engineers usually use BA (British Association) threaded nuts and bolts. The which range of taps and dies required to this standard will include 2, 4 and 6BA. If starting from scratch, which is what this book is all about, you may prefer to start by establishing a set of metric taps and dies, perhaps from M3 to M5.

*Taps and dies*

*Straight and chuck-type tap wrench.*

The tools used to make an internal thread are known as taps. All sizes of taps come in three types: taper, second and plug (or bottoming). The last of these, as its name indicates, will cut the thread to the bottom of a blind hole. There is no real need for a taper tap in our work, so second and plug taps will make an adequate set. (Taper taps are more necessary when making course threads.)

A tap wrench, preferably of the chuck type, will be needed to turn the tap. The chuck type of tap wrench effectively lengthens the tap to make it easier to position and make sure that the tap is square to the face of the workpiece. It is important to make sure that the tap is square, meaning at 90 degrees to the surface of the job, assuming that the tapping size hole has previously been drilled square to the work face.

A die, for threading a rod or bolt, is tapered on the side where the size and manufacturer's name are stamped; and that side is used to cut the thread first. If it is necessary to make a thread right up to a shoulder or step in the diameter, the die is turned over and run down again.

A die is held in a stock, which may be obtained in several standard sizes (13⁄16 in and 1in will cover our needs) and has screws to adjust the die to cut the thread to fit the tapped hole. Always tap the hole (female) first and adjust the male thread to fit.

To adjust the die, the central screw fits in the split in the die and forces it open, making the thread larger. A second pass will be needed to bring it to a size to fit the tapped hole. The side screws help to drive the die round and keep a blunt die from opening up when threading some materials. Slacken the outer screws before tightening the centre screw.

The size of a tap and die are based on the diameter of the male part (the rod or bolt from which metal is cut to form the thread). The female part is drilled to a smaller size, known as the tapping size, and metal is cut from inside the hole, by the tap, to make the internal thread. The tap is nominally the same diameter as the rod or bolt.

*Die stocks of 13/16 in and 1in.*

## Tapping Drills

It can be helpful to establish a set of tapping size drills, which are most usefully stored in a block of wood set with a row of holes for the tapping drills and two rows for the second and plug taps. A fourth row of holes could be for clearance size drills, but it is all too easy to make a mistake and pull out a clearance drill instead of a tapping drill. The fifth row is for small nails or panel pins over which the dies are placed. Of course, the tapping drill, second tap, plug tap, clearance drill and nail will be in a line in the other direction. It is a bit tedious to make one of these blocks, which uses a different size of drill for almost every hole, but it will be very handy in the long run and useful practice. Do not drill right through or your drills and taps will fall through. However, if your block is little more than ½in thick, drill all the holes right through and glue a piece of plywood or hardboard onto the underside. While marking it out include all sizes from, say, 0 to 10BA or, in another block, M2 to M12 (including M2.5 and M3.5), which is how metric threads are shown.


*Boxed set of taps and dies with tap wrench and two sizes of stock (for dies).*

Sometimes model engineering supply firms, such as Tracy Tools, offer a full set of taps, and also perhaps dies, from 0 to 10BA at an advantageous price. They may only be made from carbon steel but when else would you buy a 7 or 9BA tap? They can come in useful sometimes. Taps and dies in regular use should always be bought, or replaced, in High Speed Steel (HSS). They will not be used at high speed but they are stronger and will keep their edge for longer. The sets to which I refer are of loose taps and dies and not boxed sets, which come complete with stocks and tap wrench. Your spare cash would be better spent on other things

## DRILLS

Having advised you not to buy sets, it is, however, a good idea to buy a set of HSS drills ranging in size from 1 to 5.9mm in steps of 0.1mm diameter.

These come in very handy for tapping and clearance sizes, although tapping size drills may be obtained as a set from the same source that supplied the set of taps (Tracy Tools).

Model engineers often use or refer to ‘number’ size drills, which range from no. 80 (0.0135in diameter) to no. 1 (0.2280in diameter). This range is followed by letter drills from A to Z (0.2340–0.4130in). The metric range from 1 to 5.9mm, in steps of 0.1mm, is the modern equivalent and these are more readily available than the number set. Small sets of number 60 to 80 drills, or 0.3 to 1.6mm, are handy and cheap enough. Number drills advance in size erratically by 1 to 5 thousandths of an inch, whereas metric drills advance by 0.1mm, or about 4 thou, every time.

You must use a lubricant, such as Trefolex, when making a thread on or in most metals, except brass and cast iron, although it can also help in these. A ‘finger full’ housed in a small tin or a film cassette box will last for years: small quantities like this are sometimes on offer at a club’s annual auction.

While on the subject of taps and dies, it would be worth mentioning the ME (or model engineer’s) series of threads. These are usually termed ‘of common pitch’, but we will be working where the two common pitches overlap. We will need taps and dies of 3/16 in × 40 tpi (3/16 in diameter by 40 threads per inch), ¼in × 40, 5/16 in × 32 and 3/8 in × 32. Another block would be useful to house two taps and a die for each size from 5/32 in × 40 to ½in × 32 tpi, together with their tapping-size drills. According to convention, 5/32 is pronounced ‘five thirty-twos’:only 1/32 is pronounced one thirty-second.

*Drill set covering 1 to 5.9mm.*

## MATERIALS

Materials can be found in many places, including skips and scrap bins. If you are an office worker, a word with the foreman of the tool room or Research & Development department may bring surprising results. When they have their annual tidy up, offer to take away any offcuts and bar ends that have accumulated in the workshop. They will all come in handy one day, in the meantime helping to hold down the workbench and make it more robust. If you work on an industrial estate there may be fabricators or turners, whose works foreman might allow you access to their scrap bin. When you have specific requirements they may be willing to cut material for you. Nobody will know what you are looking for if you do not ask: tell them what you are doing and they will be most interested and helpful.

## MARKING-OUT TOOLS

First, you will need a good rule. Make sure that you can read it easily. One that you have to squint at and hold in the right light will always annoy you, so buy a good one now. Rules with a dull silvery finish are easiest to read. They are expensive, but that initial cost will repay you. You will need a 12in long rule for general use;a narrow, flexible 6in rule will come in useful on the lathe.

The rule is often used as a straight edge to guide a scriber to mark straight lines on any kind of metal, except tinplate. A scriber will mark through the thin coating of tin and cause rusting of the steel underneath, so a pencil is always used. An engineer’s square is used when marking lines at right angles, or square, to an edge or surface.

A pair of dividers is used to mark out circles and arcs. Known as spring bow dividers, they are sprung apart by a C-shaped spring at the top and held together by a screw and knurled nut for adjustment. Buy new or second-hand Moore & Wright, Sheffield, dividers rather than cheap foreign copies, which may be soft and not keep their edge.

While on the subject of marking-out tools, odd-leg callipers should be mentioned. These have a screw and nut to secure a small scriber on one leg and a small inward projection on the other leg to guide the scriber parallel to an edge, hence ‘odd legs’ or Hermaphrodite. The legs are pivoted together by a firm joint and adjusted by tapping on a hard surface (the vice) to close, or striking the back of the pivot to open them.

*Scriber with replaceable tip.*

*Dividers.*

*Hermaphrodite, Jenny or odd-leg callipers.*

## HACKSAWS

A hacksaw is adjustable to take 10 or 12in blades (some also take 9in blades). The frame can be flat or be made from oval tube; the latter are a little more comfortable for the left hand when pulling the blade (away from you) through the work. The handle end is usually moulded in Mazac, which is not very strong, so choose a frame with a loop handle, which adds strength to the blade hook anchorage.

The teeth of the blade cut on the push, or forward, stroke. There are several sizes of teeth available, described as ‘teeth per inch’ (tpi). (In metric terms this is ‘teeth per 25mm’.). You may be offered teeth per inch in the range of 18 to 32, and in a variety of materials and qualities. Generally use large teeth for soft materials and thick material, while small teeth are used for hard materials and thin sections. The teeth are ‘set’, not individually as on a woodworking saw, but by the edge of the blade being ‘wiggled’ to make the blade cut a saw-cut, or kerf, a little wider than the thickness of the blade to stop it jamming in the saw-cut. It is important that you push the saw blade through the work from end to end of the blade, especially with a new blade, because the first part of the blade to wear is the sides of the set of the teeth. If you only use the centre section of the blade, and thus only wear the set off the centre section of teeth, the blade will jam in the cut when you use a longer stroke. This is the easiest way to break the blade and, for this reason, you are recommended to buy flexible blades, which have hardened teeth, but a flexible back. You should also buy 10in blades until you have mastered the full stroke of sawing with a hacksaw. Save the purchase of high-speed blades until you have gained some experience. Although High Speed Steel blades keep their sharpness for longer, they are also more brittle and liable to break in inexperienced hands.


*Hacksaws with 10 and 12in blades.*

An important point to note is that the blade should pass through the work in a straight line, without any rocking motion, as this keeps all the teeth in contact with the work and all of these teeth cutting. This may lead you to think that if the blade has fine teeth there will be more teeth, and so more cutting edges, in contact with the work and therefore cut faster. However, there must be room for the swarf (or sawdust) to collect and that is why larger teeth are used when cutting thick material. On the backstroke, keep light pressure on the blade and this will remove the swarf from between the teeth, ready for the next forward, cutting, stroke. It is also not advisable to fit a new blade partway through a cut because the set of the new blade will be wider than the width of the kerf. The blade will jam and possibly break – which is probably the reason for changing the blade when partway through a cut.

When changing a hacksaw blade, slacken the wing nut at the front end of the saw and remove the worn blade, or the one with the wrong size teeth. Determine the correct way round for the blade, with the teeth pointing away from you, and hook the hole at the near end of the blade onto the hook at the handle end of the frame. Hook the far end onto the far hook and hold the blade and hook together with the left hand. Let the whole assembly hang from your hand and the frame will be suspended from the lower hook with the wing nut free at the top. This holds everything together while you run the wing nut down the thread to the frame and tighten by two full turns.

You are now ready to use the saw, but remember to make straight cuts (without rocking) from end to end of the blade, even banging the blade hooks on opposite sides of the workpiece. This will ensure that the set is worn off the sides from end to end and prevent it jamming and breaking.

Another useful feature of the full-size hacksaw – I never had any faith in Junior hacksaws because of their weak and soft blades – is that the hooks for the ends of the blade can be turned round in increments of 90 degrees to facilitate cutting long narrow strips.

## SCRIBER

The scriber is essentially a hard, sharp point on a handle. The point may be detachable from its handle (like a pen) or one-piece. (For an illustration, *see Marking-Out Tools above*.)

## DOT-PUNCH

The dot-punch is about 100mm long and knurled in the middle to aid a firm grip. The top section may be round or square, which aids identification and stops it rolling off the bench. The other end is tapered and pointed at 60 degrees including angle. (That means it is 60 degrees from side to side or, if you like, 30 degrees from side to centre line and another 30 degrees on the other side.) This sharper point makes it easier to see the point, by tilting it over when placing it on the crossing of two scribed lines. It is then brought upright and struck with an engineer’s ball-peen (pein) hammer. Do not use a claw hammer, which is an implement for removing nails that have been bent by the other end (peen) of the hammer. A ball-peen hammer of 1lb weight is about right.

The other punch to mention is the centre-punch, which has a 90-degree angle point and is used before drilling a hole with a drill. It makes the accurate dot-punch hole a little larger in diameter to make it easier for the drill to start where you want it to start, and not wander about.

The point of a ‘jobber’s twist drill’ is not in fact a point but a chisel edge. This is what makes the initial hole and is followed by the cutting edges, which remove the metal out to the size of hole we want. These cutting edges are relieved on the front to ease cutting. This forms the helix angle (or twist), which also aids swarf removal. The opposite side of the edge also needs clearance and must not rub or the drill will not cut. This is the underneath surface, which is ground away for sharpening purposes.

## FILES

Files come in a variety of lengths, sections and cuts, or tooth size.

Most types of files are available in lengths of 4 to 14in, which is measured from the shoulder to the tip. Beyond the shoulder is the tang onto which the handle is fitted. Always fit a handle before use. Transferring handles is not satisfactory as they don’t fit properly and come loose. Picking up a file without a handle can easily cause an accident. Whenever you buy files, buy an equal number of handles to fit.

The shape or section of a file determines the work it can do. Round, square and triangular speak for themselves and are sized by their diameter, which tapers towards the point. Half-round is also obvious, although it is rather flatter than a semicircle. It is sized by its length and also tapers. So does a flat file, but this is rectangular in section. A hand file is parallel in width, but has one ‘safe’ edge without any teeth. This is used when it is needed to file a horizontal step without damaging the upright. To locate that step, the job can be positioned in the vice and the safe edge used against the side of the vice jaws without damaging the vice, the file or the workpiece.

The proportions of files are all relative to their length. The size of their teeth is also related to their length, but here it is not as simple as the size of teeth on a hacksaw blade, which are related to how many teeth there are in one inch of blade. File teeth are named: (dead-smooth), smooth, second-cut, bastard (and rough). Dead-smooth and rough are mentioned here only for completeness: it is suggested that you buy 6in half-round and flat, smooth files, 6in and 10in flat second-cut, and a 10in flat bastard (Proops). Do not forget to buy handles in appropriate sizes.

Others to mention are the pillar file, which is narrower than a hand file, and the warding file, which is thinner than a flat file and thus is very useful to have. Do not get into the habit of throwing files into a drawer where they knock and rub on each other. They are hard and will quickly blunt each other. Keep them apart, and try not to buy files that are unwrapped and have been jangled about in a drawer. It is often worth buying an extra file, say a 10in smooth, with handle, to keep for use only on brass. Paint the handle red and keep it separate from the others. Once it has been used on steel you will find it is no longer any good on brass. The only file to be used on the lathe is the mill file, which is parallel in width and thickness with rounded edges. It is only single cut, which means that the teeth run from side to side of the file. All other files are double cut, which gives them rows of teeth. The cuts are at different angles of 70 degrees one way, and 40 degrees the other.

While on the subject of files, it is worth buying a set of what are known as Swiss needle files. These come in packs of twelve different sections, some of which are peculiar to needle files, and require a special handle (Proops). If you cannot afford the set today, buy just a round needle file, often called a rat-tail file, as these are very useful for drawing a bolthole over to line it up with the hole in the next component.

*Flat files of 10in and 6in length with handles to suit.*

*Swiss needle file set.*

## ANNEALING

This means heating to dull-red heat and letting it cool slowly. Brass will show red when hot, but it should not be heated too much. Aluminium, on the other hand, does not show any indication of heat and melts at a lower temperature. To ensure that the aluminium is heated to a high enough temperature to achieve the annealing (or softening), and yet not over-heat and melt the metal, rub a bar of soap all along the surface. This line of soap will indicate the temperature by turning brown, thus ensuring that sufficient heat has been applied to anneal the metal but not enough to melt it, provided that you stop as soon as the soap turns brown. The soap plays no part in the annealing process, except as a temperature indicator.

## LATHE

One of the most important machines in the model engineer's workshop is the lathe. If you are waiting for your own to arrive, you may have access to a lathe at a school or college evening class, where you can also get help in selecting tools and speeds. This will provide a good grounding for your developing skills. You may also use the school machinery for pieces of a larger diameter, such as the flywheel, and use your small lathe at home for the small pieces.

## RIVET SNAPS

Four tools need to be made. The first is a rivet set, which has a 3/32 in hole in the end (for 3/32 in diameter rivets) and is used to bring the components to be riveted closely together. This is followed by the rivet snap, which forms the new snap head. To prevent the rivet from bending, some experts recommend the use of an extra tool before using the snap. This has a short 3/32 in hole in the end that is only 3/32 in deep. This will swell the rivet and help to keep the rivet straight, later to be formed into the snap head. The fourth tool is another snap or dolly, which preserves the original manufacturer's head. A snap intended to be hand held, as used at the top to form the snap head there, can be held tightly in the vice with its lower end resting on the vice slide. If you make your own snap, it can be short and thick and have flats filed on, before hardening, to fit between the vice jaws, with the ends of the flats resting on the top edge of the jaws.

If you make your own rivet snaps, you could use an old drill of the same diameter as the rivet head (perhaps 5/32 in) and regrind it to a hemispherical shape. This is a tricky operation and needs considerable skill to 'back-off' the cutting edges to make it cut satisfactorily.

The alternative is to use a ‘D’ bit, which is turned to 5/32 in diameter and rounded at the end. This is then filed down to a ‘D’ shape of exactly half the diameter. This is then hardened and tempered.

The other method is to secure the embryo snap vertically in the vice, heat it to red heat, place a 5/32 in ball bearing in a short hole in the end and hit it with a hammer. Wear safety goggles, do not have anyone else in the workshop when doing this – and do not expect to find the ball bearing again.

It is sometimes necessary to grind a flat on one side of a tool in order to get it close to a corner or flange.

To harden silver steel tools, heat the working end to red hot and quench in cold water. Stir the hot tool round and round in the water to keep it in contact with the cold water and prevent a sudden change in its metallurgical properties at the water level. It will now be glass hard and easily shattered. Do not try it out until it has been tempered. Polish the side of the tip with emery cloth and heat again gently at the middle of the tool, watching the tempering colours run down the polished area towards the tip: light straw, dark straw, brown, *quench*! If it gets to purple or blue, you must start the hardening again. Leave the end, which the hammer contacts, soft to stop it shattering and grind off any sign of mushrooming before the sharp edges break off and fly about. It will take a long time to get to this stage, but it is worth looking out for when using chisels and punches.

## TAPPING AID

A simple tapping aid can be made from a short length of steel or brass of ¾in diameter. It consists of a hole that is just clear of the tap and, importantly, has the end face square with the hole. The outside of the aid could be knurled to aid grip. Hold the aid flat on the workpiece. The tap will then be square to the workpiece automatically and in line with the tapping size hole.

## MARKING-OUT BLUE

Marking-out blue, often erroneously called engineer’s blue, is a thin liquid whose methylated spirit solvent evaporates off quickly, leaving a surface that shows up scribed marks.

## ENGINEER’S BLUE

Engineer’s blue is applied to a flat surface against which a component is rubbed. The high spots that receive blue indicate where the metal should be scraped off. The process is then repeated until the component is blue all over.

## OFF-HAND GRINDERS

Off-hand grinders are not expensive and are an essential part of the workshop equipment for sharpening lathe tools and drills.

It is a good idea to plug the mains lead into a four-way adapter that also supplies the bench-drill, band saw and radio. The latter will keep you company and remind you to switch off the power when you leave. The lathe should be plugged directly into the 13amp wall socket and not via any kind of adapter.


*Bench or off-hand grinder.*

## Grinding a New Tool Blank

If using a new tool blank, position it in the tool-post on the left with 1in projecting forward, away from you. The top left edge will remain untouched, but the left side needs to be ground away in a straight line at an angle of about 5 degrees, removing about 1mm from the bottom left edge for a distance of about ¾in. This is a clearance angle. A similar amount needs taking off the top to produce top rake. This will slope downwards to the right; remember that the top left edge is untouched. The front end now needs a clearance angle both to the right and downwards, making the top left corner project the furthest.

Obviously the tool will be removed from the lathe to the grinder for this operation, but it is best to describe the desired shape when in its final position in the lathe toolpost. It takes a few minutes to make this tool but only seconds to resharpen an established shape. When it becomes necessary to sharpen any lathe tool, only grind metal from the front face, maintaining the established angles, of course. This keeps the cutting edge close to the same level and thus the same packing can be used. Another tool shape can be ground on the other end of the blank.

## STUDS

The cylinder covers at each end of a steam cylinder, or the cylinder head of an automotive engine cylinder block, are usually secured by studs and nuts. Studs should have a thread on each end and a plain section in the centre. This gives the opportunity to have a coarse thread at the end that screws into the cast iron cylinder and a fine thread for the nut to tighten down the head more tightly than a coarse thread would do. Studs are screwed into the cylinder by locking two nuts together on the outer end and screwing the stud in up to the plain part of the stud.

Our studs will be cut from continuous lengths of studding, known in America as ‘all thread’. These are screwed in right down to the end of the tapped hole. Sometimes it is necessary to apply a Nutloc or Studloc compound to the stud to prevent it from unscrewing when dismantling, especially after the engine has been painted.

When fitting studs, fit one only and check that the cover slides on without binding. Correct if necessary. Now fit one on the far side and check for clearance. If it does bind it must be the last one to be fitted. Proceed one at a time and correct as you go. If you were to fit all the studs together, how would you know which ones are at fault if the cover does not fit?

## KEYS

Keys are used to provide a positive drive between a shaft and a wheel. There are three types.

A Woodruff key is semicircular in section and fits into a semicircular keyway in a shaft, which is often tapered. A Woodruff cutter is used to cut the keyway.

A sunk-key is rectangular in section, usually with rounded ends to fit a keyway that is milled to half depth with a slot drill. It should fit the width of the keyway and be clear top to bottom.

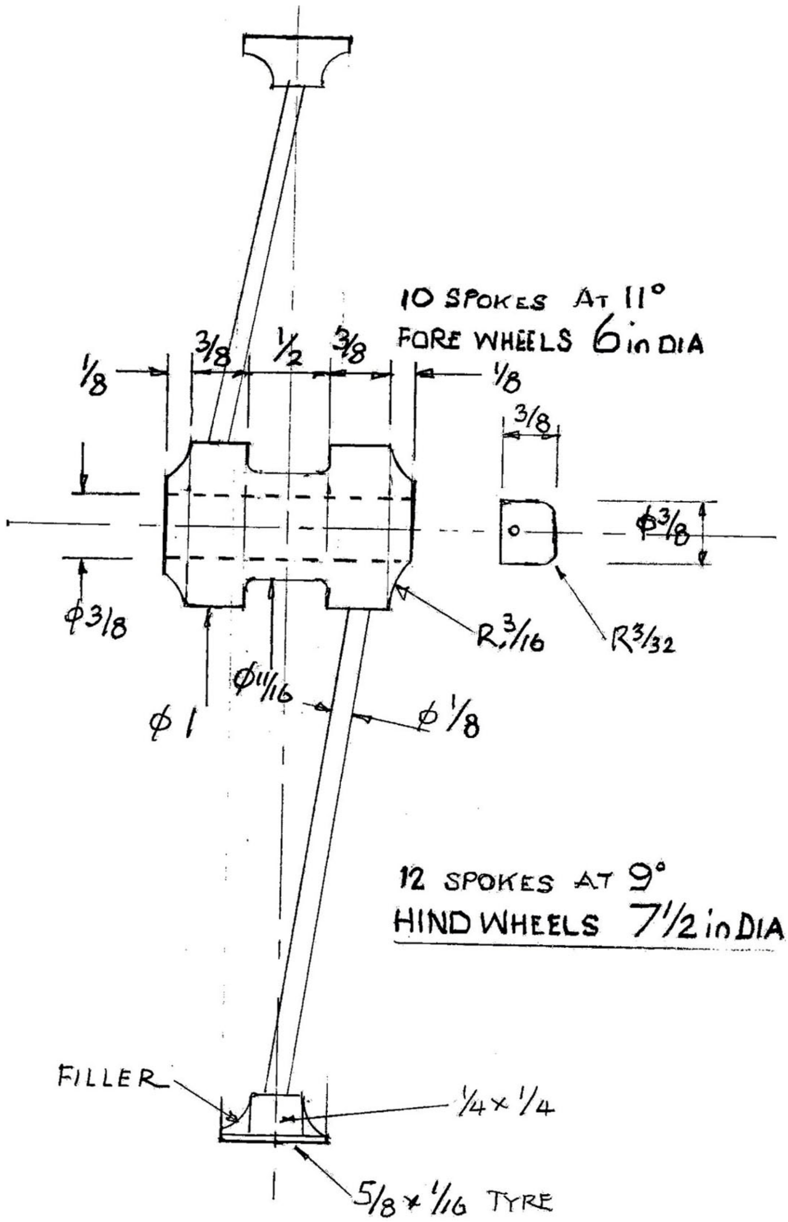
A gib-head key is tapered (1 in 100) along its length and has a head to aid removal. It is clear at the sides and fits top to bottom. It is driven into the keyway and removed to inspect the marks on the key. These are filed off before trying again. This adjusts the fit of the taper and the process is repeated until the head is ¼in (full size) from the wheel. A well-fitting gib-key will prevent the wheel from moving along the shaft. A cold chisel, or crosscut chisel, is used to remove a gibhead key.

# *3 Wheels*

The method of making the wheels chosen by Lampitts for their portable engines was to use round spokes, which were cast into the rim as well as the hub. The big problem facing the skilled foundry men was to allow for the contraction of the wheel rim as the metal cooled. This probably meant letting the rim cool down, possibly overnight, before pouring the metal into the mould for the hub.

When you have a foundry at your disposal, you use it in every way possible. This also makes it feasible to use round spokes, which would otherwise require several other processes to make use of round spokes.

Our version of these wheels will have a tee section rim, where the upright of the tee is very thick and the round spokes pass through at an angle. This enables them to line up with threaded holes in the hubs. All these holes must be at a slight angle and the fore and hind wheels will be at a different angle. The clearance holes in the rims will be drilled on the centre line of the inside face and alternate in direction.




**Drawing 001 fore and hind wheels.**

## WHEEL RIMS

It will be easier to mark and centre-punch the hole positions before bending the ¼in square material around a former. It is usually not advisable to drill any holes before bending, because the bend will take place at the weakest point (where the holes are situated).

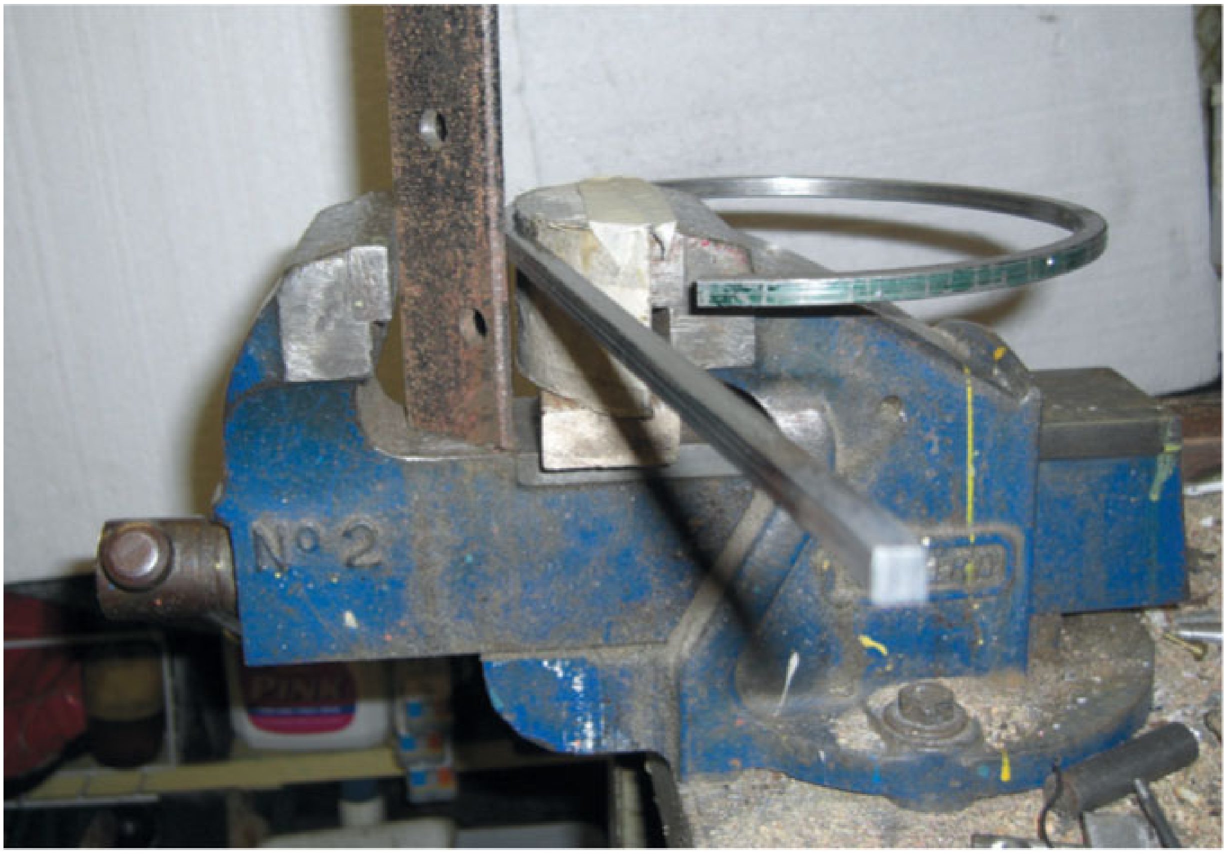
Obtain four lengths of ¼in (or 6mm) square steel, 24in long. If you are collecting this from your supplier it would perhaps be better to get two 48in lengths. The circumference of the larger wheels is almost two feet, which would make it difficult to bend to the end of the bar. The same amount of 5/8 × 1/16 in steel can be bought at the same time.

Clean off the oil and apply marking-out blue or felt-tip pen to one side of the square. Using odd-leg (or hermaphrodite) callipers, mark two centre lines along the full length of the bar. These need to be 1/16 in from each side, but you will find it almost impossible to scribe a line so close to the edge with odd-leg callipers. The solution is to mark 3/16 in from each side, which will give the same result. The large wheels will have twelve spokes at 17/8 in centres. From the end of the square bar, measure ½in to the starting point and a further 1in to the first spoke hole. Mark this point with a dot punch on the left centre line of the bar. Set your dividers to 17/8 in and mark another eleven spoke positions along the bar. This is followed by 7/8 in to the end point, which should complete the circumference. Do not cut it off yet. Check and double check that you have twelve spoke positions, which can now be dot punched alternately along the left and right centre lines. There should be 1in (plus a bit) at one end and 7/8 in (plus a bit) at the other. The aim is to drill holes for the spokes that arrive on the inside of the rim, on the centre line of the rim.

## Bending the Rims

You will need a short length, about 4in, of 1½in or 2in (40 or 50mm) angle steel. You will also need a similar length of thick wall steel tube, or solid bar. The bar will push the square rim section into the angle iron to make a curve. The ‘plus a bit’ extra length at each end of the ¼in square bar is needed because it is difficult to bend right up to the end. Make sure that the dot punch marks are on the outside of the rim.

A slice of cake, or the part of an orange we call a segment, is actually a sector: the area between two radii and an arc. A segment is the area between a chord and an arc, or the near circumference. (If a chord passes through the centre of a circle it is a diameter, and the two halves are semicircles, or hemispheres in 3D.)

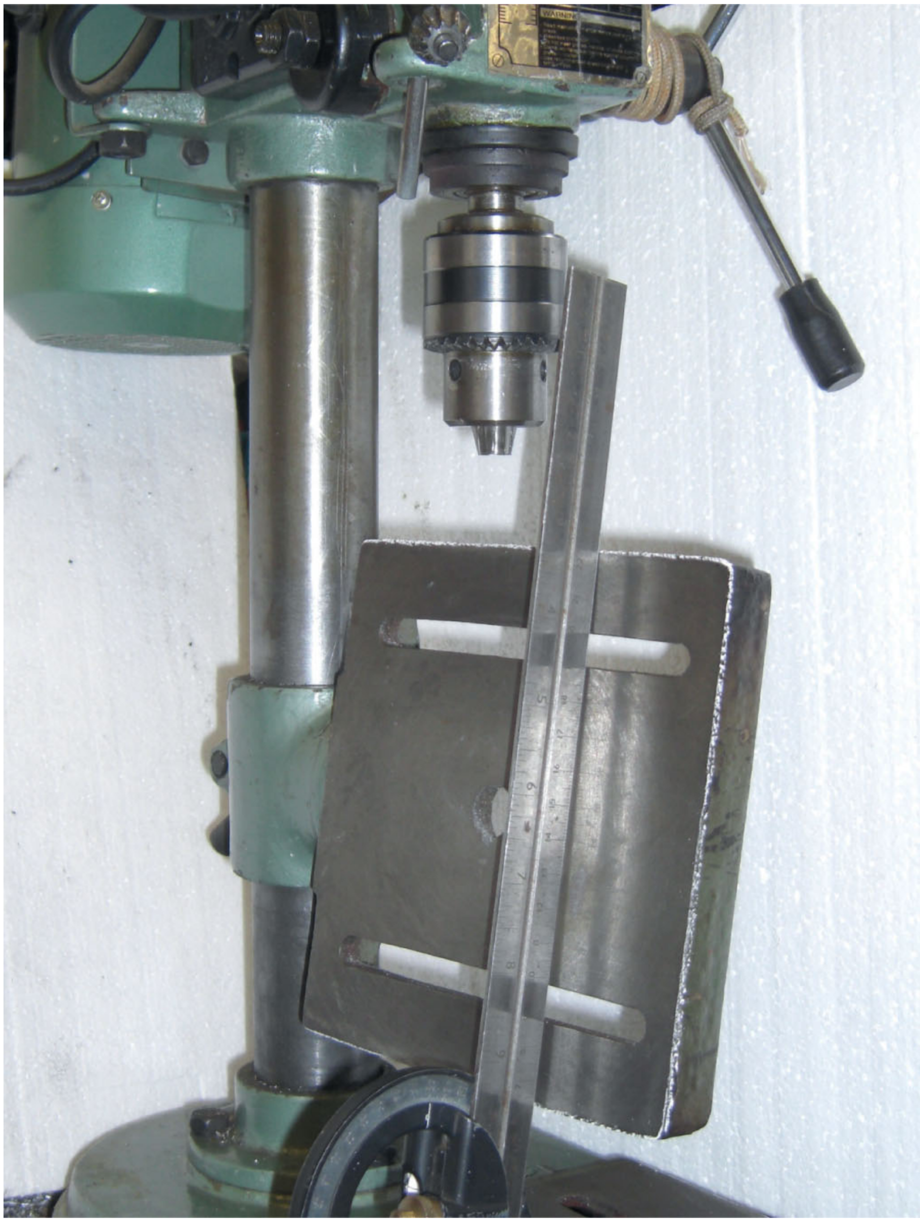



*Bending the square steel for the wheel rim.*

When you are satisfied that you have a reasonable circle, especially at the ends, cut the surplus off at both ends. The distance between the adjacent dot punch marks should be 17/8 in. File the ends square so that they meet tidily. Flux the ends and silver solder the ends together. You should now be able to dress the rim into an accurate circle, while making sure that it is flat.

The spokes scale at a diameter of 3mm, but 3.5mm could be used or 1/8 in or 10swg fence wire, if you can straighten it. The ribs of the umbrellas used to advertise beer outside public houses are usually 3.5mm diameter. Golf umbrella ribs have a ‘U’ section and are not suited to our purposes.

The holes in the rims can now be drilled. Drill all those that are on the left centre line at a 9-degree angle to arrive at the centre of the other side. Then turn the rim round and drill the others. Some bench drilling machines have a tilting table, which will aid the setting of the angle. This may be off the scale of the tilt table, so use a protractor from the base:a school protractor and a 12in rule may be enough. The angle for the large wheels will be 9 degrees; and for the small wheels 11 degrees.



*Setting the angle to drill the spoke holes in the rim.*

*Drilling the spoke holes in the rim.*

## Materials

It is important that, whichever material you choose to use, the whole wheel should be made from the same material. The only exception to this rule would be to use cast iron for the hub of an otherwise steel wheel. A steel hub would need a bearing bush to be pressed in, as would aluminium. Brass, although not ideal as a bearing material, could be used for the hub and cast iron makes a good bearing material. Cast iron is also very easy to tap, or thread, the holes for the spokes.

Both edges of all four tyres will need drawfiling. If you have cut these pieces with a hacksaw they will need some cross-filing in the ordinary way to achieve a straight edge before draw filing.

The round bar and angle bending tools will be needed again in the vice to form the tyre material into a circle. You may need to use a smaller diameter 'tool' as you will find the drawn bar quite springy. Again it will be necessary to discard the end bits after bending

Find or purchase two or three worm-drive hose clips of the same make and size, connect them together and use them to close the tyre around the wheel. The butt joint should have a gap of 1mm. Gradually cut more off until this is achieved, while making sure that the two ends are filed smooth, square and parallel, and that they are deburred. Dismantle and silver solder the ends together without attaching it to the clip. This can be helped by painting Tippex correction fluid onto the clip or sandwiching fibreglass tape between.

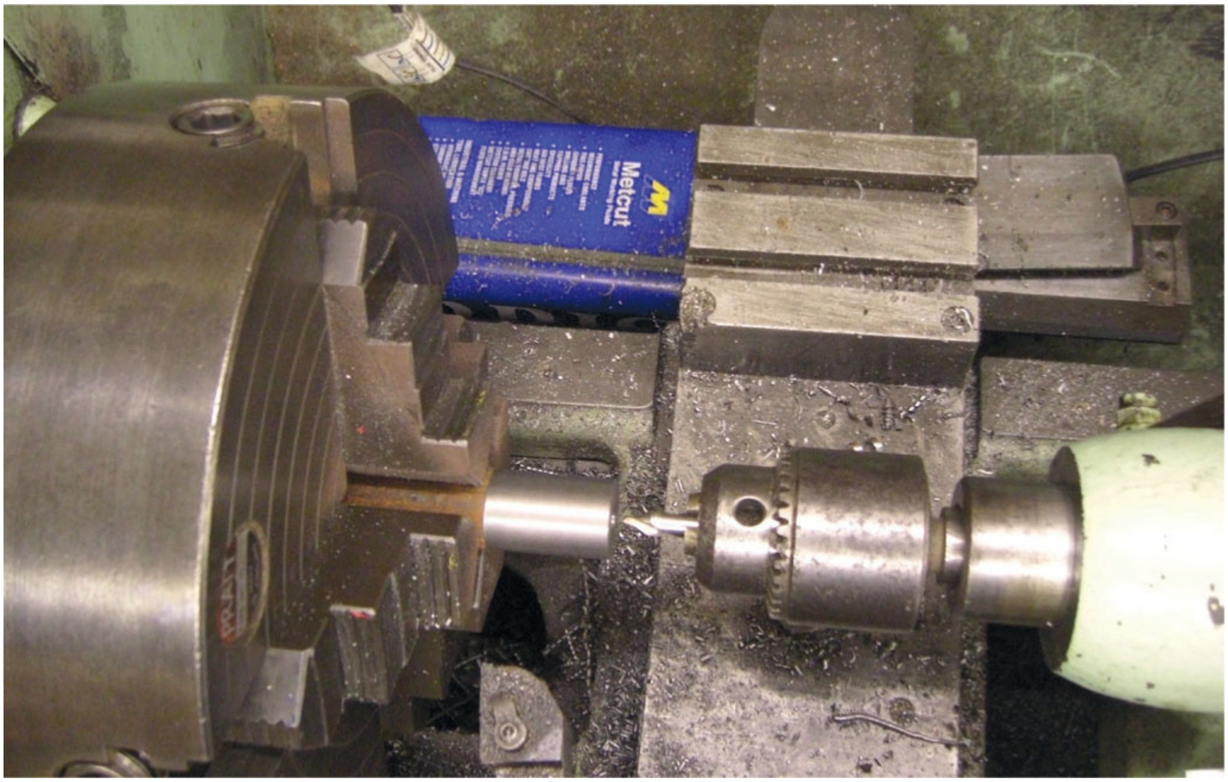
## HUBS

If you have already set up your lathe, I would suggest that you next turn the wheel hubs (or centres). There are several books available on the subject of basic lathe turning. Some of these are written around a specific type or make of lathe, and yours may be one of these. It is often of benefit to read descriptions of a process by two different authors, as one may gloss over some aspect that the other is more helpful in explaining.

Having decided on the material for the hubs, it is now time to make them. If this is your first attempt at turning, you will generally find that it is not good practice to grip rough castings, especially in iron, in the three-jaw chuck. Rough treatment like this is not good for the longevity of its accuracy. The round cast iron bar, or stick, of the size we need here is usually 'proof turned' to enable the manufacturer to examine the surface under the skin before supplying it to customers. The surface thus produced will not harm your chuck, nor will carbide-tipped tools be essential to turn it as the hard skin will have been removed.

The three-jaw chuck will be needed later. With the inside jaws fitted, grip the metal bar with about 1½in protruding and use a round-nose tool to face off the end of the bar using a slow, smooth forward feed on the cross-slide. Use the carriage lock.

When buying drills, a centre drill with a ¼in or 5/16 in diameter (S3 or S4) is a good choice. We have already said that a centre-punch is used to make sure that a drill starts where you want it. Here in the lathe, the use of a short and thick centre drill means that it does not wander away from the centre of the lathe when making the start of a hole. Grip the centre-drill in the tailstock chuck and, using a fairly high speed, drill in to almost its own diameter by turning the tail-stock hand wheel. Always slide the tailstock up to the carriage (or saddle), thus restricting the amount of tailstock barrel exposed. This keeps it rigid. Drill in for about 1¼in at about 3/16 in diameter or 5mm. Steel and aluminium hubs will need Oilite bushes and should be bored to ½in. Brass or cast iron hubs will be bored to 3/8 in diameter. You will find that brass grabs the drill and pulls itself in, especially when using new drills. To avoid this, omit the 3/16 in drill and go straight in with the bigger drill.




*Using a centre drill before drilling the hub.*

It is most likely that the drill will make an over-size hole, so only drill to a slightly smaller size and bore out the hole to the correct size. This will also ensure that the hole, or ‘bore’, is exactly concentric with the outside surface.

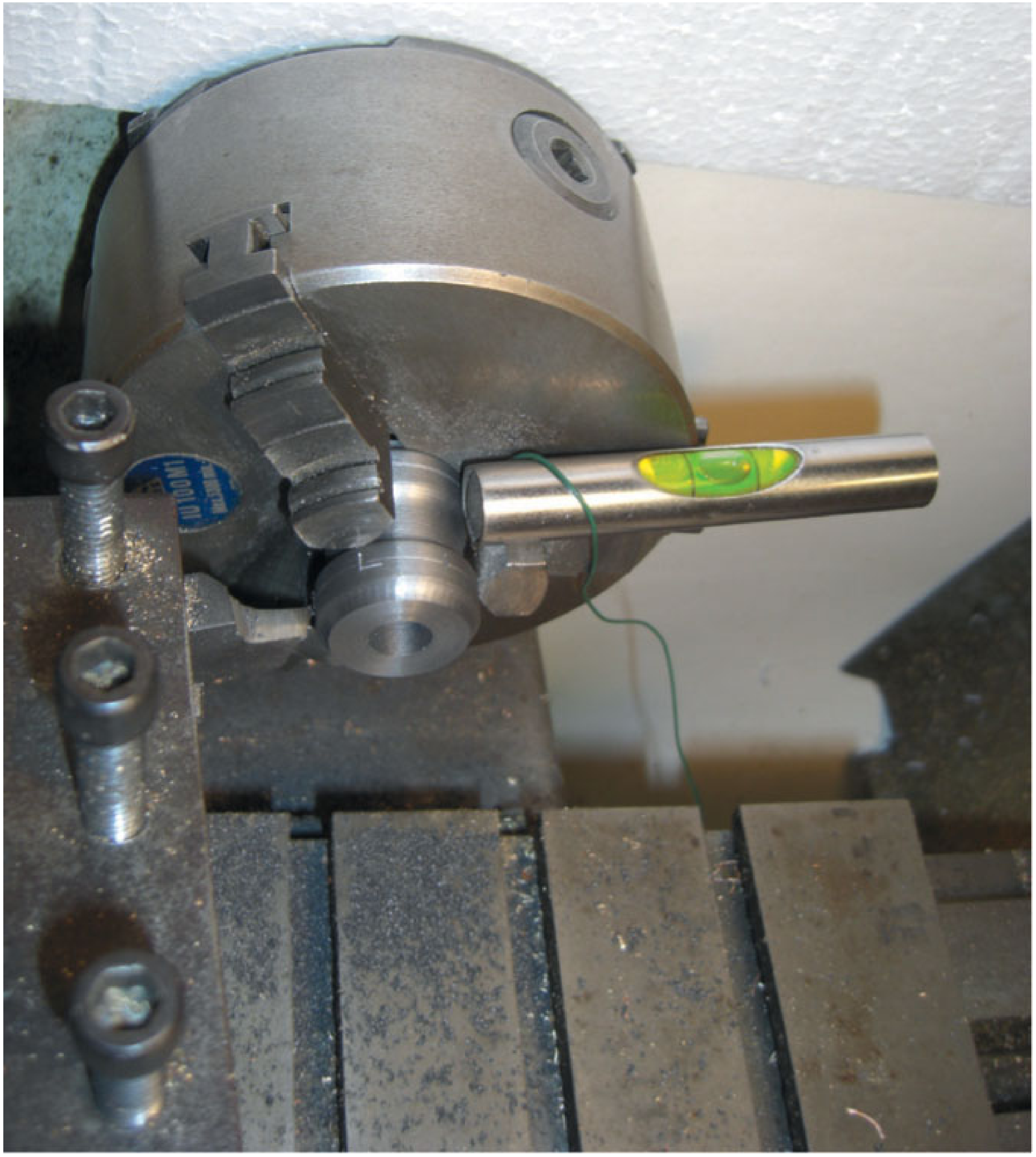
The outside of the hub needs the diameter relieving in the middle. The outside diameter can be skimmed, or a very little turned off to make it smooth and concentric, by using a round-nosed tool and feeding it slowly and smoothly from right to left. Use the slowest auto feed.

With the lathe stopped, use a scriber to make four marks at 1/8, 3/8, ¾ and 1in from the end of the bar. (A fifth mark at 13/16 in will be used later.) A chalk line along the length of the hub will show up the scribed lines better. A black felt-tip pen will do the same. The diameter between the second and third marks needs reducing to 7/8 in diameter.

The depth of cut depends on the rigidity of your lathe, but a 20 thou cut will reduce the diameter by 40 thou, so three cuts will do nicely. A metric lathe has direct reading dials, so you can advance the dial by the amount that you want to remove from the diameter. The 1/8 in length at each end is turned with a round-nose tool to form a concave feature.

The diameter can be measured directly with a micrometer, or dial or digital callipers, or by comparing it to a rule by transferring the measurement using outside callipers. Dial and digital callipers have the advantage that they will measure accurately up to 6in (150mm). A micrometer only measures over a range of 1in (25mm), but a micrometer is easier to use and thus more accurate in inexperienced hands. It is important that dial, or digital, callipers are used ‘square’ to the job, which is sometimes difficult on a lathe. A micrometer, with its wider measuring faces, pulls itself ‘square’ automatically. You should only ever attempt to measure when the lathe is stationary.

The inner and outer edges of the large diameter parts need to be rounded slightly and a scratch mark made in the middle of each part of the hub’s largest diameter, using a pointed tool. This tool is also used to make a scratch mark lengthways across one side of the hub by locating the chuck jaws with a spirit level, both on the near side and then the far side of the chuck. This piece can now be parted off at the fifth mark, leaving a little spare to face off later. You may prefer to take the piece off with a hacksaw and face it up in the lathe in a second operation. You could use the hacksaw in the stationary lathe, not forgetting the wooden chuck board, or in the vice on the bench. Three more hubs will then be needed.



*Dividing by six, using a spirit level on the chuck jaws.*

When drilling through a job like this, it is good practice to drill only to a depth equal to the length of the component plus the width of the parting tool. The next component, especially if the bar of metal has been moved up in the chuck, is then centre drilled before drilling, turning and parting off. The reason for this is to make sure that the drill starts exactly on centre each time. If the drill runs out, even very slightly, and the previous hole is followed, the next component will start slightly off-centre and each component will multiply the error.

*Drilling the spoke holes at an angle.*

When all four have been made they can be gripped in the three-jaw chuck, the other way round, and faced off across the sawn face, back to dimension. If the first operation was completed in the four-jaw chuck, the process of dividing, to mark the six hole positions, could be completed in the three-jaw chuck when the cut end is faced off smooth.

The only type of file to use when deburring or rounding off a corner, when working on the lathe, is a mill file, because it is ‘single cut’. Hold the handle in the right hand and grip the far end with the thumb and first two fingers of the left hand. With the left sleeve rolled up and the elbow held high over the chuck, file in a forward direction. Always keep the file moving forwards and brace yourself against the lathe cabinet or bench. Watch out for the left sleeve catching on the chuck jaws. Keep the mill file under the lathe where it is ready for instant use. Left-handed people have an advantage here, as they work clear of the chuck.

This has produced a hub with the positions of the six spokes on one side of the hub. The other six spokes will be between these and need to be marked and dot-punched. Rest the hub in a short length of aluminium angle cradled in the vice jaws. To mark the holes on the other side of the hub, place the point of your scriber between two dot-punch marks and transfer to the other side guided by the inside edge of the blade of an engineer's square, holding the inside edge of the stock (thick part) against the flat end of the hub. The other two hubs will have five holes in each half and these will need to be spaced out using dividers.

Do not forget that these holes will be tapping size for M3.5 or 4BA, whichever you have chosen for the spokes. They will also be at an angle of 9 degrees for twelve holes or 11 degrees for ten holes. This can be achieved by using the tilting drill table or a wooden wedge. If you have a 'V' block, this can be clamped to the drill table ensuring that the drill is in line with the bottom of the 'V'. Make sure that the angle you are drilling, either 9 or 11 degrees, is the right way round.

Carefully tap these holes with your chosen thread.

## WHEEL ASSEMBLY

### Full-Size Cast Iron Hubs

We are trying to replicate, in miniature, the spokes entering a cast iron hub. The original method used to make the wheels for traction engines, portables and a host of agricultural machines was to rivet the flat spokes to the rim and place the inner ends of the spokes into notches in special moulding boxes. Molten iron was then poured into the mould to surround the spoke ends and make the wheel complete and integral. Some makers punched or split the end of the spoke to make it key into the iron. This made it more secure, with the spokes crisp and sharp, and the visible part straight.

Here we are using round spokes that pass straight through the rim and are screwed into tapped holes in the hub. As the spokes need to turn, it is necessary for all the holes to be drilled at a slight angle.

*Truing dummy axle on assembly jig.*

## Wheel Assembly Jig

Now we come to assembling our wheels, which must be round, concentric and run true. The first essential is to ensure that the rims are truly circular by measuring the diameter in several places. The only way of ensuring this is to use a building jig. This consists of a flat board (ply, chipboard or MDF), slightly bigger than the larger wheel and at least ¾in (20mm) thick, with a dummy axle projecting vertically from the centre of the board. This axle must be 'square' to the surface of the board in all directions.

Make the axle first, about 2½in long and tapered a little (5 degrees for ½in) at one end. A 3/8 in hole at the centre of the board must be square to the surface of the board. To achieve this, bolt the board to the faceplate, When using a centre drill, you should first use a compass to draw two concentric circles of 7½in and 6in diameter, that is the same diameter as the wheels. Having established the radius, it would be more accurate to hold a pencil against the tool post and rotate the faceplate by hand to draw a circle on the board. Drill through with a 3/8 in drill. It may be possible to use the four-jaw chuck, but it is unlikely to be big enough.

However you hold the board, after the 3/8 in hole has been drilled, remove the 3/8 in drill from the tailstock drill chuck and replace it with the dummy axle. With the tapered end exposed, push the tailstock along the bed of the lathe to insert the axle into the hole in the board. It may be necessary to clamp the tailstock and wind the barrel forwards to insert the axle fully with the tapered section right through.

If your lathe is not big enough, you may have to do the drilling on the bench drill and fit the axle in place using the drill chuck to align the dummy axle. Make sure that the hole in the table is in line with the drill before you start drilling. It is important to use the chuck to insert the axle into the hole (with the drill not rotating) to ensure that it is kept as square as possible to the surface of the board.

It may be handy to grip the tapered part of the axle in the vice as a useful way of supporting the wheel jig while assembling the wheels.

The large board, shown opposite, in the four-jaw chuck of a large lathe was made for traction engine wheels. The dummy axle is being turned down to 3/8 in diameter for this job. This ensures that the dummy axle is square and true to the surface of the board. This oversize dummy axle was welded to a plate, which is screwed to the underside of the board.

## Spokes

Spokes are cut over-length from 3mm diameter steel rod and threaded M3 or 6BA. (If using 3.5mm diameter bar, this would be M3.5 or 4BA.) It is important that the whole of the thread is screwed into the hub and no evidence of the thread is seen. If the spoke cannot be screwed into the hub sufficiently, it should be removed and a little filed off the end. The part of the spoke projecting outside the rim is used to turn the spoke with pliers. Do not be tempted to use the main length of spoke as any damage will be seen. The outer ends of the spokes are sawn off and filed flush before the tyre is shrunk on.

## Assembly

Starting with one of the larger wheels, place a six-hole hub on the (dummy) axle and one of the larger rims on the board, making use of the pencil circle to get it as concentric as possible. Depending on the final diameters of the pencil circle and the rim, these should coincide. As the hub is 1 3/16 in long and the rim is only ¼in wide, the rim will need spacing away from the board. About eight spacers will be needed: these can be hexagon nuts or you can make pieces of bar or tube, parted off at equal lengths. The rim is fastened down to the board by a circle of 1¼in woodscrews. About eight will be needed, plus one or two extra either side of the join in the rim. Drill 1/16 in diameter holes in a circle just outside the rim and insert the screws. Countersunk screws will hold the rim down and, if tightened more, will press inwards and help centralize the rim. Use inside callipers to check the distance from the inner edge of the rim to the axle. Get it as true and round as you can by tightening or slackening the screws.

*Assembled wheel.*

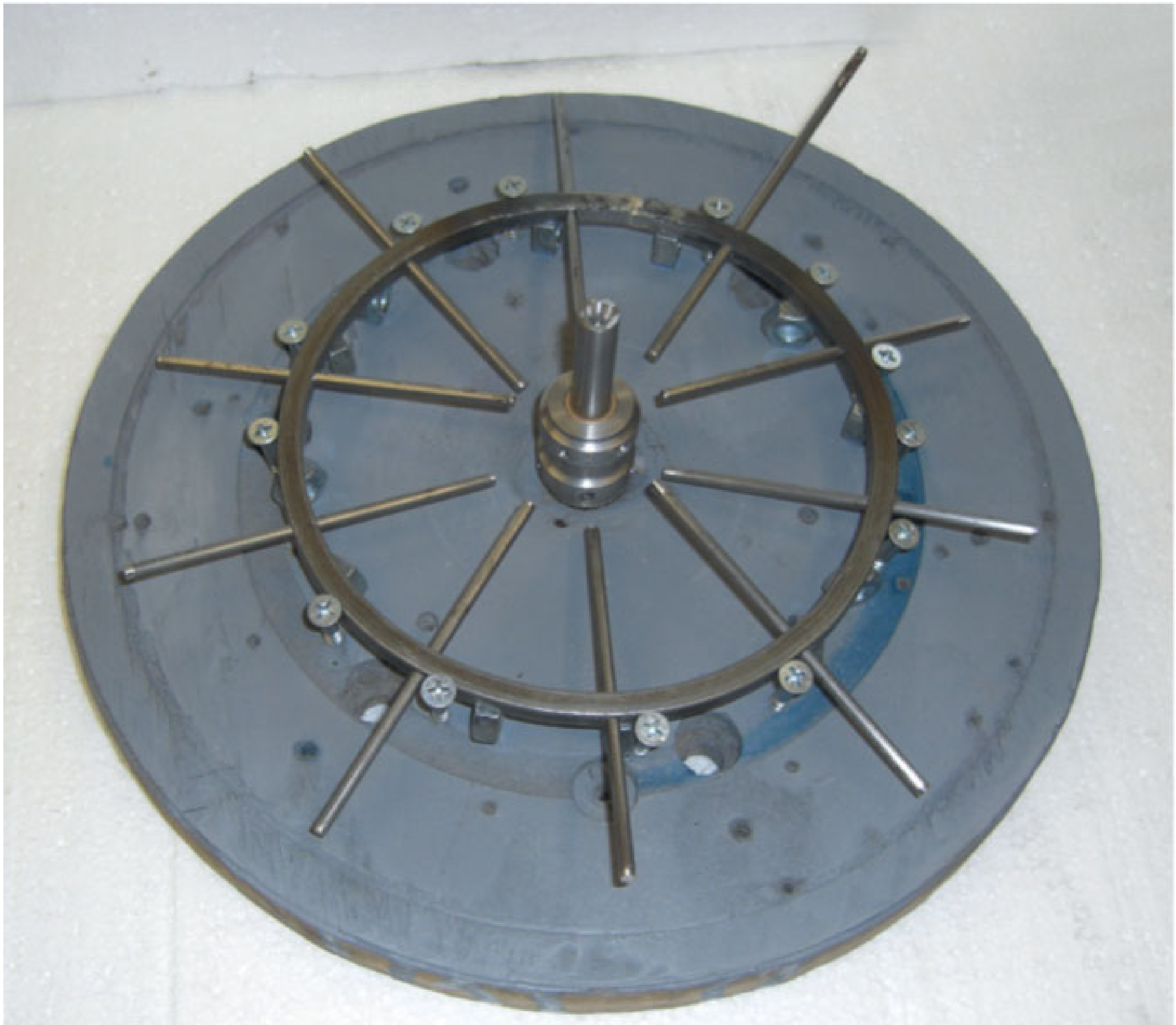
Using a pencil, mark every other spoke position around the rim of the board, using the twelve holes in the rim to guide you. Identify the direction in which these holes are angled and align the holes in the hub with the same angle. If the hub is not a good fit on the axle, it could be held close to the hub by a woodscrew and washer, clamping it down to the baseboard. If this tilts it slightly, use two screws.

Insert the screwed end of a spoke through the rim and into the tapped hole in the hub. Provided the holes in both the rim and the hub have their holes angled in the right direction, the spoke should screw in without difficulty. Screw the spoke in to the end of the thread using pliers on the over-length outside the rim. The next spoke to fit should be the one placed opposite on the clock face: 12, 6, 9 and 3 o'clock, and so on.

Please note that nuts are not fitted on the spokes, as are used on some American engines.

*Checking rim is concentric to dummy axle.*

*Rim spaced from jig.*



*Putting the spokes in place.*

*Screwing in the spokes.*

## Alternative Construction

There is an alternative way of assembling the wheels that does not require any threading. All holes are drilled to clearance size (3.1 or 3.6mm diameter) and angled correctly. After fitting the hub to the dummy axle, screw down the rim and check that it is concentric. The spokes are then put in place through the rim. Before finally inserting the spokes into the holes in the hub, place a blob of Loctite 601 retainer on the tip and the area where they will enter the rim. Each spoke is immediately assembled and the whole assembly left overnight to cure. The over-length outside the rim is sawn off and filed flush.

## TYRES

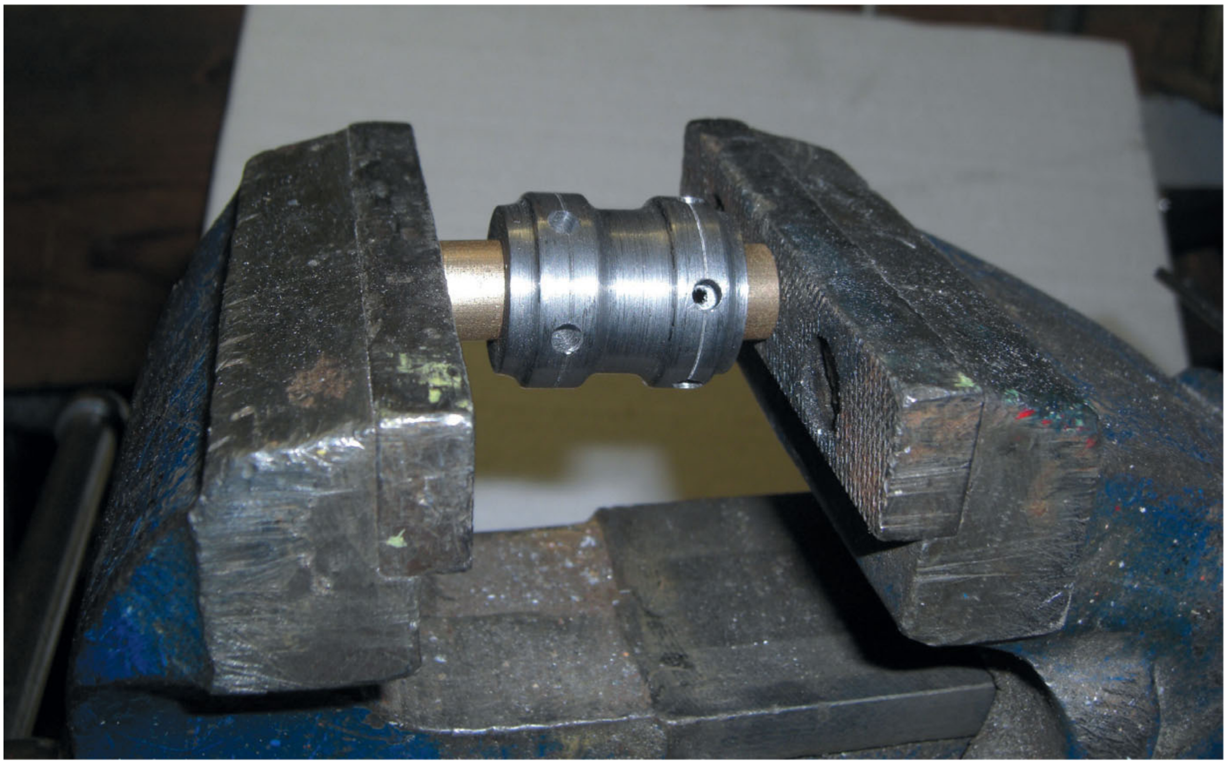
All wheels will have steel tyres fitted. These are heated and shrunk on. The material for the tyres can be obtained as 5/8 × 1/16 in flat, or guillotined from 1/16 in, 16swg or 1.5mm thick sheet steel. Otherwise you will have to spend some time cutting it down from the sheet with a hacksaw. Make sure that you start each cut with the blade cutting exactly in the right direction. This sounds obvious, but it is very easy to start cutting in slightly the wrong direction and it can be very difficult to correct. A new hacksaw blade will cut a kerf that is slightly wider than the thickness of the blade. This allows you to steer a straight line, provided that you have started off in the correct direction in the first place.

You will need four pieces, each 2ft long. The cut edges will need to be draw filed to a smooth finish to disguise their method of cutting. Make a pair of soft jaws by cutting two pieces of 1 × 1in aluminium angle a little longer than the width of your vice jaws. This will stop the knurled faces of the vice jaws from marking the workpiece.

Car body filler is spread around the rim-totyre junction on both sides and shaped with the rounded corner of the plastic spreader.

Oilite bushes are pressed into steel hubs.

*Car body filler applied and smoothed to shape with rounded corner of plastic card.*



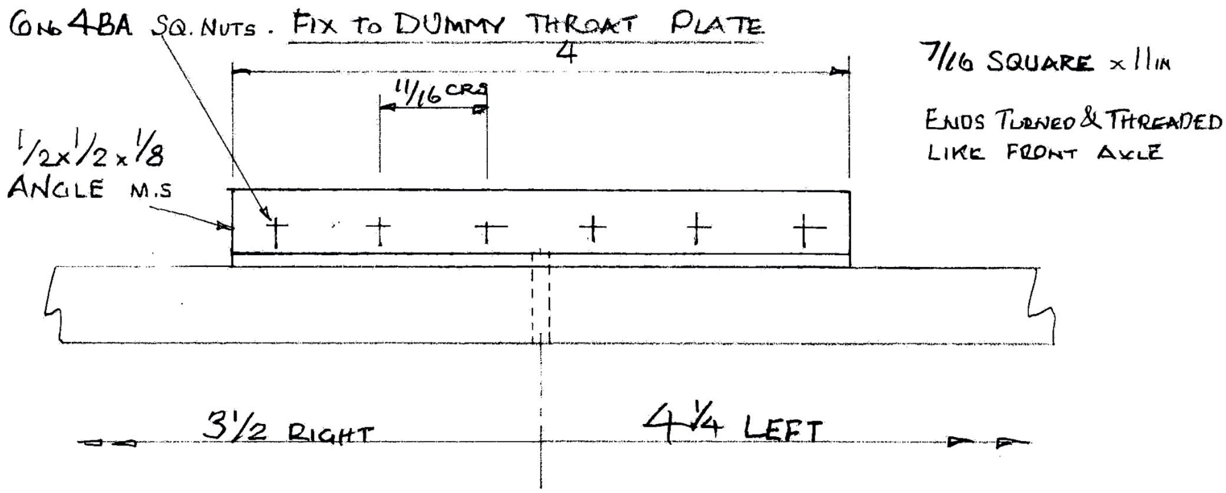
*Pressing Oilite bushes into steel hub.*

# 4 Axles and Perch Bracket

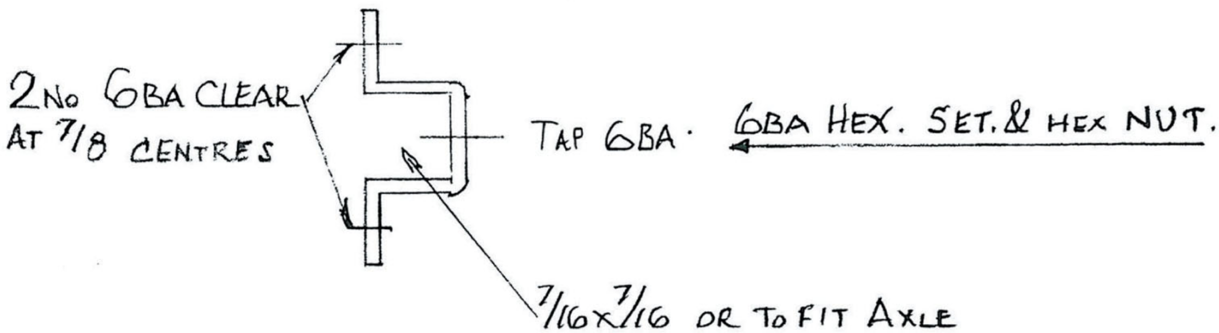
## HIND AXLE

The firebox of this boiler is very short and this makes it possible for the axle to be straight and to lie across the front of the throat plate. Most later portables had a longer firebox and the axle was bent around the front of the firebox, sometimes underneath. Stub axles were sometimes riveted to the side of the firebox. In the example shown here the boiler is supported on a length of angle steel, which is bolted to the throat plate with six bolts with square nuts and clamped in position with substantial square clamps, through which there are clamp screws with locknuts. In the centre there is a vertical bolt, which secures the perch bracket stay. Note that the boiler is offset on the axles, which makes sure that the drive belt from the flywheel is clear of the wheels.

On our model, all this will be fixed to a dummy throat plate to avoid making too many holes in the boiler itself. The dummy throat plate is made from 1.5 or 2mm thick steel sheet, the thicker the better, because it will be fixed to the hornplates by 8BA round head screws, the heads of which are similar to the 3/32 in diameter rivets in the alternate holes. A thinner piece of steel will require a thickening piece to provide enough thread to make the 8BA screws secure. Rivet a piece of steel or brass to the inside of the flange, on each side, and secure with a couple of rivets each. Drill the tapping size holes from the hornplates and open out the holes in the hornplate to clearance size. The 3/32 in holes in between are drilled and countersunk on the inside and short snap-head rivets hammered into the countersinks, making sure that they do not project above the face of the hornplate inside face.

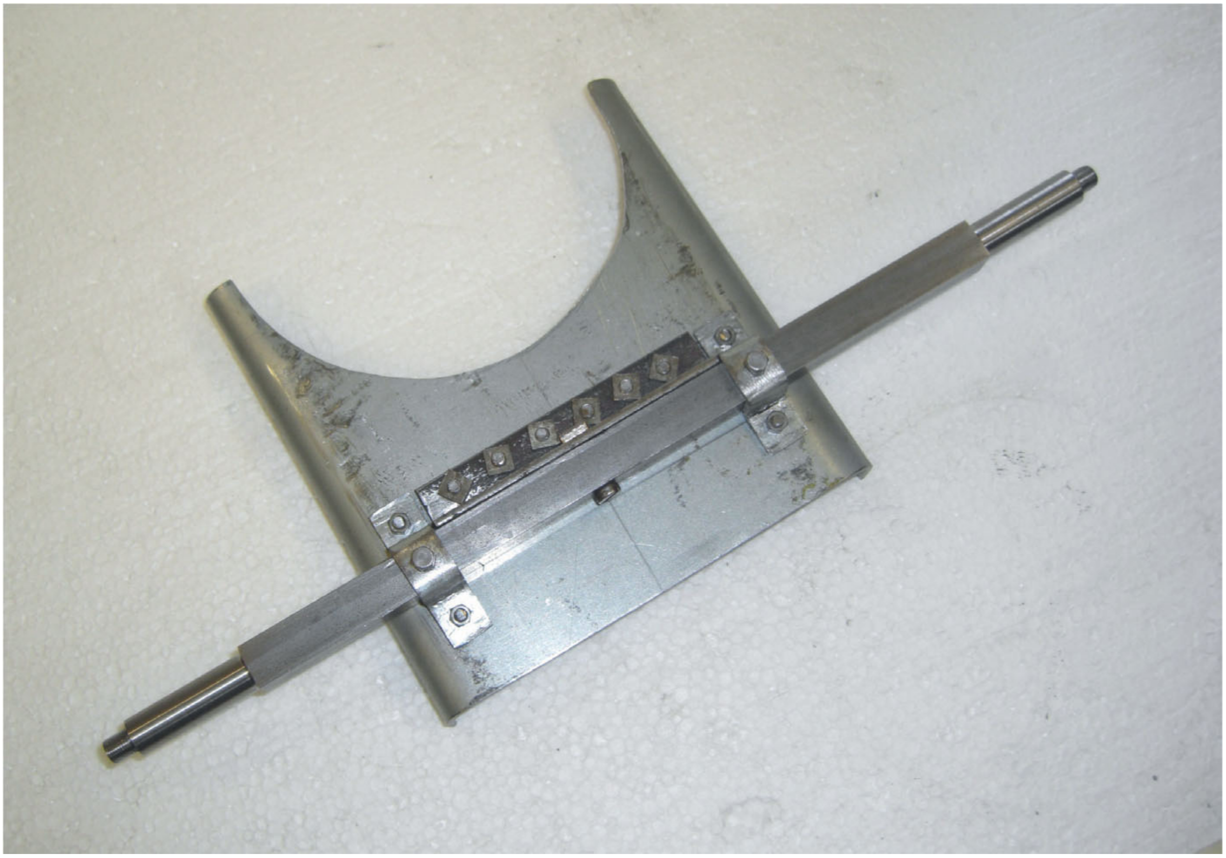



**Drawing 002 Rear Axle Steel 1 off**




**Drawing 003 3/32 × 5/16 or 2 × 8mm Steel Rear Axle Clamp 2 off**

*Rear axle support angle on throat plate.*



*Rear axle clamped to throat plate.*

## HORNPLATES

On a full-size traction engine the hornplate is an upward and rearward extension of the outer firebox side plates, to which the bearings for the crankshaft, rear axle and the intermediate shafts, as well as the tender side plates, are bolted or riveted. The hornplate, invented by Thomas Aveling in 1860, was such a good idea that every traction engine builder wanted to copy it, but Aveling jealously guarded his patent.

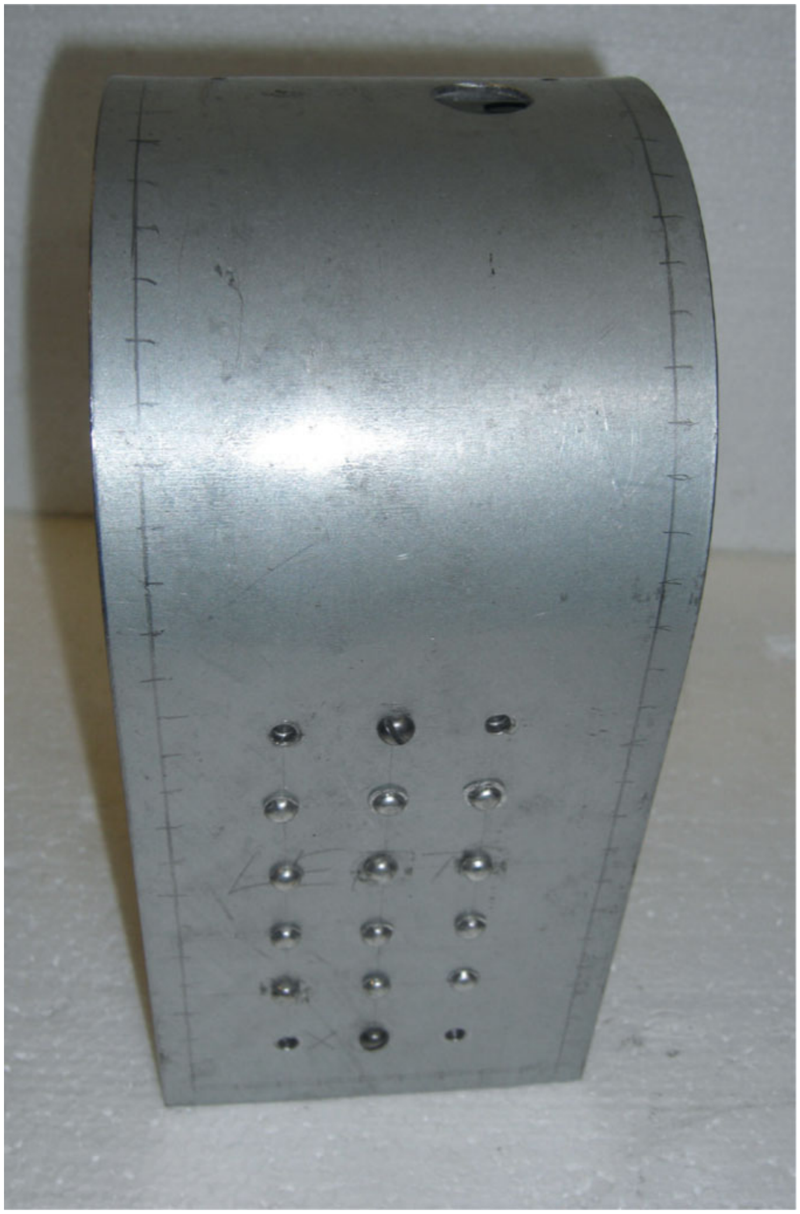
In the model world separate flat horn-plates are attached to the firebox sides by securing them to special blind threaded stays in the firebox sides. In our case we will use a straight-topped boiler and represent the raised firebox with a dummy outer firebox. This reduces the number of bolt holes needed in the boiler (and so the number of potential leaks). It consists of a hornplate that goes over the top and fixes to both sides of the firebox.

The back has a dummy door-plate flanged and riveted to the back edge of the hornplate. The front has a flanged and riveted top half, but the bottom half is secured on each side by five no. 8BA round-headed screws inserted through the front edge of the hornplate, as described above. This plate has to be detachable in order to assemble the engine.

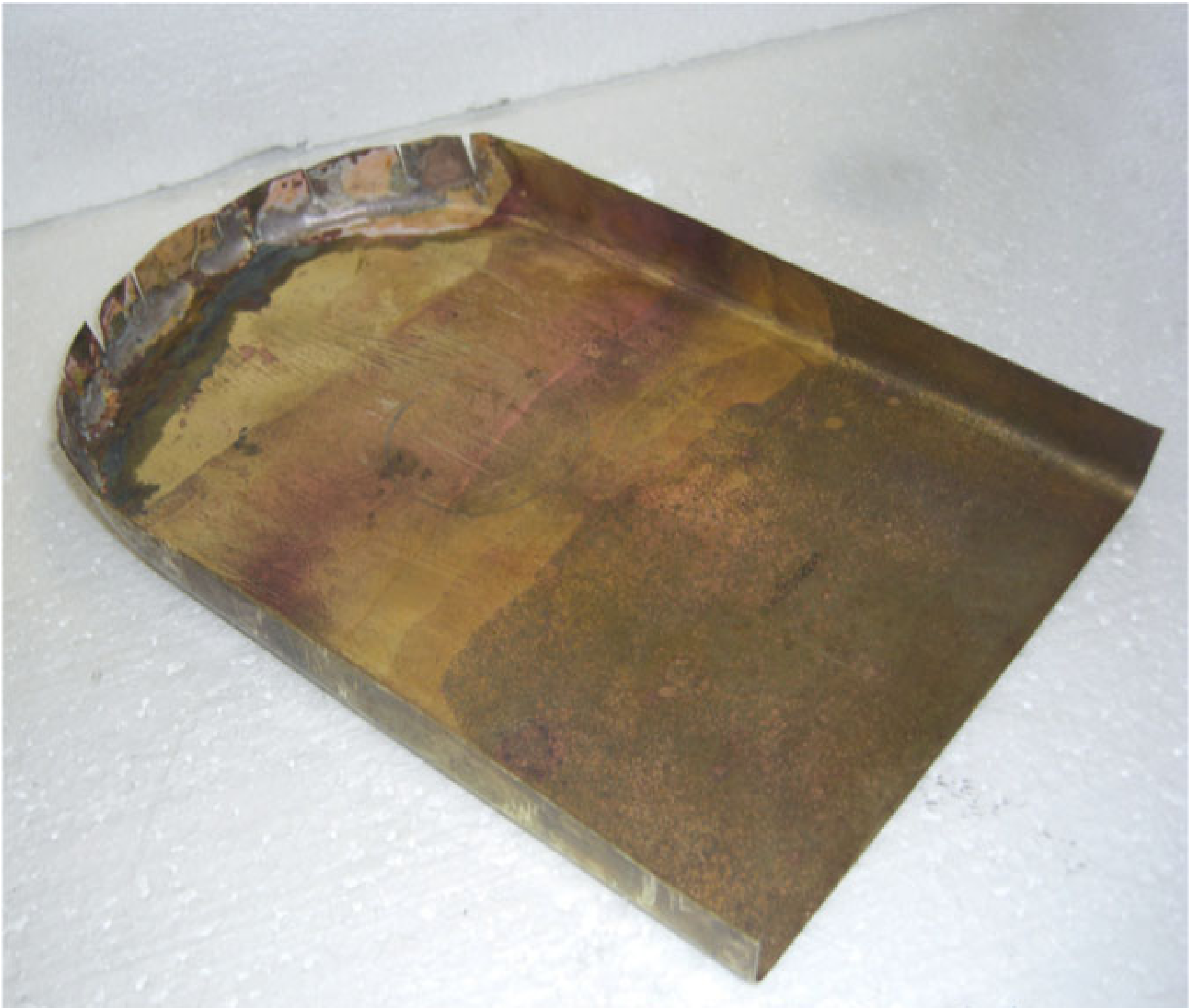
The cylinder is bolted to the hornplate top with four screws, which are screwed in from inside. It may be desirable to use Allan cap head screws, which are very strong, as their heads will be out of sight inside the dummy hornplate. The fixing holes in the cylinder flanges will be tapped 6BA. The projecting ends will have nuts fitted to act as locknuts. This will help to make the cylinder as securely fixed to the hornplate as possible. It may be desirable to drill and tap two extra holes into the flange, midway along. These must be cut and filed off under the cylinder and then painted over so as not to be obvious.

Both sides of the hornplate, the doorplate and the throat plate will need dummy stays fitted to simulate the stays of the real boiler, which is hidden inside. These are simply shortened 3/32 in snap-head rivets, which are peened over on the inside.

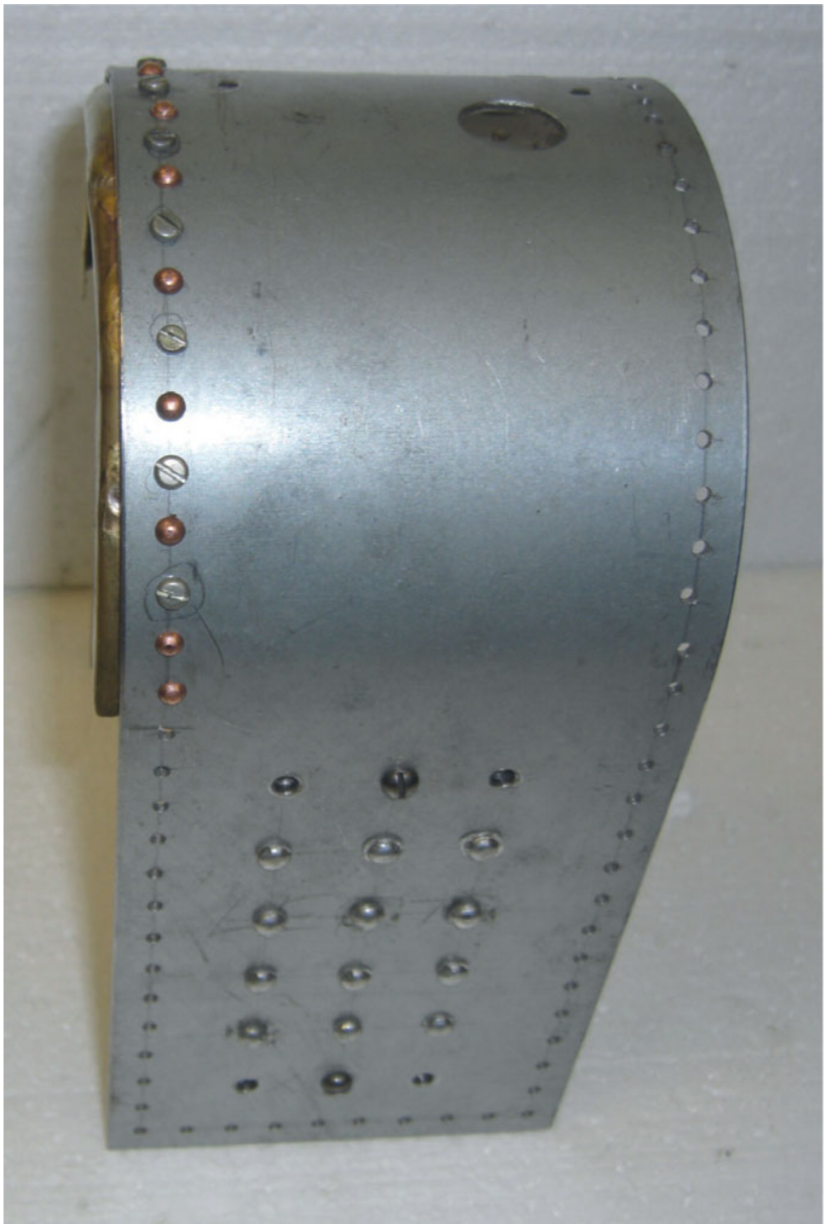
The rear edge needs a couple of drawing-back hooks, which are there to assist in pulling the engine back to tighten, or keep tight, the belt that will be driving the machinery. These would have been made by a blacksmith and should look as if this is how they were made. Low down at the front of the hornplate and either side of the door-plate are the inspection plugs for cleaning out the water space above the foundation ring.



*Dummy firebox/hornplate.*



*Dummy door-plate.*



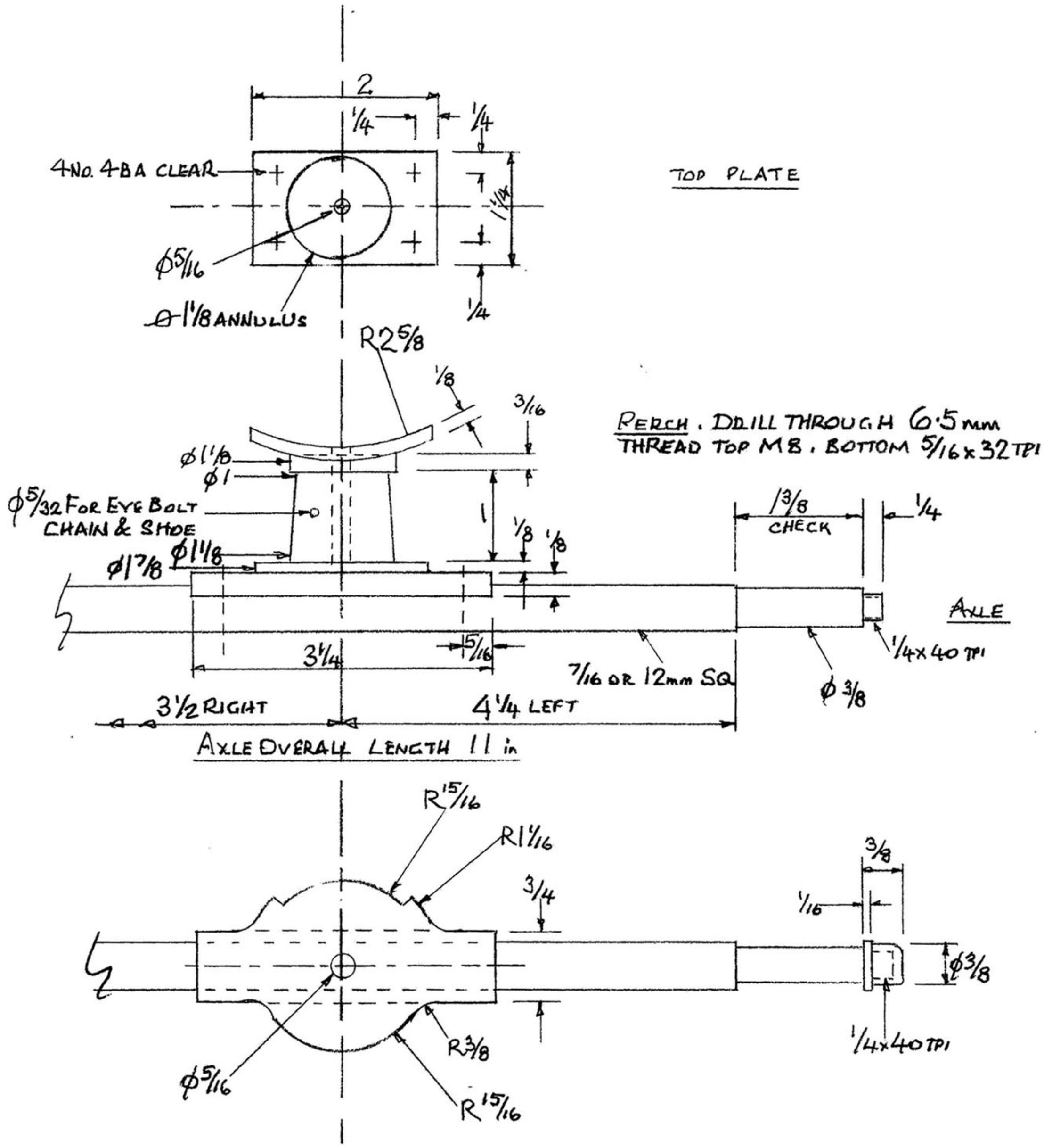
*Screws and nuts in alternate holes of throat plate hold it in place while riveting.*

## FORE AXLE

Both axles are based on square bar, which is turned down to 3/8 in diameter at each end to provide journals for the wheels. If there is a shortage of square bar in your workshop, you could drill each end 3/8 in diameter to at least 1in deep and insert a length of 3/8 in round bar. Loctite 601 retainer (or the equivalent from another manufacturer) is used to fix it, but make sure that you leave a hole or flat on the round bar to allow the trapped air to escape. The fore axle supports a roughly circular plate, which has ears for bolting to the axle and is reduced in radius at the back to accept a tongue from the lower end of the perch bracket to limit the lock and prevent the wheels jamming under the boiler.

*Fore axle with central plate to limit lock.*

The perch bracket is slightly conical and will need a large quantity of metal removed from it. There is a curved plate on top to support the smokebox. The usual way of making the top curved face of the perch is to fly-cut the curve to accept the top plate, but I prefer to face it off flat, except for the 5/16 × 32 (M8) threaded stub (or tapped hole) to screw through the curved plate, which has a flat bottomed recess machined (faced) on the underside. The stub also passes through the smokebox and has a nut inside the smokebox. An alternative is to drill and tap a hole in the top face of the perch bracket and use a 5/16 in or M8 setscrew through the smokebox and perch bracket top plate.




**Drawing 004 Perch Bracket & Front Axle 1 off each Steel**

*Perch bracket top plate.*

*Perch bracket.*

The bottom of the perch is also drilled and tapped to take the pivot pin for the axle.

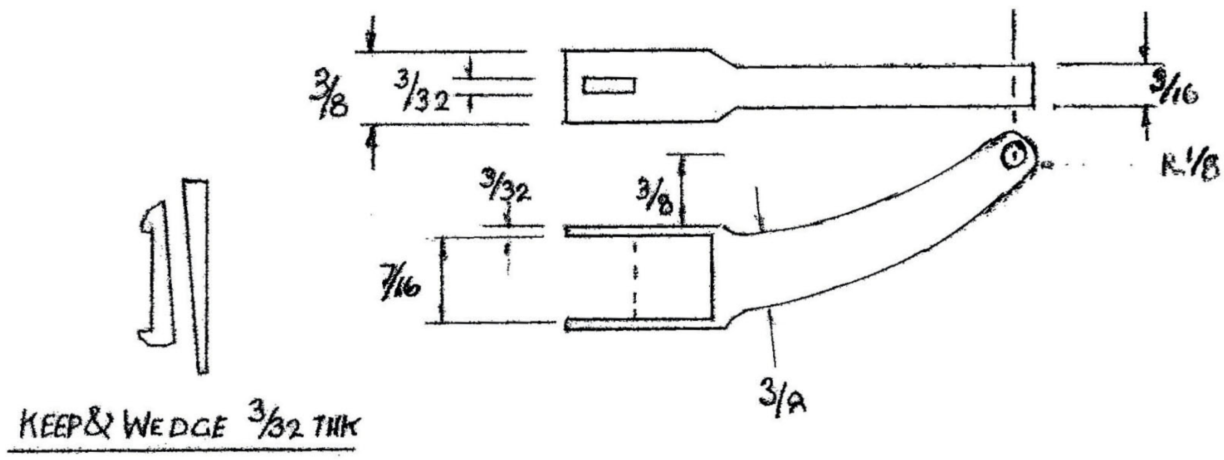
The front axle also has two brackets clamped to it, to which the shafts for the horse are pivoted. These consist of a ‘U’ shaped clamp around the axle, which is held in place by a keep and wedge. A bracket from the closed end of the ‘U’ sweeps up to an eye at the same level as the turntable.

The ‘U’ can be bent from 2mm thick steel around an offcut of front axle material, while the bracket is cut and filed up from 5mm thick steel. Depending on the facilities available to you, the two can be held together by electric welding, by brazing with oxyacetylene or by using silver solder. The junction is then filled with car body filler.

The whole piece could be machined in the milling machine.

The keep and wedge can be cut from 2mm thick steel. The top and bottom projections are there to stop the ‘U’ from spreading and the back of the keep is angled to match the angle of the wedge. If the two parts are made together and the angled cut goes a little off, then both the keep and wedge will be at the same angle. File them to make them smooth, finishing with draw filing and de-burring.

*Towing eye for horse shafts, clamped to front axle of preserved engine.*




**Drawing 005 Towing Eye 2 off**

# 5 Boiler Construction

Some of the boilers of early portable engines were of the vertical pattern, with a self-contained engine. The whole was mounted on a chassis frame fitted with four wheels and equipped for haulage by two horses. By the 1860s, the period of our prototype, the format of the portable had become based on a locomotive-type boiler with the engine mounted on top: indeed the boiler was part of the structure of the engine. This format later became the basis of the steam traction engine.

As its name suggests, a locomotive boiler was a type used on railway locomotives and in other situations. It consists of a cylindrical horizontal part connected to a vertical rectangular part containing the inner firebox. The inner firebox is connected to the outer shell by a foundation ring (actually rectangular) of heavy square bar, between the bottom edges of both the inner firebox and the outer shell. This provides a water space all around the firebox. The fire bars, which are on the same level as the foundation ring, support the fire, which is fed with coal through the fire-hole door in the door-plate. This plate is called the front plate on a traction engine, but the back-head on a railway locomotive.

The hot gases from the fire pass through a nest of tubes between the front of the inner firebox, inside the cylindrical part (or barrel) of the outer shell, to a front-tube plate at the front of the boiler. Here they pass into a cylindrical extension to the boiler, known as the smokebox, which supports the chimney and is in turn supported by the perch bracket, fore axle and wheels.

Unless the water level is maintained above both the tubes and the firebox top, the metal and joints will overheat and burn. This would result in a catastrophic failure of the boiler and a sudden release of steam with devastating results. All will be safe, however, if the water level is maintained at the correct level and the safety valves are capable of releasing the maximum amount of steam that the boiler can make. The design of the safety valve will be discussed in Chapter 6.

Prototype boilers were originally made from wrought iron and later from steel. The boiler of our miniature will be made from copper, because it does not readily corrode, is easy to work and join. The boiler's structure is based on a large tube, five flanged plates and two wrapper plates. This is not intended to be a detailed treatise on the art of boiler-making and, if you have little experience of the subject, I would suggest reading books by authorities such as K. N. Harris, Alec Farmer or Martin Evans.

By the time you come to making your boiler, I hope you will have met some knowledgeable people who can help and advise you. If you have made all the parts yourself, you will need a willing friend to help you silver braze it all together – a second person is vital – or a professional may be willing to help here. You will also have acquired the necessary skills to cut and shape the copper sheet and prepare it for assembly.

Fortunately, copper tube is available from model engineers' suppliers in the size that we require, together with the foundation ring material. This is supplied roughly cut to length. To help save on the postage costs, it may be possible to order it for collection at an exhibition you are planning to attend. The foundation ring, bush and stay material, silver solder and its flux can all be bought at the same time.

File up the roughness of the sawn edges and across the ends of the tube with a long second-cut file and use a half-round file inside. Make sure that the thickness is preserved, as we want all the structural strength we can get. Check that the ends have been cut off square at right angles to the sides. It does not matter too much as both ends will be inside and therefore hidden. Some authorities advocate facing up the ends in the lathe, but this makes it difficult to grip the end of the tube in the chuck without distorting it. Copper is not the easiest material to machine: the cut will be a long way from the chuck and cause problems. The simple advice is not to try it.

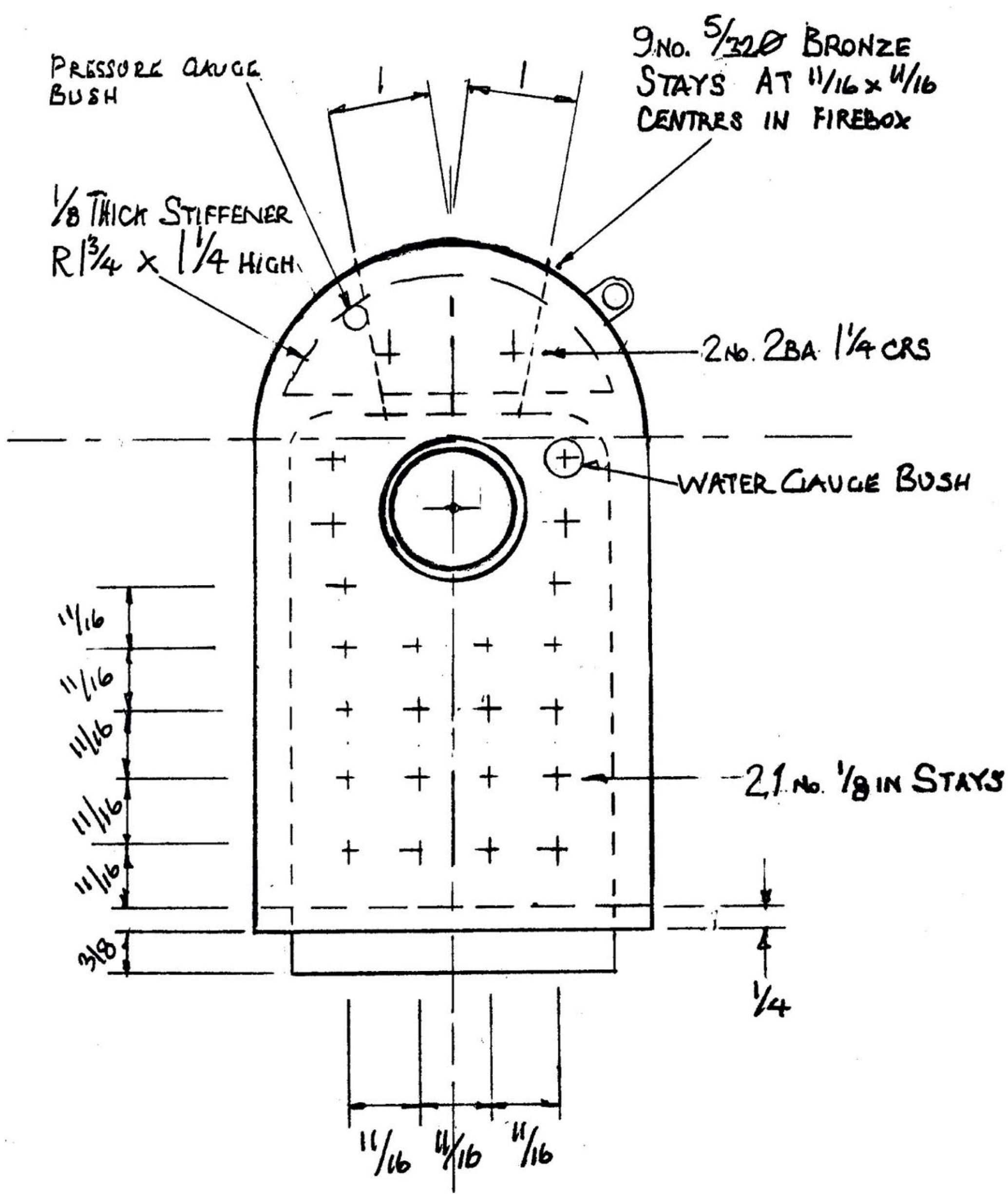
Copper sheet is needed in two different thicknesses. It can be obtained from model engineers' suppliers (or College Engineering, Noggin Ends) or, if you are lucky to have one locally, from a non-ferrous metal stockist. Either may cut it to size for you and the latter may allow you to rummage in the offcut box. This is worth doing as it will be cheaper than cutting from virgin sheet. Go prepared with card templates of every piece you will need (the card from cereal packets works well for this), including every duplicate. Ensure they are clearly labelled and include a note of the thickness required. Do not forget to include the flanges where required on the templates you make.

Copper sheet now comes in metric thicknesses, so 3/32 in is equivalent to 2.5mm and 1/8 in to 3mm.

Excellent formers for the flanging of two relatively thin pieces of copper can be made from hardwood, such as beech or oak. Thick birch ply could also be used, but not chipboard as this will crush under the strain of hammering. The formers, which should be at least 10 or 12mm thick, will be needed for the outer door-plate (and throat plate) and the firebox door-plate (and tube plate), as well as the circular front tube plate. After cutting them to size, they will need to have the top corners rounded off and this can be finished off with a bastard file. Don’t forget the handle on the file tang before you start. Try and get the filed edge square to the surface of the former and concentrate on the outside edge of the formers.

Preparation of the copper plates must all be done by hand, (except that the plain rectangles may be guillotined to size). In order to cut the semicircular tops, because it will not be possible to cut round the curve, make a series of straight cuts with a hacksaw fitted with a blade with 18 teeth per inch. Always grip the workpiece in the vice to enable the cut to be made vertically. If the workpiece makes a vibrating noise when sawing or filing, move it down so that the area being worked on is as close to the vice jaws as possible. It will probably be easier to grip the offcut in the vice. Chain drilling helps to saw round a corner.

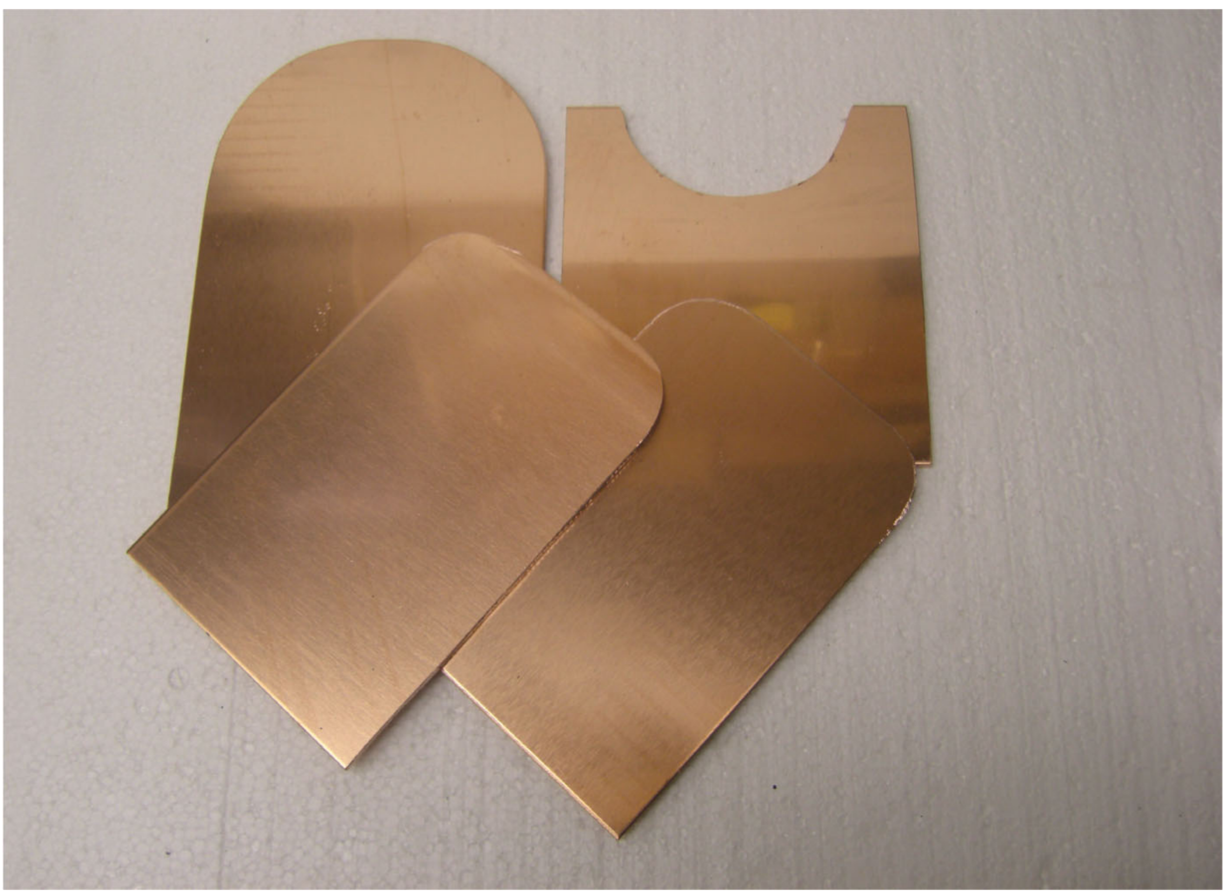
When all this is done and you are ready to make a start, the outside edge of the copper plates will need to be annealed. Copper both work hardens and tends to age harden. It will not be in a workable state when you buy it and should be cut and filed before annealing. When copper is bent repeatedly, it hardens and becomes too stiff to bend without endangering its strength. To anneal it you will need a large gas torch or, more correctly, a torch with a large nozzle. Gas torch equipment is a considerable investment and may have been deferred, but a job on this scale can be done on a kitchen or caravan gas cooker. Heat the plate you are going to work on to red heat and either leave it to cool or quench it in cold water. The thermal shock of quenching it usually makes the black scale flake off. If it does not, though, it can be removed using wire wool or pickling it in citric acid, which is much safer than dilute sulphuric acid. If you use wire wool, hold the copper plate flat on the bench or other flat support. If you allow the plate to bend, even if only a little, it will start to harden and defeat the object of annealing. Do not use emery cloth to remove the scale as this will remove some copper and contaminate the surface: we need all the metal we can have.



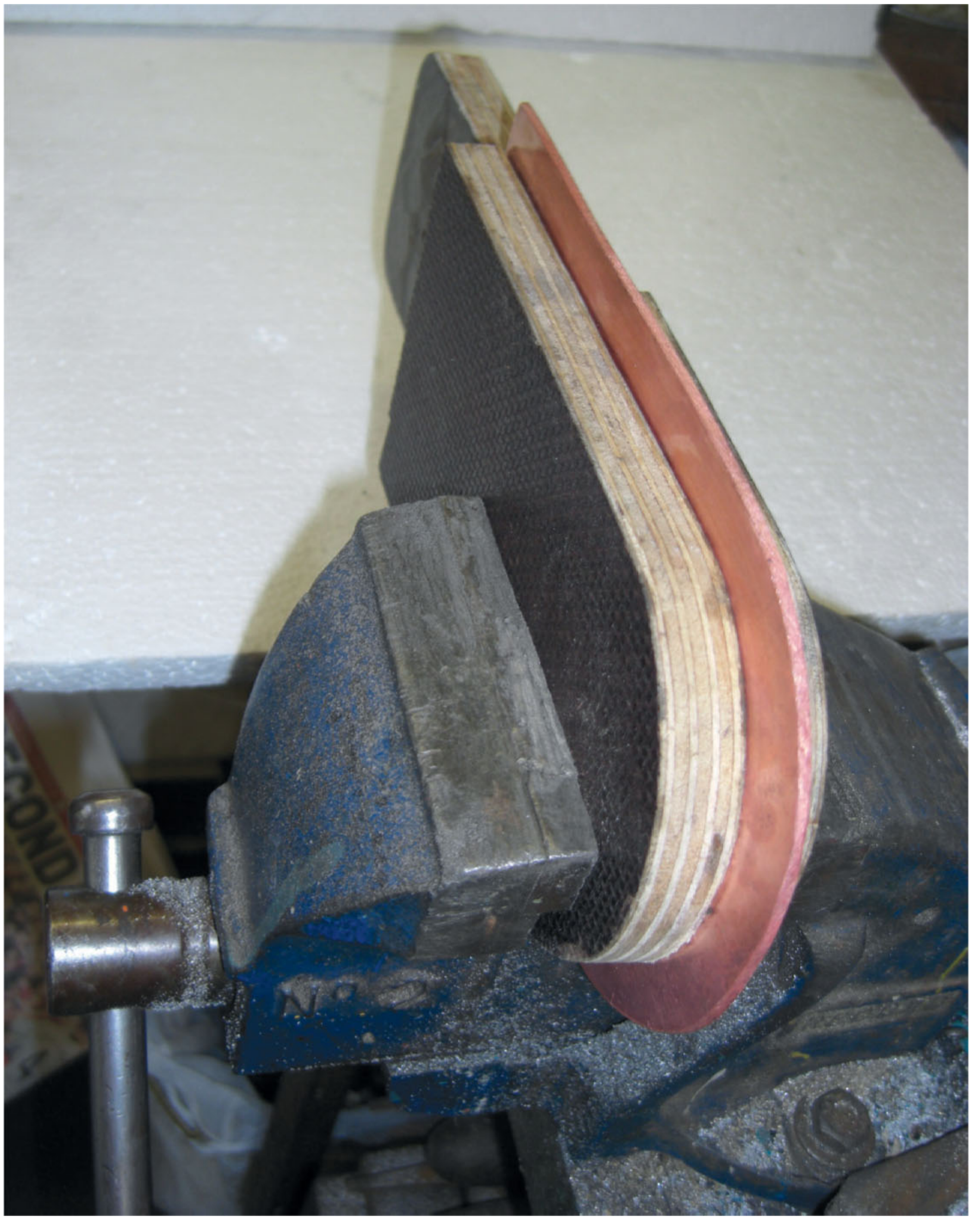

**Drawing 006A Door Plate**

## FORMING THE FLANGES

Start with the door-plate, which is one of the larger pieces, 3⁄32 in (2.5mm) thick, with a half-round top. Locate the former and backup centrally with an equal amount on both sides and over the top rounded edge of the former. Place this ‘sandwich’ in the vice and double check that nothing has moved. It is important that you double check now as it will be difficult to relocate it afterwards, but it will quickly become self-locating. Using the flat peen of a ball-peen hammer, start from the top of the curve and lightly hammer the edge of the copper with one tap to bend it over the former about 20 degrees. Continue to tap every half-inch or so round the edge to the bottom corner. Reposition the sandwich in the vice and tap down the edge from the top down the other side to the bottom corner. The sandwich will need repositioning in the vice several times. It is essential that the hammer blows contact the edge of the copper and do not trap the copper against the edge of the former. Now repeat the series of blows to bend the flange over by another 20 degrees or so. If any wrinkles are created in the flange, they must be removed immediately by dismantling and gently hammering out against a hardwood block. Try not to trap the copper as this is a sure way to work harden the copper.

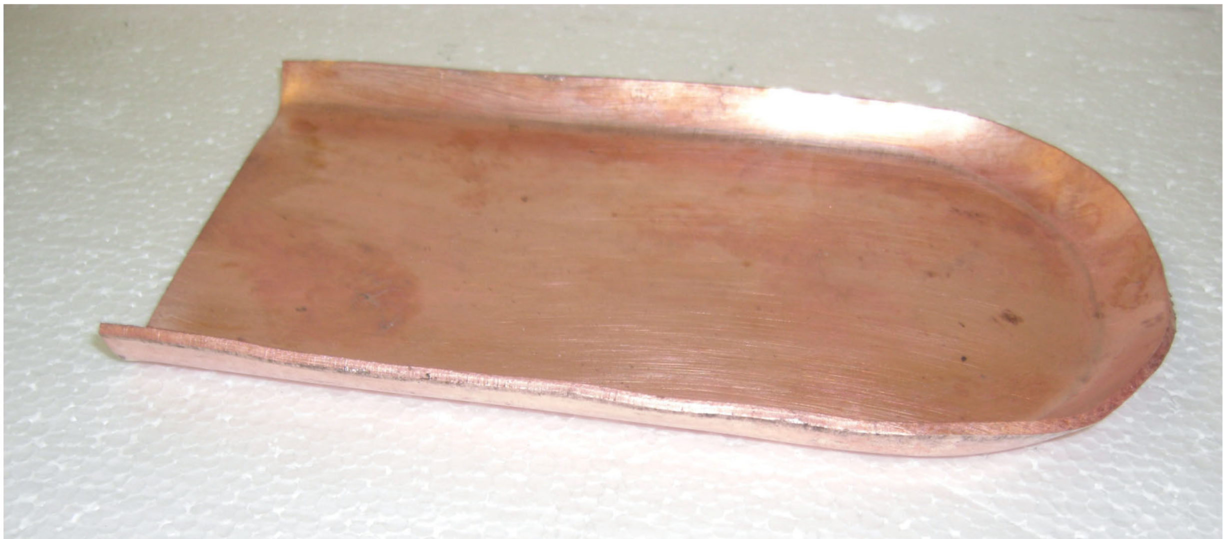


*Flat boiler plates before flanging.*



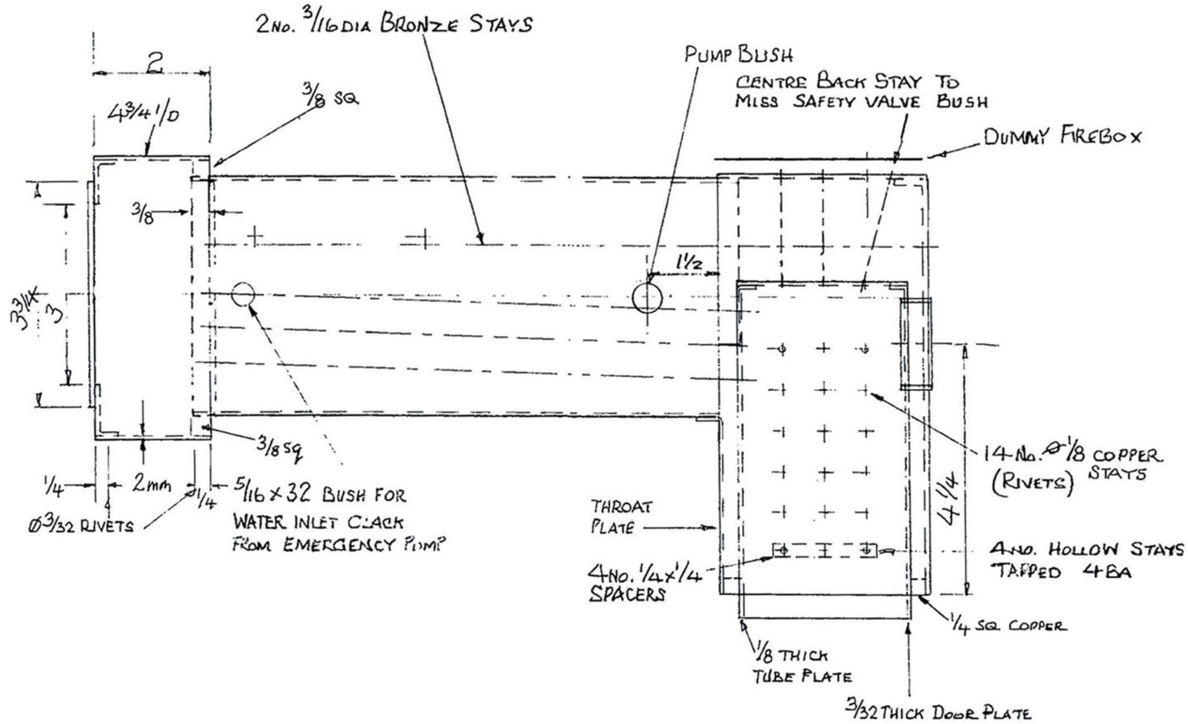
*Former and backup in position.*

After about three circuits, it will be found to be more difficult to bend the copper sheet. It will have work hardened. Remove any wrinkles and anneal the copper again. Reassemble the sandwich and carry on bending the flange over until it is tight against the edge of the former. The opposite flanges should be parallel to each other and should present a 9 or 10mm wide surface to the neighbouring component. That will come later. With the backup laid flat on a solid concrete floor, and the copper flanged over the former above, a couple of good whacks with a heavy hammer will flatten the main area of the plate. The outside of the flange of the semicircular top of the doorplate should match the outside diameter of the barrel tube.



*First circuit of flanging. Time to anneal again.*

The next plate to work on is the throat plate, which is 3/32 in (2.5mm) thick and has a semicircular cut-out in the top edge. This edge is flanged outwards (or forwards) and the two sides are flanged inwards (or backwards). As these are straight bends, it will be easier to do these first and use them to locate the plate on the former for the forming of the top edge. You may be tempted to grip the flange in the vice and use the width of the plate to bend it over to form the flange. The problem is that the bends may not work out to be exactly the correct distance apart and it will be difficult to correct. Use the flanging former and backup in the proper way and the two flanged plates will come out at the correct width. The semicircular cut-out in the former can be at the opposite end to the rounded end, thus saving material.




**Drawing 006B left side**

It would be logical to flange the inner firebox plates next. These are of a similar shape to the door-plate, but smaller. Watch out for the thickness: flange the thin one first (the door-plate), since the other is a little thicker and we want the width to the outside of the flanges to be the same, the former should be made 1/16 in narrower. It would be easier to use the backup for this plate.

Perhaps the easiest former to make is that for the front tube plate. This and its backup can be screwed with four woodscrews to a square of wood about 1in thick and then secured in the four-jaw chuck. The former and backup can then be turned to size in one go. Cut the corners off the blanks first and make sure that you do not run the tool into the chuck jaws. When you have finished turning the former and backup, unscrew them but leave the block in the chuck. Mark their orientation and, after flanging the front tube plate, screw the former only onto the block again (noting its orientation) and fit the tube plate onto the former. Use the backup and pressure from the tailstock (using a revolving centre, if you have one) to provide enough grip to drive the job round, skimming the outside of the flange to make an easy fit in the boiler barrel. Countersink the screw holes in the former to make sure that the tube plate contacts a large surface area of the former. If it needs more than a skim you must go back to the flanging process and hammer the flange tight onto the former. This may need another annealing and you will find that it works much more easily when soft. Note the safe method of holding the workpiece. Rivet the reinforcing plate to the front tube plate before silver soldering. A similar reinforcing plate is riveted to the outer door plate at the other end to the boiler.

*Partly flanged plates.*

Do not anneal any piece of copper ready for working on it tomorrow, since by then it will already have started to age harden. Anneal immediately before working on copper (it helps to warm up the workshop as well).

*Door-plate.*

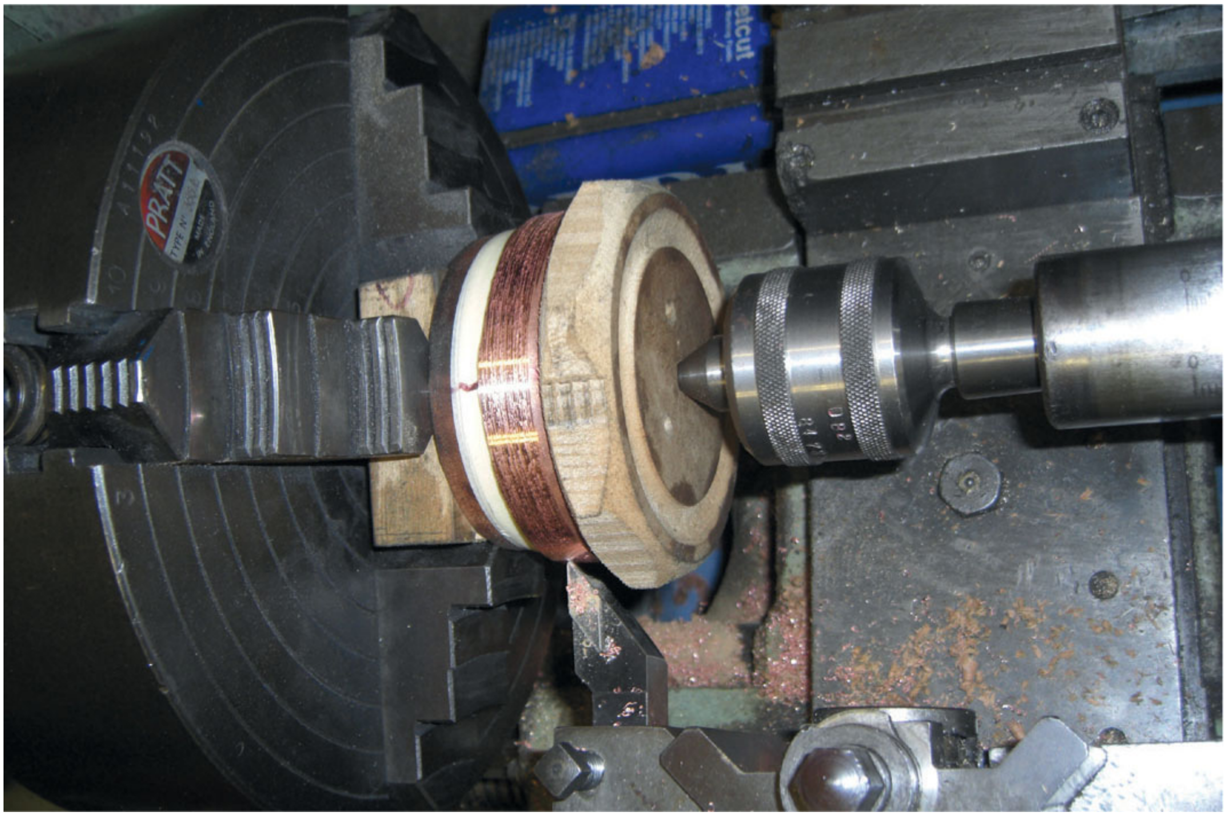
*Door-plate.*

*Throat plate.*

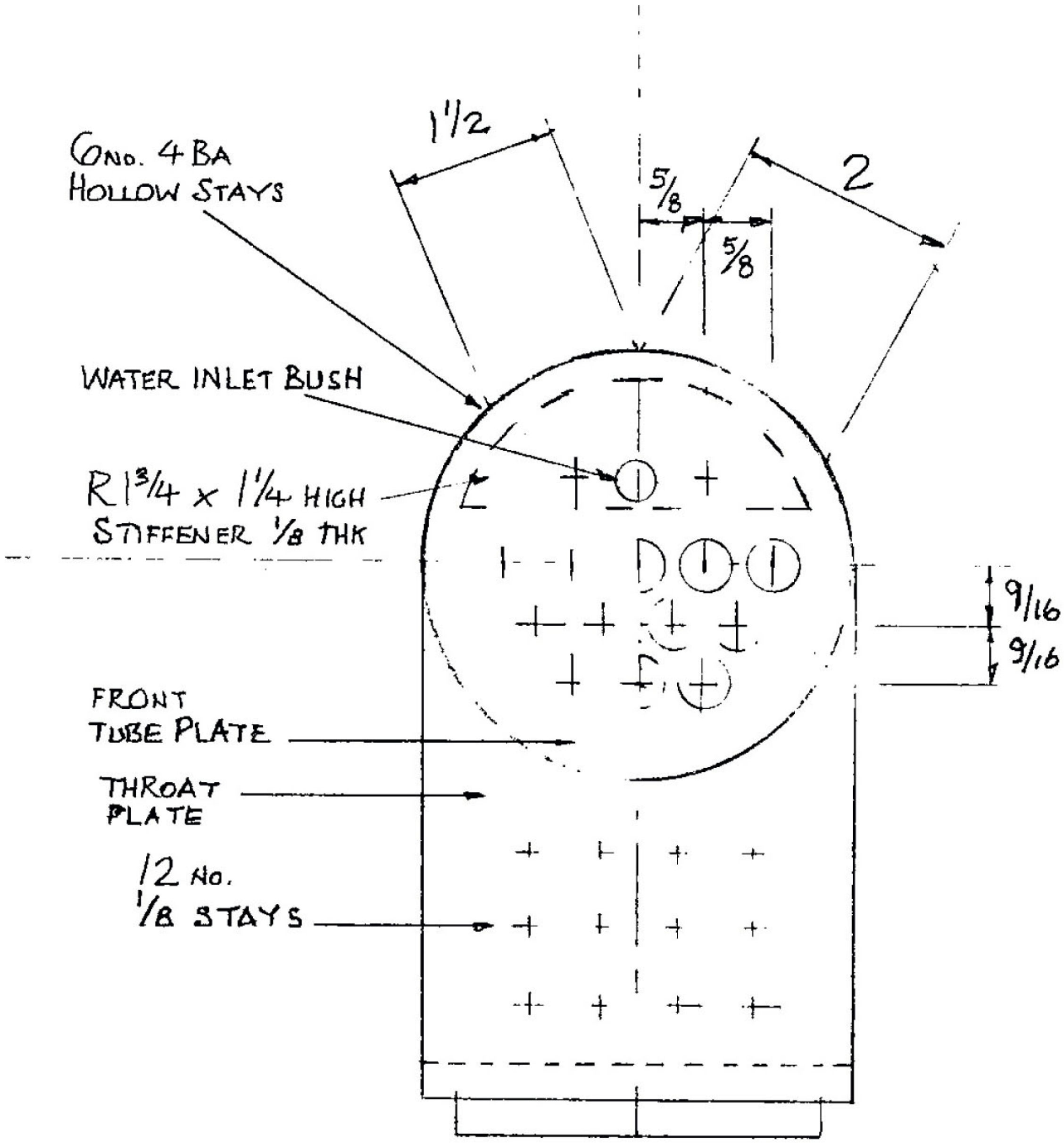
*Throat plate.*

*Inner firebox tube plate.*

*Inner firebox door-plate.*



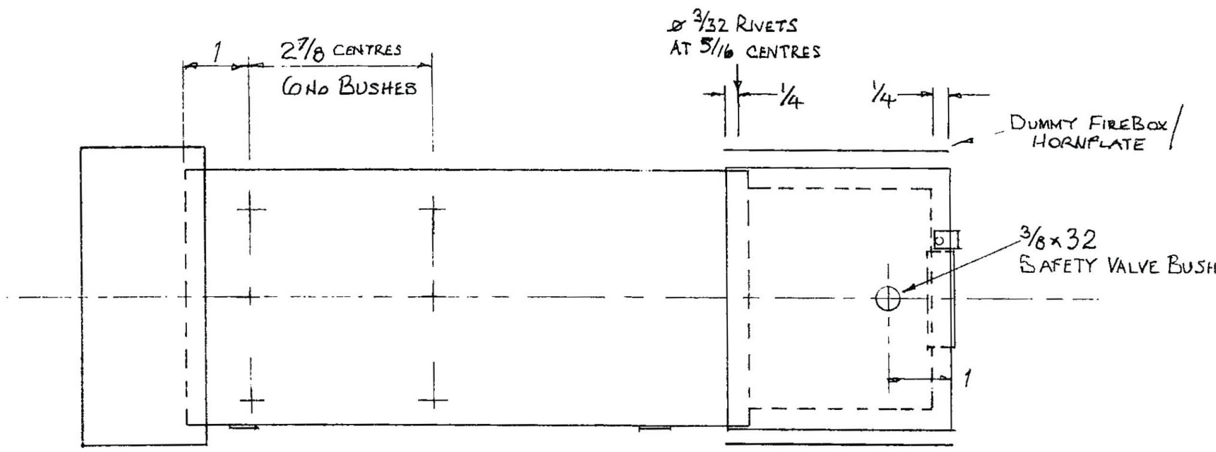

*Turn the outside of the flange of the front tube plate on the former.*




**Drawing 006C Front Tube Plate & Throat Plate**

*Safe work holding to drill the tube holes in the front tube plate.*

*Reinforcing plate riveted on before silver soldering.*




**Drawing 006D Plan Working Pressure 80psi Silver Soldered Copper Boiler**

**Test Pressure 160psi Drawn Half Size Scale 2 inch to 1 foot**

## WRAPPER PLATES

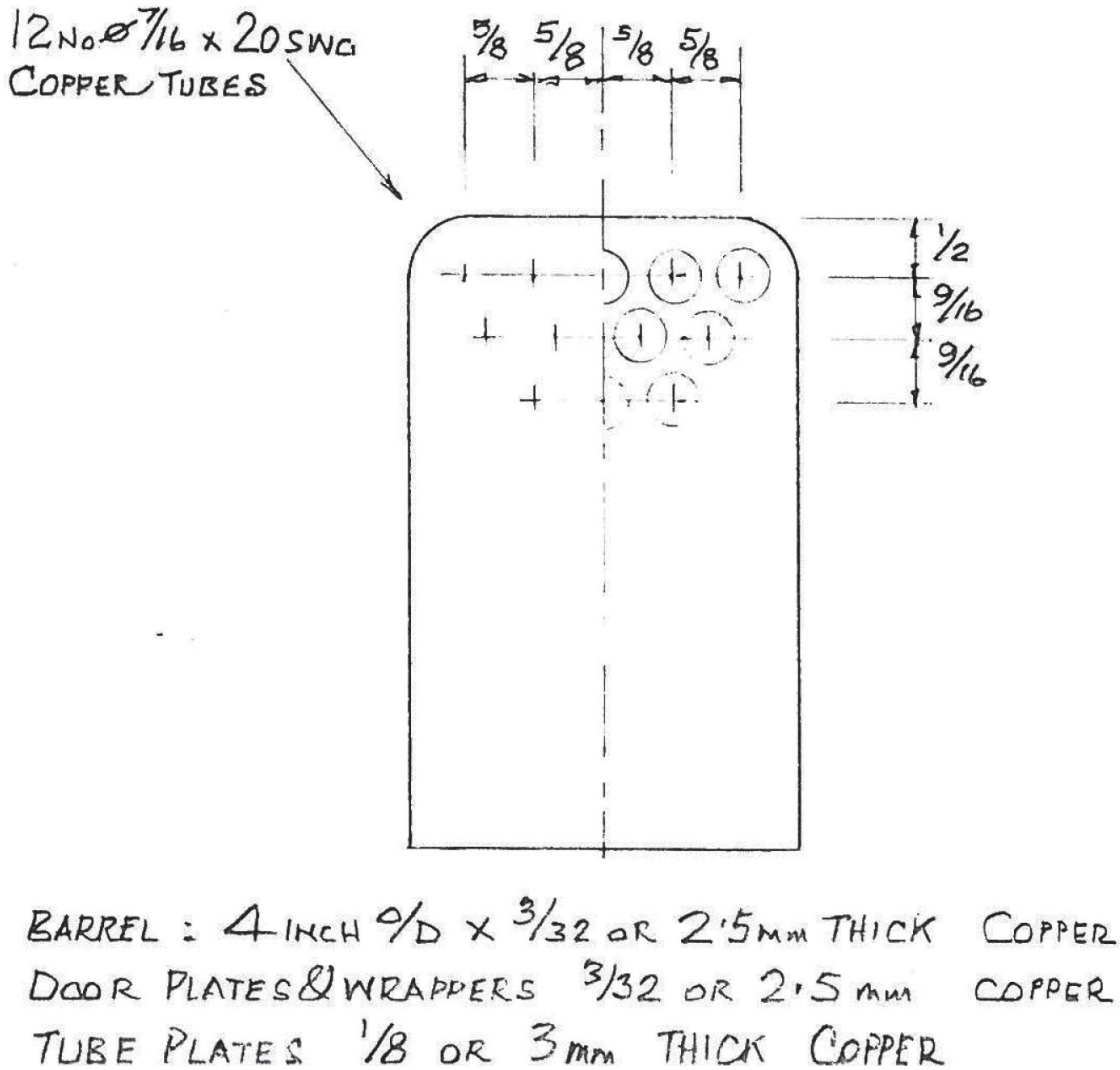
The wrapper plates are the next to be tackled. The larger one is easier to work on as it only has a semicircular curve at its centre. Rearrange your annealing/brazing hearth to take the largest piece of copper and heat it up in the middle. Smaller pieces will achieve the same temperature all over because of the high heat conductivity of copper, but here there is a chance of obtaining the necessary temperature at the centre without bringing the ends up to temperature, although they will still get pretty hot. A large bath or the garden hose may help to quench the wrapper. If the ends of the sheet are not annealed, there is a good chance that they will remain reasonably stiff and stay straight and flat. It is all down to the size of your torch and how quickly it heats up and gets quenched. If you use a plastic bucket for quenching, keep hold of the copper with your tongues, otherwise the hot copper will melt a hole in the bucket before the water has cooled it enough to be safe.

To form the semicircular curve, mark the centre of the length of the piece with a pencil line, square to the sides, place it over the barrel and carefully align the pencil line to the centre line of the barrel. Now push down on both sides together, bending the piece over the barrel. This is not really difficult, but you may run out of clearance for the ends of the sheet.

As it will be difficult to correct any misalignment, check and recheck the alignment before bending. Do not overbend: it is easier to bend a little more than to straighten out a bend. You may find that the top of the curve lifts up as you bend the sides down, To prevent this, clamp a length of bar or wood along the top of the barrel, holding the wrapper plate in position. You will find that the semicircular bend will spring out a little. Do not worry as we are going to fix the wrapper to the outside of the barrel. If the spring-back is excessive, you may not have annealed it well enough. Definitely do not over-bend. Instead you should re-anneal and have another go. To check that it is not twisted, look across the front edge of the wrapper and check that the two edges are parallel to each other. Placing the same edges on a flat surface will also tell the same story. Any slight misalignment can be twisted out by hand.

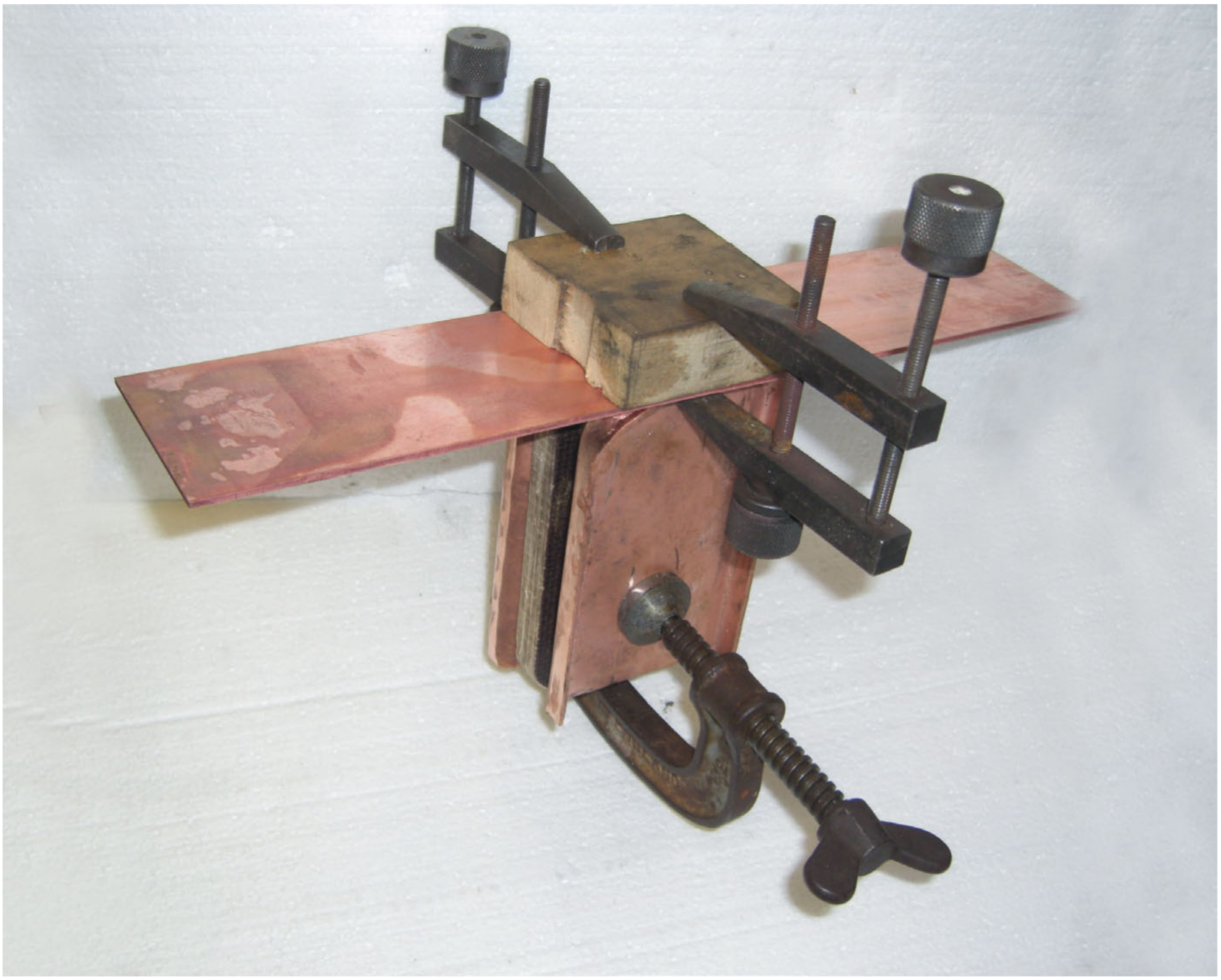
*Clamp the annealed wrapper plate square to the tube before bending.*

*Finished wrapper plate.*

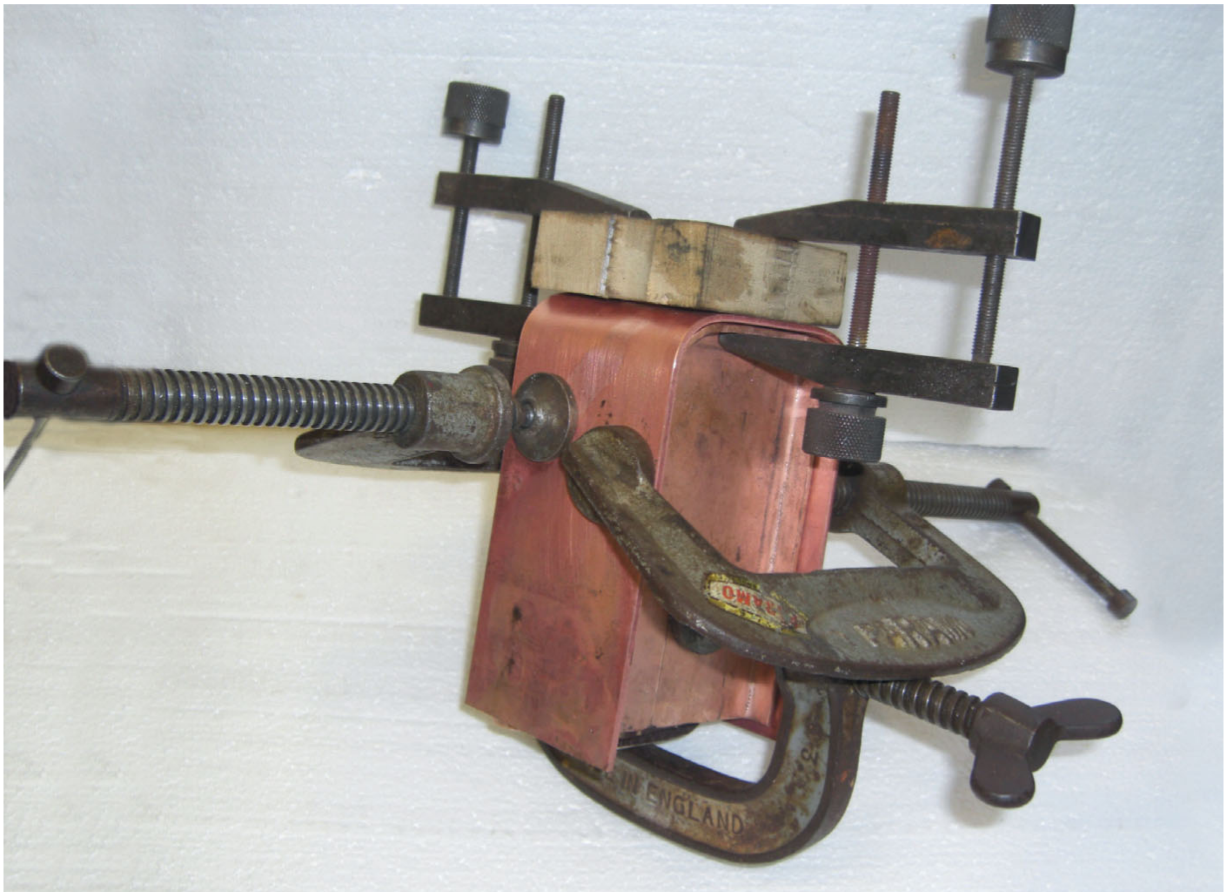



**Drawing 006E Tube Plate Inner Fire Box**

The wrapper for the inner firebox is treated in a similar way. This has a flat top, which tends to lift as the sides are bent down. For a former, use the firebox flanged plates on their formers and with the backup pieces (and others) between and clamped up in a ‘G’ cramp or vice. Then (after annealing) clamp the plate down on to the top before bending down the sides. A solid block of wood, cut to shape, would make a better former. Check for twist and correct.



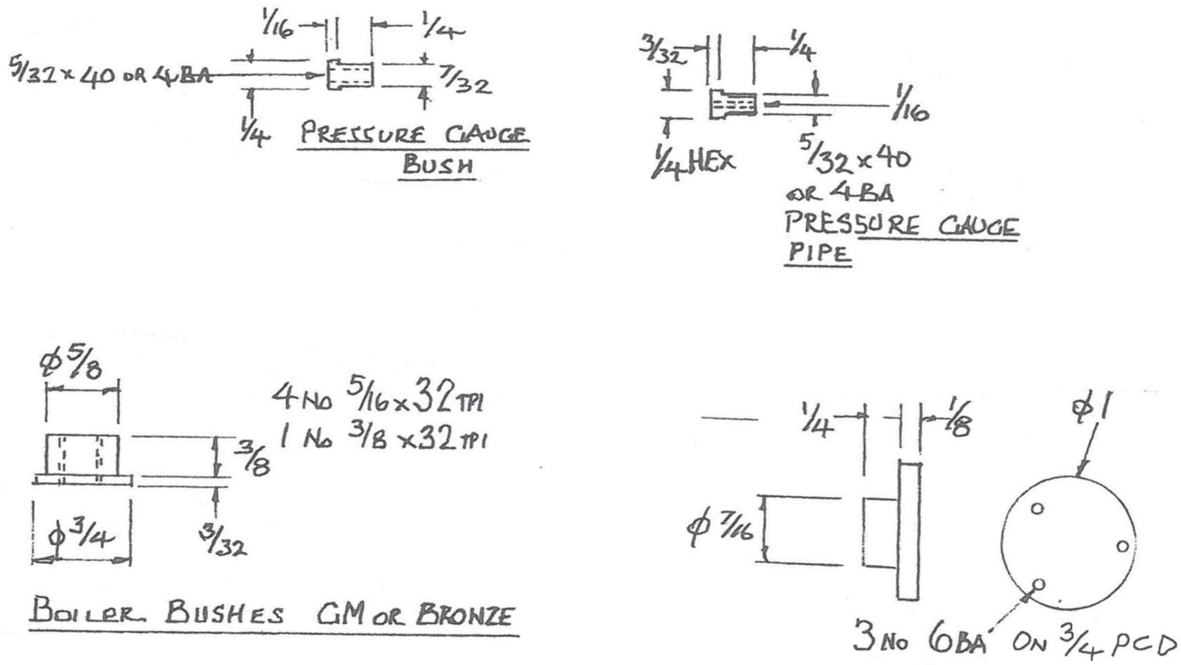
*Clamp the flanged inner firebox plates back-to-back and clamp the wrapper plate to the flanges before bending.*




*Completed bends.*

*Inner firebox wrapper. Check that the edges are parallel.*

Another method is to clamp the firebox flanged plates back-to-back against a block of wood and clamp the annealed wrapper to the flanges with two engineer's clamps and a bar across the top. This will hold it together to make sure it is all square.




**Drawing 007 Pump mounting Bush**

## ASSEMBLY

To assemble the boiler's outer shell, the barrel is fixed to the outer wrapper by three bronze screws of 6 BA or M3 size. Many boilers have a straight top, which requires a butt joint. To provide strength and ease of location, a semicircular ring is fitted between the two as a butt strap. In our case, as the boiler should have a pronounced step in the top, we will lap the wrapper over the barrel tube across the top two-thirds of the joint. The remaining third of the barrel will have 3/8 in cut away to ensure circulation of the water at the top of the throat plate. The lower half of the barrel will be attached to the curved flange of the throat plate and the side flanges fixed to the front edges of the wrapper. Do not put any screws too low down the sides as they will get in the way of the foundation ring. The door-plate, which will go to the rear end of the wrapper, should be left until the foundation ring has been fitted. All joints should be checked and adjusted as necessary, to be as close as possible all the way along. Time spent here will make the difference between a satisfactory silver soldered joint and a big problem in correcting it later. The door-plate, just fitted, is the last joint to be silver soldered, but this will come later.

*End of barrel tube cut back and shaped on trial assembly.*

*Barrel, throat plate and outer wrapper ready for silver soldering.*

The firebox is assembled in a similar way, but the screws holding the door-plate to the inner wrapper need to be screwed in from inside. This plate is next to the last joint to be made and has to be assembled from inside. It is far easier to drill tapping size for these screws and thread the inner plate (except the inner firebox door-plate) and open out the other hole to clearance size. This will save fiddling with nuts inside and it is impossible to fit a nut in some places anyway.

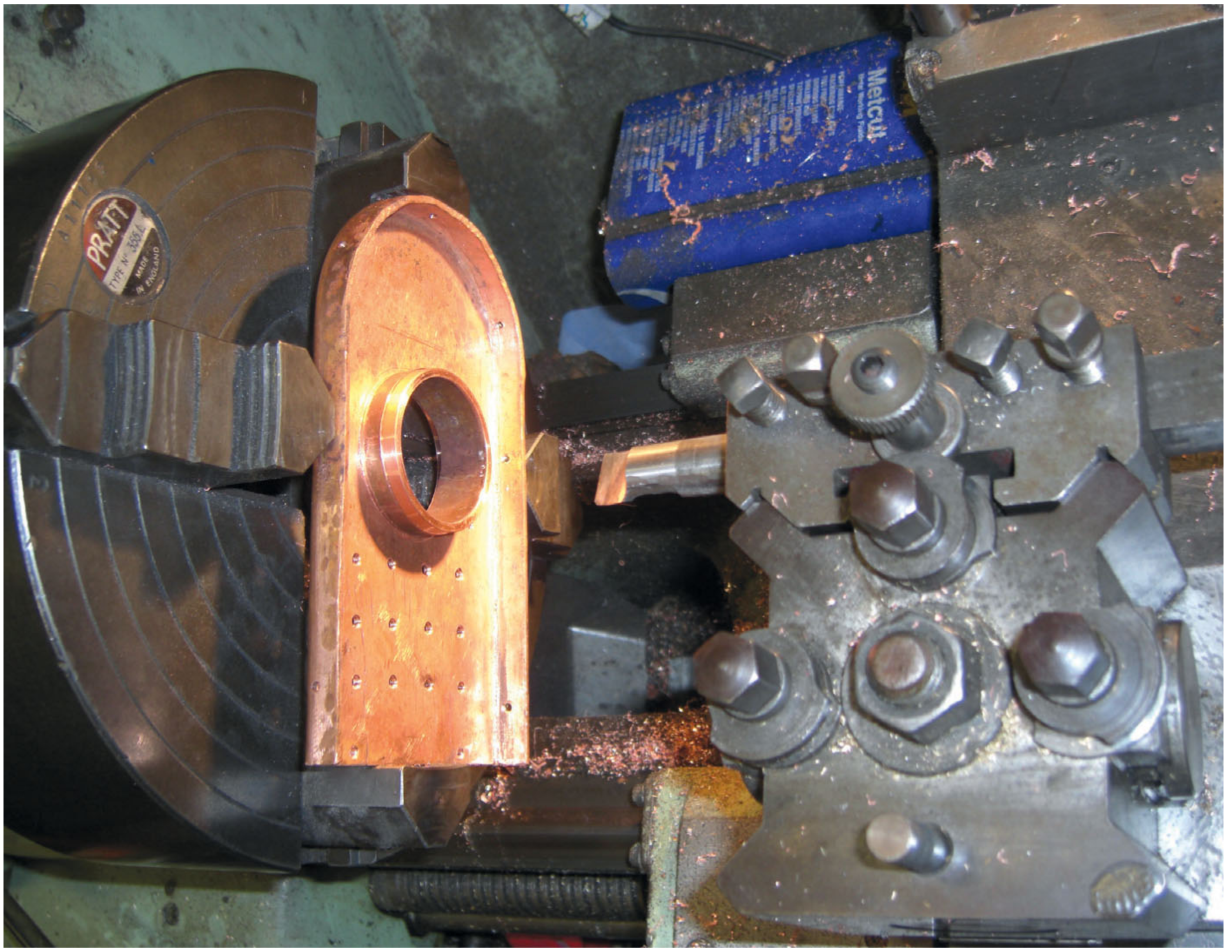
*Inner firebox trial assembly. Note that the screws are inserted from the inside.*

*Trial assembly.*

It is now possible to assemble the inner firebox into the outer shell using the front section of foundation ring to attain the correct position and fit the rest of the foundation ring in sections around the bottom edge. Note that the inner firebox hangs down by 3/8 in and the foundation ring is flush with the lower edge of the outer shell. Two screws will be needed in each side. The back and front pieces of the foundation ring should be made first to fit between the flanges of the plates.

The side pieces will need to have cutouts to clear the flanges. Before cutting the foundation-ring material (copper) to length for the sides, cut the step needed to clear the flange at the front left corner. This will require some trial and error, and it should be filed to ensure it fits closely. At the other end of the piece of material, cut the step for the front right corner. When satisfied that you have a good fit, cut each piece to length and cut the steps in the rear corners. The reason for all this is that, if an error is made when making the steps in the front corners, it is possible to cut off a small piece and start again. If it had been cut to length there would be no spare material to play with.

The door-plate can now be fitted and screws fitted to the top, one each side, screwed in from inside. Make sure that the top screws are pulled up tight before drilling and tapping for the side screws. To ensure that the fire-hole ring will fit closely to the holes in both plates and that these holes are exactly in line with each other, drill a 5 or 6mm hole through both plates, making sure that the hole is square to the plate surface. When the boiler components are next separated, these holes can be picked up and centralized in the lathe four-jaw chuck and opened out to fit the fire-hole ring.




*Bore the door-plate to suit the fire-hole ring.*

The fire-hole ring is either a piece of thick-wall tube or a piece of 5mm thick copper rolled, or bent, round to the correct diameter and silver soldered. It is then turned down by 1/16 in diameter at each end, leaving ¼in (or 6mm) between, which is the width of the foundation ring.

Now is the time to take your masterpiece to show the boiler tester at the next club meeting. Boiler testers like to see a new boiler at this stage. Do not be surprised to be told that the joints are not close enough (so check them first) and be prepared to rework some areas. This can make it impossible to align those carefully drilled and tapped screw holes again, so it is well worth checking yourself as you go along. It is much easier to make it right first time than to correct it later.

## STAYS

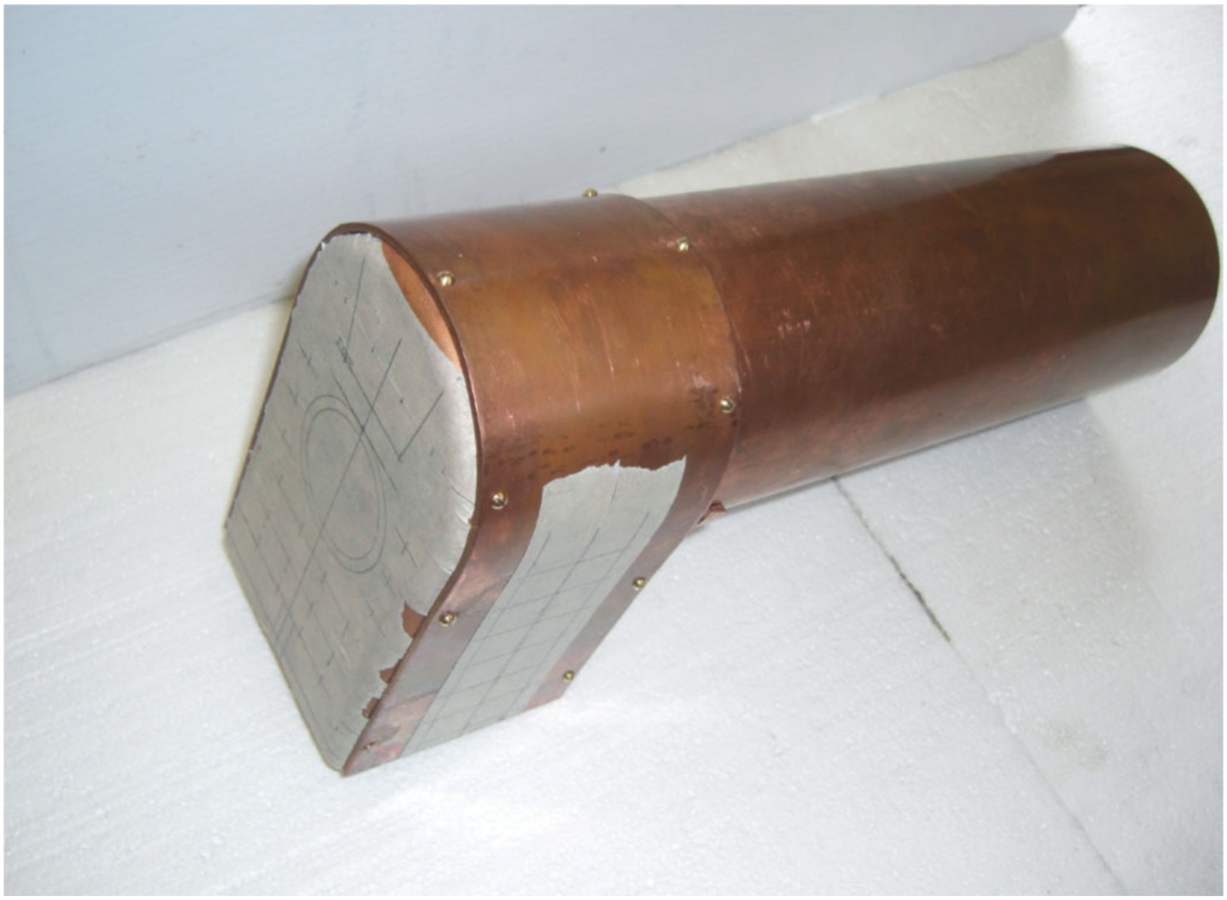
If you blow up a balloon it will achieve a spherical shape because the internal pressure to the left will equal the pressure to the right, top to bottom, back to front and so on. The long sausage-shaped balloons favoured by children's entertainers are 'balanced' top to bottom and side to side into a tube, but the ends will be hemispherical. Many road tankers have dished ends to resist the internal forces of the pressure inside the tank. In our boiler we have a cylindrical part that will be self-supporting, like the sausage balloon, but the ends are flat (the reasons for this will be discussed below). Now it gets interesting. foundation ring. The five sides (including the top) of the inner firebox and the four sides of the outer firebox are essentially flat. Internal pressure between these plates will make each plate of the outer shell bulge outwards and the inner firebox plates bulge inwards. Apart from appearance and interfering with the surrounding machinery, it would induce a catastrophic failure of the boiler. This we must avoid at all cost. If the flat plates are tied together at regular intervals with stays, which are either long screws threaded into both plates or rivets silver soldered to both plates, and which collectively restrain the bulging effect of the internal pressure, we are able to contain the bulge, preserve the shape of the boiler and make it safe. The outer wrapper over the firebox is inherently strong, but the top of the inner firebox is flat and needs staying to prevent the firebox top from being forced downwards.

This can be achieved either by fitting girder stays to strengthen the flat top of the fire-box, or by providing rod stays between the firebox top and the top of the outer shell. Girder stays have fallen out of favour as they restrict the flow of water onto the top of the firebox. This area is just below the water level and is the hottest part of the fire-box. Since the water here will evaporate quickly, there must be ready access to water to prevent overheating and failure, usually by melting the silver solder.

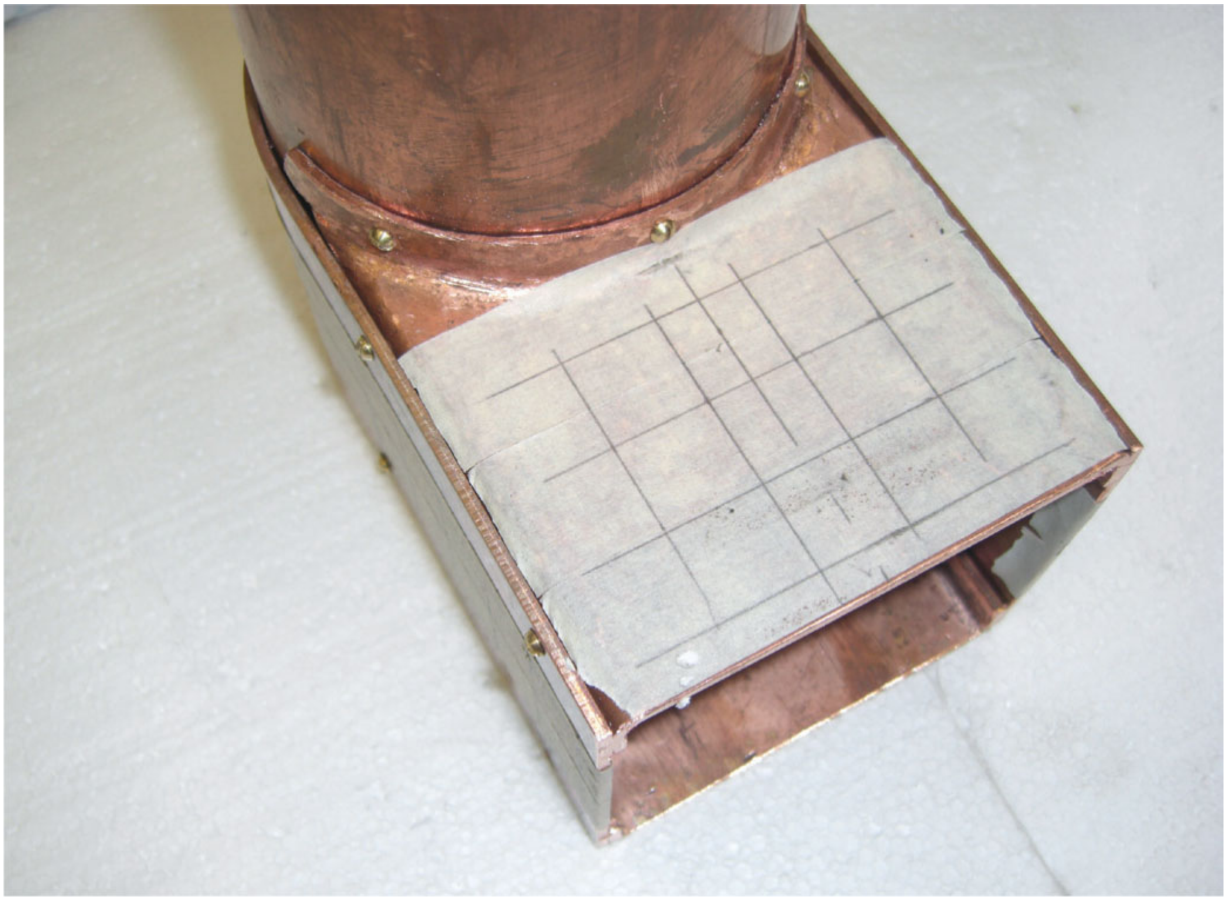
The door-plate is supported by the fire-hole ring and the stays below, but above this there is a flat area that must be stayed. Conveniently at the front of the boiler barrel is the front tube plate (the round one), which will be stayed by the tubes at the bottom but will need stays at the top. The semicircular tops of both these plates have stiffening plates silver soldered inside; long 3/16 in diameter bronze rod stays go from end to end to equalize the internal pressure.

The diameter and spacing of the stays is calculated from the thickness of the flat plates and the working pressure of the boiler. This comes out at 5/8 in to 11/16 in and their actual positions are detailed on the drawing. These are marked out, gently centre-punched and drilled 1/8 in diameter through both plates. Do not forget that the four corner stays on each side are special hollow stays needing a 7/32 in diameter drill. On dismantling, all plates will need de-burring on both sides using a larger drill turning at a slow-ish speed. (A 3/16 to ¼in [5–7mm] drill would be fine.) Aim to make a slight countersink. Do not use a new drill as it might grab and pull itself in and enlarge the hole. Use a used drill, not blunt but with not too keen an edge. Remove and collect all the swarf. This can go in the scrap box to take all your brass, bronze and copper. Aluminium, however, must always go in its own box. It may also be worth collecting steel and cast iron, but only if you are taking the brass and aluminium to the scrapyard at the same time. The accompanying photo shows how a twist drill is sharpened to drill thin metal for the tubes and bushes.

*Masking tape provides a surface on which to set out the stays.*

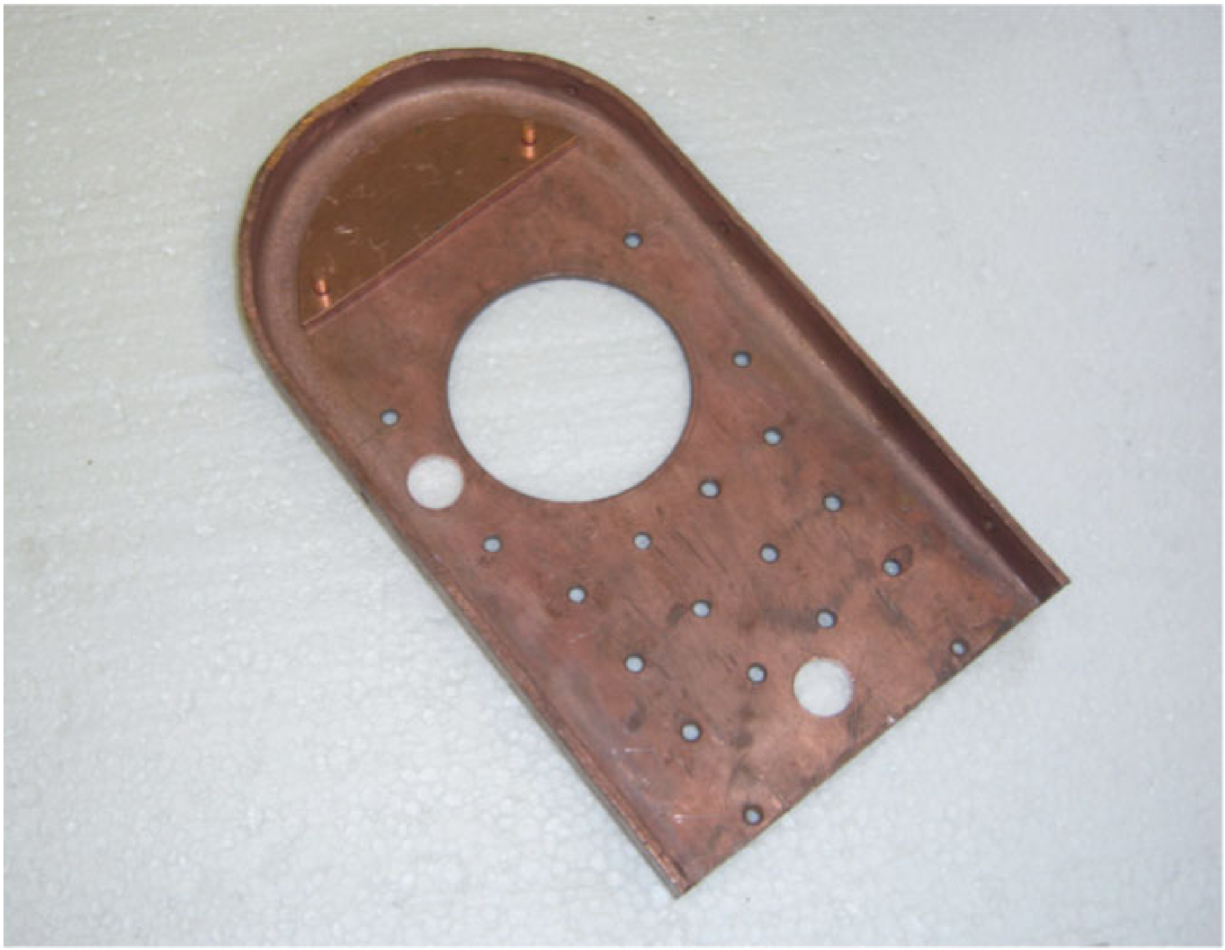


*Door-plate and firebox side with stay positions marked out.*



*Throat plate stays.*

*Door-plate with fire-hole chain drilled.*



*Door-plate with reinforcing plate riveted on. Note that the water gauge bush should be higher.*

*Firebox tube plate. Stay holes and tube pilot holes drilled.*

*Twist drill ground to drill thin sheet.*

## SILVER SOLDER

Do not confuse this product with plumber's or electrician's solder, which is a soft solder using a lead-tin alloy (mixture of metals) that melts at 180 to 260°C. This is not high enough for our purposes.

Hard solder is a brazing or silver-containing alloy (sometimes called a silver brazing alloy) that has a melting point between 600°C and above 900°C. Alloys with a lower melting-point have more silver in them and are therefore more expensive. It is often advised to use a higher melting-point silver solder for the first joints to be made so that they do not re-melt in subsequent heatings, but the grade of silver solder usually used for boiler making has a higher remelt temperature and this can safeguard us from re-melting an earlier sound joint. The silver solder that has usually been specified is a Johnson Matthey product known as Easy-flo No. 2, which had to be used on brass because its melting point is only a little lower than brass. Unfortunately Easy-flo No. 2 contains cadmium and its manufacture has been banned. The suggested cadmium-free alternative from the Johnson Matthey range is Silver-flo 55.

## BOILER ASSEMBLY

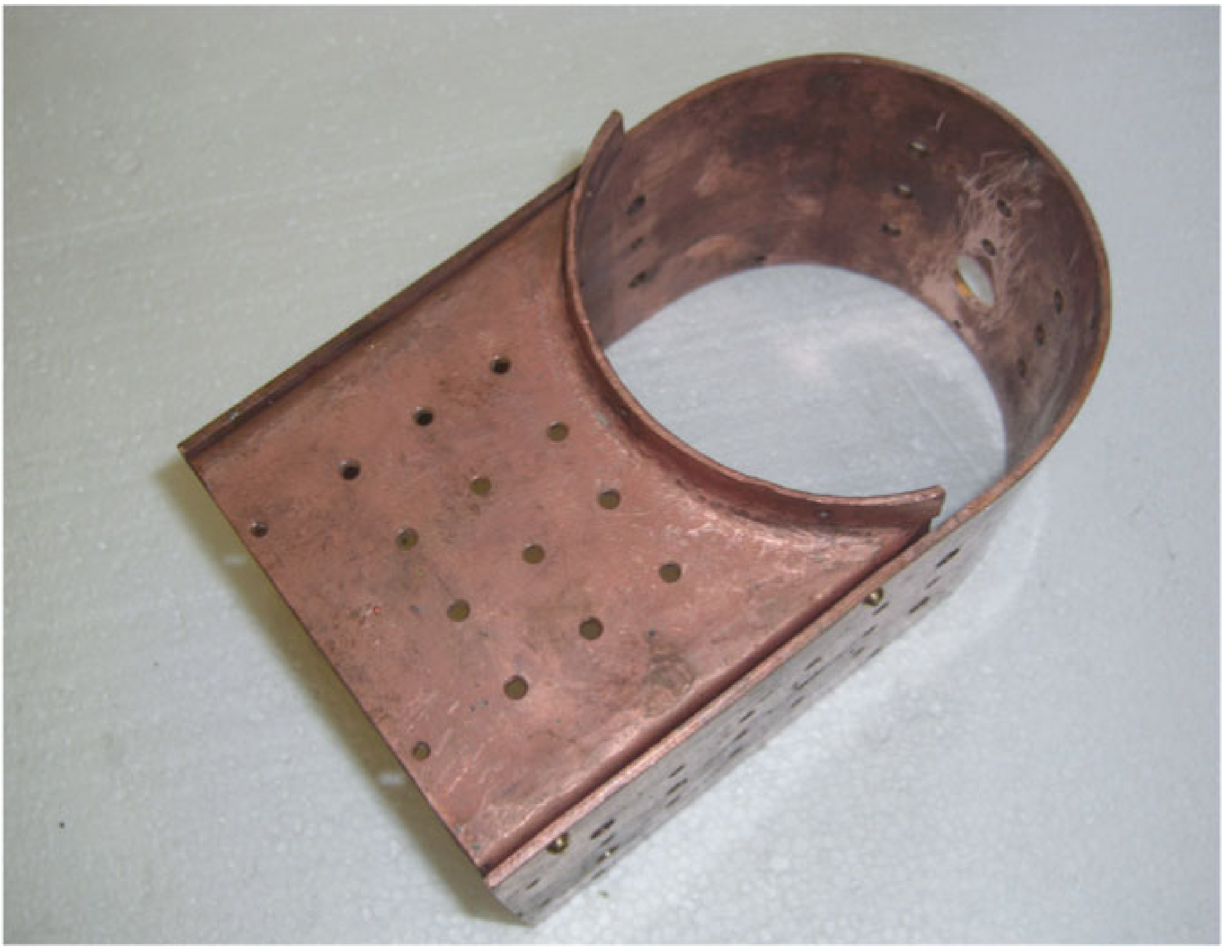
The process of silver soldering depends on five factors: silver solder, flux, close-fitting joints, heat and cleanliness. The first four are obvious, but do not forget cleanliness. To achieve this, a bucket of acid pickle is prepared from citric acid crystals, which can be obtained from brewing and wine-making shops. This is far safer than dilute sulphuric acid, which releases hydrogen when in contact with steel or iron. Fine steel wool can be used to help the initial clean-up of the copper. Do not use emery cloth.

Mix a small quantity of the correct flux for the silver solder to be used with water until it has the consistency of cream. A drop of washing-up liquid will help ‘wet’ the surface and stop it drying out too quickly. After cleaning, apply the flux to both sides of the joint to be made. A shallow steel tray is a good starting point for a brazing hearth. Heat-resistant fire bricks can be laid flat on the bottom and built up at the back to make a hearth that will contain as much heat as possible. Do not use concrete blocks or stone as they retain heat, whereas brick reflects heat.

### Sequence

On dismantling the boiler after drilling for the stays, de-burring and removing the swarf, the barrel and throat plate can be left screwed together. This will make the first joint to be silver soldered.

Always let the job cool to a temperature that can just about be handled before placing it in the pickle bath. Screw the outer wrapper to the throat plate and complete this joint.



*Throat plate and wrapper.*

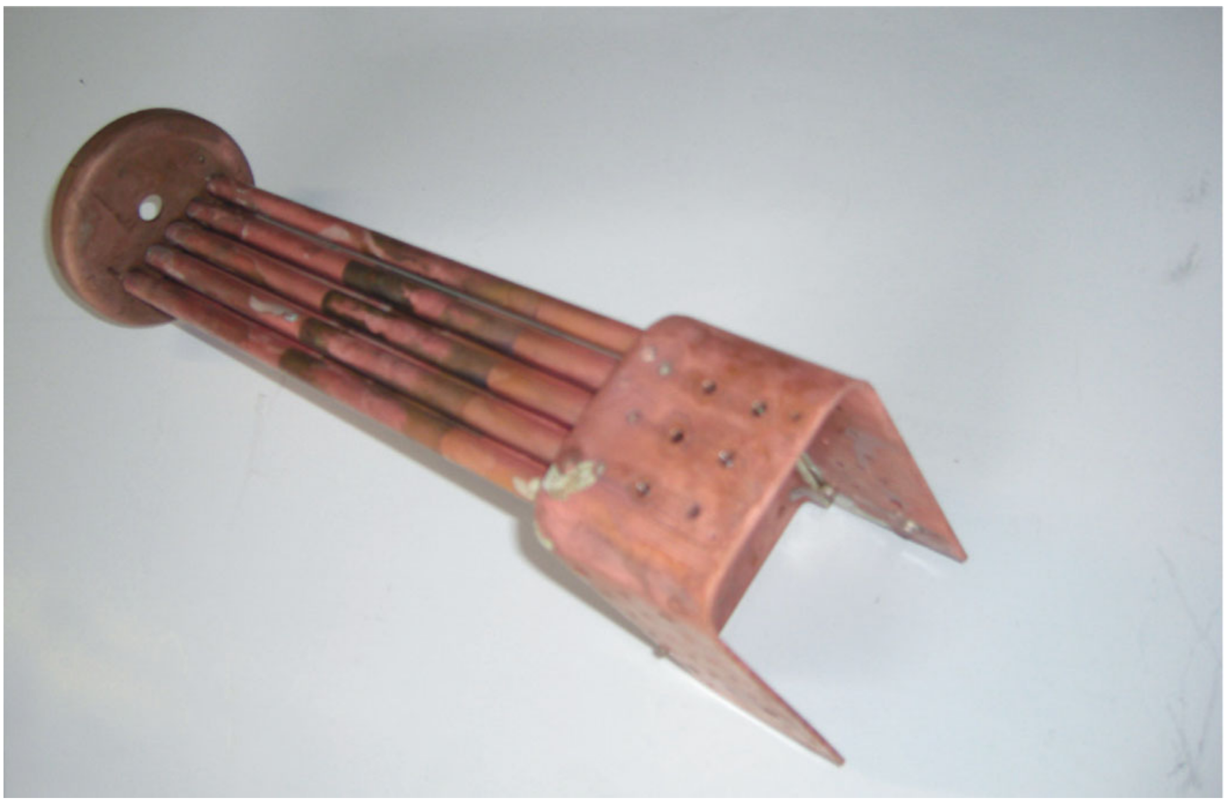
*Barrel, throat plate and wrapper silver soldered together.*

Silver solder the tubes into the firebox tube plate, using the front tube plate to locate the other ends of the tubes. If the middle tubes are assembled first, a ring of 1mm diameter silver solder can be placed round each tube where it enters the tube plate. Applying flux around each tube, on both sides of the tube plate, will tend to secure the rings in place. Next, assemble the other tubes into the tube plate and fit a ring around each one and flux. This can now be stood up in the hearth, heated and the silver solder rings should melt and run into the joints. To stop the tubes from falling through the tube plate, either support them on a fireproof brick or dimple each tube from inside. The wrapper can be assembled to the tube plate and silver soldered at the same time. Do not fit the door-plate.

Assemble the firebox tube assembly (without the front tube plate) into the outer wrapper-barrel assembly, located by the front section of the foundation ring. Assemble the foundation ring side-pieces, screwing it all together, and then flux and solder them together. Now is the time to fit all the stays to the sides and front of the firebox area. These are 1/8 × 1in long copper rivets, pushed in from the inside. To stop the stays on one side from falling out during the soldering process, bend them over a little. The four corner stays on each side are the special hollow stays, which are drilled blind and tapped 4BA. Fit them with the threaded hole outwards. Flux all the stays and place the ‘boiler’ on its side with the bent stays uppermost and the shell supported to leave the stays free to hang down. Make sure that all the stays are fully into their holes and solder the heads of the stays inside the firebox. You will find that the now considerable amount of copper will take a lot more heating and patience will be needed. The gas flame from your largest burner can be directed into the firebox and exit through where the door-plate will be fitted. If this plate had been fitted the flame would have to exit the same way, putting out the flame. It would also be pointing towards you and make soldering impossible.

Turn the boiler over to the opposite side and, making sure that all the stays are pressed in to their heads, continue to solder the stay heads on the inside. While the temperature is still high the crown stays in the firebox top can be soldered. This is a good time to do the throat plate stays, inside and out. This can be followed by soldering the outside of the side stays, now at the top. This area should have cooled slightly and the solder solidified so there is little danger of disturbing the stays. Turn the boiler over again and do the outside of the stays on that side. Finally, turn the boiler the right way up and solder the top ends of the crown stays. While everything is hot, the foundation ring can be soldered. Let the whole thing cool down and pickle. Examine every joint and stay for evidence of a good joint.

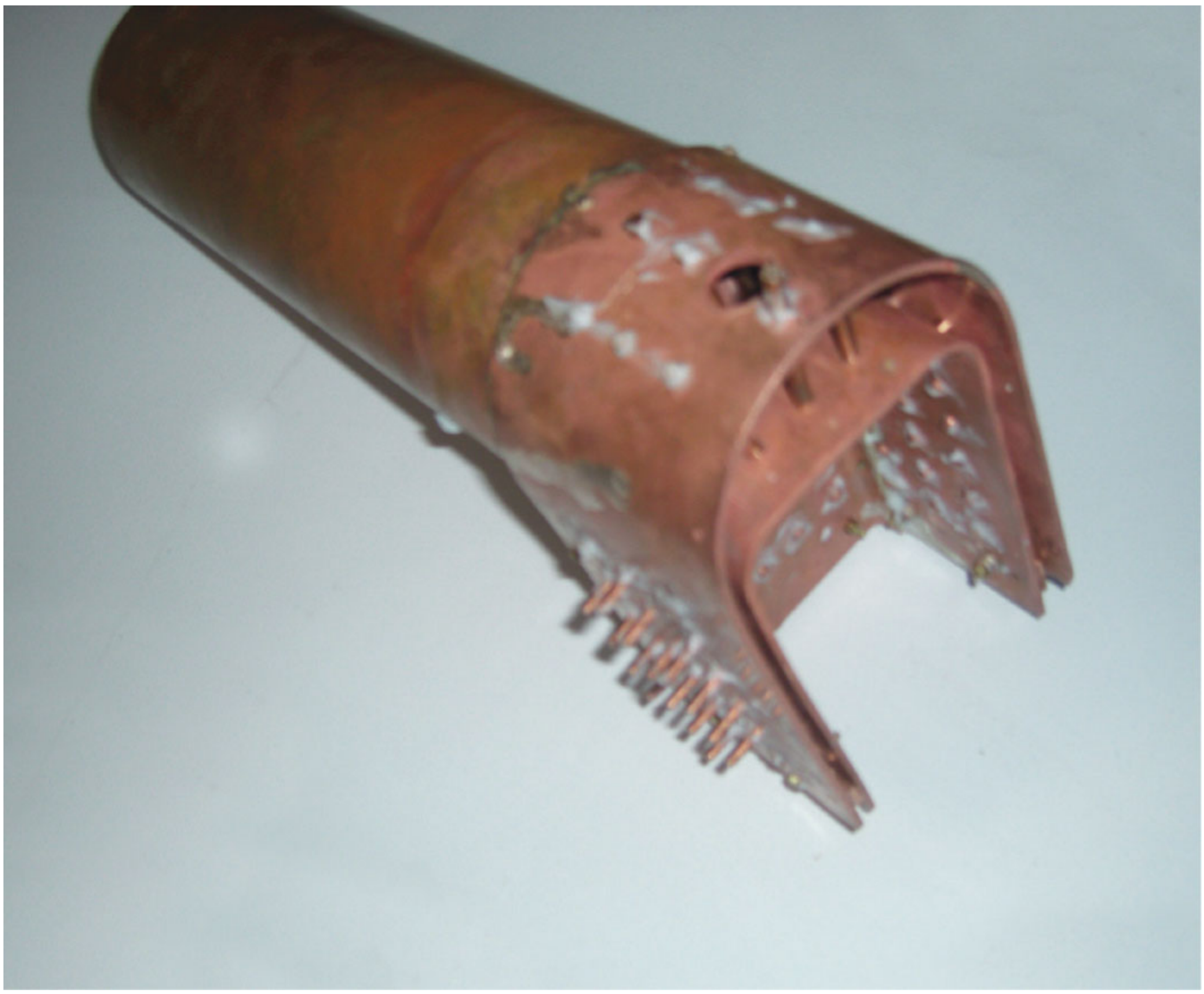
While it is cooling down, this is a good opportunity to put the stays in the inner door-plate. Prepare the stays by tapering the ends with a file or in the lathe. Grip the rivets in the three-jaw chuck with the head in the first groove in the clamping surface. The heads should not then be damaged. Support the plate on the fire-hole ring, side flanges upwards, and push a stay through each of the lower stay-holes, flux and solder the stays and fire-hole. Leave the top stay-holes empty for now, ready for the long stays, but the semicircular reinforcing plates can be silver soldered in place. Check on the other side to make sure that the solder has run right through. Pickle. Assemble the inner door-plate to the firebox, which is why the screws are fitted from inside. This must now be fluxed and silver soldered between the inner door-plate and the inner firebox wrapper. The outer door-plate can now be fitted over the stay ends and the fire-hole ring. This will be a bit of a wriggle but the stays will be soft from the previous soldering and will bend easily, which is why you tapered them. Make sure that they do not bend too easily. Locate with the screws, flux and silver solder.



*Tubes silver soldered to inner firebox.*

File a bevel on the outer edge of the front tube plate flange. Fit the front tube plate over the tube ends, flange outwards and tap in until the flange edge is flush with the end of the barrel. It is usual to fit the front tube plate flange first, but we need the extra thickness of the flange to provide a secure fixing for the smokebox. The bevel will provide a natural channel for the silver solder to run round and penetrate the joint.

Before soldering, make the long bronze rod stays and pass them through from the front tube plate and screw through the door-plate. Flux and silver solder at the door-plate end first. Make sure that you melt enough solder into the joints, because you will not be able to inspect the other side of the joints and this could be the source of a leak when tested. A ring of silver solder around each tube will melt as you heat it all up to silver solder the outside of the tube plate, followed by the stay ends.

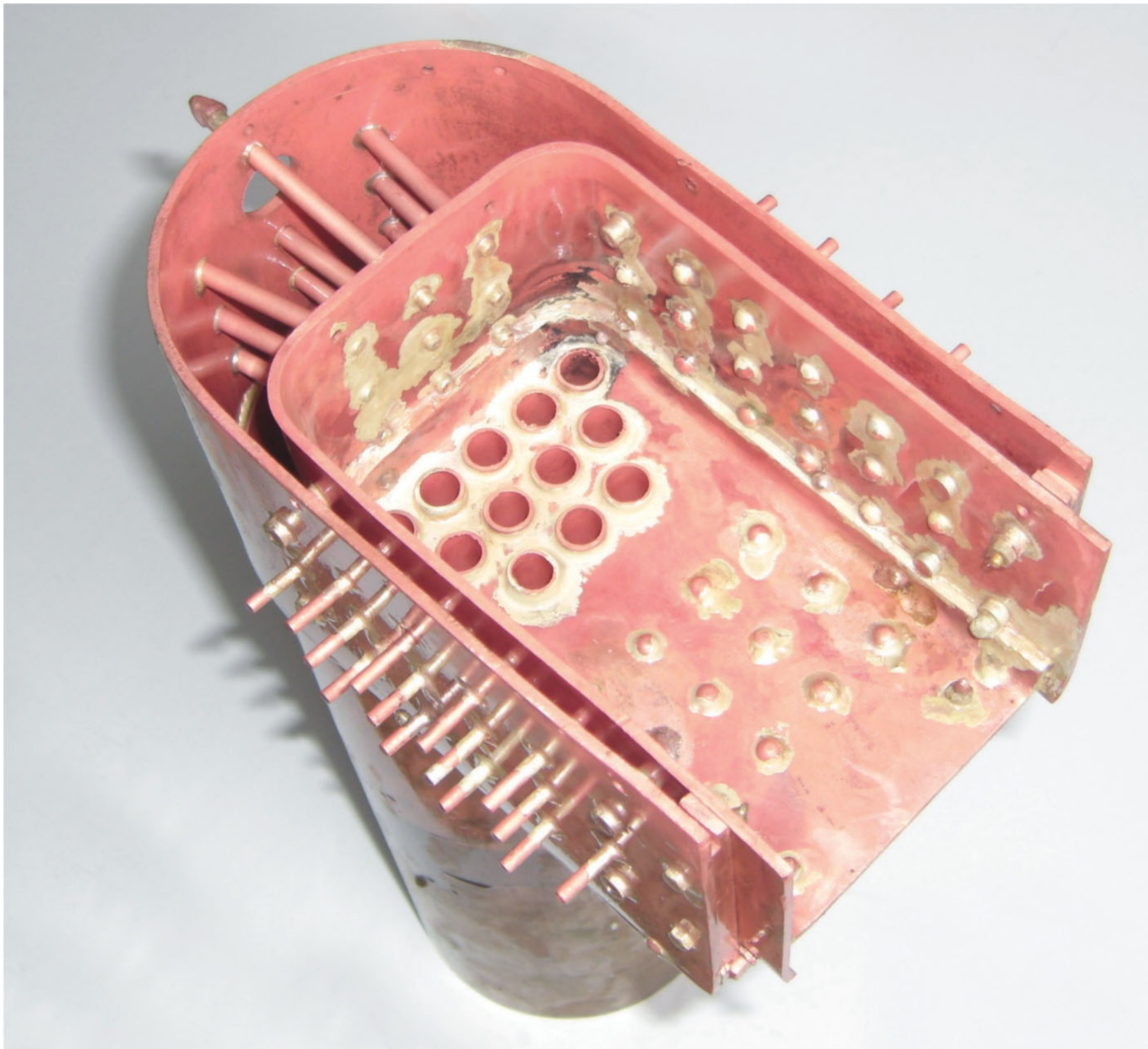


*Stays silver soldered in place.*

*Firebox wrapper and tube plate.*

*Firebox wrapper and door-plate.*

After the inner and outer parts of the boiler have been put together, you will need to use a second torch to heat up this weight of copper. Copper, being a good conductor of heat, will run away with all the heat you can throw at it. It is essential to have an assistant for this task, ready with a torch.



*Stays and tubes after pickling.*

After silver soldering, cool, pickle and flush out several times to remove all the flux.

## BOILER TESTING

The bushes for the fittings should have been threaded for only a couple of turns. This ensures that the thread is ‘square’ to the face of the bush and that the flange on the fitting will close up parallel, with a soft washer between. Now is the time to tap them out fully. If a drop of molten solder is inadvertently dropped into the thread during the hot silver soldering process, it can be filed or drilled out and the hole tapped out. If the bush had been fully threaded it would be more difficult to maintain a good thread.

Make up a set of plugs to fit all the screwed bushes. After thorough pickling to make sure that all the flux has been removed, fill the boiler completely and apply pressure from a small pump. This water pump can be borrowed from another model, the emergency boiler hand pump, or one made for this model. Any leaks found will have to be dealt with before presenting it to the boiler tester for his approval.

The top gauge-glass fitting is screwed into a special bush on top of the boiler shell. This is made from hexagon gunmetal or drawn phosphor bronze of ½in across flats. This is drilled blind and tapped 5/16 × 32tpi (threads per inch). The closed end is drilled across (through the hollow part) for a 6BA screw that fits a 6BA thread in the boiler wrapper. After silver soldering of the boiler is complete, the screw is removed (though it probably breaks), and the hole is drilled right through into the boiler and tapped 3/16 × 40tpi at the outer end for a plug. Try to get the end face of this special bush in line with the face of the lower bush, otherwise it will be necessary to space out the gauge-glass fittings with fibre washers. Copper washers that have been annealed can be used, but do not use aluminium washers as the different metals cause corrosion.

The pressure gauge should read to 120psi (pounds per square inch). The working pressure should always be about the mid-range of the gauge. The cover will have to be carefully removed and a red line painted onto the face at 80psi. To paint the line, have some red paint handy in the lid of the paint pot and pull a short single hair from the back of your hand with tweezers. Drag the hair across the surface of the paint to charge it and lay the hair along the line of the 80 mark in a similar action, drawing the hair lengthways towards the outside of the dial and leaving behind a trail of paint. One line will be enough.

*Firebox door-plate with fire-hole and stays silver soldered in place.*

*Firebox door-plate silver soldered in place.*

It is important that the pipe bringing pressure to the gauge is a ‘U’ shape, so capturing a little condensate in the ‘U’ and thus protecting the gauge from the heat of the steam. Use 1/16 in diameter copper tube and silver solder the nipple that came with the pressure gauge onto one end. Make sure that the nut goes on the right way round. The other end is silver soldered into a bronze plug that has a 3/16 in × 40 thread to match the bush at the top of the boiler door-plate. Leave the tube straight for this operation.

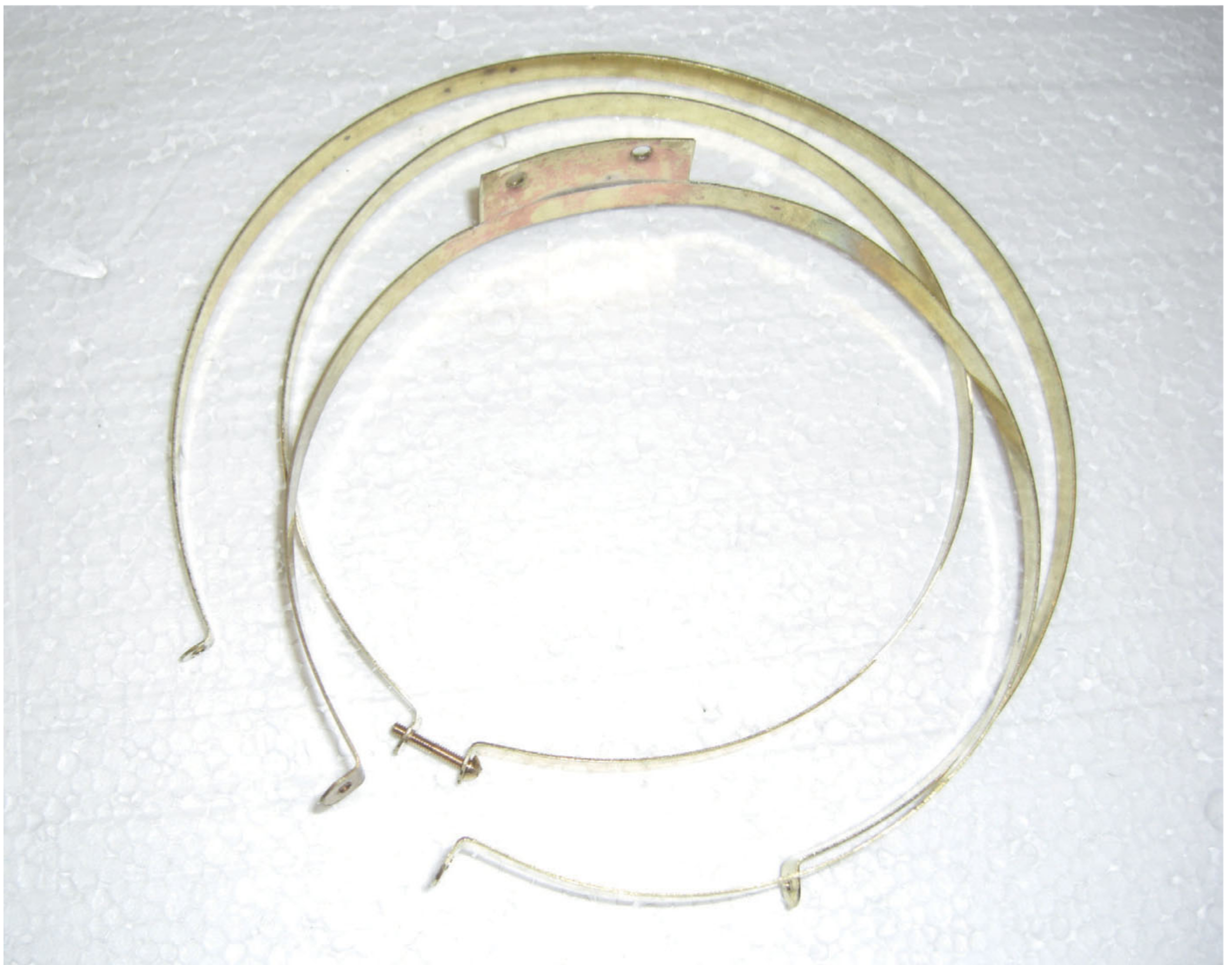
After it is screwed into its bush, the tube can be bent down and round to the left to present a vertical connection to the ¾in diameter pressure gauge.

A feature of the original engine was a small plate on the door-plate to indicate the top of the firebox. Its position is critical. The height of the firebox is measured, internally, down to the firebox skirt. To this distance is added ¼in and measured up the outside of the door-plate. Drill a hole, in the dummy door-plate only, and insert a short brass or copper rivet. Gently mark a line across with a chisel. It is essential that the water level remains above this mark. The added ¼ in is to allow for the thickness of the firebox wrapper plate and the minimum amount of water over the firebox.

## BOILER CLADDING

The boiler barrel is clad with sheet brass of 24 or 26swg, or, if you are not going to steam it, tin-plate. Catering-size coffee tins are not quite long enough, but they are the only ones I know that are not corrugated for rigidity. You will need two sections of cladding. Railway practice used the boiler bands to tighten the cladding (sometimes referred to as cleading) sheets onto a metal frame with just air as the insulating medium. Traction engines usually had strips of wood as insulation and support for the cladding. We will use layers of cereal packet cardboard, although I do not know how it will stand up to the heat and oil. An alternative is sheet gasket material, which can often be found on auto-jumble stalls. Model engineers' suppliers stock a white insulating material for the purpose. The number of layers will depend on the thickness. Another product that I have tried with great success is the felt used to protect dining tables from heat. This has a plastic material on one side that survives very well if kept away from direct contact with the hot boiler. It can be removed and replaced, whereas plain felt falls apart when soaked with oil. Unfortunately it is a bit too thick for this engine.

Measure the length of exposed boiler barrel and the circumference. Cut out and fit the first layer. This can be used as a template for the second layer, which is cut overlength so that it fits over the first. This is now the template for the third layer, but you may decide to stagger the joins. You will need three or four layers. This can be your template for the metal cladding, which overlaps itself by ¼ in at the top. If there is any undercut between the smokebox and the spacer ring, it will not be possible to fit the cladding sheet in one piece. The best place to make a join in the length of the cladding is 1⁄8 in behind the crankshaft mounting bracket. This will put a step in the rear piece and the join will be hidden under the boiler band. There will also be a short, narrow piece between the smokebox and the bearing bracket. This will be hidden largely by the front boiler band.



*Boiler bands.*

## BOILER BANDS

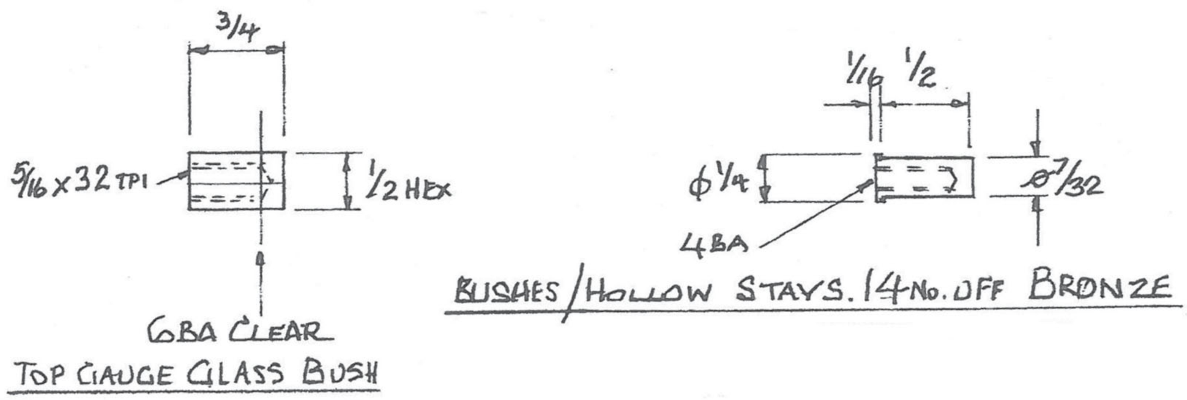
The cladding sheets are clamped in place with ¼in wide brass bands. These are very carefully cut to width with shears. One handle of the shears gripped in the vice will steady the operation and improve the result. They will twist and may curve to one side and take some careful straightening. Polish the brass on both sides before cutting. It is much easier to polish now than when separate narrow strips.

If you are fortunate enough, you may be able to ask the guillotine operator in a fabrication shop to use odd-leg callipers to mark the ends of the cut, or maybe a pre-set stop. After the first cut, the sheet brass is turned over before marking and cutting, then turned over, marked, marked, cut, turned over, marked, marked, cut and so on. The reason for this is that the guillotine will round the top edge of the cut and leave a ragged edge underneath. This results in one edge of your band being rounded and the other edge sharp. Turning over between cuts will give you both edges rounded and save you much filing. You will need four bands but you should cut more, just in case.

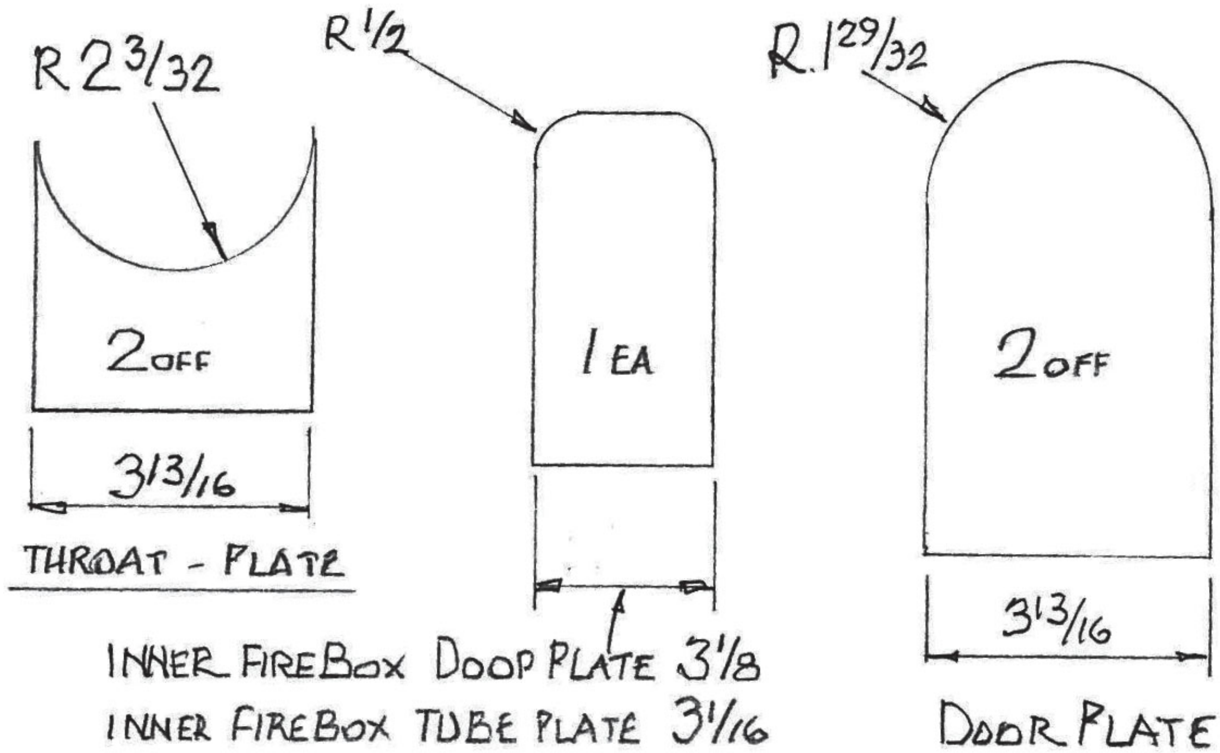
The ends can be simply drilled, rounded and bent to accept an 8BA (6BA or M2.5) screw and nut. To avoid losing small nuts, you could make two small brass tubes (one tapped and one clearance size) and file a flat on each one. The flat runs from almost the hole to nothing along the side of the tube. The filed area is silver soldered to the end of the boiler band. The angled tubes thus formed will be aligned when the band ends approach each other on the underside of the boiler barrel. Four bands will be needed, one in front of the crankshaft bearing bracket and three behind. The middle one of these will have a sideways extension silver soldered on, to which the slide-bar support bracket is bolted. This saves a fixing to the boiler. The same band has a hook, made from an offcut of band, riveted to the band on the other side of the boiler, below the water pump. This is to provide a transport hook for the brake shoe, which is placed under a hind wheel before descending a hill.

After making the slide-bar support bracket and securing the band in place with the screw centrally underneath, determine the position of the sideways extension. Cut a piece of boiler band material to fit the bracket foot and mark its position on the band. Dismantle and secure the extension with a couple of wire ties. Flux and silver solder on the inside.

The slide-bar bracket has countersunk holes in the foot for the thin brass of the band extension to be pulled into. This makes an excellent fixing, but must be flush underneath.



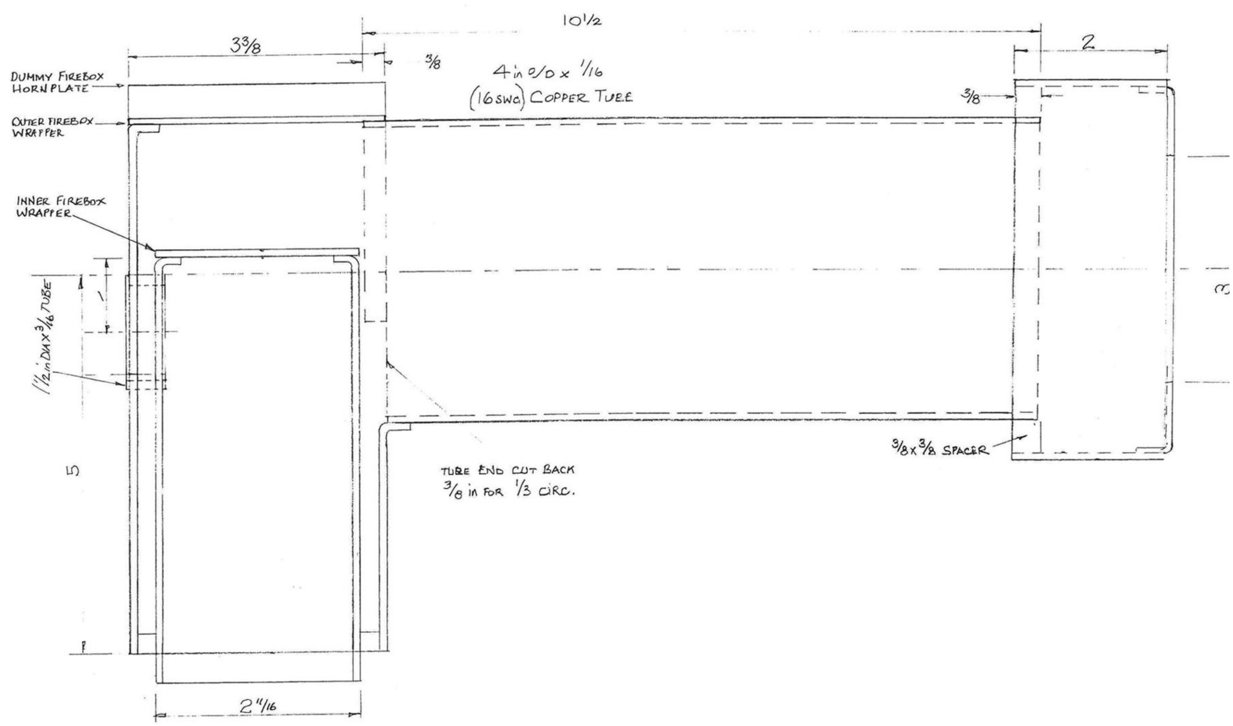

**Drawing 008 Boiler Bushes**




**Drawing 009 Formers.**

## SMOKEBOX

The smokebox is rolled up from 2 or 2.5mm thick steel sheet. If possible, however, use a piece of cast iron or steel tube of the right diameter. The smokebox is also larger in diameter than the boiler barrel and will need stepping out with a 3/8 in square spacer. This could be copper, which is expensive but easier to bend and compatible with the boiler, or steel, since the smokebox is steel. A model engineers' supplier (such as Reeves, Blackgate, Polly) might have a casting in iron or gunmetal. This is a common feature on locomotive smokeboxes, where it is used at the front of the smoke-box for the door to close against. In our case the door is much smaller than on later developments of steam engines. The front plate could be made from a ½in slice of cast iron or gunmetal. This would have the exposed outside edge rounded to simulate the flanged plate and be hollowed out for lightness. Steel rivets are used to secure it in place; copper rivets are easier to close but can be revealed by an unwanted chip of paint.




**Drawing 010 Smokebox Steel 1 off**

The alternative method is to flange the front plate of the smokebox over a former (*see above*). This will present a radius to the exposed corner as the front plate stands 1/8 in proud of the front edge of the wrapper plate. This is as near to the prototype as you can get and should be the method adopted.

Chain drilling the aperture for the door will not distort the flanged plate. The flanged front plate is then riveted in place.

At the bottom will be a 5/16 in or 8mm diameter hole for the perch bracket bolt (for an illustration, *see* Chapter 4) and at the top a larger hole for the chimney base. You will find it helpful to arrange the join in the wrapper at the top and the hole for the chimney half in each end.

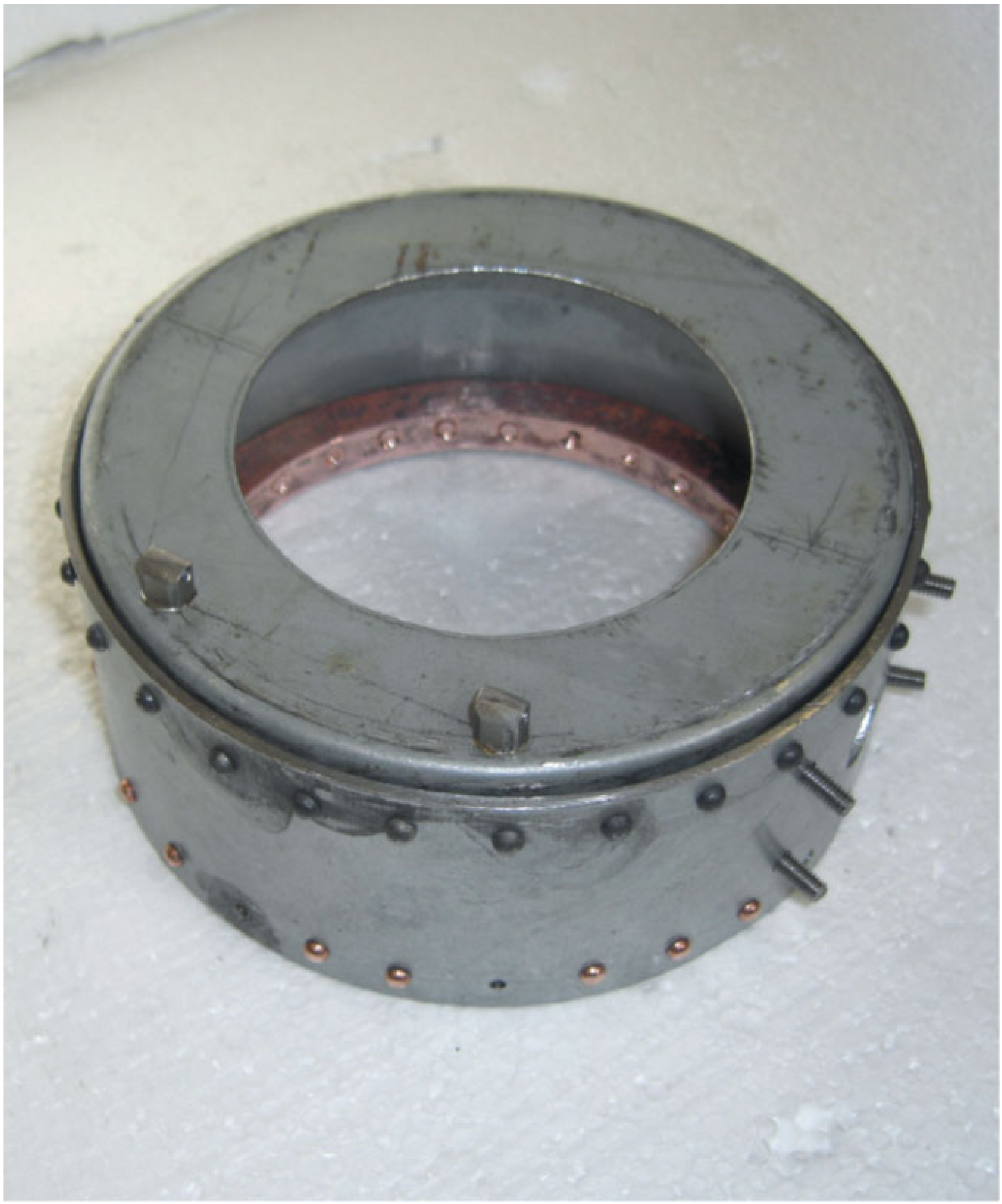
The smokebox door is cut from 2mm sheet steel and hinged on the left side. Make sure that the strap-hinge rivets are within the aperture in the front plate. If one does foul the front plate, it could be countersunk for a flush rivet. Four rivets and spacers support a baffle plate on the inside. This keeps the heat off the smokebox door.

The latch can be made from ¼in square steel with the handle entering a square hole that is filed in with a square Swiss file. It will be found easier to file one corner of the hole, followed by the diagonally opposite corner. The other corners are filed in between. The square on the handle can be filed in the same manner: file the opposite sides and check that they are parallel, then the other two sides, checking for squareness.

*Smokebox and perch.*

*Smokebox front plate flanged.*

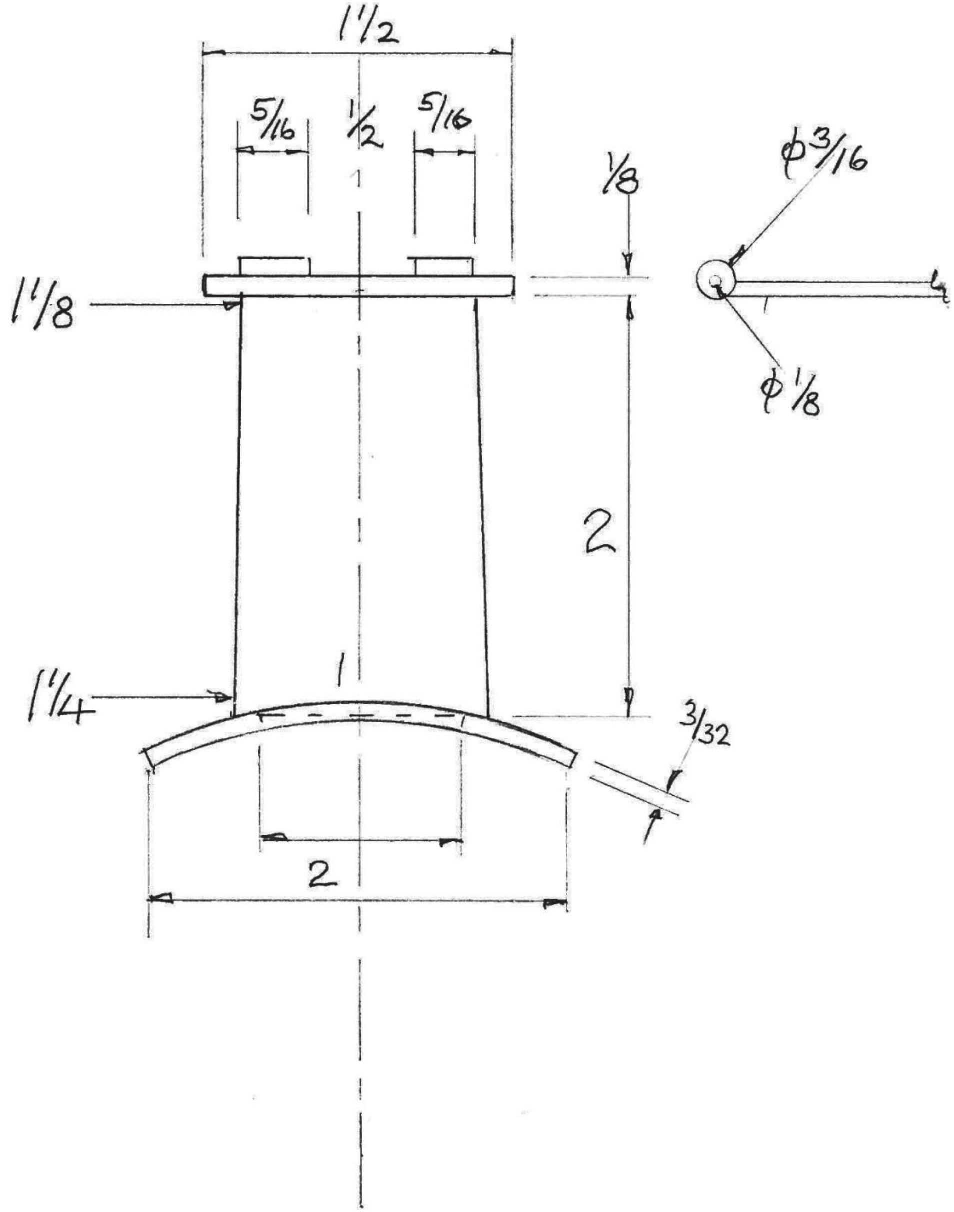
*Chain drill the aperture for the smokebox door.*



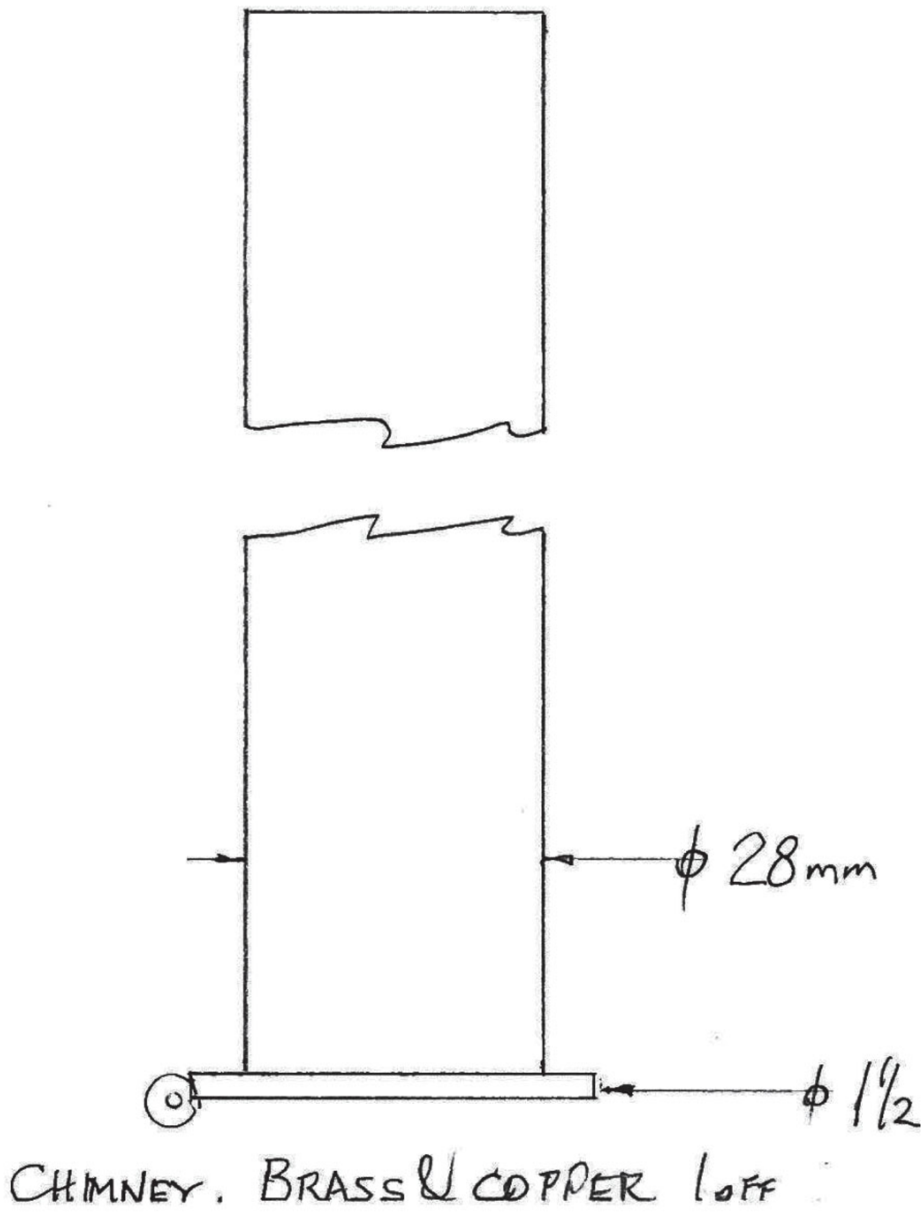
*Front plate riveted to smokebox.*

If the threaded portion and the square portion of the handle are turned on some round steel bar, the stock material can be held in the vice in order to file it, but having a washer to prevent the file contacting the shoulder. This washer will also leave a round section the thickness of the smokebox door. If you make a mess of it, not much metal will be wasted. Cut it off and start again. When satisfied with the fit of the latch – it may fit better one way than another – return it to the lathe and turn the taper part of the handle and part off. The end should be rounded.

Fit the latch in the door, check the best fit of the square and decide which way it should be bent to a downward position when the latch is locked. The bend will take place at the smallest diameter of the taper without much trying.




**Drawing 011 Chimney Base Steel 1 off**




## CHIMNEY BASE

There are several ways of making the chimney base. The top flange and the tapered tube can be turned from a solid piece of steel bar. Have the large end (bottom end) of the tube outwards in the lathe chuck. This will keep the chimney flange close to the chuck and the boring of the tapered bore will be easier with the large end outwards. The top slide of the lathe is used for this and the same setting used for inside and outside.

If the parting or sawing of this thickness is beyond you, the whole chimney base could be made the other way round, which will make the parting process only the thickness of the tube wall. However, the bored hole will be larger at the chuck end.

If your lathe is not up to removing this amount of metal, start with a smaller diameter piece of steel and turn only the tubular part and silver solder (or weld) the top flange in place at the same time as fixing the curved bottom flange. The bottom flange has a circular face, the same diameter as the tube base, machined in the top face. This saves the usual fly-cutting of the bottom of the chimney base tube.

*Chimney base components.*

The chimney is simply a length of 28mm outside diameter (or 1in inside diameter) copper tube, as used by plumbers. To this is silver soldered a base flange and top cap. The base flange is hinged to the chimney base to allow it to rest on the crutch formed on the top of the safety valve. The pivot pin is deliberately loose in large holes, which must be in line with the flange faces.

Chimneys on portable engines are usually much longer than those on traction engines, because they are not in use during transit. The extra length improves the natural draught through the fire.

(For details of constructing the perch bracket for the fore axle, *see* Chapter 4.)

When fixing the smokebox to the front of the boiler, make sure that the chimney is truly vertical and square to the crankshaft. After fixing the chimney base, perch bracket and smokebox ring to the smokebox, ease the smokebox onto the end of the boiler by 3/8 in and check that the back edge of the smokebox is square to the boiler barrel, both from the side and the top.

Place the engine on its wheels on a large flat surface. With the crankshaft bearing bracket in place, complete with crankshaft, check that the chimney is truly vertical from all directions. Check again that it is square to the boiler and drill through the side rivet holes, tapping size for 6BA round head screws. Try to get screws with a head size to match the 3/32 in snap heads of the rivets that hold the smokebox to the spacer ring. Six long brass screws will be needed and it is recommended that the smokebox is fitted to the boiler at a late stage as, if it is removed, it will be difficult to realign the tapped holes for the 6BA screws.

This will be a good time to fix the smoke-box door hinges. The hinge straps across the door are prominent features on the front of the engine, so they must be exactly horizontal.

# 6 Boiler Fittings and Lubrication

## CYLINDER LUBRICATION

The next stage will keep you busy for a couple of days. Before the invention of the mechanical lubricator in the 1890s, the only way to lubricate the cylinder was to fill the fat cup with tallow or animal fat, and allow the heat of the steam to render the fat down and let it run into the cylinder. This would be better fitted to the valve chest to lubricate the valve as well, but here the fat cup is clearly fitted to the rear cylinder cover.

Two tools need to be made. The first is made from 3/16 in or ¼ in diameter silver steel and a one in twelve taper turned on one end with the smaller end of the taper less than 3/32 in diameter. Make sure that your turning tool is sharp and exactly at centre height. This taper is about 4.5 degrees included angle, so the top slide should be set over to just over two degrees. The precise angle does not matter as both components are made while the top slide is set over to this angle.

Do not rely on being able to reset the top slide to this, or any, angle a second time, because the top-slide pivot on the cross-slide is usually rather loose and affects the accuracy of the angle set.

A short section of knurling will aid its use if you have a knurling tool. Before parting off to length, hold the stock length in the vice and file away exactly half of the diameter, all the way along the length of the taper. Carefully measure the diameter and check for half of this figure from the flat to the back at exactly the same point on the taper. Do not de-burr as this will remove the cutting edge.

If the hardening is done before parting off, the other end of the silver steel can be used as a useful handle. Heat the tapered part to red hot and quench in water. Carefully polish the flat side on an oilstone, carborundum or diamond file. Even fine emery tape, which must be kept flat, can be used. Place the flat side on the abrasive surface and push to and fro until bright. This will allow you to see the tempering colours pass along the taper. Heat the body of the job and be patient. Try to get all the taper to yellow and quench again. Polish on the abrasive again and place ready to ream the cross-hole in the fat cup.

This is the way to make a ‘D’ bit, which can be made to ream a hole to size or shape. This is a very useful model engineer’s tool and is often made to create a flat-bottomed hole, or square shoulder, for the valve seats in pumps and clacks, or to ream a hole to size. A model engineer’s ream is turned to the correct diameter and then sawn in a long taper. The saw cut is filed and polished, hardened and tempered. After polishing to sharpen the edge, it is used to ream a hole to size.

The second tool is a form tool to make the spherical part around the cross-hole. This also reduces the diameter above and below. It can be carefully ground on an off-hand grinder, taking great care to observe all the necessary clearance angles. It could also be filed with a diamond file, assuming that the starting point is an unused high-speed steel lathe tool.

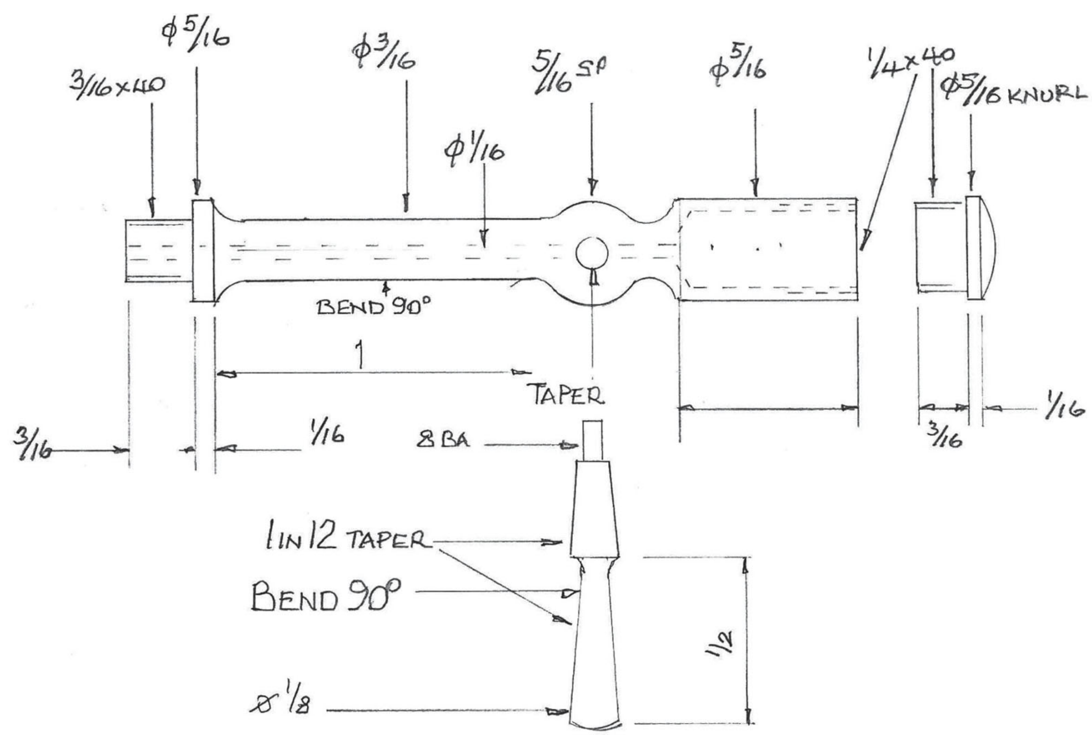
An alternative is a piece of silver steel or gauge plate. In its soft state this can be filed with ordinary files and afterwards hardened and tempered to yellow. To turn brass, the top face of the tool should be flat.

## Fat Cup

Start with a length of 5/16 in diameter brass, face and drill 5.5mm (11mm deep) and tap ¼in × 40 tpi, 6mm deep. Leaving 13mm of the outside diameter untouched, use the form tool to make the spherical area around the cross-hole. This will also reduce the diameter above and below the cross-hole. Using a round-nosed tool, reduce the diameter of the lower part (towards the chuck) to 3/16 in (5mm) diameter. This length is where the bend comes and must be drilled before bending.

Remove from the chuck and, after centre punching, drill the cross-hole in the centre of the spherical part 3/32 in diameter followed by the tapered ‘D’ bit at a slow speed. Do not go too far. Return to the chuck and drill 1/16 in diameter (1.5mm) from the bottom of the fat reservoir until it breaks into the cross-hole. A small drill like this must be withdrawn every 1/16 in to clear the swarf. The fat cup can now be cut off from the stock material.

It may sound odd to move on to another component, but the cap is needed to make sure that nothing gets mis-shaped. From 5/16 in diameter brass, turn down to ¼in diameter and thread ¼ × 40, making sure that it screws freely into the fat cup. Even after reversing the die the thread will not go up to the shoulder, so a small groove can be turned, with a parting tool, just below the shoulder. The outside diameter needs to be knurled for grip. This should be straight knurl, or diamond if that is all you have, or you could use a pointed tool on its side and plane small teeth around the circumference, moving the chuck round by one tooth of the bull wheel each time. This is best done into a groove, which will be the start of the parting off.




**Drawing 012 Fat Cup Brass 1 off twice full size**

A parting tool ground from a HSS tool blank can be shaped to form a domed top to the cap before the final parting off. Alternatively, after parting off, the cap can be screwed into the fat cup and the cup gently gripped in the three-jaw chuck for final shaping and rounding. This is best done with a tool rather than trying to file it to shape in the lathe.

Make the cock and handle utilizing the taper, which is already set up. The 3/16 in diameter part in the middle is where the bend will take place. Heat this area to red hot – but do not over-heat – and let it cool. Do not try to bend it hot as brass is ‘hot short’ and will crumble and fracture.

With the cap and cock fitted, the fat cup can now be chucked the other way round to turn down to 3/16 in diameter and thread 3/16 in × 40tpi. This puts a strain on the component, especially around the cross-hole, but the cock should prevent distortion.

An alternative would be to drill a 3/16 in diameter hole in a short length of round brass, which is then sawn in half. The two halves fit round the neck of the fat cup, which can then be chucked to prevent any strain on the cross-hole or thin wall of the cup.

While this way round, and with the cock removed, drill from the bottom. As this is a long way to drill 1/16 in diameter, use a 5/64 in or even a 3/32 in diameter drill (2–2.5mm) to within 1/8 in of the cross-hole, then use the 1/16 in drill for the last bit.

## Assembly

The cock needs to be drilled before the main body is bent, but first you should ream the cross-hole until the taper of the cock is fully fitted and the large end is still projecting a little. The handle should be pointing down in the normal operating (open) position. With it held in this position, perhaps using the nut and a few washers in place of the spring, use the drilling machine to drill 1/16 in diameter from both ends. Just make a dimple in the taper of the cock. If you drill right through, a burr will be formed where the drill breaks through and this could damage the reamed taper cross-hole. Dismantle and drill from both sides to meet in the middle.

The main body needs to be bent after annealing (heated to red hot and allowed to cool), but the cock and the cap should be assembled to prevent distortion and screwed into the cylinder cover before bending.

The crankshaft main bearings need lubricators. Those on this engine are of a unique shape and style. The spherical top is turned with a form tool ground up from a HSS tool bit, or filed up in silver steel, hardened and tempered. Centre and drill the ¼in diameter hole for the oil reservoir, followed by 1/16 in diameter. Use the form tool to shape the slightly squashed spherical shape of the body, finishing with a neck at the top and part off. A form tool is a good way of repeating the same shape, but because of the narrow drilled neck it is important to do all the drilling and threading before turning the outside. As this component is impossible to hold for a second operation, do all the shaping and polishing before parting off.

The bottom piece is turned from ¼in hexagon brass. Turn the 3/16 in diameter first and thread 3/16 in × 40 threads. Centre and drill 1/16 in, and then turn the neck and ¼in diameter, which should be a push-fit in the reservoir. The two parts are silver soldered together. This construction gives you a reasonable size of oil reservoir and you do not need to mill a hexagon on the lower part.

Drill and tap a hole in the main bearing caps. Drill 1mm diameter through the top half of the bearing. The small hole regulates the flow of oil into the bearing. If oil leaks between the cap and the bearing, place a paper gasket between, with a hole in it, of course.

The big-end bearing, which does all the work, is drilled and tapped 3/16 in × 40 on the top joint line, which is followed by a small 'V' groove down the joint line to convey the oil to the bearing surface. One of the big-end bearing bolts will pass through a clearance hole and the thread will allow the flow of oil.

## NON-RETURN OR CLACK VALVE

A clack valve is used to get water into the boiler without releasing any steam pressure from the boiler. It is simply a stainless steel ball resting on the edge of a hole, which is the inlet passage. No springs are usually needed, so the valve chamber must be vertical to allow gravity to rest the ball in place.

In our case we will need a normal, gravity clack for the hand pump feed. The only place where a spring-assisted clack valve is needed is in the water heater outlet double elbow. Indeed, if you are not going to steam your engine the bush in the boiler could be blanked off with a plug. The full-size engine had a boiler feed clack valve at the bottom of the smokebox tube plate, below the tube nest.

To avoid having the clack in the dirty and hot environment of the smokebox, it can be built into the output double elbow of the feed water heater. It will, however, be in a vertical, downward passage, which will need a spring to keep the ball on its seat.

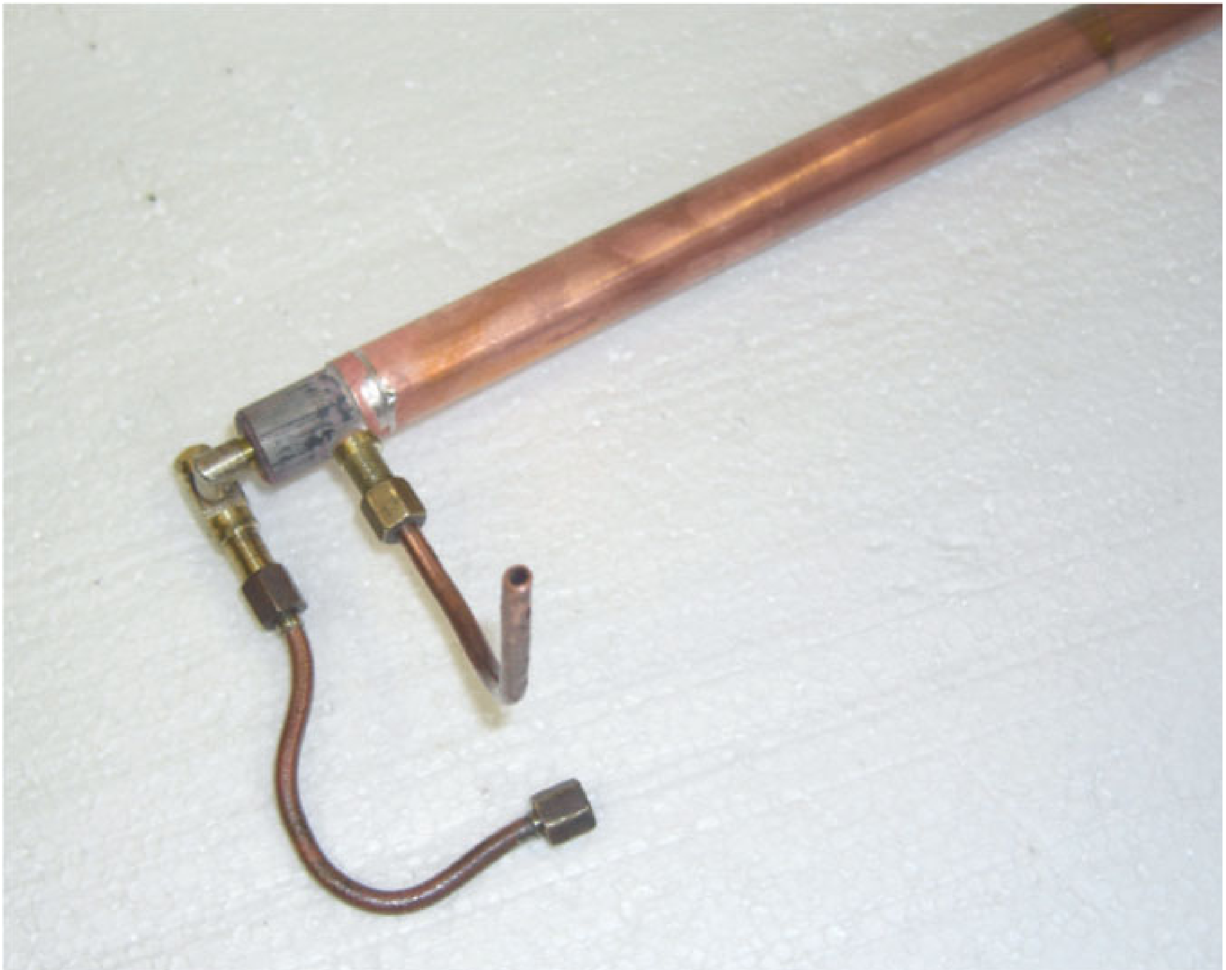
When making a clack valve, always make sure there is enough room around the ball to allow the water to pass and that the ball must be restricted in its lift. This stops the ball wandering about looking for a hole to fall into. The position of the side hole in the valve chamber must be clear of the seat. The ball must not be allowed to cover this hole, otherwise a restriction or hydraulic lock will be made.

## BOILER FEED WATER HEATER

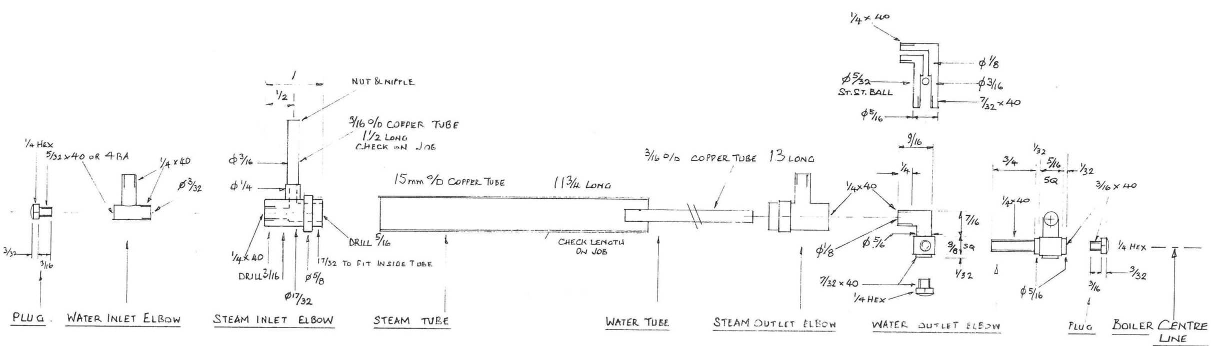
The exhaust steam is used to warm the ingoing water, and is the long tubular item on the right-hand side of the boiler. The outer tube is 15mm outside diameter copper tube, as used by plumbers for water and central heating pipes. The inner, which carries the water, is 3/16 in diameter copper tube. This is bought for the job, or you could use replacement copper brake pipe, supplied to garages in a coil, if you are too far from a model engineers' supplier.

The two end plugs are the same and have an abutment to help locate the outer tube. The abutment could be a 3/16 in wide ring from the same outer tube material. Both plugs are tapped ¼in × 40 at the ends and both have ¼in × 40 connections in the side. The stub at the inlet end is drilled 3/16 in, for the exhaust pipe, from the cylinder. These can all be silver soldered at the same time, together with the nipple for the connection to the cylinder. Don't forget the nut. You may decide to delay the fitting of the nipple until the length of exhaust pipe has been determined to keep the water heater horizontal and parallel to the boiler in all directions. At the outlet end there is a long ¼in × 40 stub with a long thread to take a nut, to secure the heater to the smokebox and the connection for the blast pipe. This directs the exhaust steam up the chimney to draw air through the fire.

*Feed-water heater outer tube.*



*Blast pipe and water delivery pipes.*




**Drawing 013 Boiler Feed Water Heater Brass & Copper 1 off**

A ¼in × 40 Tee piece with a 3/16 in × 40 plug in the end is screwed into the inlet end. The branch is held by an 'M' wire while the concave end is silver soldered. The hole in the branch is then drilled through the wall of the main part of the Tee. This way you do not have to worry about alignment of the holes while silver soldering.

The outlet, or right-hand, end is a little more complicated as there are two rightangle bends and a feed-water clack to incorporate. The first elbow is made from two pieces of ¼in diameter brass, drilled 1/8 in diameter and threaded outside ¼in × 40. Cut off at 45 degrees ready to silver solder back together. To make the long end, drill 3/16 in diameter through the square body and tap 7/32 in × 40 for the plug in the end. Internally, this end has the tapping size for 7/32 in × 40 thread squared off at the bottom of the hole with a ‘D’ bit to make the seat for the valve ball. The long end is then passed through the 5/16 in square part of the body and silver soldered. A 7/32 in × 40 plug is made for the end. Make all threads before drilling or silver soldering. Both plugs are made from ¼in hexagon brass.

*Making the outlet elbow. The long bar is 5/16 in square.*

The inner and outer tubes now need to be soldered to the ends. The elbows can be unscrewed and do not play a part in this assembly. The 3/16 in diameter tube must not be allowed to enter the ¼in × 40 threads for the elbows. One end of the 3/16 in tube can be silver soldered to the inlet end when the side stub is silver soldered on. To achieve this, set the inlet end and inner tube vertically in the brazing hearth and drop flux and a small length of silver solder down the steam hole. On heating, this will melt and run into the joint.

The inner tube may be at a different temperature from the outer tube during service and this difference may be variable. To stop any possible stress, the inner tube is zigzagged slightly to enable it to flex and vary its length without straining the end connections.

Assemble the heater and check that the inner tube does not penetrate the ¼in × 40 thread at either end. The orientation of the outlet fitting (with the long thread) must be set by assembling it to the cylinder and smokebox. Scribe a line along the outer tube and the end plugs in the area of the joins at both ends to enable the ends to be reassembled in exactly the same orientation.

*Complete feed-water heater.*

Drop flux and a small length of silver solder into the steam hole at the outlet end and assemble the inner and outer tubes to the outlet end. Stand up on end and heat to melt the silver solder inside and more applied to the outer tube.

The outer tube at the inlet end needs soldering and this could be accomplished with soft solder, using the correct flux.

The inlet elbow screws in to a vertical position and connects to the delivery pipe from the pump, via a Tee piece. The outlet double elbow exits horizontally on the boiler/smokebox centre line and is secured by a nut, with convex face, to the inside of the smokebox. To this end is screwed the water delivery pipe, which goes to a fitting in the bush in the front tube plate above the tube nest. A longer union nut at the water heater end will help in assembling this pipe.

## BOILER BLOW-DOWN VALVE

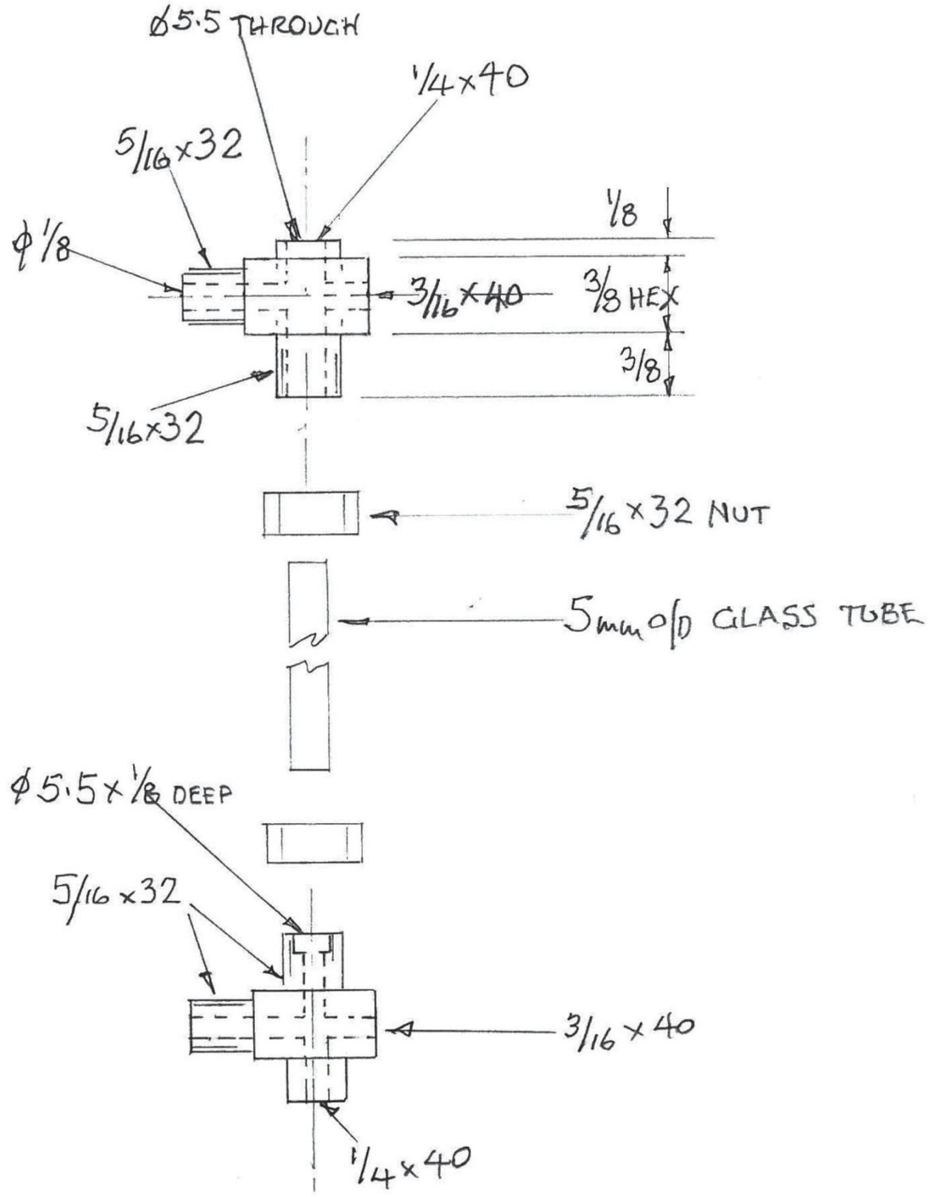
To drain water from the boiler there is a valve at the bottom of the door-plate. A pop-pit valve is used to keep this valve as small as possible. Its head is inside the boiler and seals against the end of the water passage. This passage is reduced in size to a thread into which the valve spindle is screwed. The only difficulty with this construction is that after the spindle has been screwed in from the inside, the hand wheel, or lever, has to be secured to a square at the end of the thread. This means that if the lever boss, or hand-wheel, is threaded, so that it can be screwed onto the spindle and pinned, a better fixture can be made. The hand-wheel is turned clockwise to open, but it cannot be unscrewed completely for hot water to be released through the spindle hole.

It is important to fit the outlet tube, not only so that it directs the water away, but to allow the fitting of a rubber tube to the open valve to siphon water into the boiler at the start of the day.

Use 3/8 in hexagon drawn gunmetal or phosphor bronze to make the valve body and stainless steel for the spindle. Screw the valve into position in the boiler before deciding which flat of the hexagon should be drilled for the outlet stub. This could be screwed in by a couple of threads before silver soldering, or you could use an ‘M’ wire to hold a stub of tube (or drilled rod) and drill through the body wall after silver soldering.

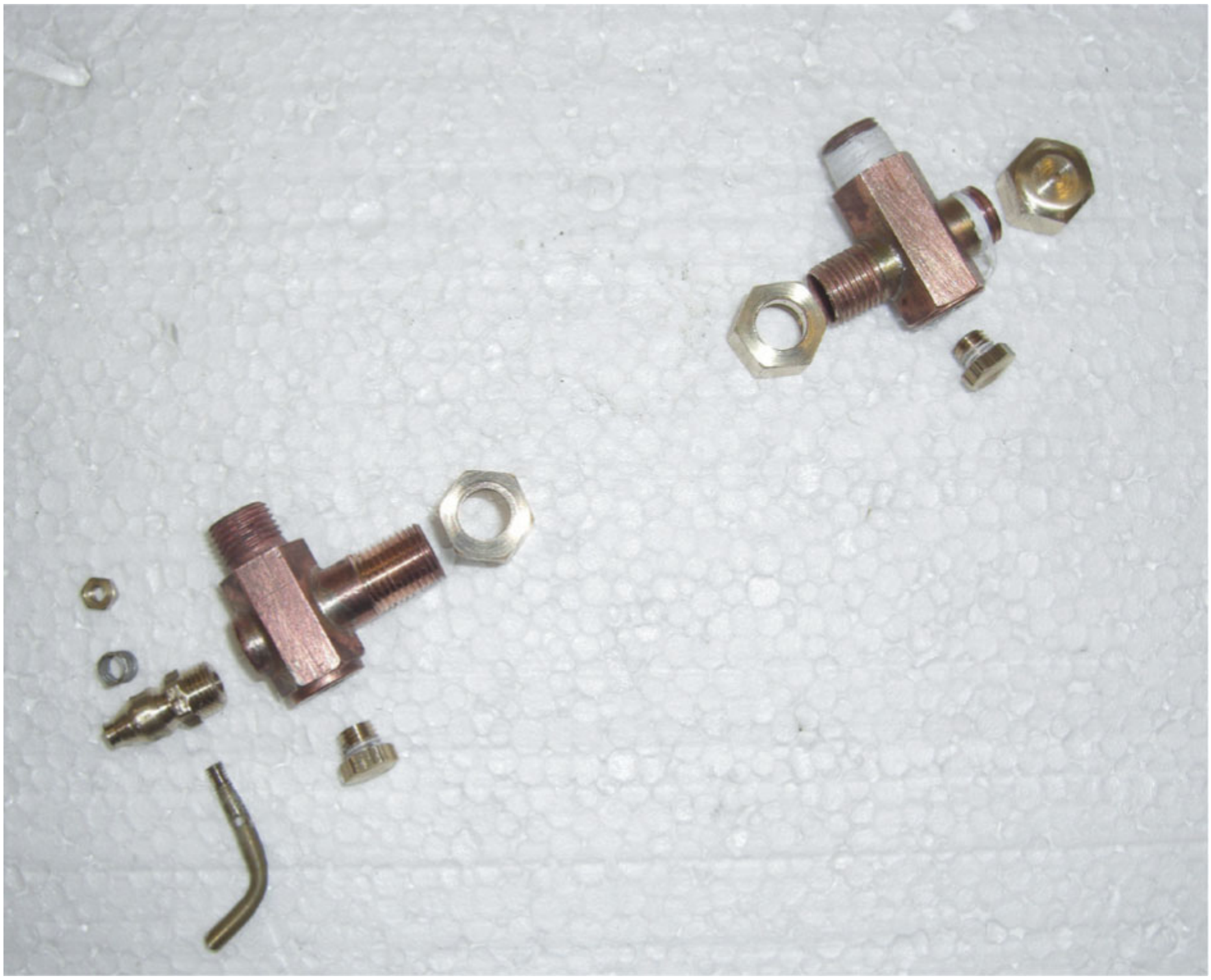
## BOILER WATER-LEVEL GLASS FITTINGS

It is most important to know how much water there is in the boiler, that the water covers the inner firebox, or that the level is so high that water is carried over into the cylinder with the steam. This is called priming and must be stopped to prevent a hydraulic lock in the cylinder.




**Drawing 014 Gauge Glass Fittings GM or PB 1 off**

*Gauge glass fittings.*



*Water level gauge components.*

The original engine had test cocks on the door-plate of the boiler. A quick ‘on-off’ of the taps will emit a ‘hiss’ or a ‘sch’, depending on whether steam or water is being discharged. These taps would be installed just above and below the correct water level. Two dummy valves are fitted to the dummy door-plate. These are made at the same time as the cylinder drain cocks and are secured by thin 3/16 in × 40 nuts inside the dummy door-plate. A full set of four drain cocks could be purchased but their levers need changing to handles. Those installed on the cylinder must not have any connection between them.

Check that the bushes for the gauge glass fittings in the door-plate of the boiler are exactly in line and parallel to each other. Any inaccuracy can be resolved when making the bodies.

Again working with 3/8 in hexagon drawn gunmetal or phosphor bronze, start by turning down to 5/16 in diameter and threading 5/16 in × 32 tpi. Centre and drill through. Repeat this at the other end of the hexagon bar and, before cutting off, drill for the vertical parts of the body, taking into account the previous paragraph. To make it easier to grip the hexagon securely in the drill-vice, file across one of the points of the hexagon and centre punch in line with the remains of the edge. This leaves two flat faces for the vice to grip. It is also easier to use a spanner on these flats.

The essential difference between the two fittings is that the top one has a clear 5.5mm passage through to take the 5mm glass right through; 5.5mm is the tapping size for the ¼in × 40 plug at the top. The lower fitting has a short 5.5mm diameter counter-bore, followed by a smaller diameter to prevent the glass dropping though. At the bottom is a thread to take a blow-down valve. This clears the bubbles from the glass. The outer ends of the bodies have plugs to enable a wire to be poked through to dislodge any accumulation of debris in the body. These can be threaded after the vertical parts have been silver soldered in place and the body cut off, faced, drilled and tapped.

*Water level gauge complete.*

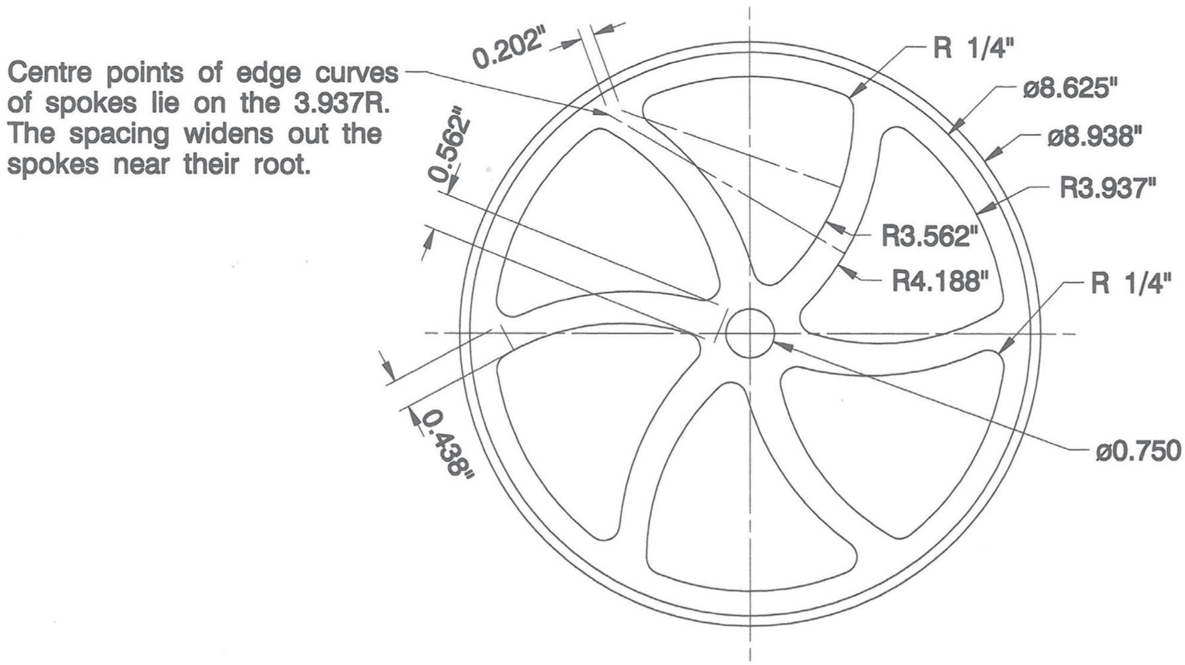
*Laser-cut flywheel disc.*

## FLYWHEEL

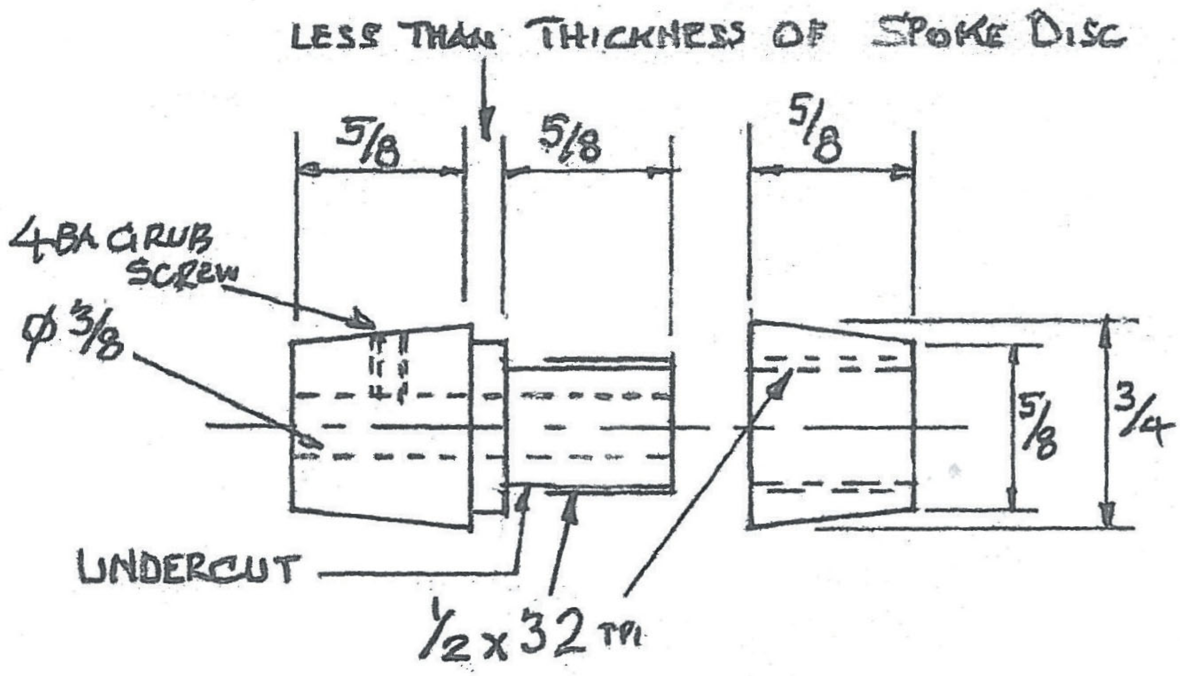
There are several ways of making the flywheel. The original was a single-piece casting in iron, as was standard practice in Victorian times. The elegant curve of the spokes reduced the risk of fracture as the iron cooled in the sand mould.

You could use a casting, if a model engineers' supplier offers one of a suitable size. The next method involves a lot of drilling, sawing and filing. This is to follow the accompanying drawing and drill three holes in each of six spaces between the spokes. The curves either side of the spokes and inside the rim are too great for hacksawing, so they will have to be chain drilled with a small drill; all this in 4mm thick steel. An alternative to this, and one that model engineers are increasingly coming to accept, is to have it laser-cut in 4mm thick steel. Either way the spokes need the edges rounding off to an oval section all along to completely disguise the flat face of the original steel plate. A large quantity of metal can be removed from the corners and edges with a small angle grinder, if you have one. It will be found that only one end of a spoke can be dressed and the other end has to be approached from the opposite end of the spoke. Never use an angle grinder in the workshop. All those sparks are red-hot pieces of steel that fly everywhere, including the slideways of your machine and wrecking your expensive investment. Outside, keep the sparks away from uPVC window frames as they embed themselves, go rusty and appear as orange spots that cannot be removed.

The rim is rolled up from 1 × ¼in (or 25 × 6mm) steel. Bright steel can be had from the usual suppliers, but if you can get a suitable length guillotined from 6mm steel plate, it will be found to be much easier to roll. The bright steel will need annealing (heat to just red and allow it to cool) and the ends will remain straight. When the correct diameter has been rolled, the ends can be cut off. Use a worm-drive (Jubilee) hose clip or several joined together to close the rim onto the spoke disc. It may be necessary to trim a little more from the rim until there is just the thickness of a saw cut between the ends. Remove the rim and tighten the clip to close the saw cut gap. (It would be best to space the worm-drive clip away from the rim with offcuts of steel before the next operation.) Weld the rim ends together on the inside, remove the clip and weld on the outside. Take care not to burn the edges away. It is important that the rim is welded, otherwise the join will show when the rim is turned to size.




**Drawing 015 Flywheel in 2" scale 1 off 4mm S 275 Steel**




**Drawing 016 Flywheel Hub or Boss Steel 1 off**

File the weld off the inside of the rim and heat the rim to expand it until it will drop over the spoke disk. The disk can be supported on a dozen M8 nuts on a board or faceplate. The rim drops over and down to the board and this should keep everything central. Check and adjust before it goes cold. Loctite run into the joint between the rim and disc ‘glues’ it together, and this is followed by an application of car body filler on both sides.

*Spokes carefully dressed with an angle grinder*

*Finished, ready for the rim*

The rim needs turning and facing by holding the rim, which should not stress the Loctite joint. The outside of the rim is turned to 3 degrees from each side to meet exactly in the centre. This makes the centre of the flywheel rim slightly larger and the flat belt will ride up onto the largest diameter and thus keep the belt on the pulley.

The centre boss is made in two parts. One is drilled and reamed, turned and threaded, and finally tapered before parting off. The second part is drilled and tapped, taper turned and parted off. If the second part is made first, the tapped thread can be used to gauge the male thread. Also the second part can be screwed onto the first, before it is parted off, for finishing off the cut face. Neither piece is easy to hold for a second operation. Make sure that the length of the spigot, onto which the spoke disc is pressed, is less than the thickness of the spoke disc. This ensures that the opposing faces of the boss will clamp the disc firmly. After a trial assembly, drill and tap a couple of holes, half and half into the disc and the boss. Screw in two screws, or grub screws, before fitting the second part of the boss. A grub screw set into a dimple in the crankshaft will take the drive.

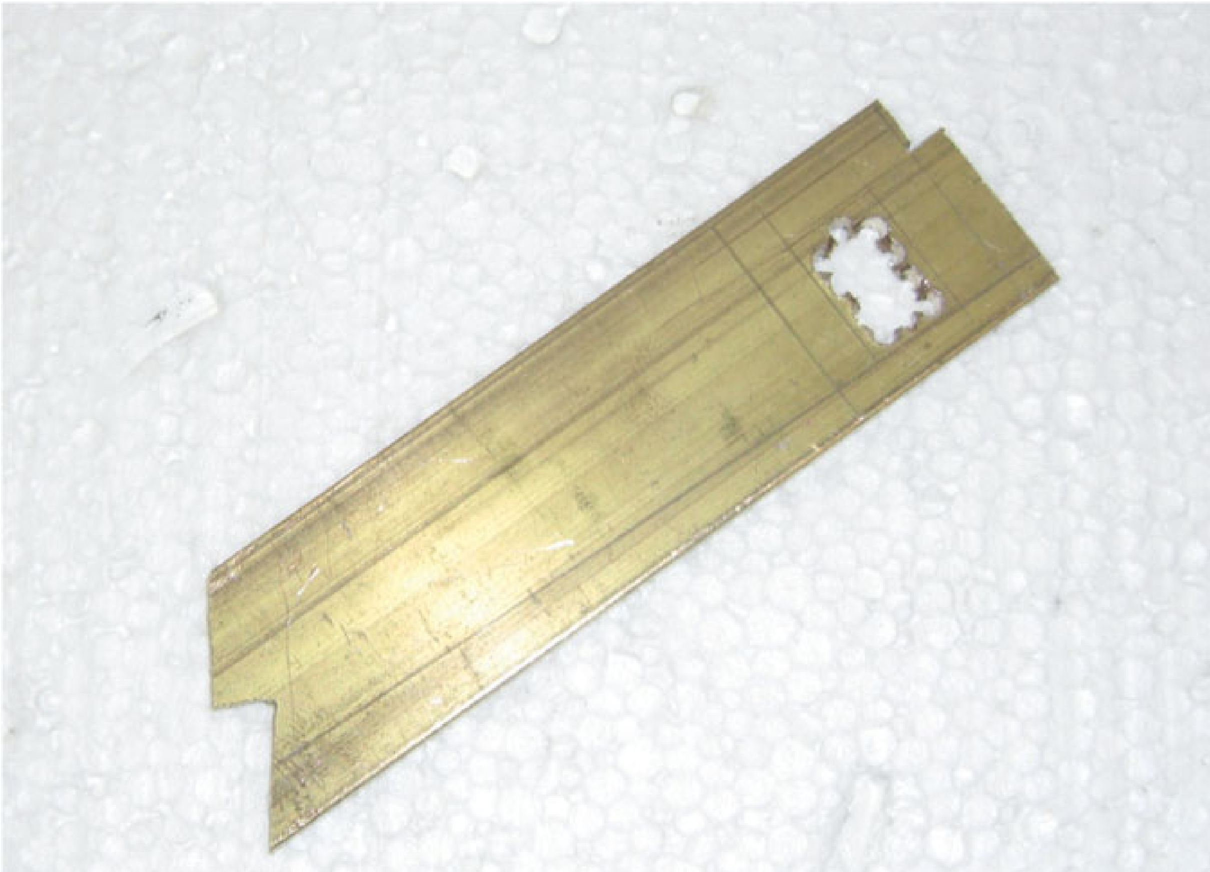
There should be a keyway in the crankshaft and the flywheel, with a gib-headed key fitted.

The flywheel and the belt that it drives are the reason that the engine is offset on the axles to provide extra clearance on that side.

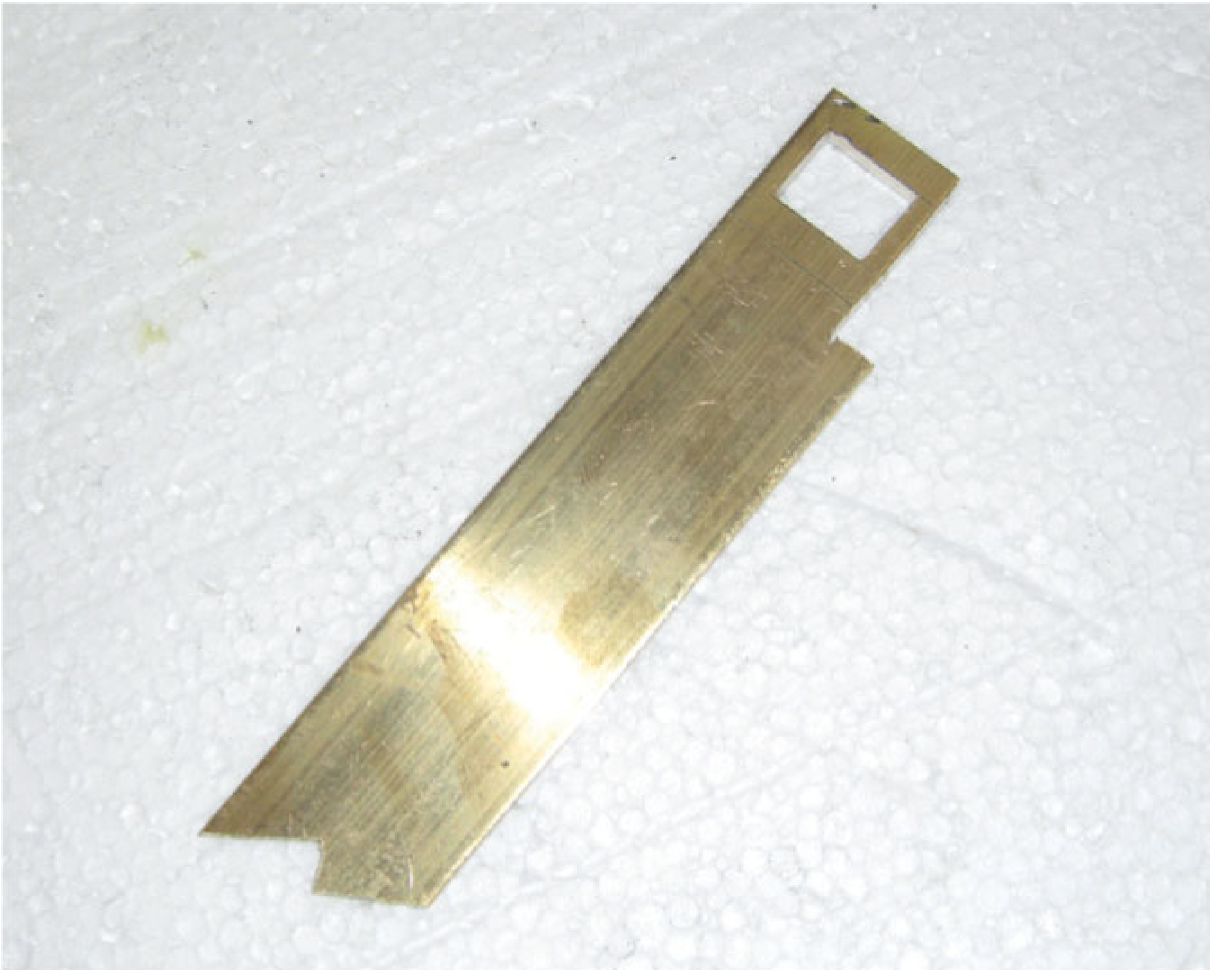
## STEAM VALVE

The steam valve was planned to be driven by a buckle, but this is rather tricky to make. A simpler solution is to move the centre-line of the valve rod off-centre, using a ¼in square brass vertical bar nut in a vertical groove in the back of the valve and a continuous valve rod in a 3/16 in horizontal groove. The valve rod is threaded 3/16 in × 40 tpi and it screws through the vertical nut. It is important to point out that the valve must be allowed to lift off the port face to release trapped condensation in the cylinder. Steam pressure will push it back.

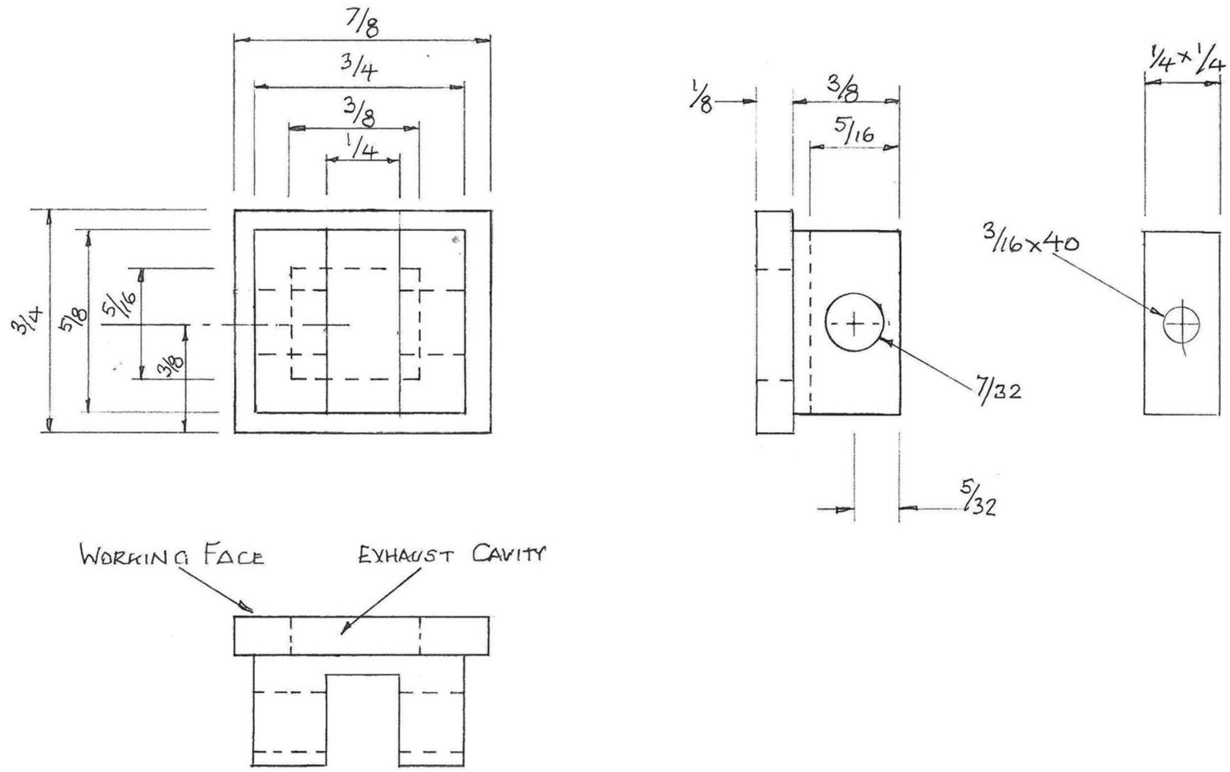
The valve rod must be supported in two places to resist the sideways thrust (actually up and down) of the valve rod. The rod is always supported in the gland and either on a bearing surface alongside the slide-bars, or the valve rod passes right through the valve chest to be supported in a bush on the other side. We will use the former method.



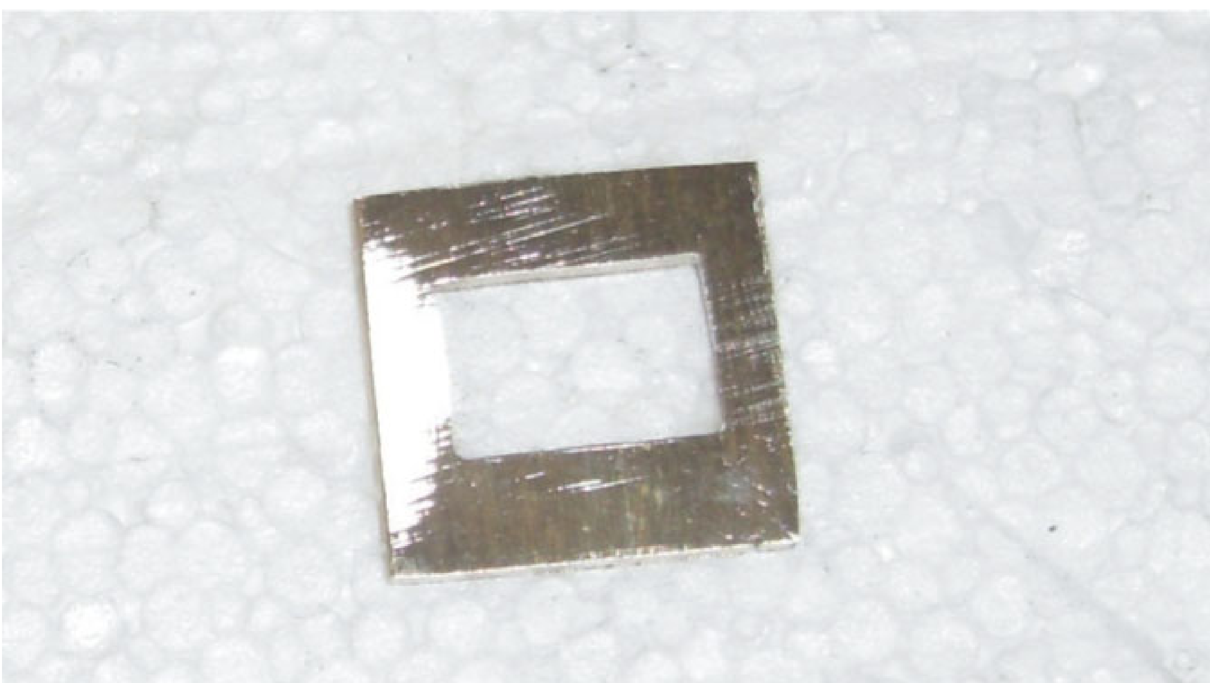
*Chain drill the exhaust cavity in the steam valve.*



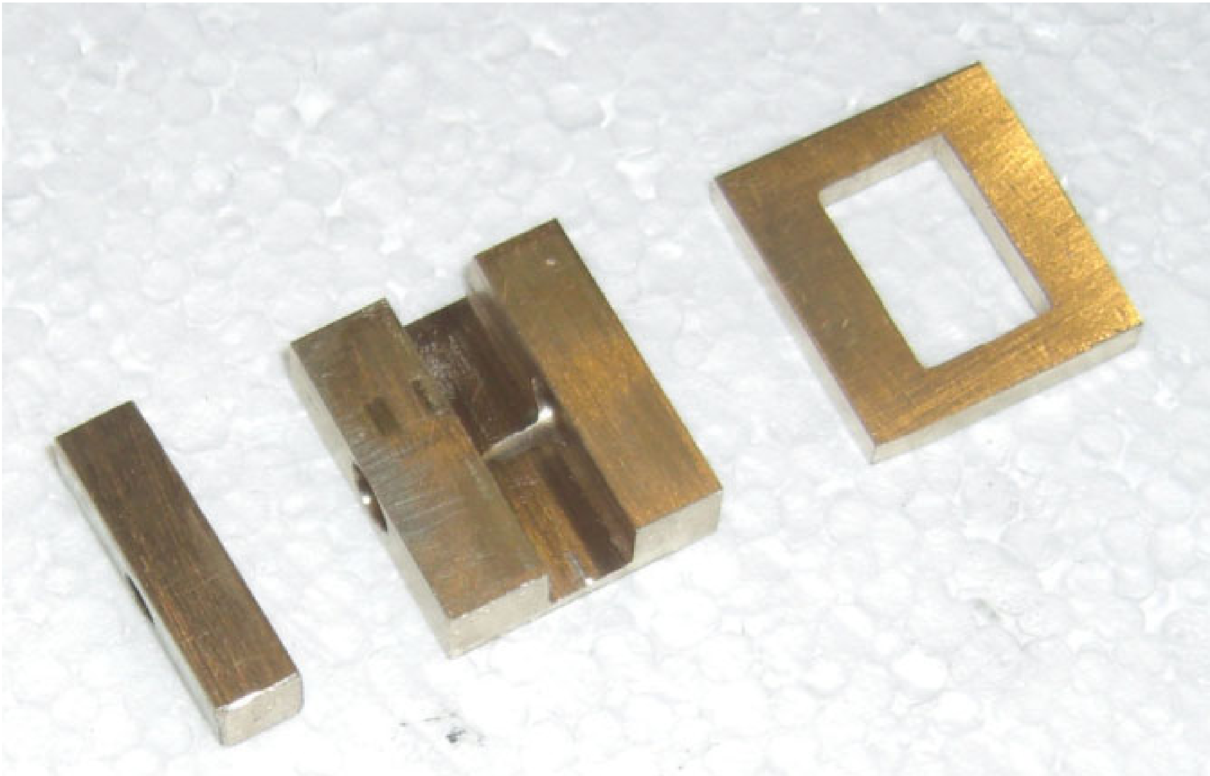
*File the exhaust cavity to dimension before cutting from stock.*



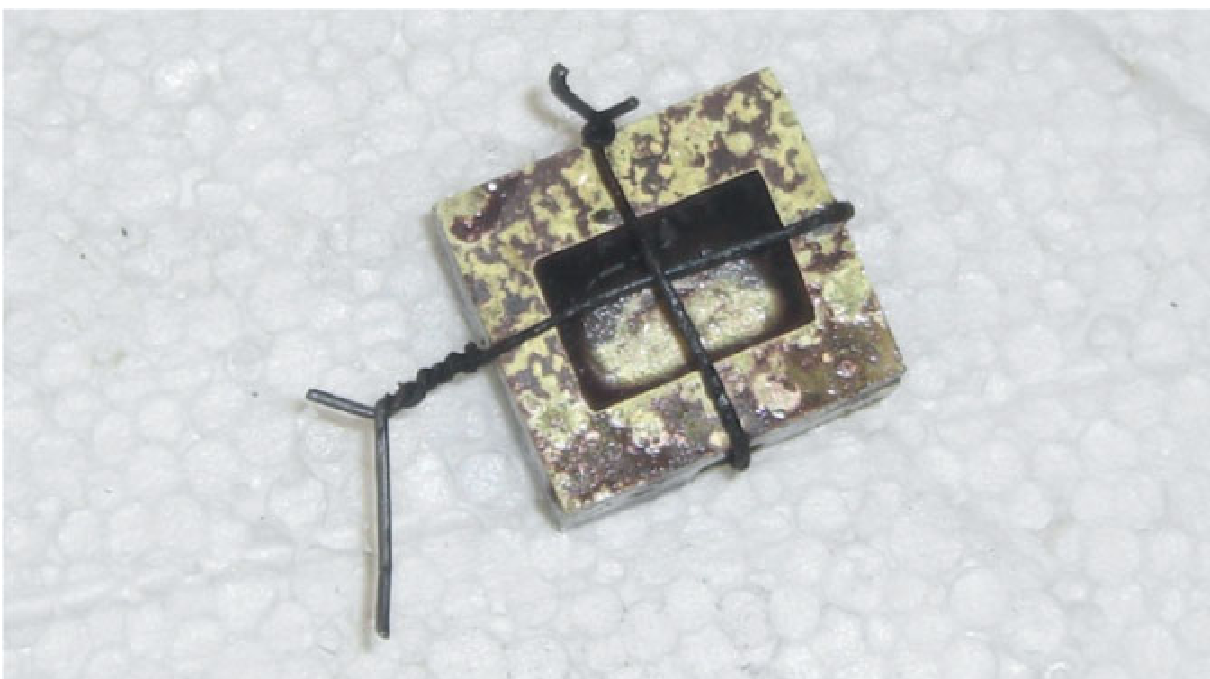

**Drawing 017 Slide Valve & Nut Brass 1 off twice full size**



*Finished valve face.*



*Steam valve components.*



*Steam valve wired and silver soldered together through the exhaust cavity.*

The working face of the valve has a rectangular exhaust recess in it that is the same length as the distance between the inside edges of the steam ports. The easiest way of making the square corners of the recess is to make it in 1/8 in brass with a hole going right through. This is silver soldered to a slightly smaller square of 3/8 in thick brass. For silver soldering them together, place the one with the hole at the top. When it is red hot, dab the silver solder into the hole and it will form a fillet between the parts and round off the internal corners.

Turn the job over and hold it in the vice by the projecting flange. The ¼in wide vertical groove and the 3/16 in horizontal groove can be milled or made with a hacksaw and file. The 3/16 in groove could be a 7/32 in hole to provide clearance for the 3/16 in valve rod. The ¼in one must be a free-sliding fit for the square nut, but not a sloppy fit. The depth of both of these grooves must keep 1/16 in clear of the flange to avoid breaking through into the exhaust recess on the other side. To make sure that the threaded hole in the nut is in line with the 3/16 in groove (or 7/32 in diameter hole), clamp the nut in its groove and pass a 3/16 in (7/32) drill down the hole to make a mark or dimple in the nut. Dismantle and drill tapping size and tap 3/16 in × 40 tpi. You will need to file about 15 thou off one side of the nut to allow for it to lift off the port face to release condensation.

The safest way of getting the gland in line with the valve nut is to measure the distance from the working face of the valve to the centre of the valve rod, allowing for the condensation clearance. Mark this distance from the port face on the cylinder, across the cylinder mounting bracket on the valve side of the mounting bracket. Project the centre line (height) of the ports across the mounting bracket and dot punch the intersection.

Assemble the dummy valve chest cover, including the gland, with its five bolts. The bottom two need to be countersunk on the valve side and threaded 6BA. The side bolt is hexagon headed and the two top hexagon bolts should be long enough to allow for the thickness of the valve rod support bracket.

Dismantle the bracket from the cylinder and drill 3/16 in from the dot punch on the inside through the bracket and the valve chest cover. Reassemble the bracket to the cylinder and the valve chest to the port face. Drill the valve rod hole through the end of the valve chest 3/16 in diameter.

Dismantle the bracket from the cylinder and open the hole in the bracket and cover to 5/16 in. This forms the gland stuffing box. The gland can be assembled to this hole and the stud holes marked through and drilled tapping size for tapping 6BA. The other side is countersunk to allow two 6BA countersunk screws to be screwed in to form the studs for the gland.

On reassembly, with paper gaskets everywhere and a short tube of PTFE for the gland packing, the valve rod should pass freely through the valve rod support bracket, gland, stuffing box, valve chest end bearing and screw into the nut in the groove in the back of the steam valve, and slide to and fro freely.

This may seem a lot of assembly and dismantling, but the alternative is a series of accurate measuring, marking and drilling of related holes where slight changes in dimensions can have knock-on effects. It would also mean accurately marking and drilling both items that are to be bolted together. In some cases there is no easy way of measuring between two datum faces to which other dimensions are related.

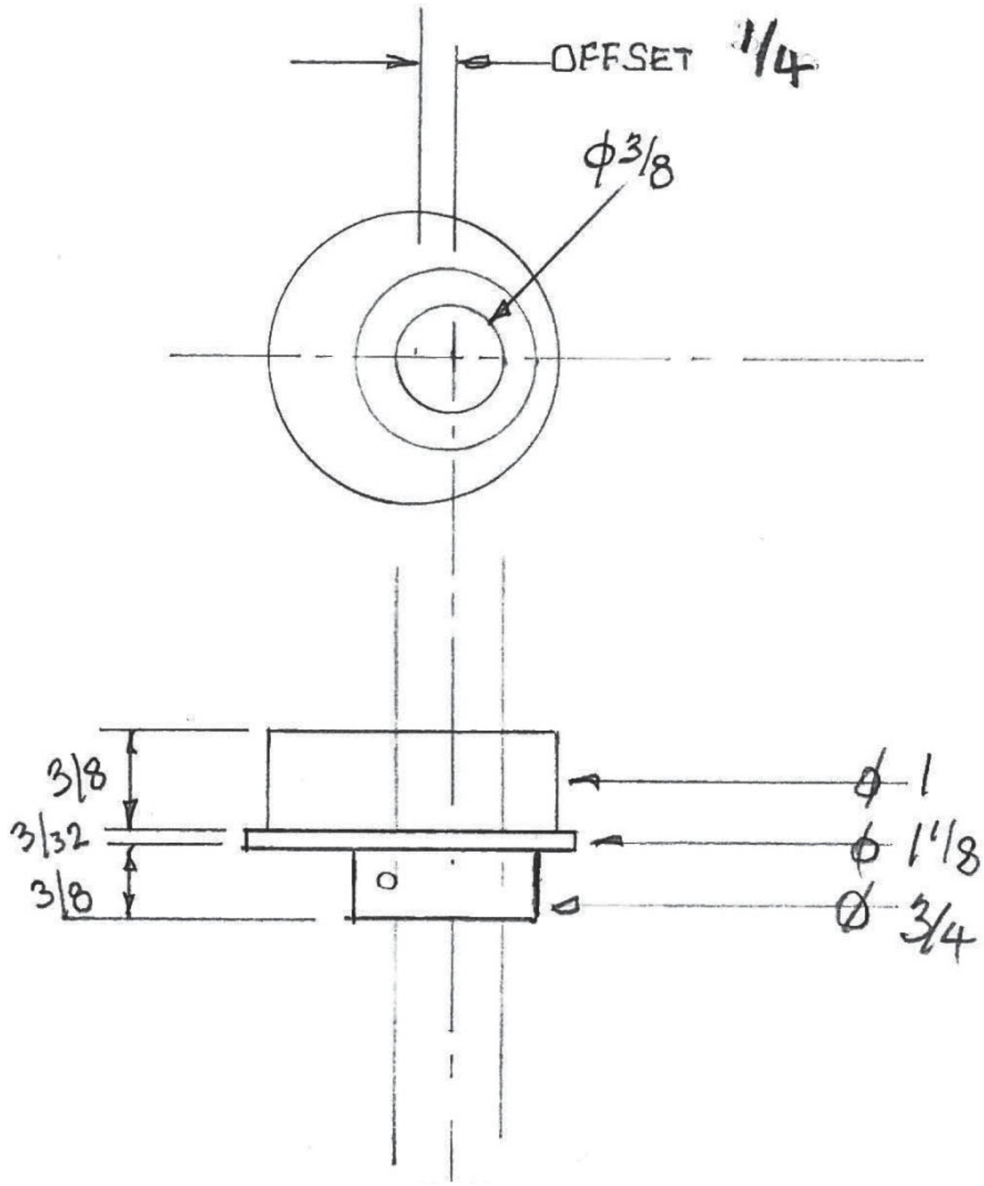
## ECCENTRIC

The valve has to be pushed and pulled across the port face, in time with but ahead of the crank. This is achieved by using an eccentric. The full-size eccentric was adjustable around the shaft for timing purposes. A flange and boss are keyed to the shaft and the flat face of the flange is bolted to a curved slot in the eccentric. A flat disc is also bolted to the other side of the eccentric to stop the eccentric strap from working its way off the side of the eccentric.

Choose a piece of free-cutting mild steel for the eccentric as it will give a smoother finish and create less wear. Face off and turn sufficient to make two eccentrics, the second one having a rib round the centre. Carefully make the two halves the same diameter. The drawing states 1in diameter, but if you only have 1in bar to start with, skim it up to the biggest diameter you can and make the strap to fit.

Now for the offset. When the end of the bar is faced, the centre of the bar is usually visible. Measure 5/32 in from the centre of the bar and dot punch the face. Check the position.

Using the four-jaw chuck, set the bar to run true to the dot punch mark. Centre, drill and ream or bore to a close fit on the crankshaft. Part off or saw and face up as your skills demand. You could bore one eccentric, cut it off and then deal with the other one. Do not forget that the other one, for the feed pump, needs a boss on one side.



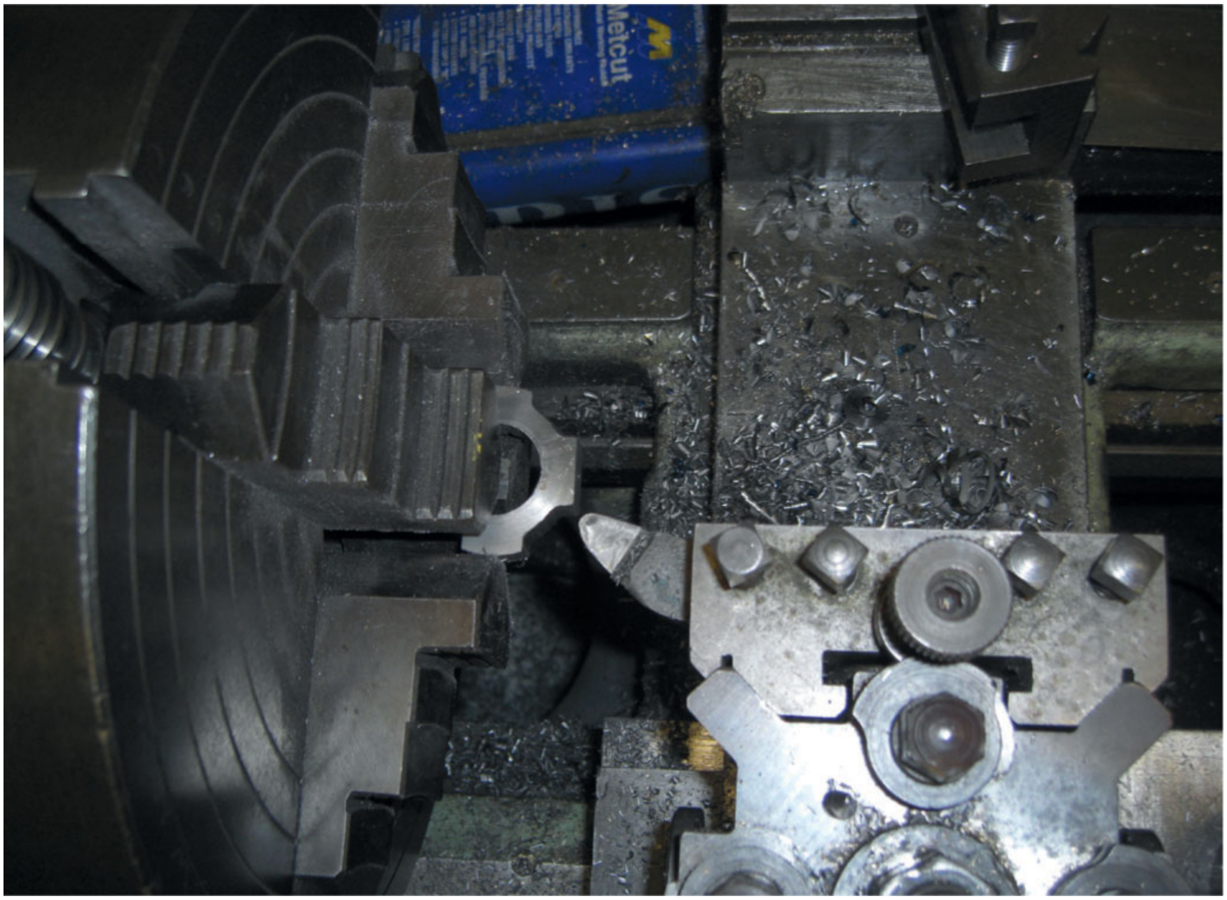

**Drawing 018 Eccentric Steel 2 Off**

## Eccentric Straps

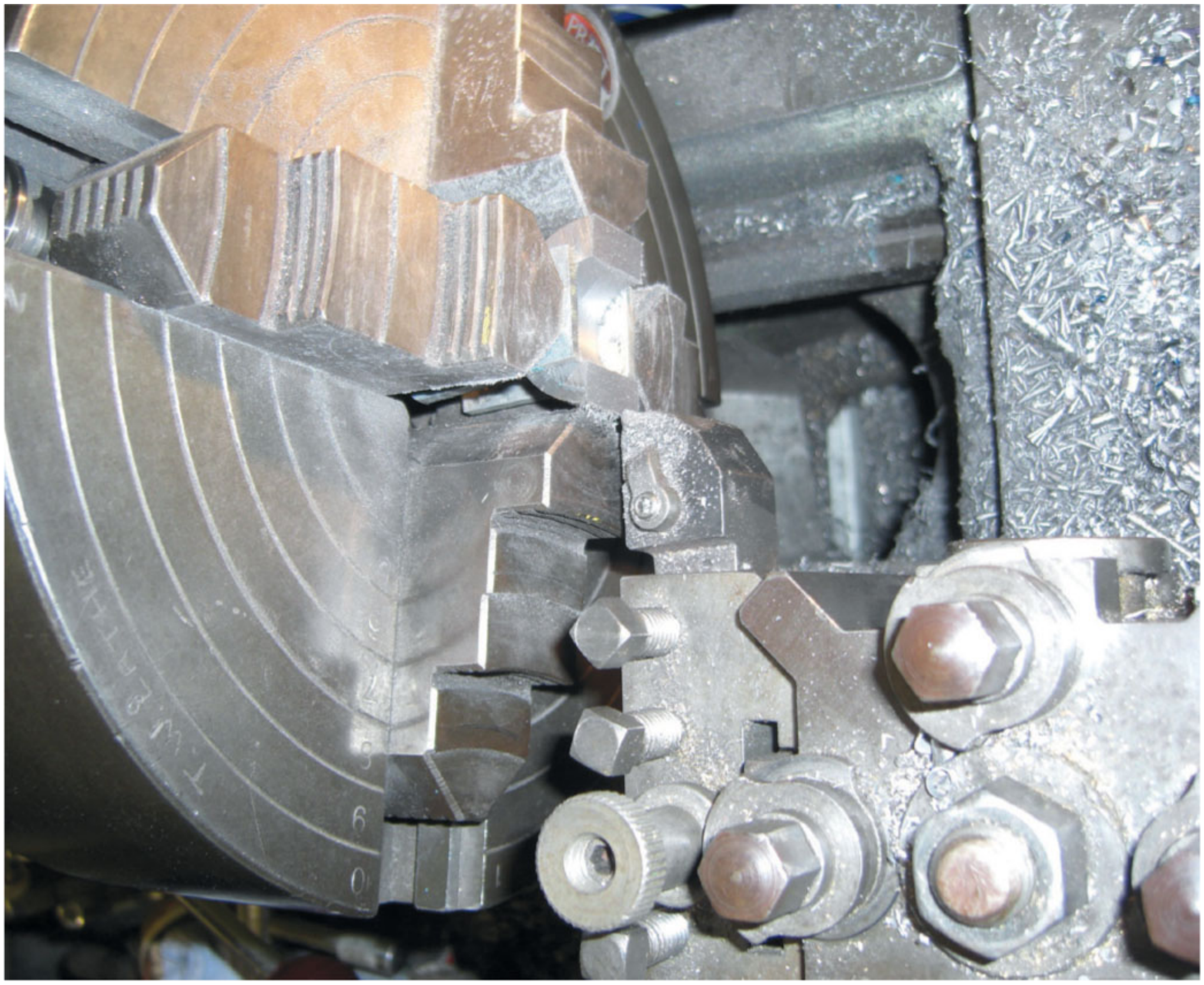
These are made from slices of 1½in diameter cast iron. Tapping size holes need drilling at 1¼in centres before cutting in half, trueing up the cut faces, tapping the holes in one half 6BA and open the others to 7/64 in, the clearance size for 6BA. The hole can now be drilled and bored on the cut line. One will need a groove machined in for the rib in the middle of the eccentric. The rest is hacksaw and file work, not forgetting the face for the eccentric rod end plate. Two 6BA screw holes are needed for this. These can be drilled right through into the bore to save tapping to the bottom of a hole. Make sure that the screws do not reach the bore. The rest of the hole can be a useful oil reservoir. The other side of the strap can be faced off on a stub mandrel.

## Eccentric Rod

The rod is threaded into a central hole in the end plate and silver soldered. The other end is threaded into a fork and pivoted to the valve rod with a 3/32 in silver steel pin, which is drilled for a 1/32 in split pin. The end of the valve rod is supported in a bush in an arm, which springs from the top of the cylinder support bracket. The arm is doglegged to align the bush with the valve rod.

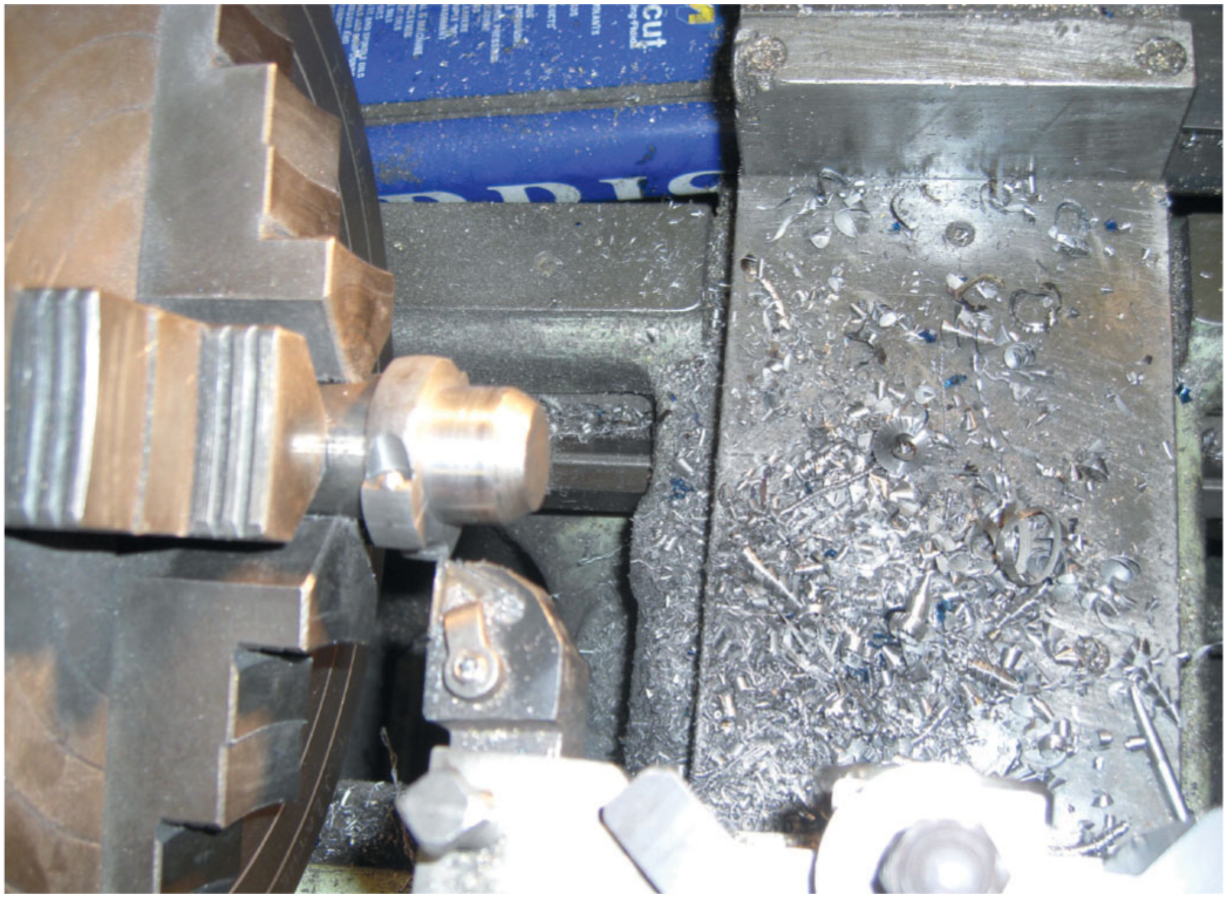



*Machine the face for the eccentric rod.*

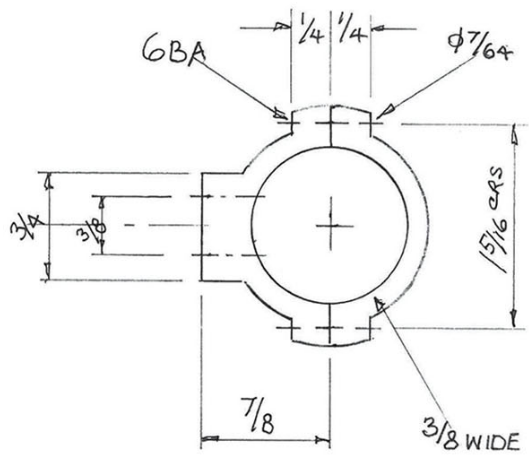


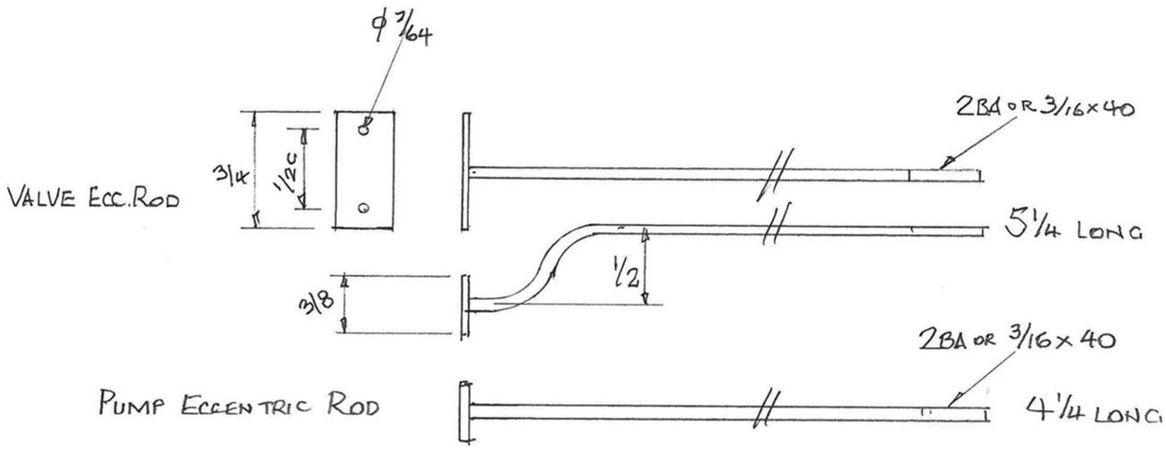
*Machining the cut faces of the eccentric strap. This could be milled.*

*Bore the eccentric strap.*



*Face off the other side of the eccentric strap on a stub mandrel.*




**Drawing 019 Eccentric Strap C. I. 2 off**

## REGULATOR

The original full-size regulator was simply a flat plate that covered and uncovered a hole connecting the regulator chest to the valve chest. The rod that controls this plate must pass through a steam-tight gland as it is at full boiler pressure. The outside end is controlled by a lever, which pivots in a pillar screwed to the ‘ear’ on the rear cylinder mounting plate.

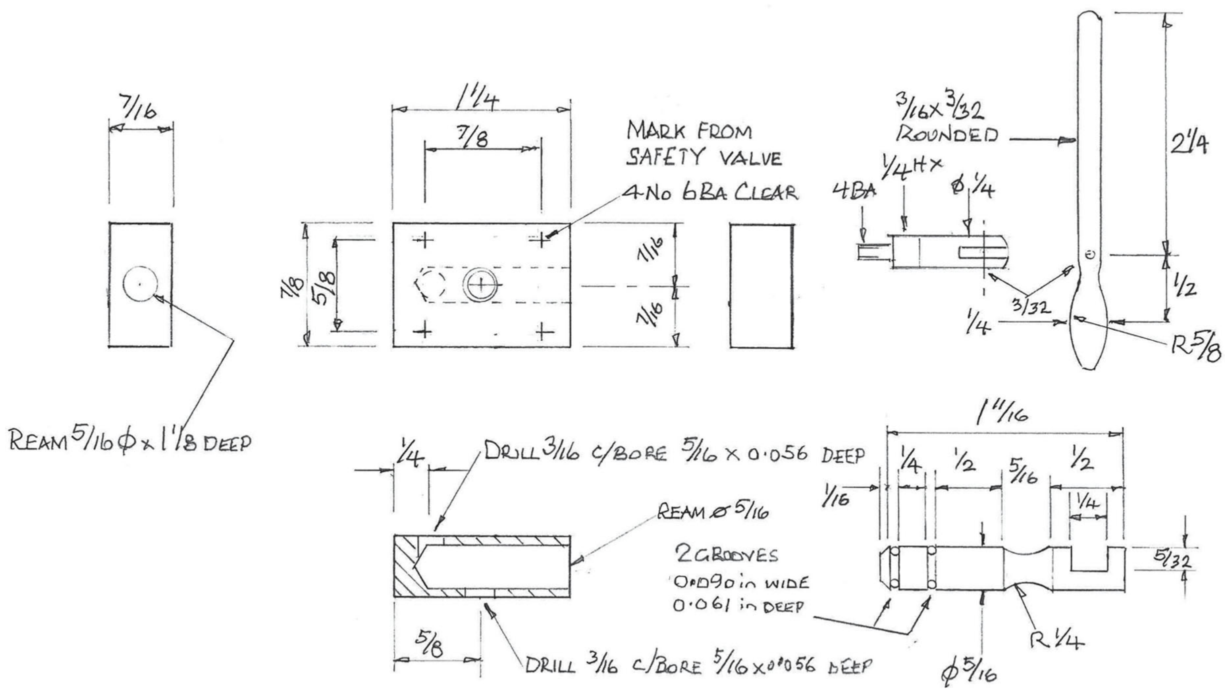
*Passages in regulator chamber counterbored for ‘O’ rings*

The method that we will adopt uses a 5⁄16 in diameter stainless steel rod in a reamed hole and has an ‘O’ ring on each side of the inlet passage from the safety valve. The end of the rod is chamfered to allow free passage for the steam from the safety valve to the valve chest. You will need to find a way of rounding, or countersinking, the inside end of the steam entry hole or the ‘O’ ring will be chewed up by the sharp edge where the steam entry hole meets the 5/16 in reamed hole. This can be achieved by passing a small spherical grindstone down the steam hole and carefully grinding the edge with the back of the sphere. Do not try to access via the 5/16 in hole as there is the possibility of damaging the smoothness of the reamed hole.

The easy way of locating the grooves for the ‘O’ rings is to insert the stainless steel rod, faced and chamfered, into the bottom of the hole and use a scriber to mark the stainless steel rod down the steam hole. Remove and make the grooves just clear of the marked ‘hole’ with a square-ended parting tool 70 thou wide (0.070in) by 65 thou deep.

The other end of the rod has a half-diameter cut-out where the oval end of the regulator lever works without any backlash at any part of its movement.

The regulator lever pivots in a slot cut in the end of a short length of ¼in hexagon bar. Stainless steel would be better than brass for this. It is just possible to make two hacksaw cuts and open out with a warding file to give a free, but not sloppy, fit for the lever. If the pillar is screwed into the ear, the best direction for the slot can be determined. The 3/32 in pivot pin has to be fitted after assembly and can be riveted over only at the top, before screwing the pivot into the 'ear' in the rear cylinder mounting bracket. The riveting will stop the pin from falling out.




**Drawing 020 Regulator Chamber C.I. Valve Lever & Pivot Pillar StSt 1 each**

# 7 Engine

## CRANKSHAFT BEARING BRACKET

The crankshaft bearing bracket is cast as a box with a curved base that fits as a saddle over the boiler. Both bearings are bolted to this box, which enables the crankshaft to be set up on the bench and later fitted to the boiler if you wish.

Check the positions of the six special bushes in the top of the boiler barrel. The base plate is curved to about 2 1⁄16 in radius to fit over the boiler, depending on the thickness of the heads on the bushes. Make sure that the curve is square to the plate or it will not sit straight on the boiler.

A piece of stiff paper over the boiler could have the six holes poked through with a scriber. Make sure the front of the paper is identified. The paper is then transferred to the underside of the curved plate and the holes transferred. Identify the front of the plate. Dot punch the hole positions and drill 7⁄64 in (2.8mm). The bushes will need tapping out 6BA (M3). Check that the screws will pass through easily and the plate fits snugly down onto the boiler bushes.

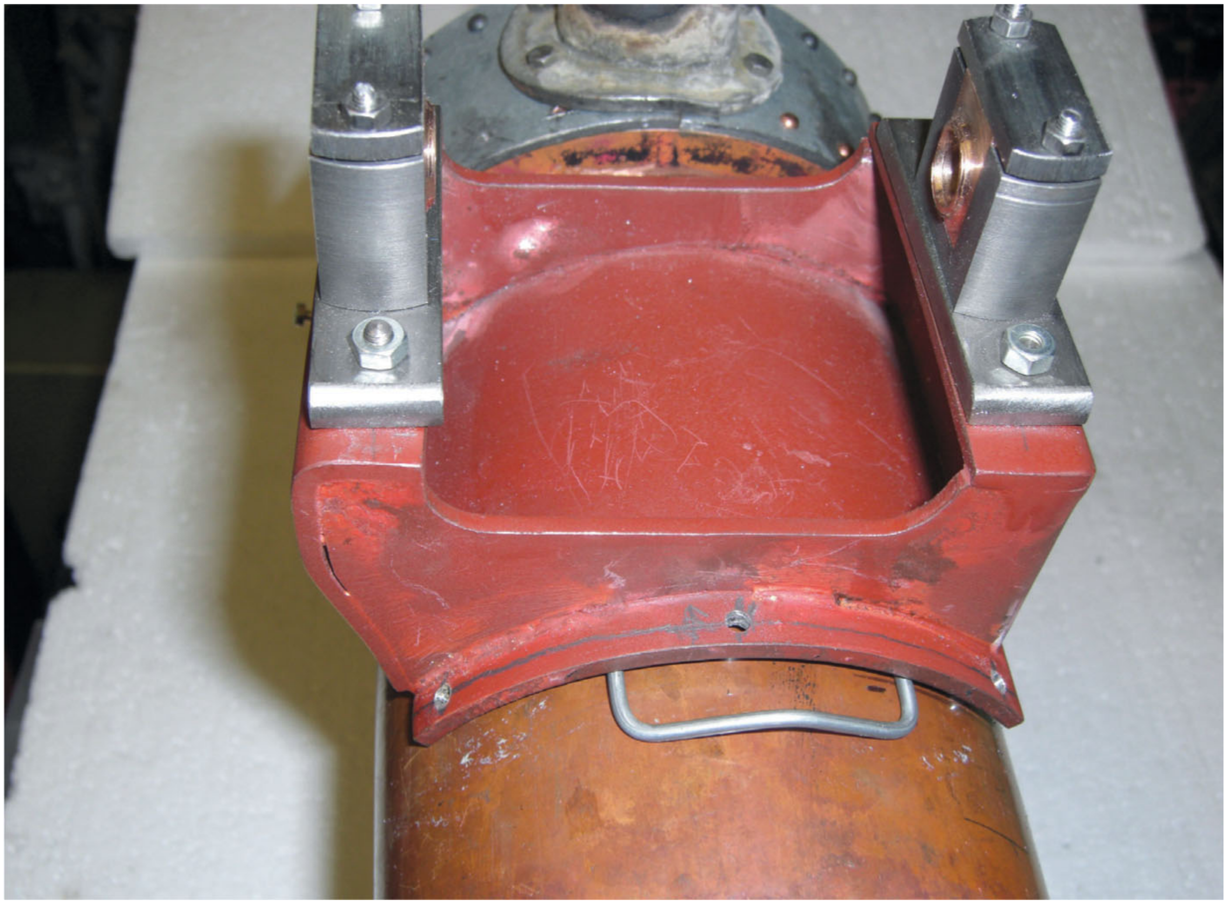
The box is formed from a piece of 2.5mm (3⁄32 in) steel sheet, which makes the back cross-plate, right side and front cross-plate in one piece. When positioning the bends, make allowance for the thickness of the end pieces. The left side is curved to fit that side and it will be found easier to make the left plate curved and file the ends of the back and front cross-plates to fit, rather than trying to curve the plate to the already finished ends.

The shallow cut-out in the top of the back and front cross-pieces should be flanged inwards to enable the governor to be bolted down. These could be separate flanges, curved up at each end, or even a ¼in (6.3mm) square piece of steel riveted into the inside of the back and front cross-plates.

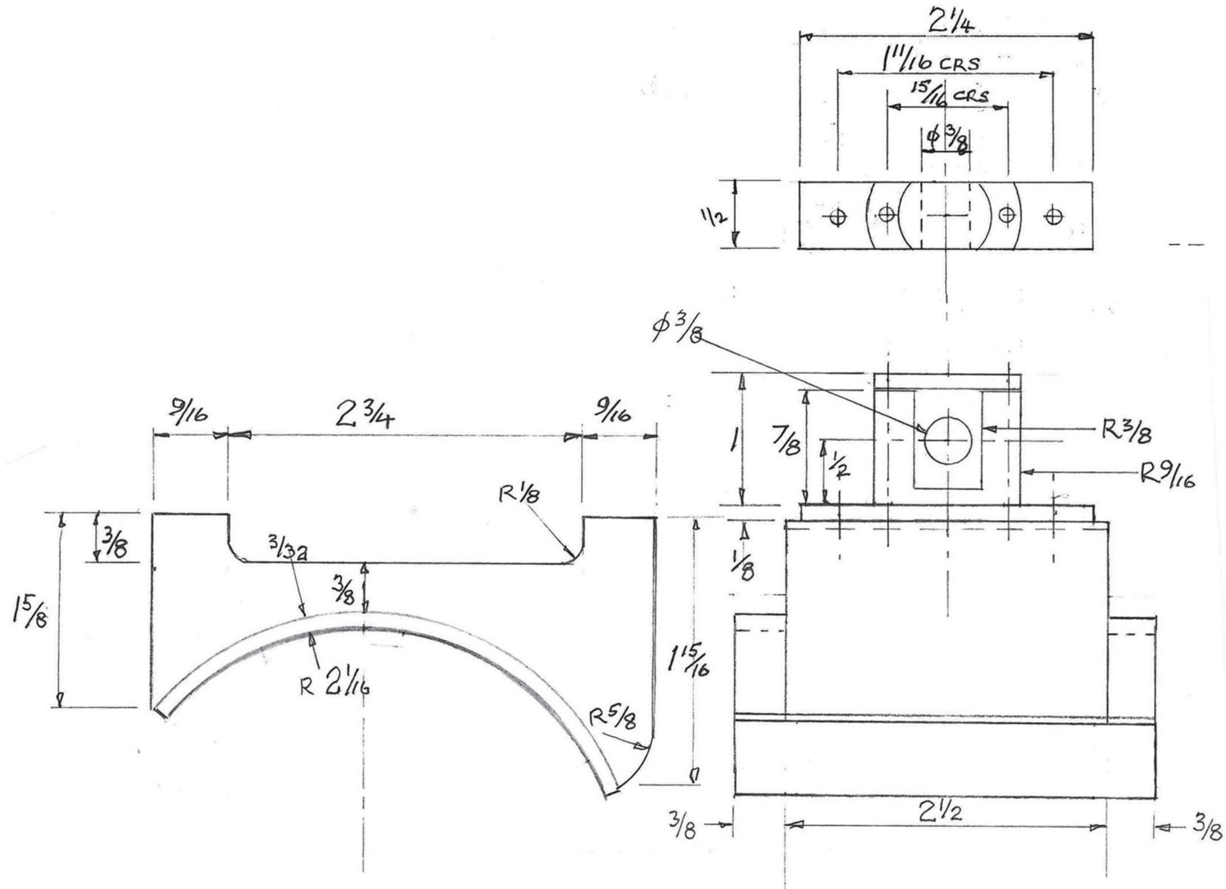
Check the fit of the parts and wire it all together to silver solder. The largest burner will be needed or it could be brazed if you have access to oxy-acetylene welding equipment.

*Development of sides of crankshaft bearing bracket.*

*Crankshaft bearing bracket.*



*Crankshaft bearing bracket with bearings.*




**Drawing 021 Crankshaft Bearing Bracket 1 off MS**

## CRANKSHAFT BEARINGS

The original bearing housings were ‘U’ shaped castings with feet. An almost flat keep plate held the square bronze bearing in place. Without using castings, it is speedier to approach them a different way. You may have seen one of those trick dovetail joints, looking like a cube with a dovetail on four sides, that cabinet makers create from contrasting woods. They appear to be impossible, but in fact the two dovetails run diagonally and you cannot detect on the surface that the joint is not square to the surface. We will use this subterfuge in the construction of our bearing housings.

Chuck a piece of 1 1/8 in (30mm) diameter cast iron or steel and face and bore it for the bearing, making sure that the bottom of the bore is flat and has sharp corners. Cut or part off to make two examples. Drill for the two fixing studs 6BA clear at 15/16 in centres.

Make the bearings from gunmetal and part off at 5/16 in and 7/16 in and make sure that all faces are flat. Insert a 5/16 in followed by a 7/16 in piece into each bearing housing. The top of the bearing must be higher than the housing to ensure that the keep plate on the top presses on the bearing even after the mating faces have been reduced to take up wear. Make the bearings first from ¾in diameter gunmetal, which will need a skim off the outside. Make the bearing housing bores to suit. Make the keeps from 1/8 in steel with clearance holes for the studs, and make the feet from 3/16 in steel with 6BA tapped holes at 15/16 in centres and 4BA clear at 1 11/16 in centres.

*Crankshaft bearings.*

Make the studs 1¾in long as they will be screwed through the feet, pass through the flange of the bearing bracket and be nutted underneath. (The foot also has two 4BA bolts and nuts.) The bearing housings should slide onto the studs and be secured by the keep plates and nuts.

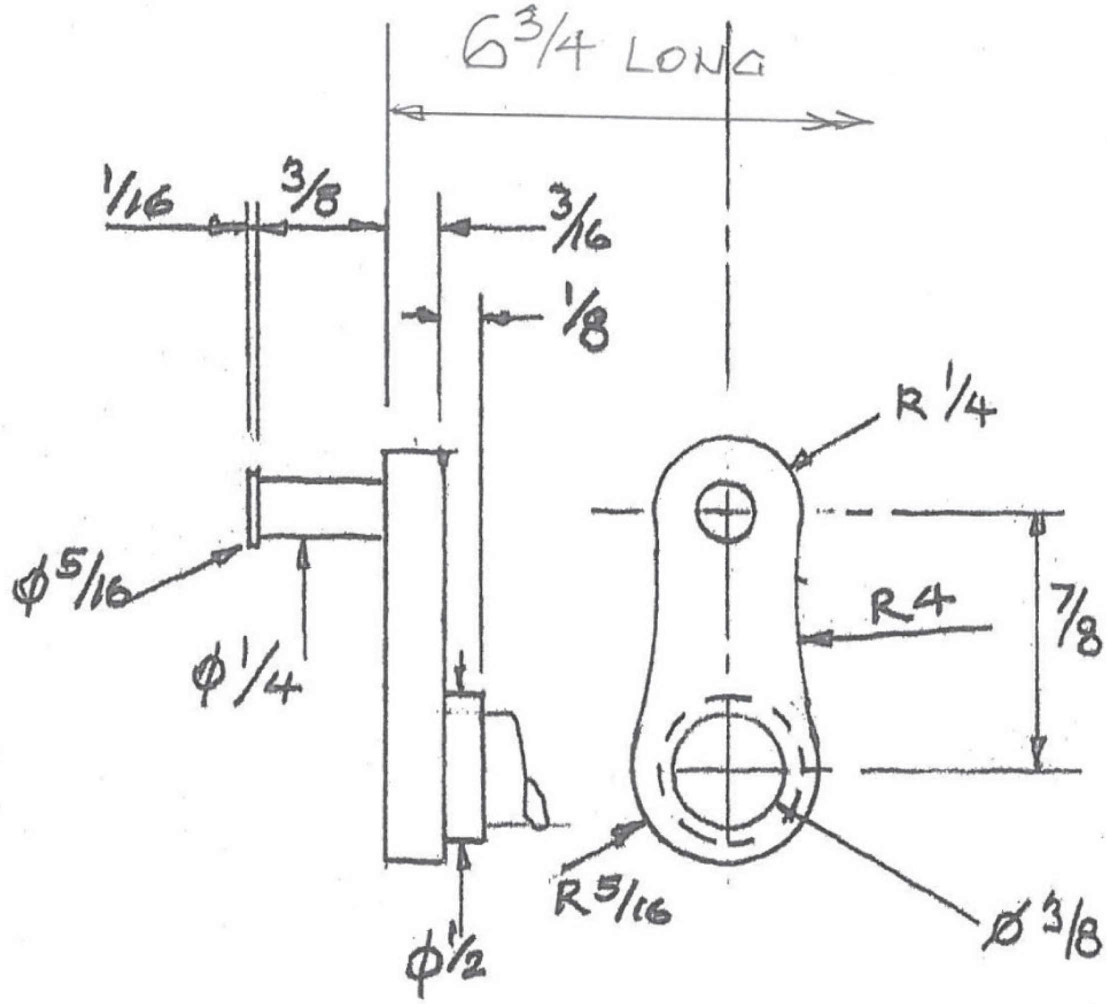
With the 5/16 in bearing half in place, measure down from the top of the bearing housing. Mark this distance down the outside of the housing.

Run the studs through the bearing housing and the keep plate, with the whole bearing in place, and set up in the four-jaw chuck with the four 6BA nuts flat against the chuck jaws and the measured mark on the lathe centre-line. It will be found that the jaws at the top and bottom of the bearing assembly are securely holding the workpiece. However the other jaws will be bearing against the curved cylindrical surface. To extend these two jaws forward, bend a piece of 3/16 × ¾in (5 × 16mm) steel into a ‘U’ shape and place behind the job with the ends extending the jaws forward to improve the grip of the chuck. Face back until the bearing is exposed. Check that this is in the centre, left to right, and adjust accordingly. Now face back using the keep plate as a guide to final thickness. Centre, drill and bore, or ream, for the crankshaft bearing.

Repeat on the other one, then turn them round to face back to finished width. The last few facing cuts could leave a 1/32 in ring at each end of the bearing.

## CRANKSHAFT

The crankshaft is built up from 3/8 in diameter silver steel with a mild steel crank throw and a turned silver steel crank-pin. These are pressed together or retained by Loctite 601 if the sizes do not work out right for a press fit. Make sure that the holes in the throw are parallel to each other and square to the throw. It is worth setting up in the lathe four-jaw chuck to achieve this. Make the holes before final shaping of the throw to save jaw marks on the job and use the holes to guide the file around the shape of the holes. If it is intended to use Loctite, a few thou clearance is needed for it to work properly. Loctite in a press fit does not help because the press fit will remove all the Loctite. In either case, drill for a 1/16 in pin or grub screw, half and half in the end of the shaft and throw. The throw is slightly waisted between the two end radii and this simple shaping improves the appearance of the crankshaft.

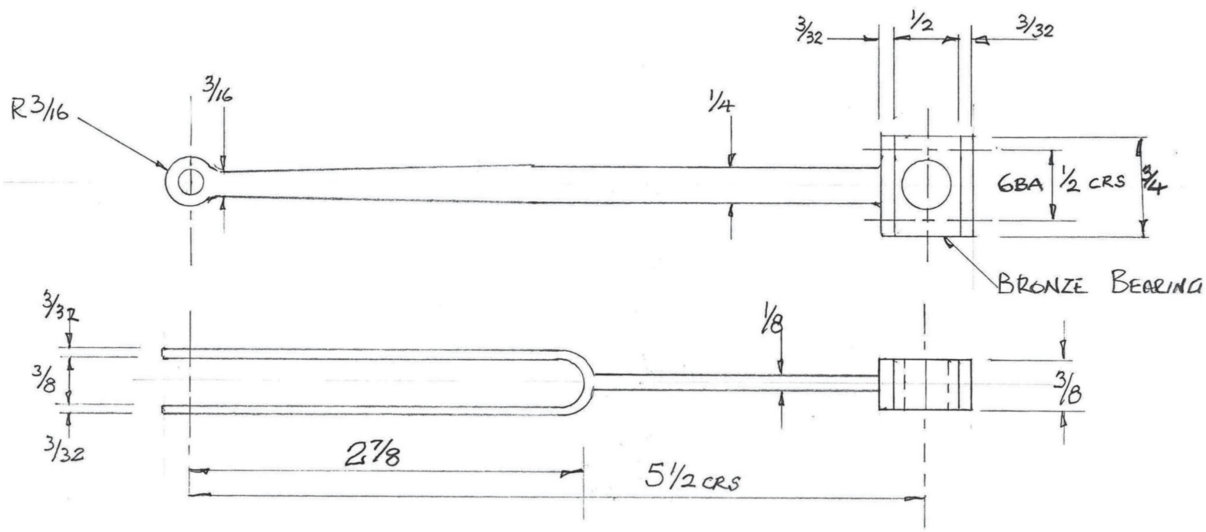



**Drawing 022 Crank & Crank-Pin MS**

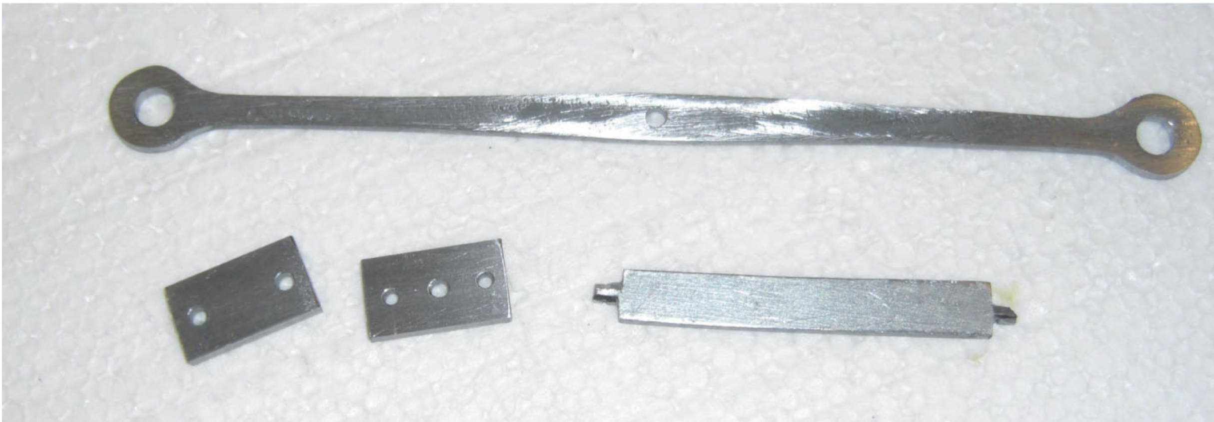
## CONNECTING ROD

The connecting rod has a marine type big-end bearing and a long fork at the crosshead end. The fork is made in one long piece, which is bent round a ½in diameter bar. A small hole is drilled in the apex for a small tang that is filed on the end of the single bar and silver soldered. The other end of this bar has a similar tang, which is silver soldered to the central hole in the cross plate. This plate has the two halves of the bearing and a similar plate as backup secured with two long bolts.

As the name implies, this type of big-end was used on marine engines. Traction engines often used the strap and wedge type, which was smaller and lighter. Internal combustion engines tend to use a split-forged connecting rod, with later ones having replaceable shell bearings of white metal, but this depends on a pressure oil feed and enclosed sump.



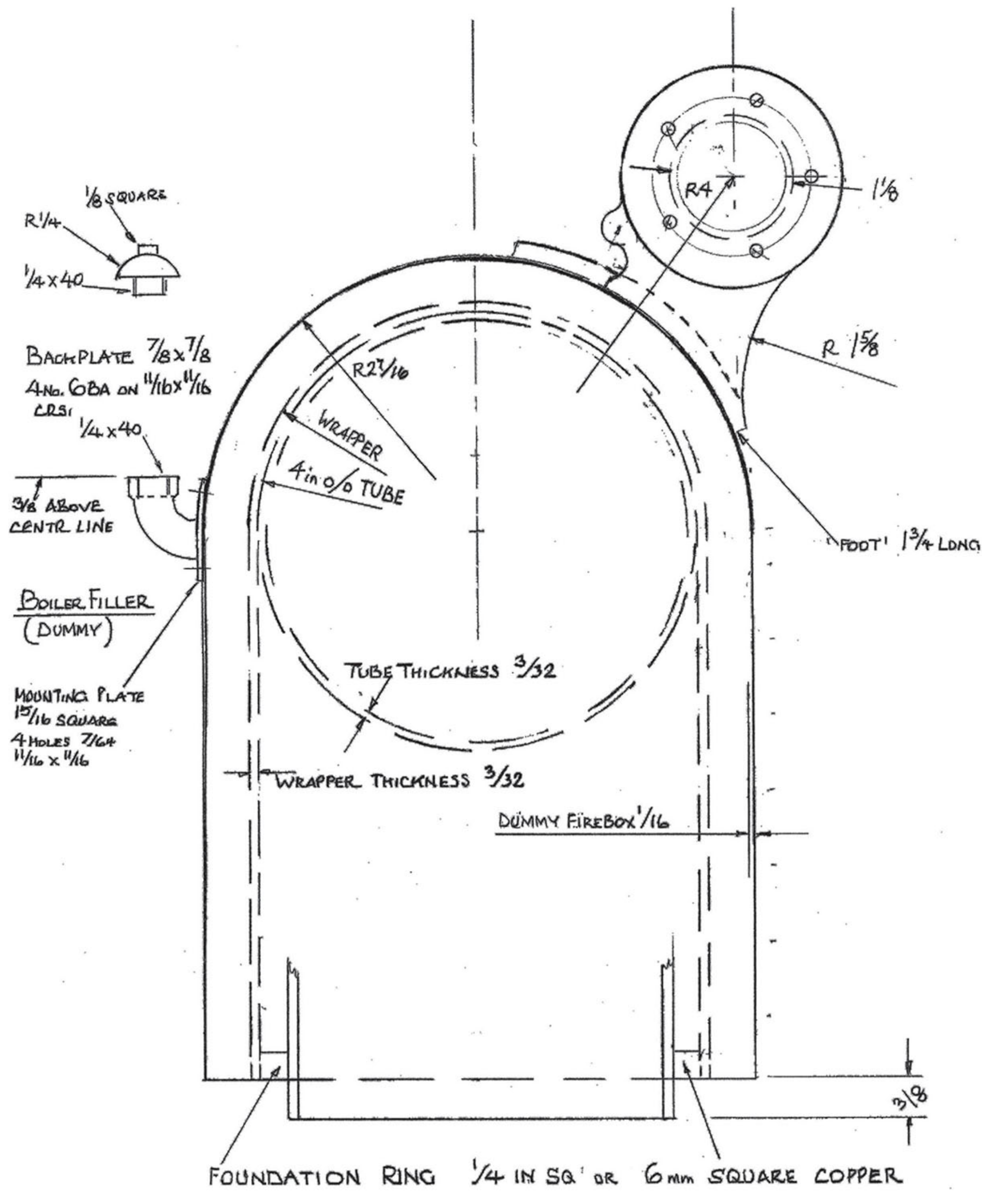

**Drawing 023 Connecting Rod 1 off Mild Steel**



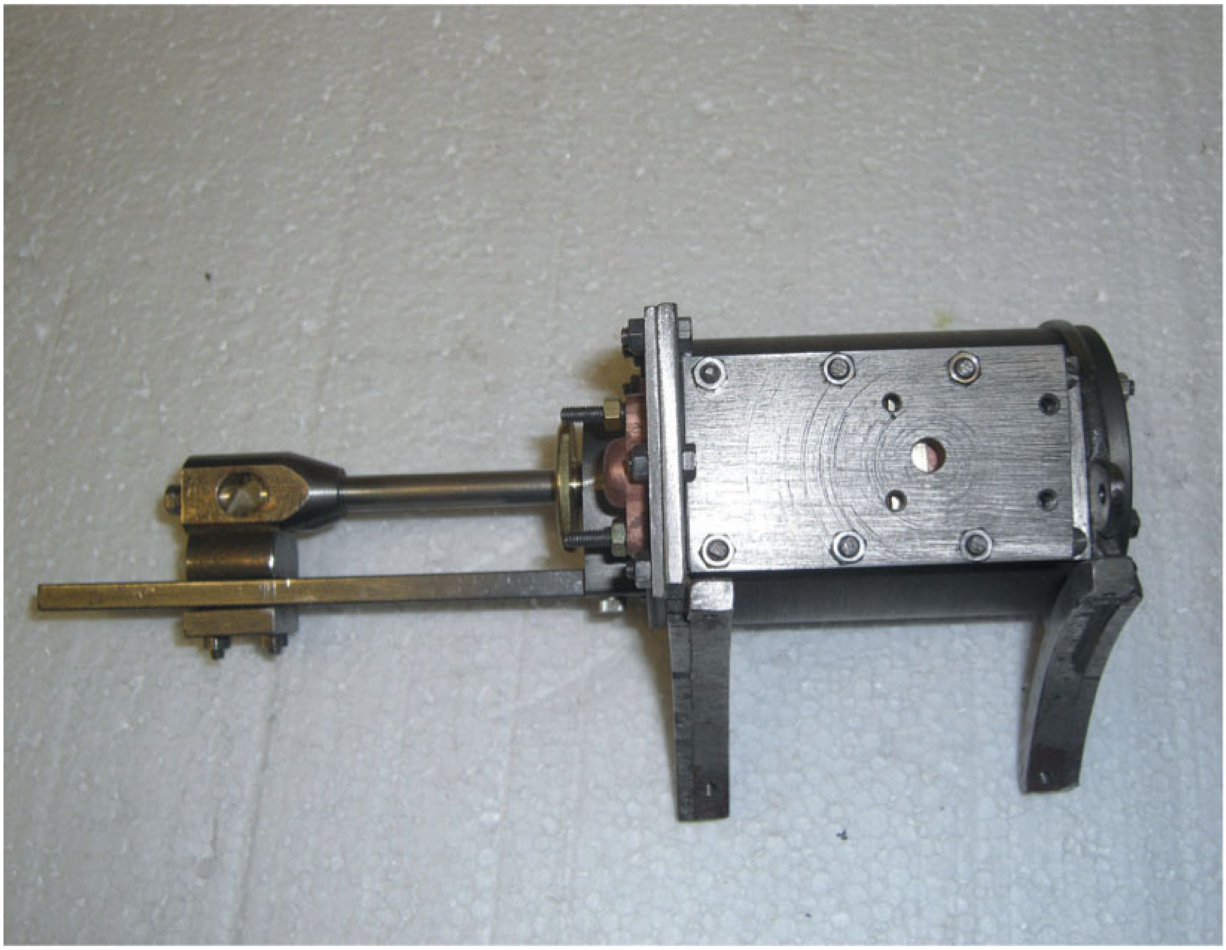
*Connecting rod components.*

## CROSSHEAD

The little-end of the connecting rod has a plain turned pin that runs in a split bearing in the crosshead. The crosshead has a round section containing this bearing, which is held in place by a screwed plug and adjusting screw with lock-nut. At the other end is an internal thread to take the piston rod. This round section is silver soldered to a flat plate, which slides on the slide bar. A long slot in the slide-bar allows a spacer to another flat plate underneath to take the upward thrust. The two flat plates, which slide above and below the slide-bar, should be cast iron or bronze.




**Drawing 024**



*Cylinder assembled with crosshead.*

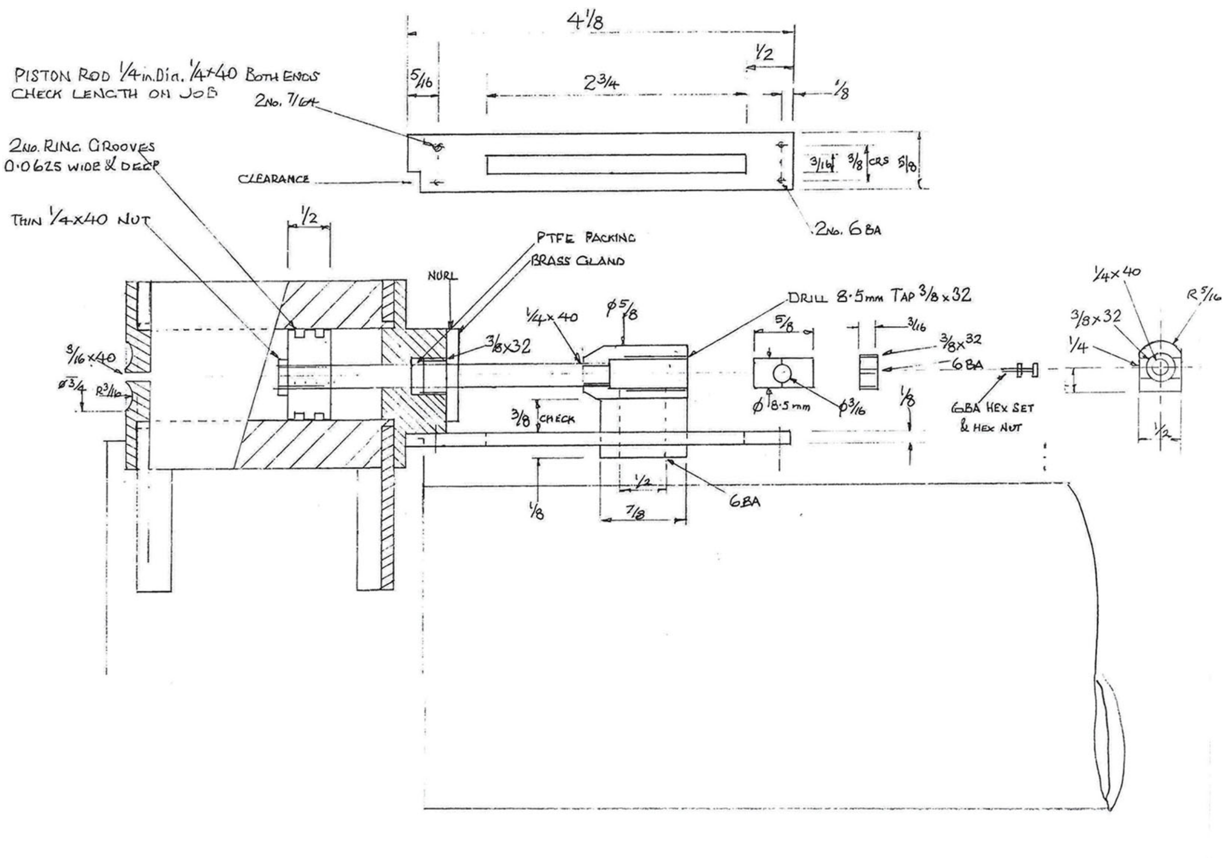
*Cylinder assembled with crosshead.*

## PISTON ROD

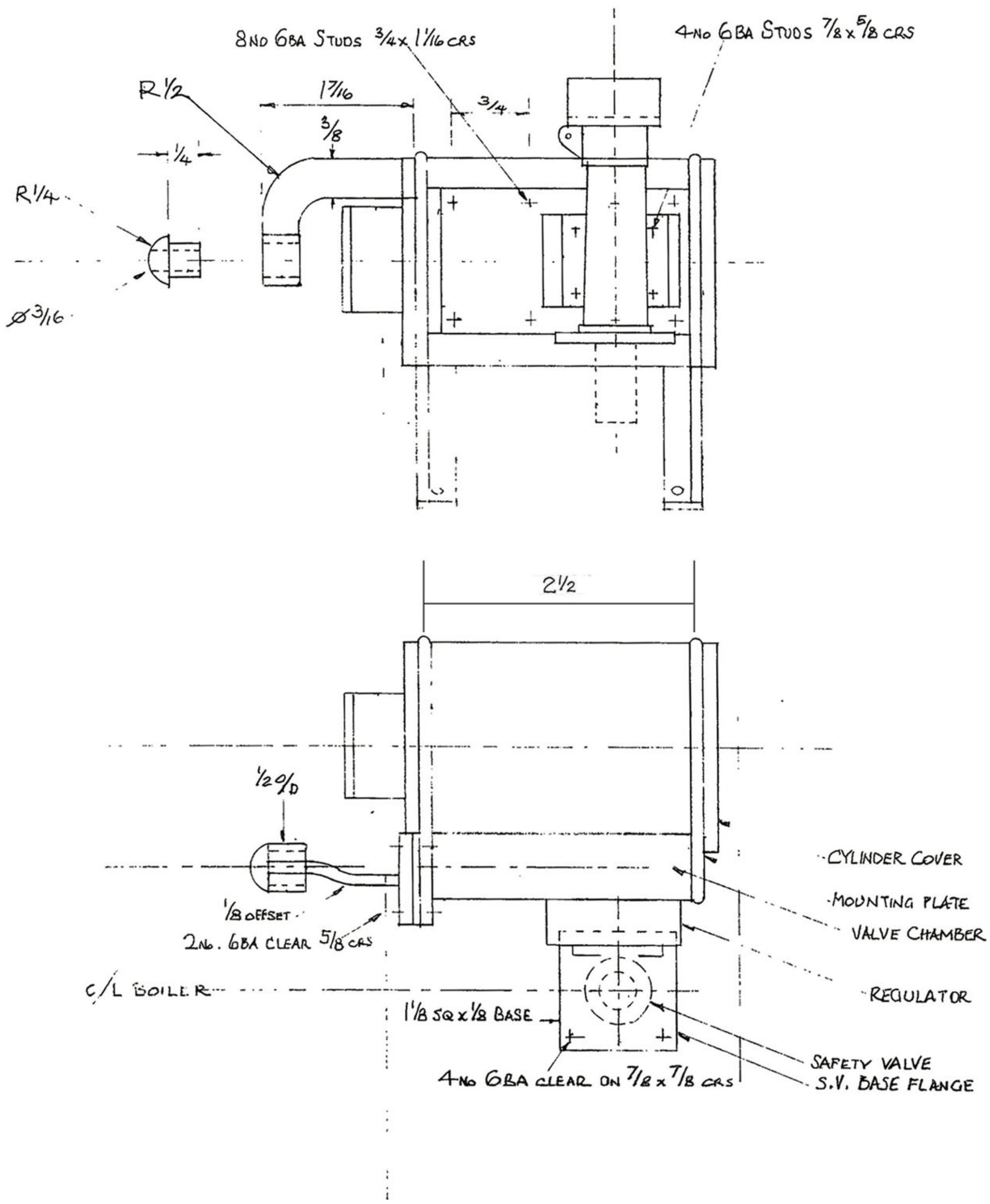
The stainless steel piston rod has a ¼in × 40 thread on each end. After passing through the gland and stuffing box it is screwed into the piston. The piston carries two cast iron piston rings. The gland has a large disc with straight knurling on the outside, a 3/8 in × 32 threaded piece on the inner side to compress the stuffing and a rounded projection on the outer end to match other glands on the engine. To get the thread all the way up to the disc, make the disc from 1/8 in thick brass sheet (or flat bar), drill and tap and Loctite or silver solder to the threaded end of the centre portion.

## PISTON

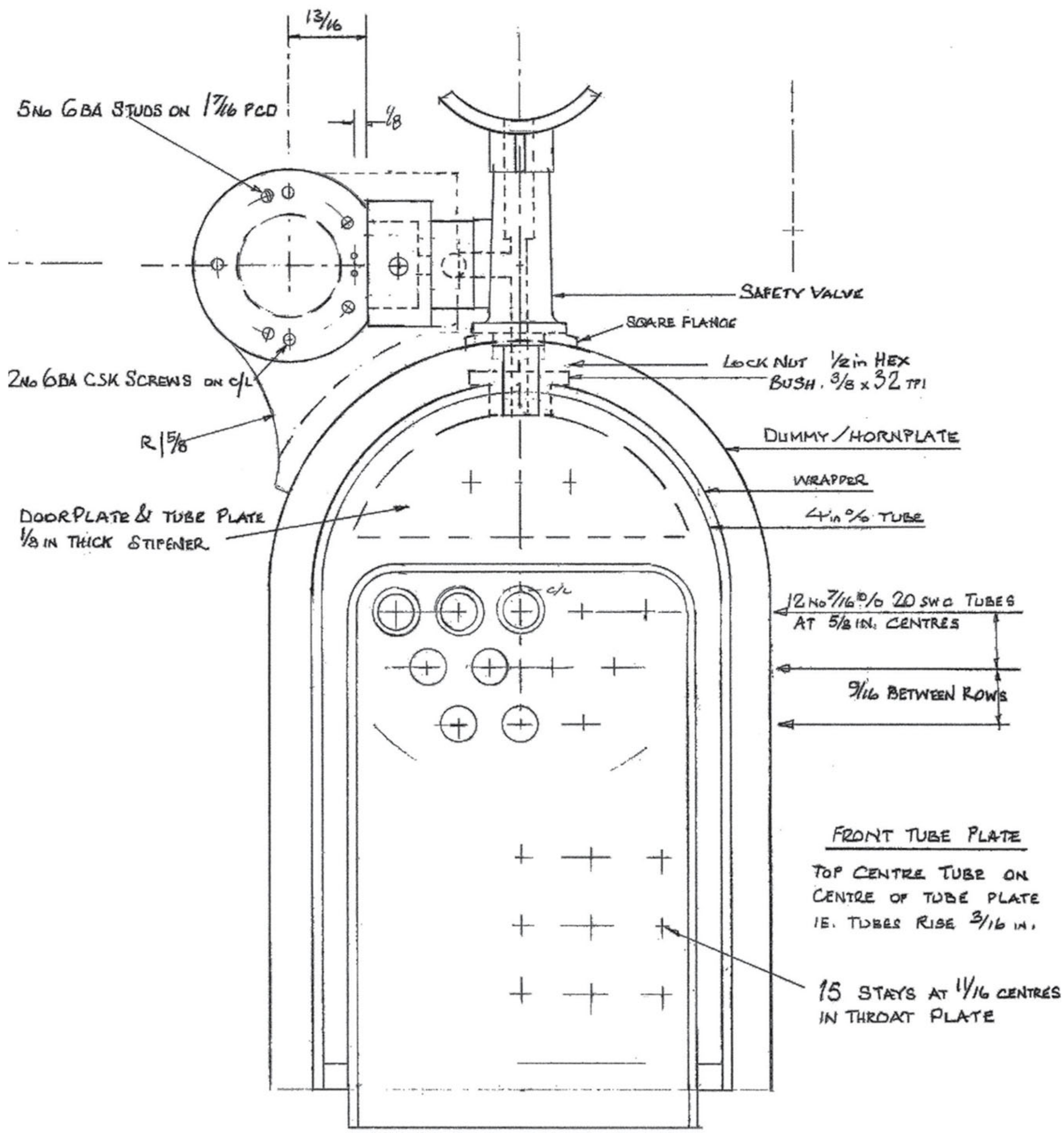
When buying the cast iron for the cylinder it would be worthwhile to also buy a piece of about 11/8 in or 30mm diameter, which is also needed for the crank-shaft bearings. This will save on cost and machining time, much of which is dependent on the size of your lathe. Turn down sufficient length for the piston and four rings, while not forgetting to allow for five parting cuts. When the outside diameter is five thou above the cylinder diameter, change to drill and bore to 13/16 in diameter. Part off four rings 1/16 in wide. If the width of the parting tool is measured and added to the ring width of 62.5 thou (0.0625in), this is the amount by which the top slide is advanced towards the chuck between cuts. If there is more material, make another one.




**Drawing 025 Slide-Bar & Crosshead**




**Drawing 026 Cylinder Assembly**




Using a 1/16 in wide, square-ended parting tool, make the grooves for the two rings. There is no harm in going too deep as the piston is not hollow, but allow for the piston being oversize at the moment. Turn the piston material to a sliding fit in the cylinder. Doing it this way round ensures that any burr created by the grooving process will be removed in the final sizing of the piston.

Centre, drill and tap for the piston rod. The first 1/16 in is drilled the full diameter of the piston rod to help keep the rod and piston concentric to each other.

The piston rings are split with a fine piercing saw. Cut them square, as an angled cut will induce a twist in the next operation. (If you do not have a piercing saw, turn the rings to a sliding fit in the cylinder and, after parting off, drive a taper through them until they split.) Open up the rings and fit a 1/8 in steel spacer to wedge them apart. Assemble a large washer at each end onto a bolt and coat the outside of the rings with silver soldering flux, borax or soft soap, heat to red heat in your brazing hearth and allow to cool overnight. They will be found to have annealed to the wide gap and will spring closed to fit the cylinder. Slide them across a sheet of 320 wet and dry abrasive paper to polish the sides and allow them to slide freely in the piston grooves.

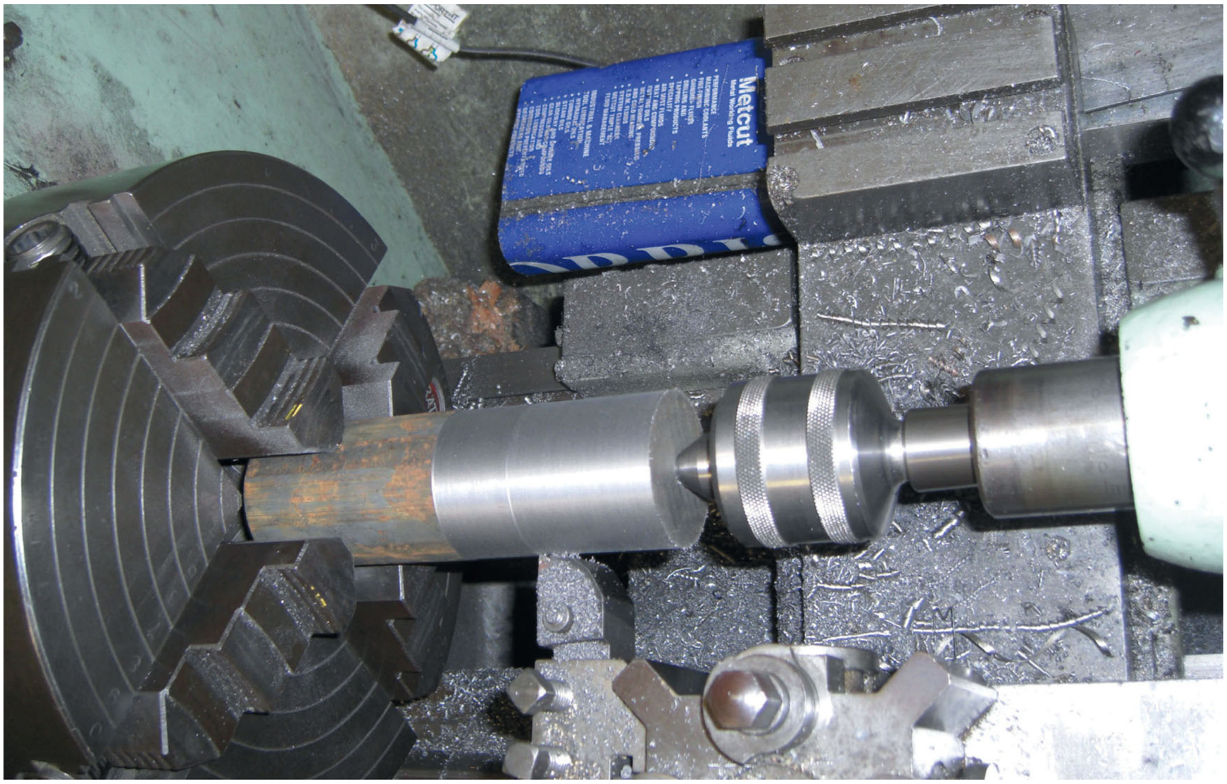
## CYLINDER

This is made from 2in diameter cast iron bar. Skim the outside to clean it up. Face the end and centre, drill and bore to as near to 1in diameter as you can. The last three or four passes should be bored at the same setting and the slowest feed. This will help to keep the bore parallel.

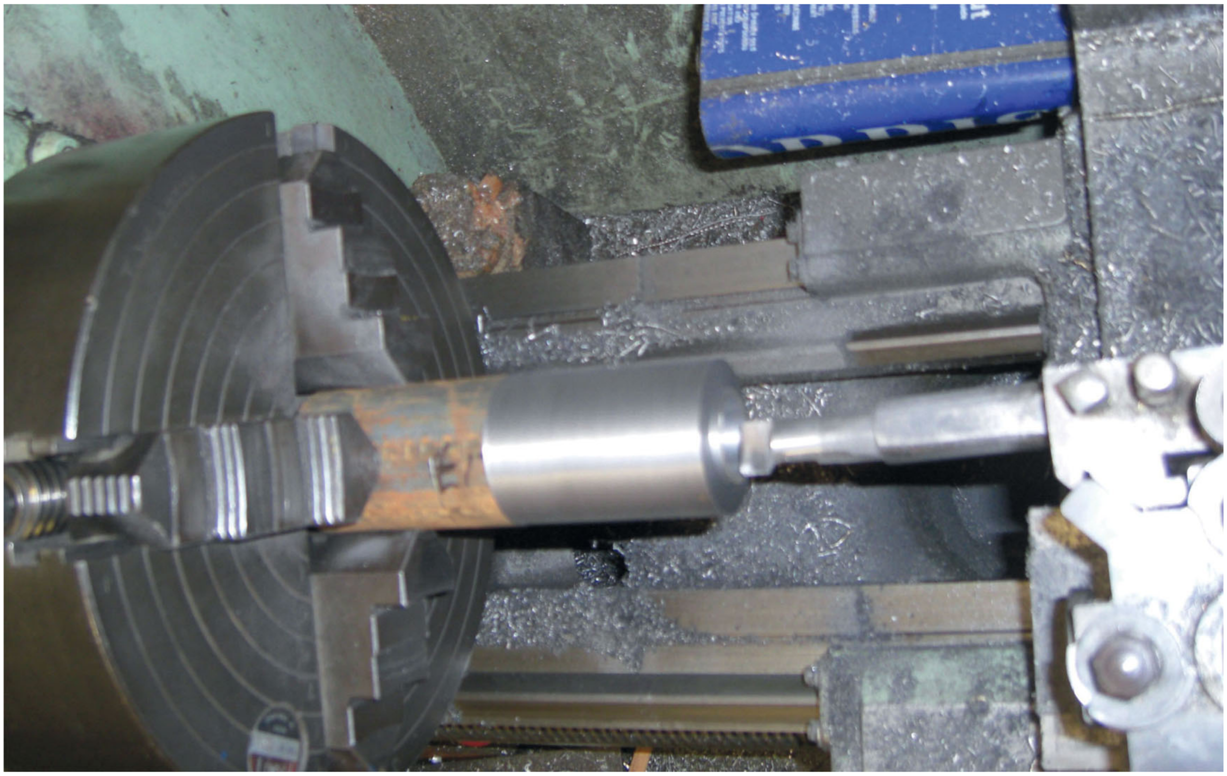
Face back the end to leave a spigot 1/8 in long by 11/8 in diameter. Part or saw off at the correct length and face up the end, not forgetting the spigot. Try to get the two spigots to the same diameter. The first end to be machined should be marked as it will be more accurately square to the bore and should be used for the front-end cover, that is the end with the slide-bar attached.

It is interesting to note that the term for the front cover with the slide-bar attached is still used on a traction engine, where the whole motion is reversed on the boiler and the slide-bar is at the back.

Using the four-jaw chuck, secure the cylinder sideways in the chuck using soft aluminium sheet packing between the ends of the cylinder and the jaws. Face off the side of the cylinder to the correct dimension. After taking the first facing cut, check that the new surface is parallel. If not, a sharp clout with a copper mallet at the wide end should put it right. There will be scope for two or three goes at getting it parallel.

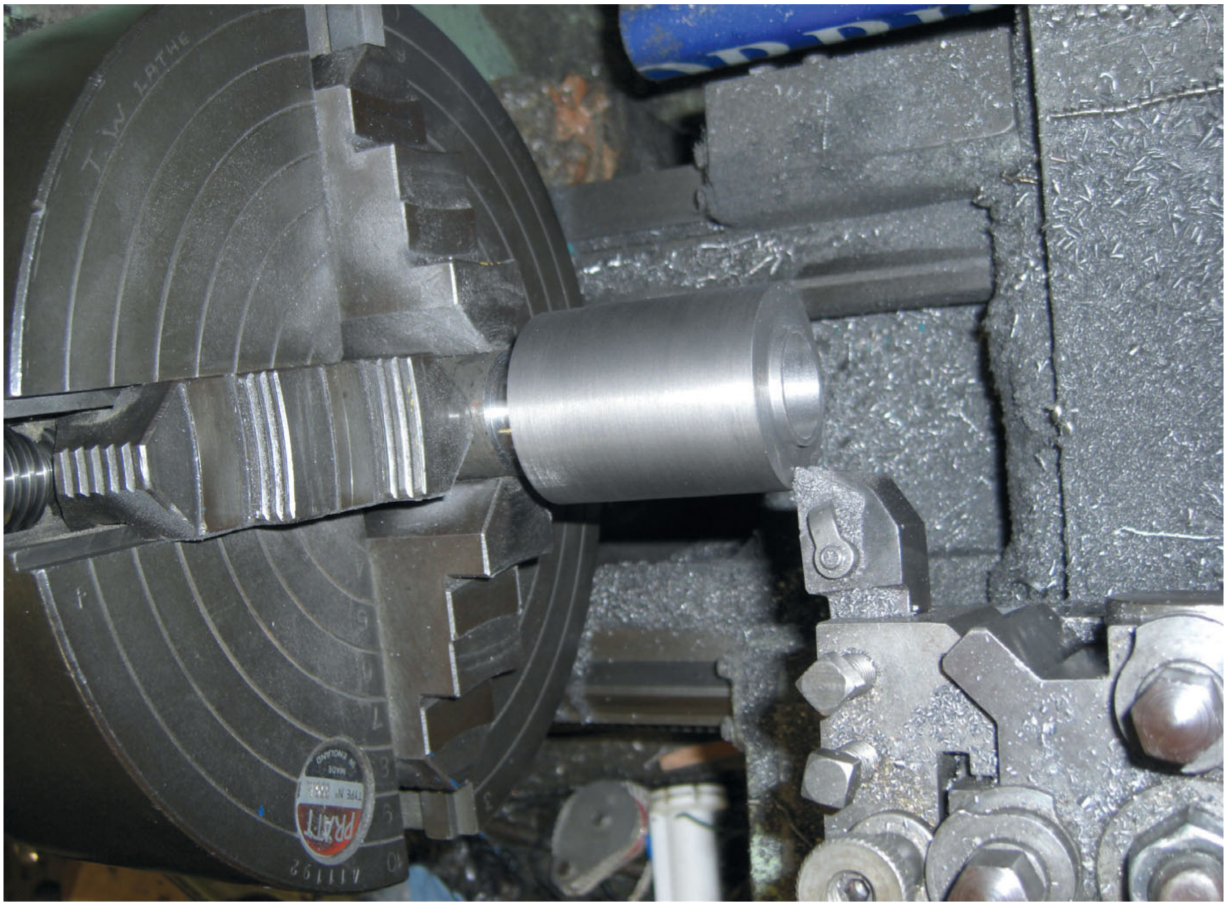



*Skim outside of cast iron bar.*

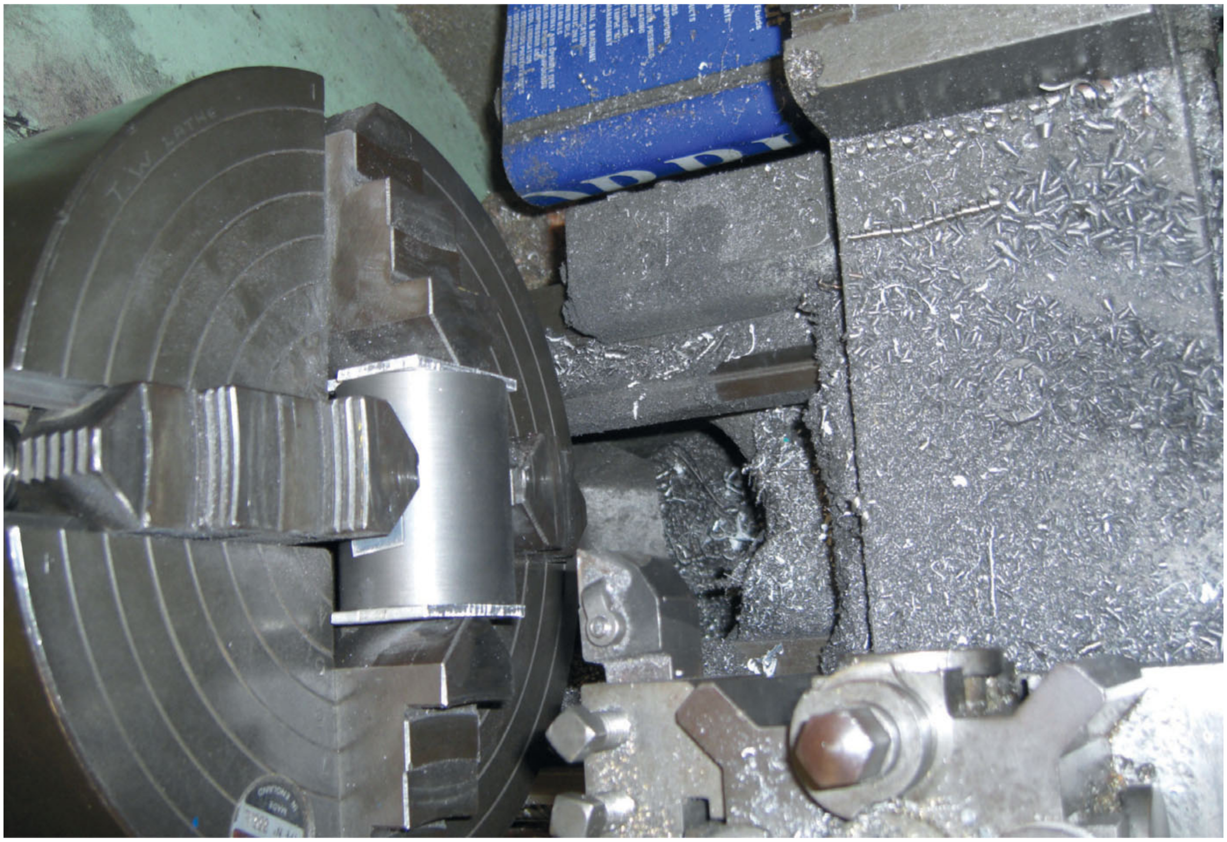


*Bore the cylinder.*

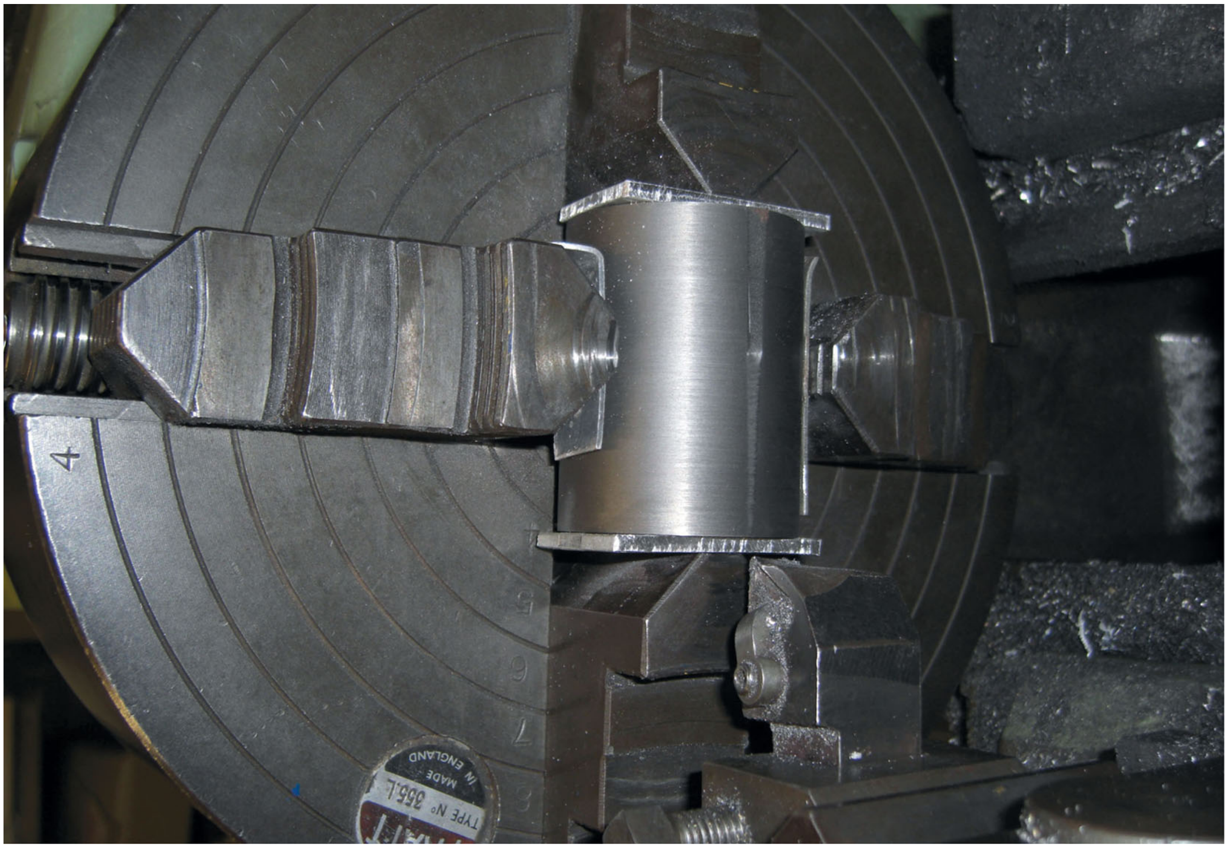
This new face will be the port face for the steam valve to slide along and should be as flat and smooth as you can get it. To make the ports, a special cutter is made that will make all three ports in one operation. This is turned up from a piece of ¾in diameter silver steel (drill rod), hardened and tempered and mounted in the chuck with support from the tailstock. The cylinder is clamped against the tool-post by using a smooth round bar through the bore and two lengths of studding back to a stout clamp bar. The height of the cylinder is the trickiest part of this operation and is where a quick change tool-post is the easiest option, unless you have a vice on a vertical slide. Mill in to the maximum depth that the cutter will allow.



*Machine spigot on end of cylinder.*

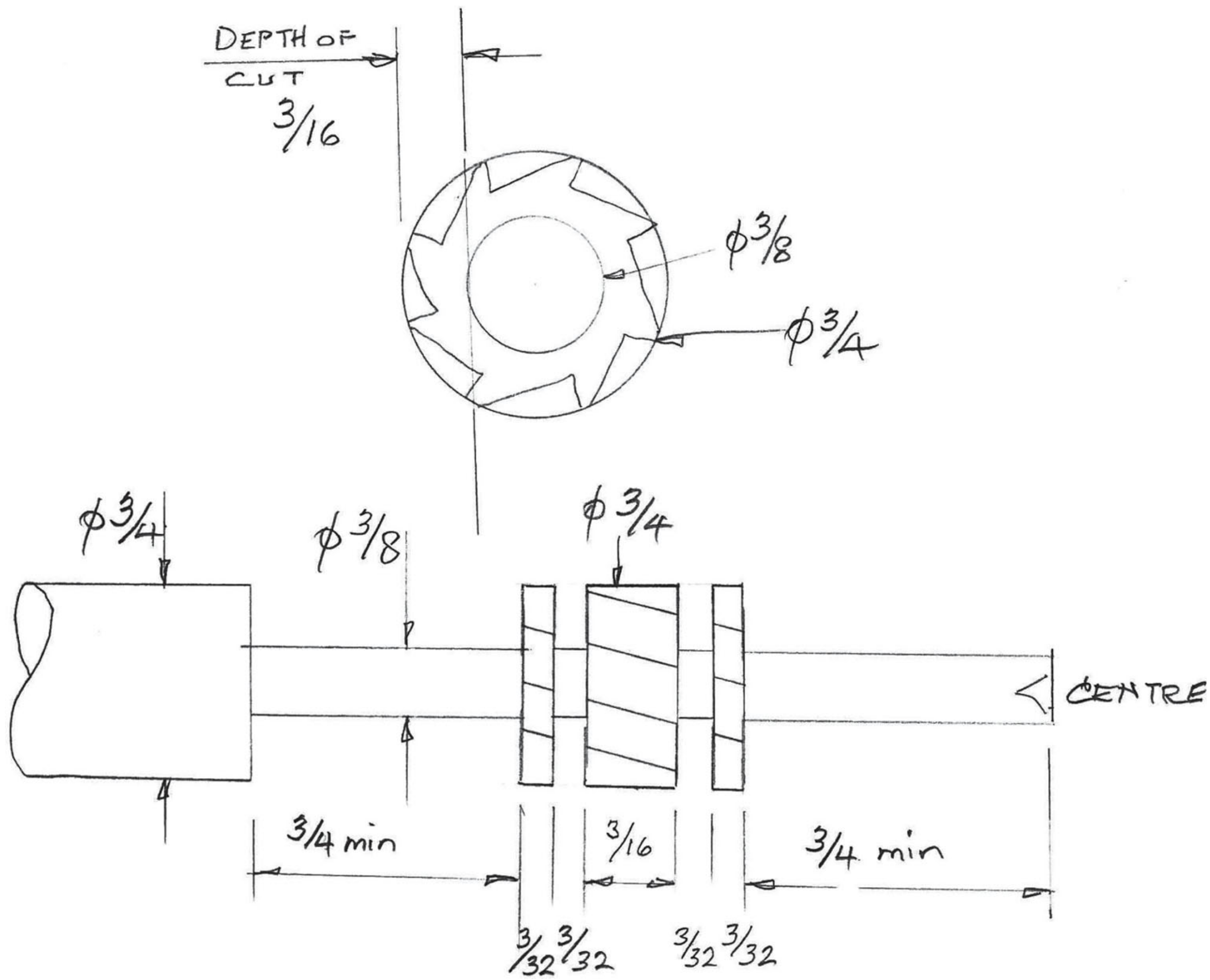


*Grip sideways in four-jaw chuck and face.*



*Check new face is parallel.*

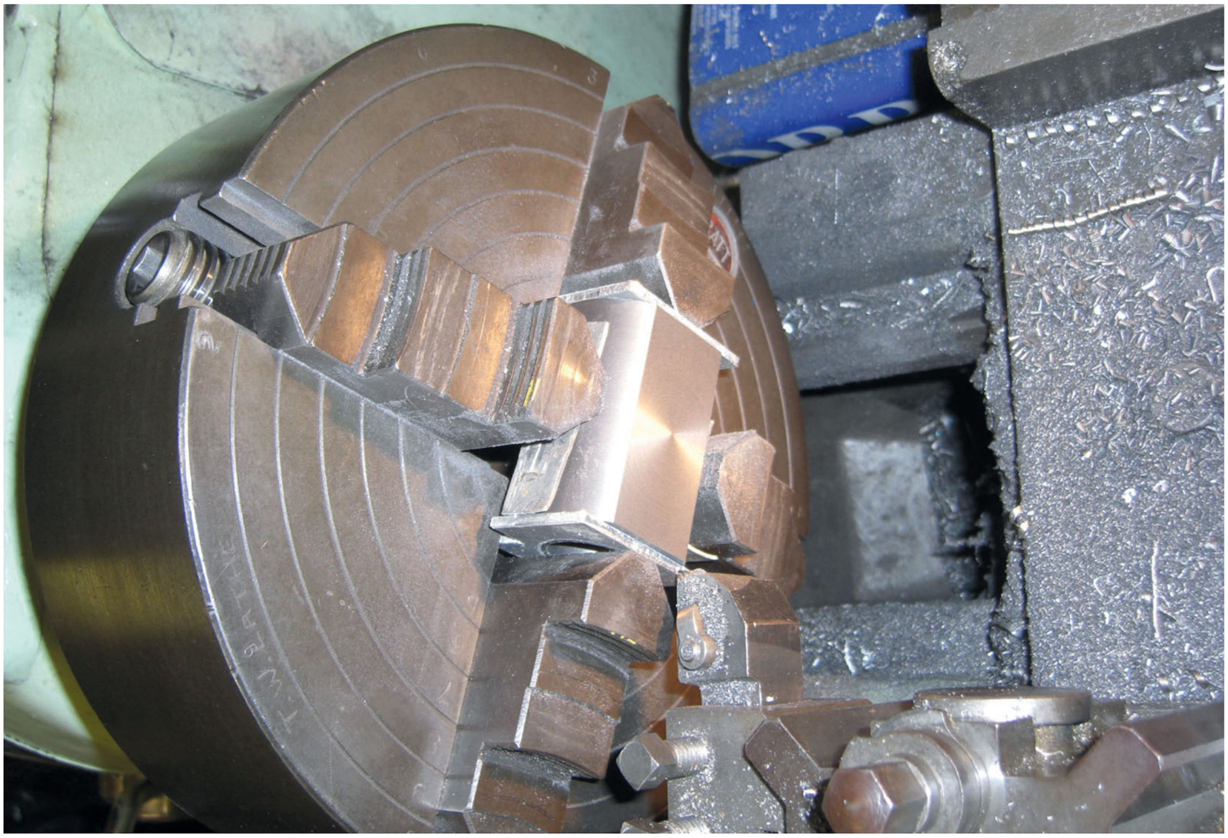
The steam ports need to be connected to the ends of the cylinder. This is achieved by drilling two 3/32 in holes close together from the cylinder end face to the steam port. These holes should be parallel to the cylinder in every direction. A piece of metal about 3/16 in thick should have a hole bored in it to take the spigot at the lower end to give support to the whole end surface. Remove all burrs from the edges. This should ensure that the flat end face of the cylinder sits firmly in the drill vice to ensure that the holes are drilled vertically and parallel. The port face should be against the fixed jaw of the drill vice with soft packing protecting the port face. Before drilling, check the distance from the cylinder end face to the near side of the steam port and apply adhesive tape to the drill to indicate this distance. Do not drill deeper than this. This is the point at which the drill breaks through into the steam port. Repeat at the other end.



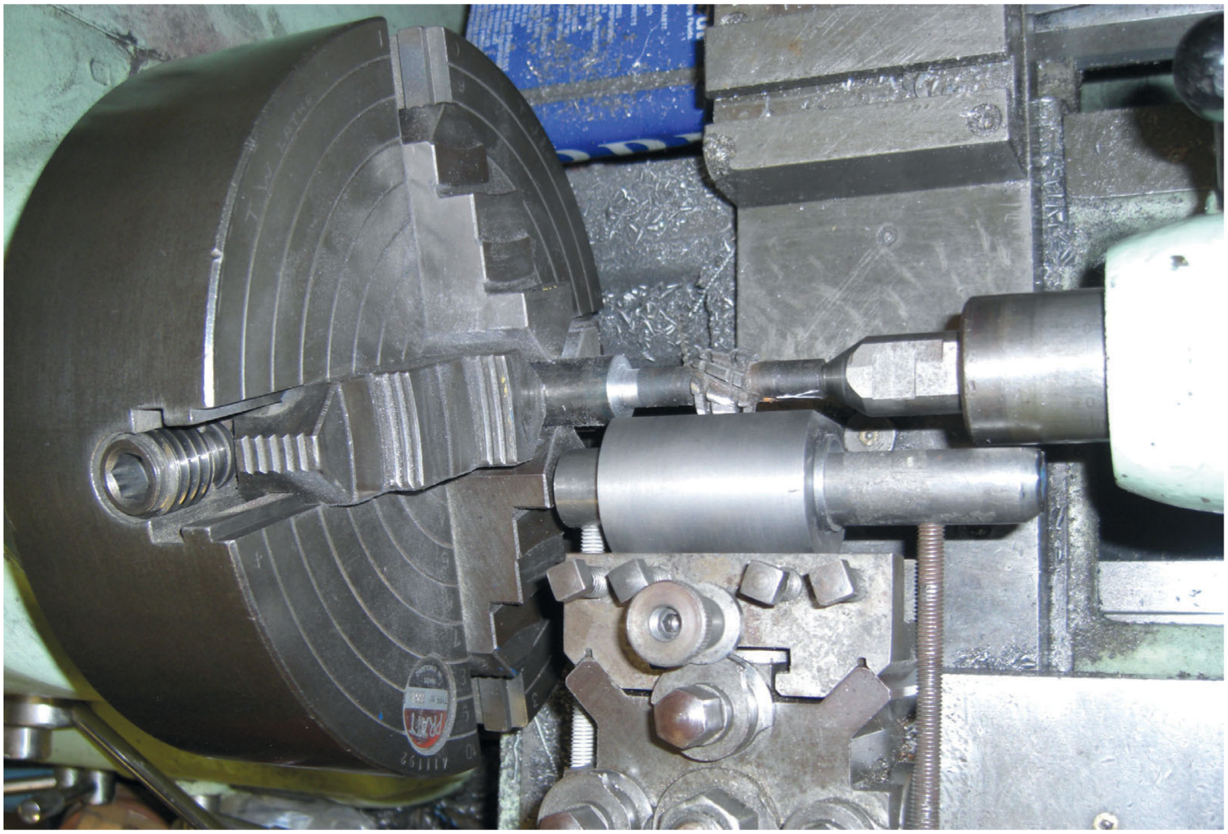

**Drawing 027 Steam Ports & Exhaust Port**

The outer end of the drilling will be blanked off by the mounting bracket, and the steam needs turning towards the cylinder bore. This is the tricky bit. Inside the cylinder bore, dot punch 3/16 in, down and in line with the long drillings. Carefully set up the cylinder in the drill vice to drill these two holes and two at the other end.

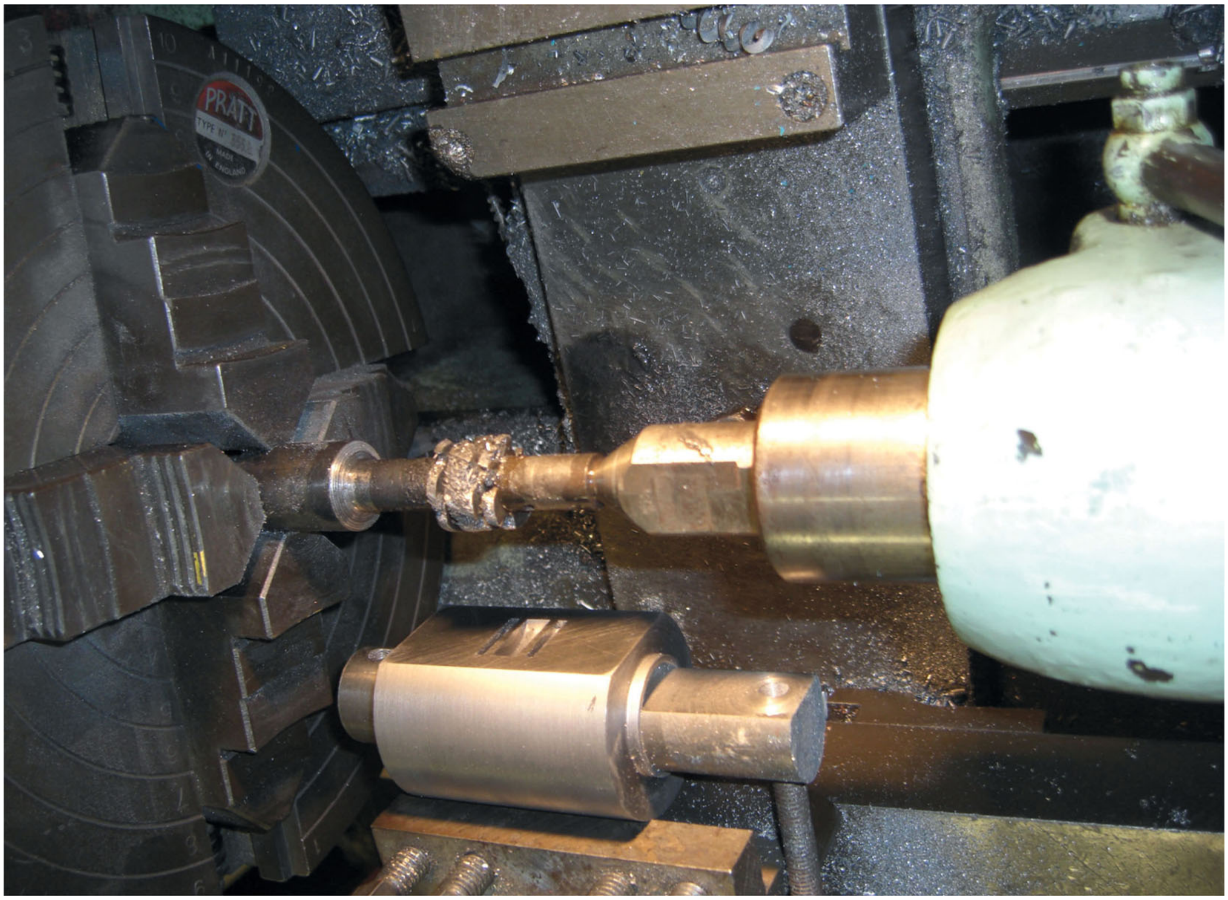
*Ports complete.*



*Achieve a smooth face.*

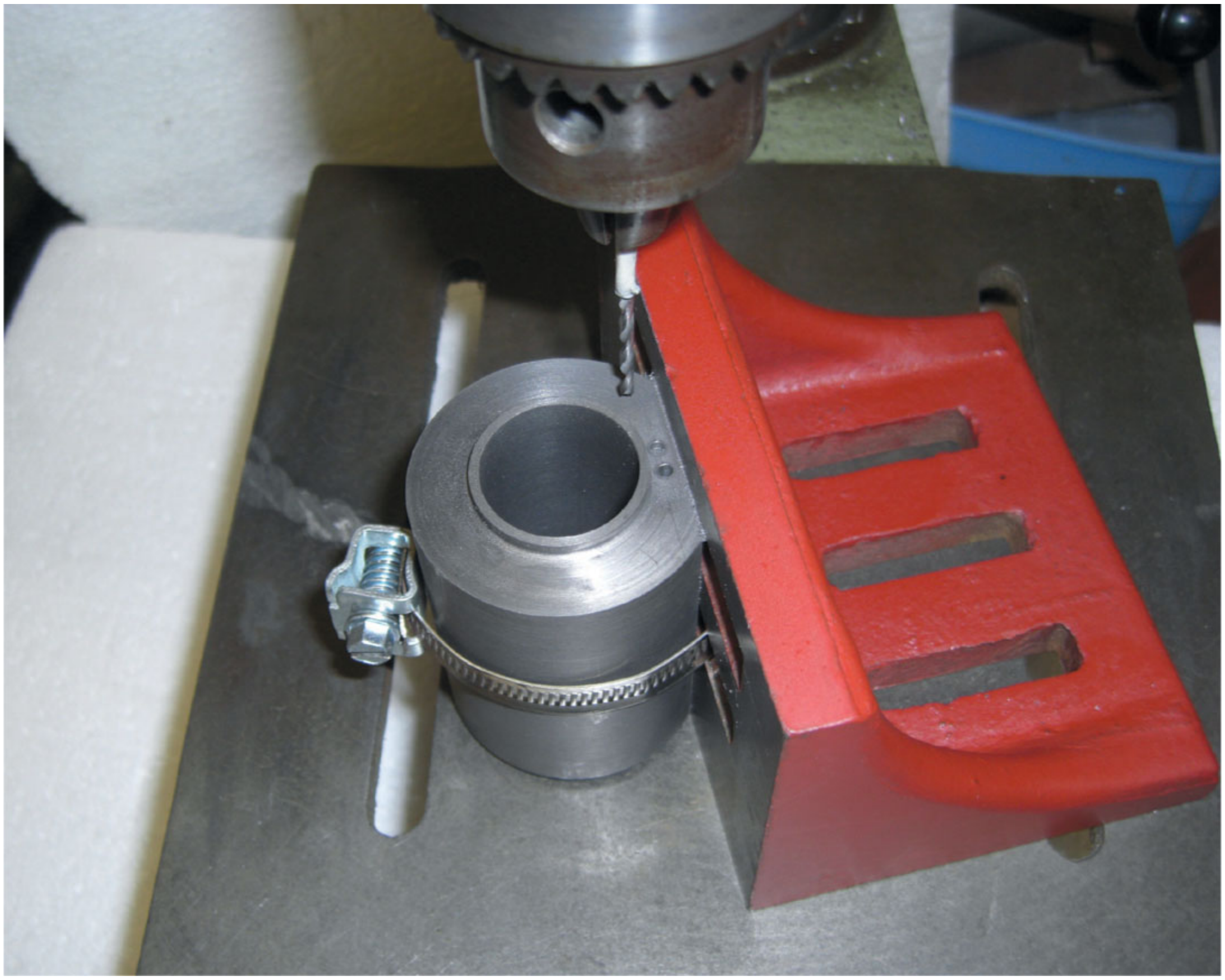


*Cutting ports with special cutter.*




*Special cutter and finished ports.*

*Checking drill length.*



*Drill steam passages. Keep cylinder vertical.*

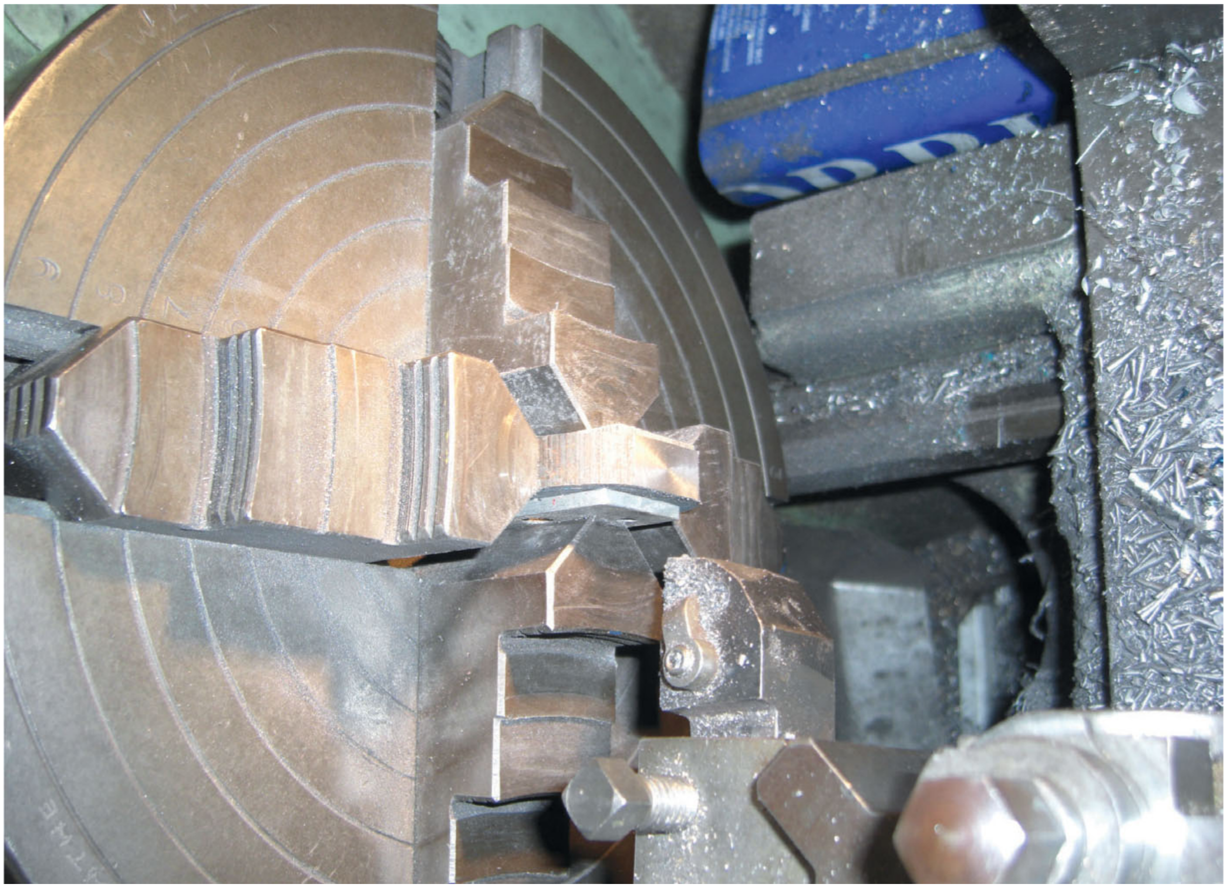
The central port, which is the exhaust port, has a drilling from within the steam port down to the bottom of the casting. Do not damage the sides of the port. The point where it emerges needs to be opened up to 7mm diameter. and tapped 5/16 in × 32 tpi.

Low down at the ends, two 4mm holes are tapped 3/16 in × 40 for the condensation drain taps. These need further drilling1/16 in diameter to arrive at the cylinder bore 3/16 in from the ends and as low down as possible.

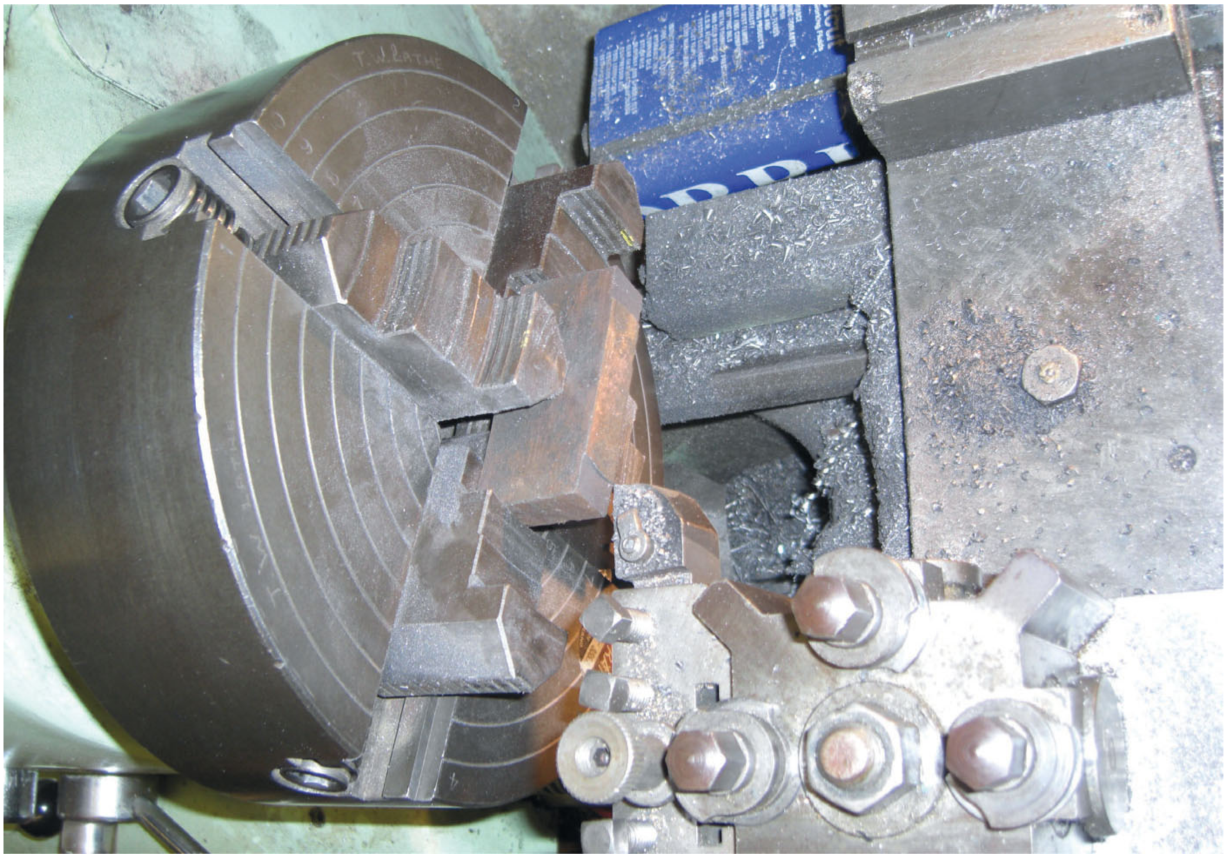
Two drain taps, obtained from model engineers' suppliers, are fixed to the dummy back-head to represent the test cocks that were used to check the water level before the invention of the glass tube water gauge.

## VALVE OR STEAM CHEST

The valve chest is usually a rectangular box with a separate cover. This allows valve timing to be carried out before fitting the cover. The Lampitt engine, however, has a rectangular box with a fixed cover, which makes valve-timing interesting. The regulator chamber, which receives the steam directly from the safety valve, is mounted on the outside of this cover (for an illustration, *see* Chapter 6).



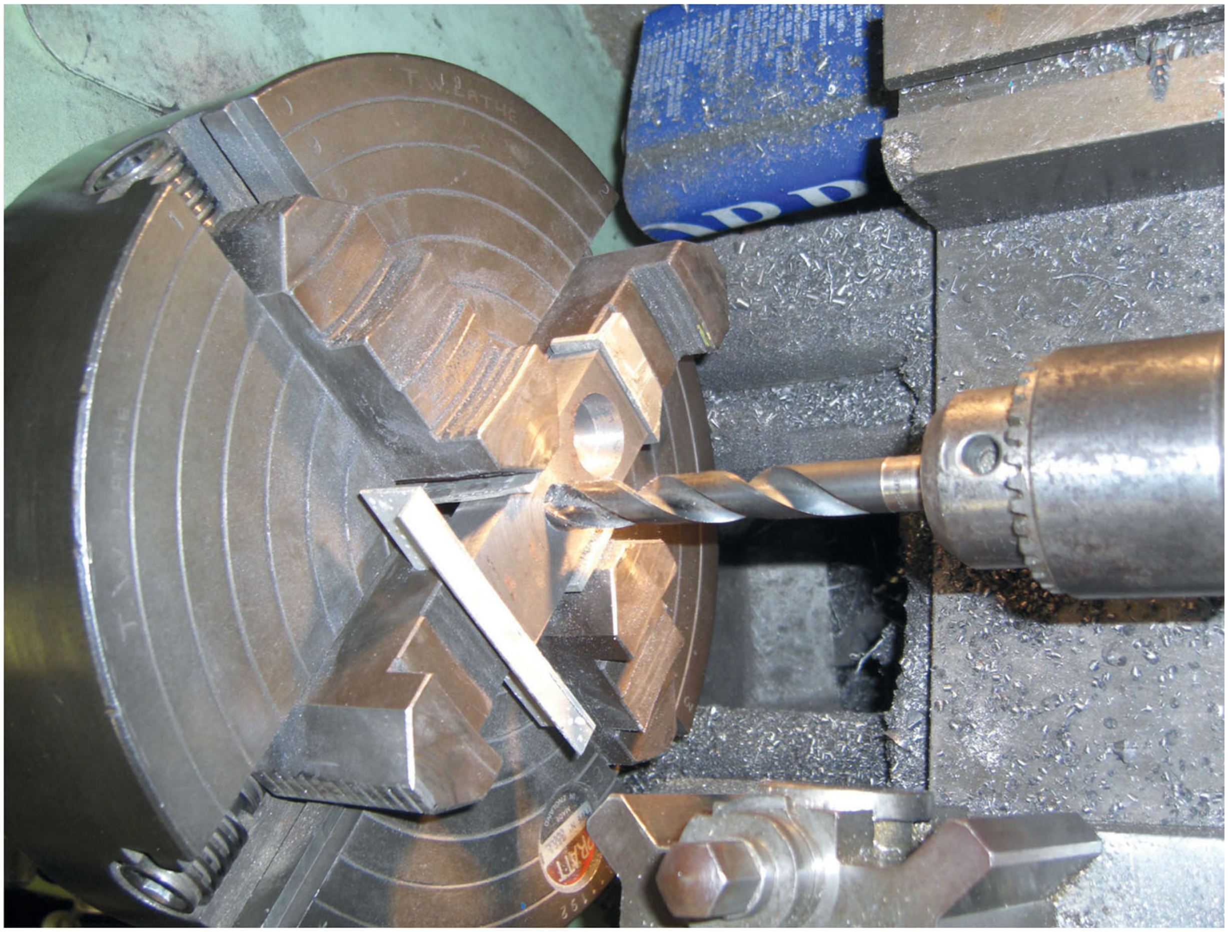
*Facing the end of the valve chamber.*



*Cast iron block set up to machine.*

The valve chest should have flanges at the top, bottom and rear end. The front end has an external flange. This arrangement does not work on the model, so a simple block is used with long studs and the external flange is part of the cylinder mounting plate, which fits on the end spigot of the cylinder. The block is cut lengthways from the same material as the cylinder and faced up to size.

This presents difficulties when making the cavity in the valve chest. Without a milling machine or a vertical slide on the cross-slide of the lathe, mount it in the four-jaw chuck and drill and bore a flat bottomed hole. Adjust the jaws to move the block along a bit and bore out the side of the hole to the same depth and the same cross-slide dial reading. Repeat this movement until the cavity is long enough. The slight ridges in the sides can be removed with a file. The port face must have flat metal around all the studs and the valve face must be continuous above and below the ports to provide a continuous seal for the valve as it slides to and fro.



*Drill and bore to make a blind cavity in the valve chamber.*

On the original engine, the front end of the steam chest – with its external flange – was flush with the front end of the cylinder. The rectangular end cover was secured by five bolts, all of which were in the steam chest flange: there was nothing to secure the cover to the cylinder and make it steam tight. Fitting a cover over a joint is not very good practice and not having any fixings to one casting only makes this worse. The cylinder cover has a flat on the outside edge to provide a close fit for the steam chest front cover. This cover contained the valve rod gland.

To improve the construction, the cylinder mounting bracket extends across the front of the steam chest and, together with the steam chest front cover, has a 5/16 in hole to provide a gland for the valve rod. The 3/16 in hole in the end of the cast iron steam chest supports the valve rod and provides a good bearing surface.

A second bearing support is provided by a bush on an extension bracket, the base of which is bolted to the two top bolts of the steam chest front cover. This bracket has a dogleg bend to align it with the valve rod. The bottom two (of five) bolts are screwed into tapped holes that are countersunk on the inside to clear the valve chest.

## REGULATOR CHEST

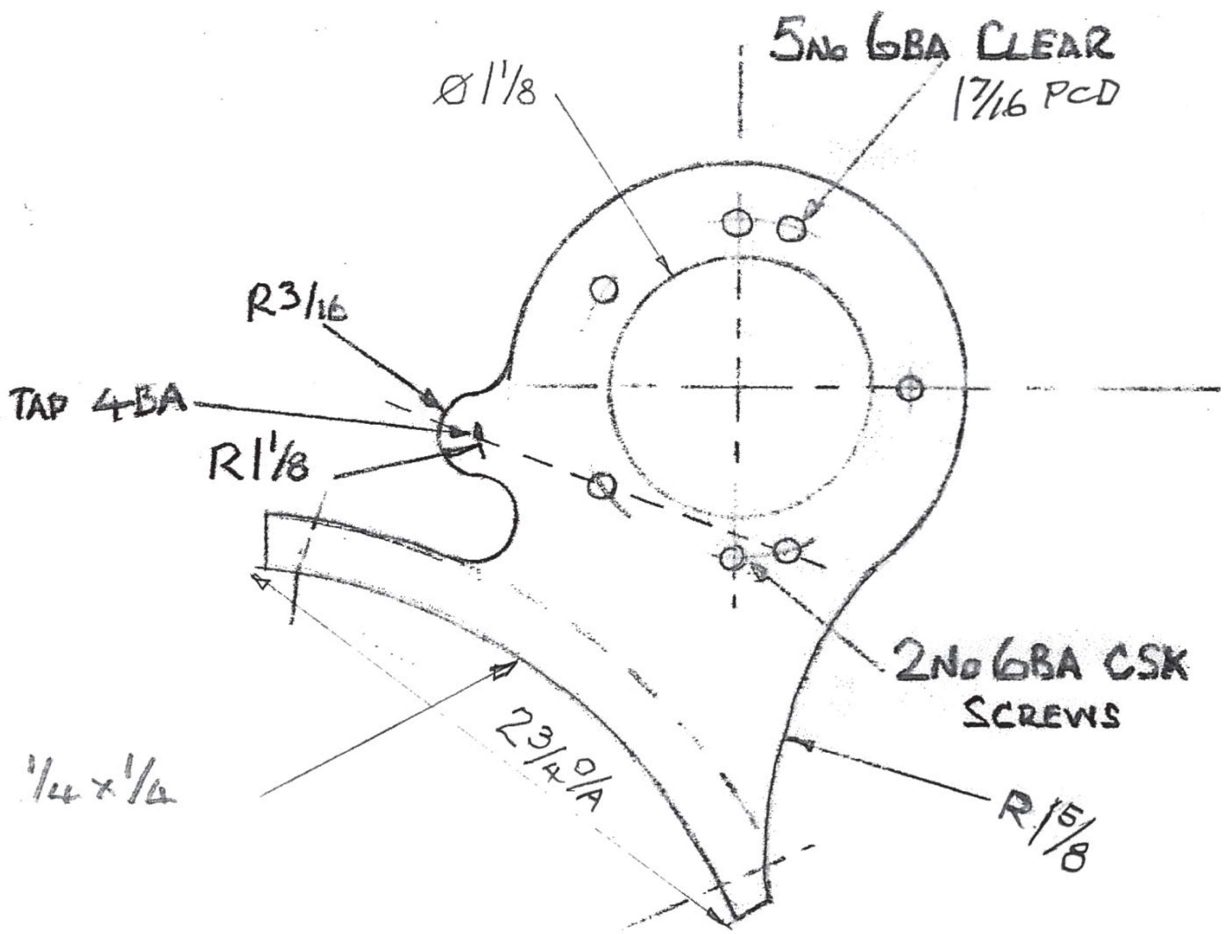
The regulator chest is a simple block of cast iron with a steam inlet in the centre of one face and the outlet towards the front of the opposite face. This communicates with a similar hole in the back of the valve chest. These holes are counterbored for an ‘O’ ring seal (for an illustration, *see* Chapter 6). The rear end has a 5/16 in drilling for the regulator, which has ‘O’ ring grooves each side of the steam inlet hole. The safety valve is secured with the same four studs.

*Regulator chest with ‘O’ ring recess around the steam passage.*

## CYLINDER MOUNTING BRACKETS

The steam cylinder of the Lampitt engine is offset to the right of the boiler centre line by 14¼in, full size. This would be 2 3/8 in in our scale and makes the cylinder almost directly over the vertical side of the boiler firebox. The mounting brackets were part of the same casting as the cylinder and must be made to look so.

*Cylinder mounting plates and flanges.*



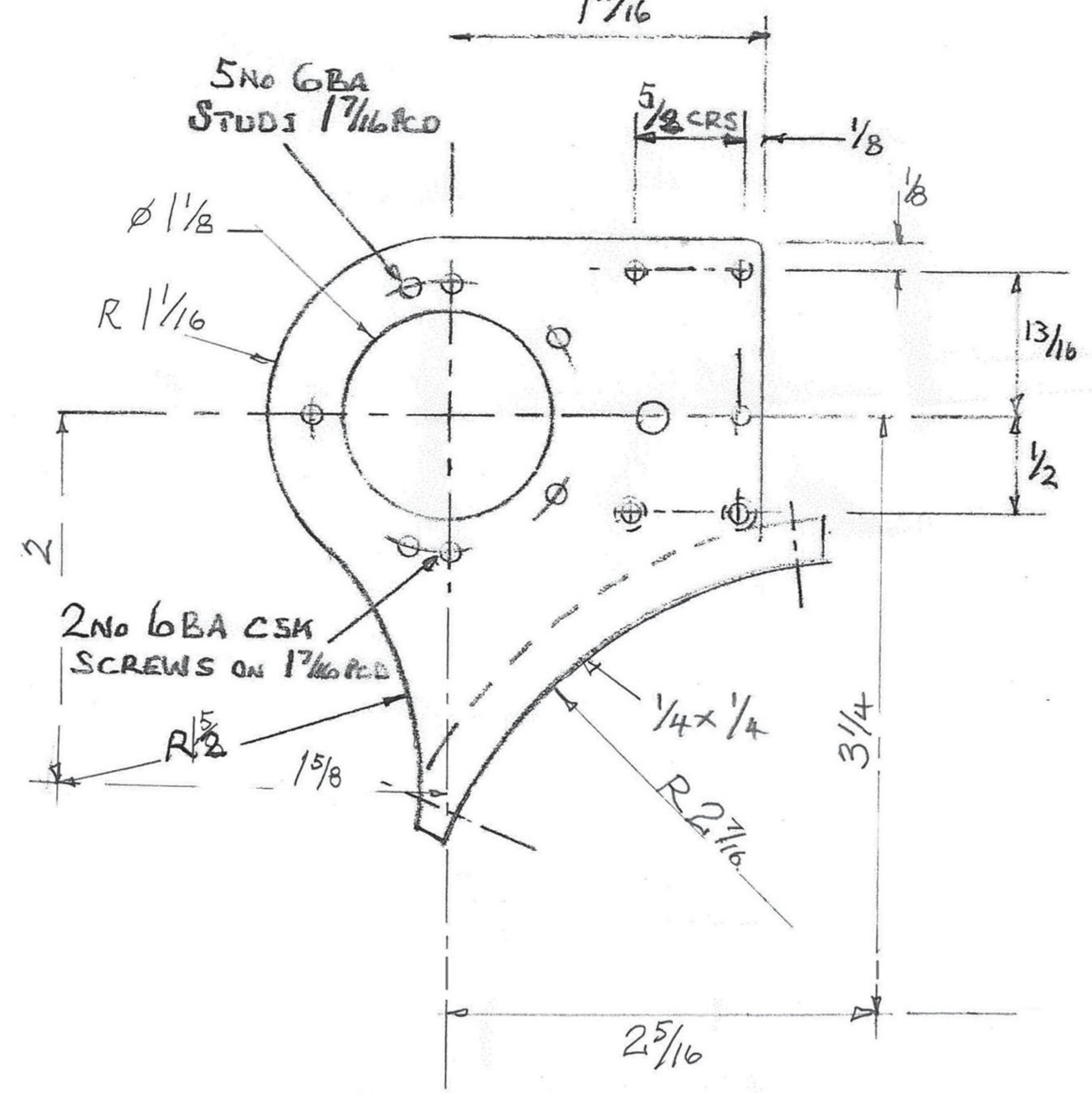

**Drawing 028 Rear Cylinder Mounting Bracket**

The spigot diameter, outside edge and mounting flange to the boiler dummy firebox (hornplate) are the same on both plates. Do not forget the ‘ear’ for the regulator pivot bracket on the rear plate and the steam chest flange on the front plate. Both plates have a flange of ¼in square steel (left over from the wheels) riveted to the inside of the base arc before silver soldering. All external edges are rounded to make them look like ridges on the casting.

The safest method is to assemble the plates to the cylinder and clamp the base flanges on the dummy firebox, preferably with the valve chest, regulator and safety valve in place. This assumes that the dummy firebox is already mounted on the boiler.

The safety valve curved square mounting flange will be secured to the dummy firebox top with four 6BA brass screws and nuts at the top. It is not attached to the safety valve, the circular flange of which contacts a flat circular surface machined into the top face of the curved square mounting flange.

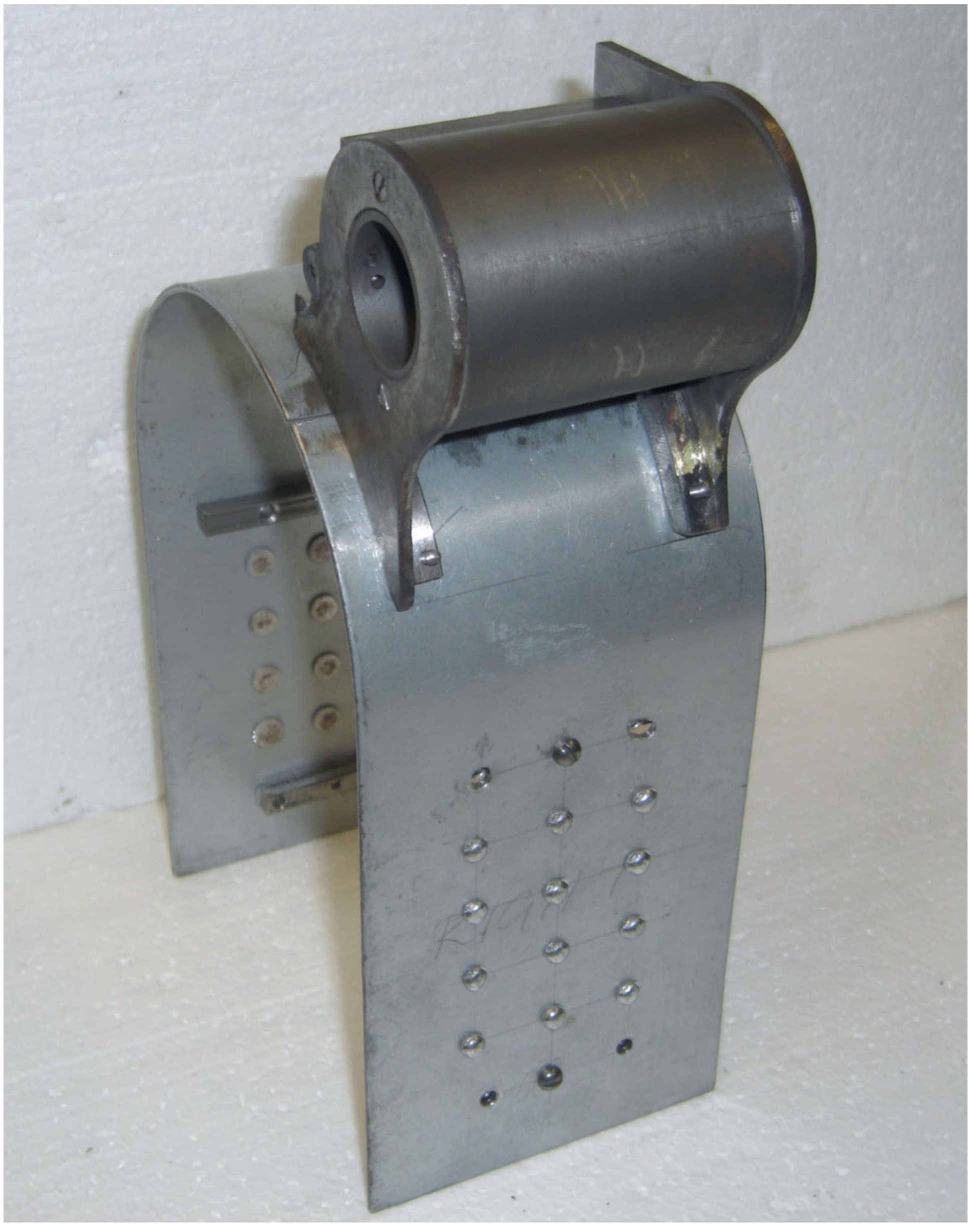
To screw the safety valve into the boiler with its outlet flange intact, the regulator chamber is left off and fitted afterwards. The common studs have nuts silver soldered to their ends as the studs have to be screwed in after assembly. Make sure that the front studs do not penetrate the valve chest and obstruct the movement of the valve.




**Drawing 029 Front Cylinder Mounting Bracket**

*Cylinder components.*

*Cylinder components.*



*Cylinder fixed to hornplate/dummy firebox.*

At this point, the port face of the cylinder should be in a vertical position. It is now time to fix the mounting plates to the cylinder ends and mark the base-flange holes on the hornplate. Two 6BA countersunk screws pass through the mounting plates into tapped holes in the cylinder on the vertical centre line. The countersunk holes in the mounting plates could be drilled before this exercise but this is best left until now. Only five studs and nuts are used to hold the cylinder end covers in place so they will not conflict with these countersunk screws. It is more important to avoid the steam ports as they approach the cylinder ends. The five studs at each end pass through clearance holes in the mounting plates. This should ensure that the nuts holding the cylinder covers in place also seal the join between the back of the plate and the cylinder end surface. A paper gasket will keep it steam-tight.

The curved flanges at the base of the mounting plates, made from ¼in square steel, will be bolted to the dummy firebox by four bolts at their extremities. To make them as secure as possible, the holes are tapped 6BA and the bolts, which could be hex socket cap screws, are inserted from inside the hornplate. A nut goes on the exposed thread outside and acts as a lock-nut. Engine manufacturers found that a few bolts holding the cylinder to the boiler worked loose and started to leak. The number of bolts was therefore increased to a dozen or so. If you intend to make this engine work for its living, you may consider drilling two extra holes through the dummy firebox into the centre of the ¼in square flange and tap these holes. Screws inserted from inside could have the top end filed off flush with the flange and then painted over.

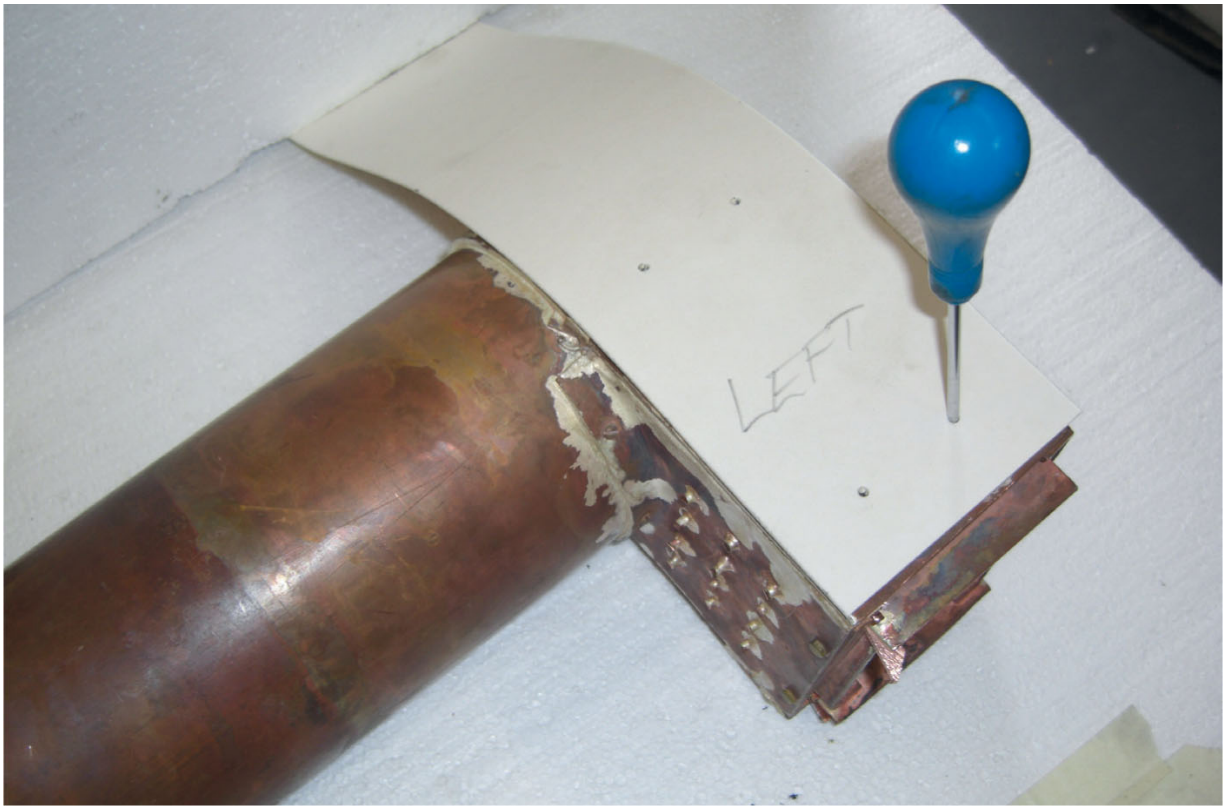
## CYLINDER COVERS

The rear cylinder cover has a 1/8 in long spigot as its location in the cylinder. The outside is simply shaped in a traditional manner to save material and keep the thickness of the cover as uniform as possible. It has a 3/16 in radius groove with a maximum diameter of ¾in.

The front cover has a 1in diameter projection on the outside to provide the gland for the piston rod and the support for the slide-bar. The latter has to have a corner cut out to clear the bottom stud and nut. This may be a place where a socket head screw could be used. Two more can be used to hold the slide-bar to its mounting on the underside of the gland.

The slide-bar mounting is made from a disc of cast iron, which is bored to a close fit on the gland housing. A square-ended piece is cut out of the bottom. Before the sides are cut off a hole is drilled and tapped 6BA in the underside for a countersunk screw. Cut the sides off, making sure that the nut on the other bottom cover stud and nut is clear, and secure the mounting with the countersunk screw. On either side of this screw, drill and tap for the slide-bar securing screws, which will go right into the gland and help secure the slide-bar mounting to the gland.

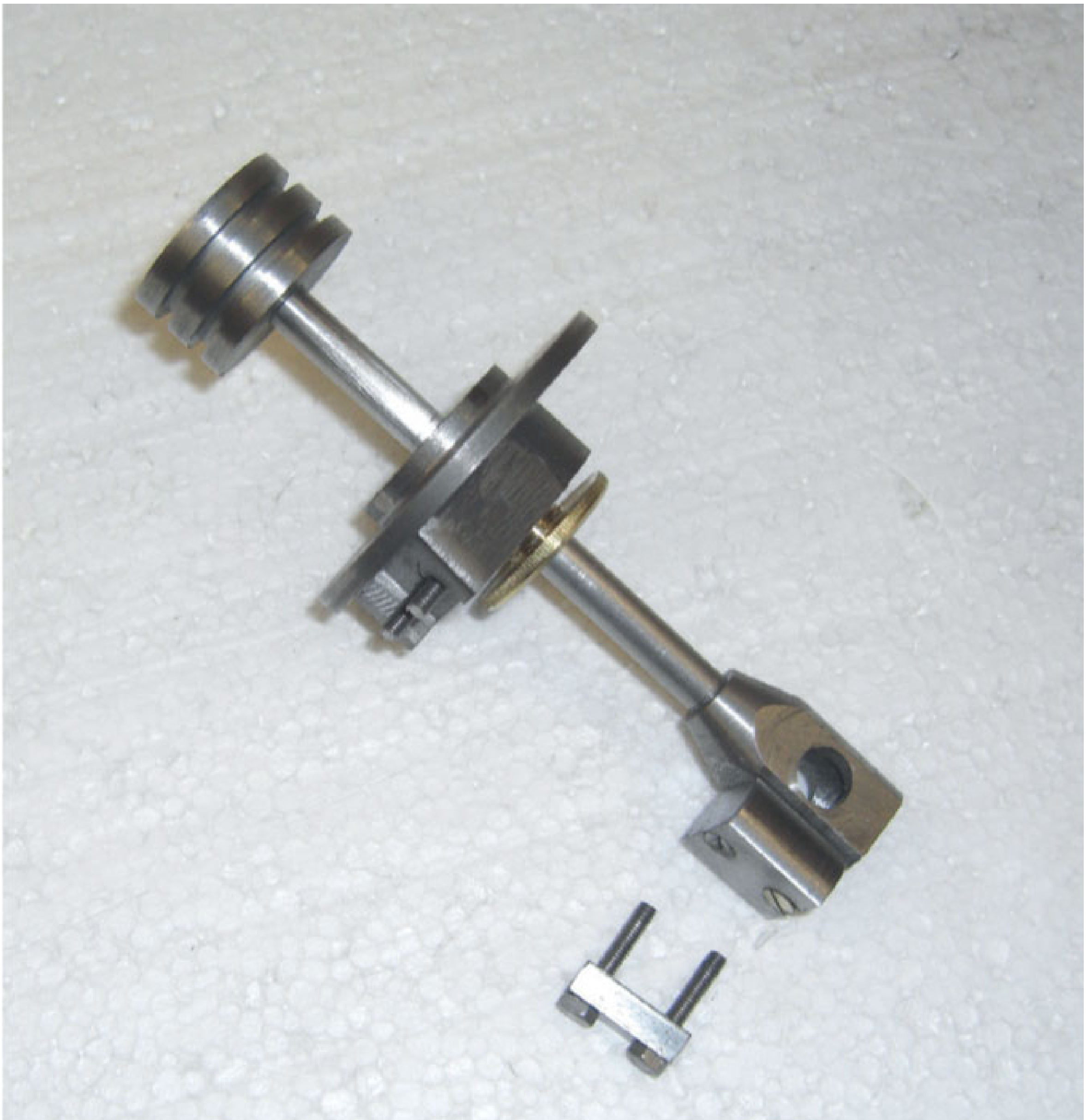
*Checking the slide-bar is square before drilling the mounting.*




*Locating special tapped bushes in boiler side.*

*Piston, cylinder cover, crosshead and slide-bar.*

*Cylinder front cover and slide-bar mounting being made.*



*Cylinder front cover and slide-bar mounting being made.*

An alternative method is to make the gland housing 13/16 in diameter and bore the slide-bar mounting to suit, then cut the slide-bar mounting top to ½in radius over the top and shape the lower part as before. The slide-bar mounting face could then be the correct ½in distance from the piston rod centre line. Make the crosshead to fit.

The outer end of the slide bar is supported by a bracket, which should be attached to the boiler barrel. To save drilling more holes in the barrel or fitting bushes, the slide bar bracket is screwed to a sideways extension to a boiler band. Deciding on its location will require a little trial and error.

## VALVE SETTING

It is essential that the valve, driven by the eccentric, is set about a quarter turn ahead of the crank that drives the piston in the cylinder.

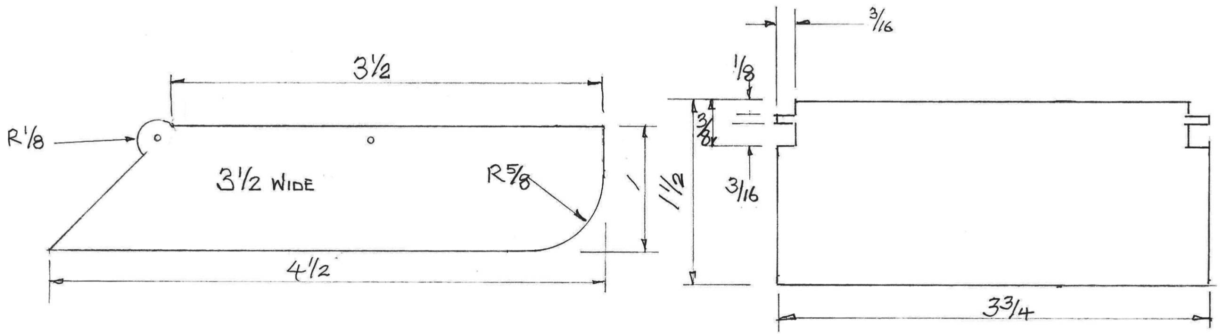
Looking at the engine on the left (flywheel) side, the engine should turn to the left, or anti-clockwise. As the crank passes back dead centre and the piston reaches its maximum travel to the right, the valve, which is already travelling to the left, should just start to crack open the right-hand steam port to let steam pass to the right-hand end of the cylinder and push the piston to the left. The same thing should happen at the other end of the cylinder. This will make sure that the engine makes equal beats, or chuffs, up the chimney.

To adjust the timing, move the eccentric on the crankshaft; and to achieve equal beats, screw the valve rod in and out of the ¼in square nut on the back of the valve.

The construction of the Lampitt engine makes it impossible to view the position of the valve when assembled. Before final assembly, drill and tap a hole 6BA in the back end of the valve chamber. Using a stout piece of wire, mark on it the distance from the back, outside face of the valve chamber to the right-hand end of the valve when the valve is just cracking open the right hand steam port. Make another mark where it is just cracking open the left-hand steam port. This will indicate the position of the valve when all is assembled.

## ASH-PAN AND DAMPER

Under the firebox of the boiler is the ashpan, which supports the fire grate and damper door. The ash-pan is simply a tray with the sides bent up at right angles and the front curved up to improve the appearance and smooth the passage of long grass and mud when travelling over rough and rutted roads. The rear edge of each side is angled with a semicircular projection that forms a hinge for the damper door. The door is flat and when closed it should fit all round and restrict air from entering the fire.




**Drawing 030 ashpan & Door 20sWg st. steel 1 off each**

The exhaust steam from the cylinder creates the blast up the chimney, which draws air through the fire to make it burn more brightly. The fire is then controlled by the damper door, which restricts the flow of air into the fire. This can be regulated by a simple chain, which passes through one of the drawing back hooks to a weight on the other end.

The ash-pan and its door should be as air-tight as possible. To achieve this the ashpan should fit closely to the outside of the Ashpan should fit closely to the outside of the inner firebox skirt and up against the foundation ring. Hold the ash-pan up in position and drill through the top edge of the ash-pan and the firebox skirt on both sides, ensuring that they are in line. A long rod or wire (coat hanger) with a loop on one end is passed through to support the ash-pan and grate. This simple fixing gives you a quick way of dropping the fire in an emergency, for example if the water level is low, and is handy at the end of the day when removing the fire.

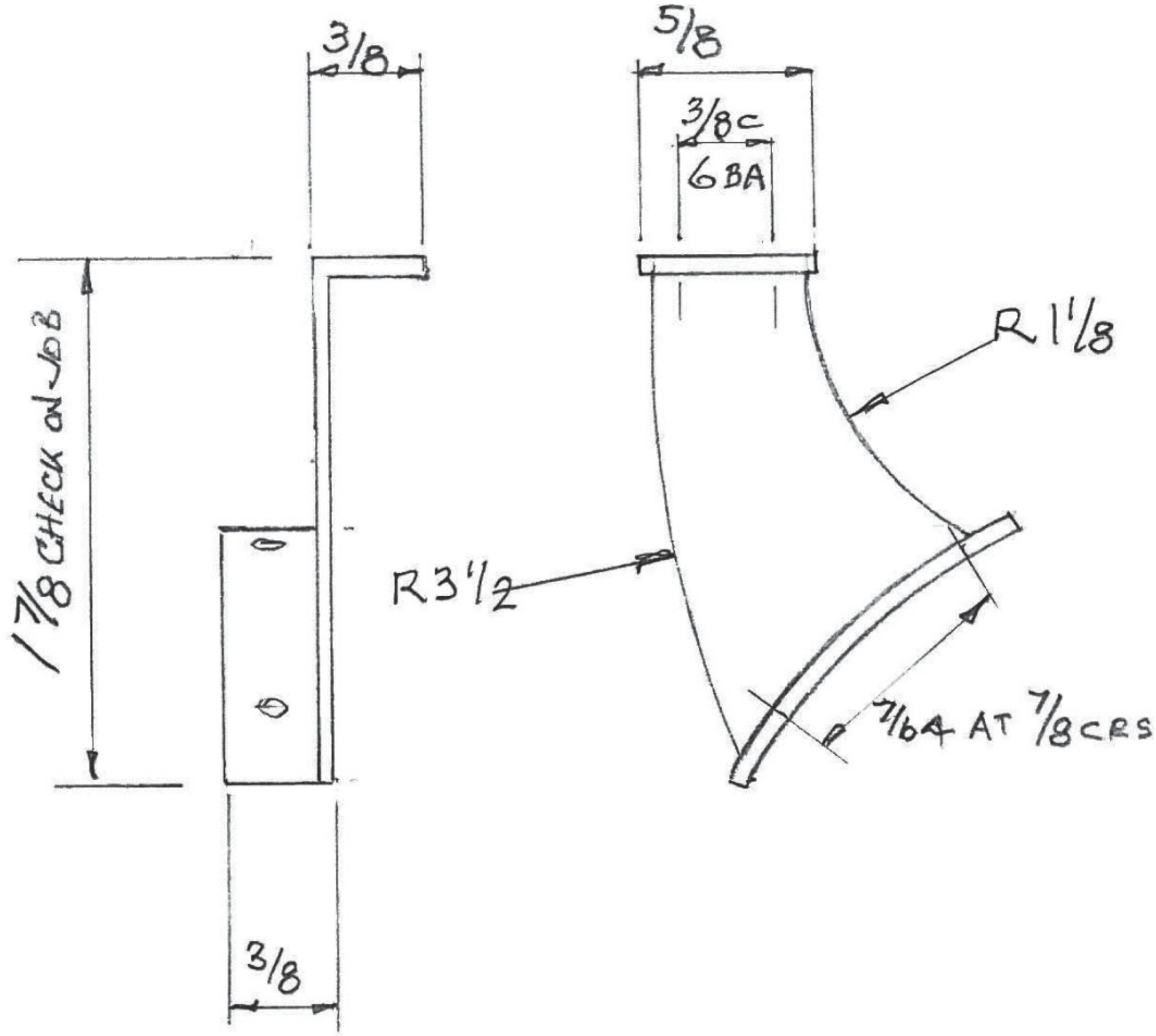
The grate is made from steel, preferably stainless, or you may find a cast iron grate that fits at a model engineers’ supplier. These are usually made with four integral legs, which is handy, but the legs get in the way of raking out the ash during the running period.

The grate is fabricated from 1⁄2 × 1⁄8 in flat steel bar with 3⁄16 in spacers, which are drilled 5⁄32 in diameter to take 4BA studding or rod that has been threaded at both ends. Legs replace the spacers near the corners.

To improve the appearance and make the ash-pan as near to the prototype as possible, it could be made the full width of the dummy firebox, but this will need the vertical pieces to fit the skirt as before. This would make the bottom double and the fixing rod would go through three of the four side-pieces. The front and the damper door would be full width, but the door must close to the narrow ash-pan side edges.

## SLIDE-BAR SUPPORT

This is simply three pieces of steel, silver soldered together. The vertical part, with the curved sides, can be cut from card to try on the boiler and the top trimmed to fit the slide-bar. Do all of this after the cylinder and cover are finished and the lagging and cladding is all in place. In other words, when the boiler bands are fitted, the middle one can have a sideways extension silver soldered on.

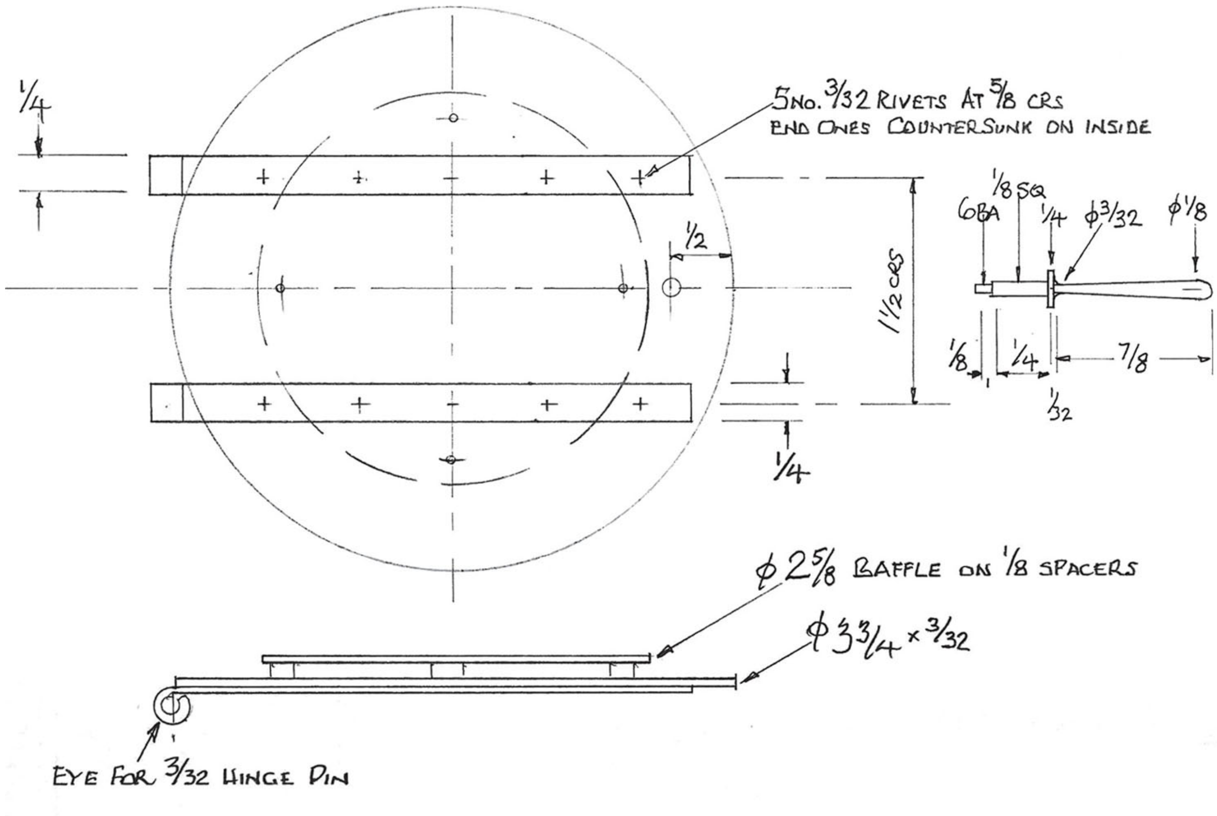



**Drawing 031 Slide-Bar Support Steel 1 off**

*Arm and spring.*

## SMOKEBOX DOOR

The smokebox door is simply a couple of discs of steel, which can be stainless steel or Zintec (zinc plated steel). Make sure that the baffle inside does not foul the opening when hinged open. The hinges on the smokebox front are made like long headed bolts, with a 3⁄32 in hinge-pin hole across the head.



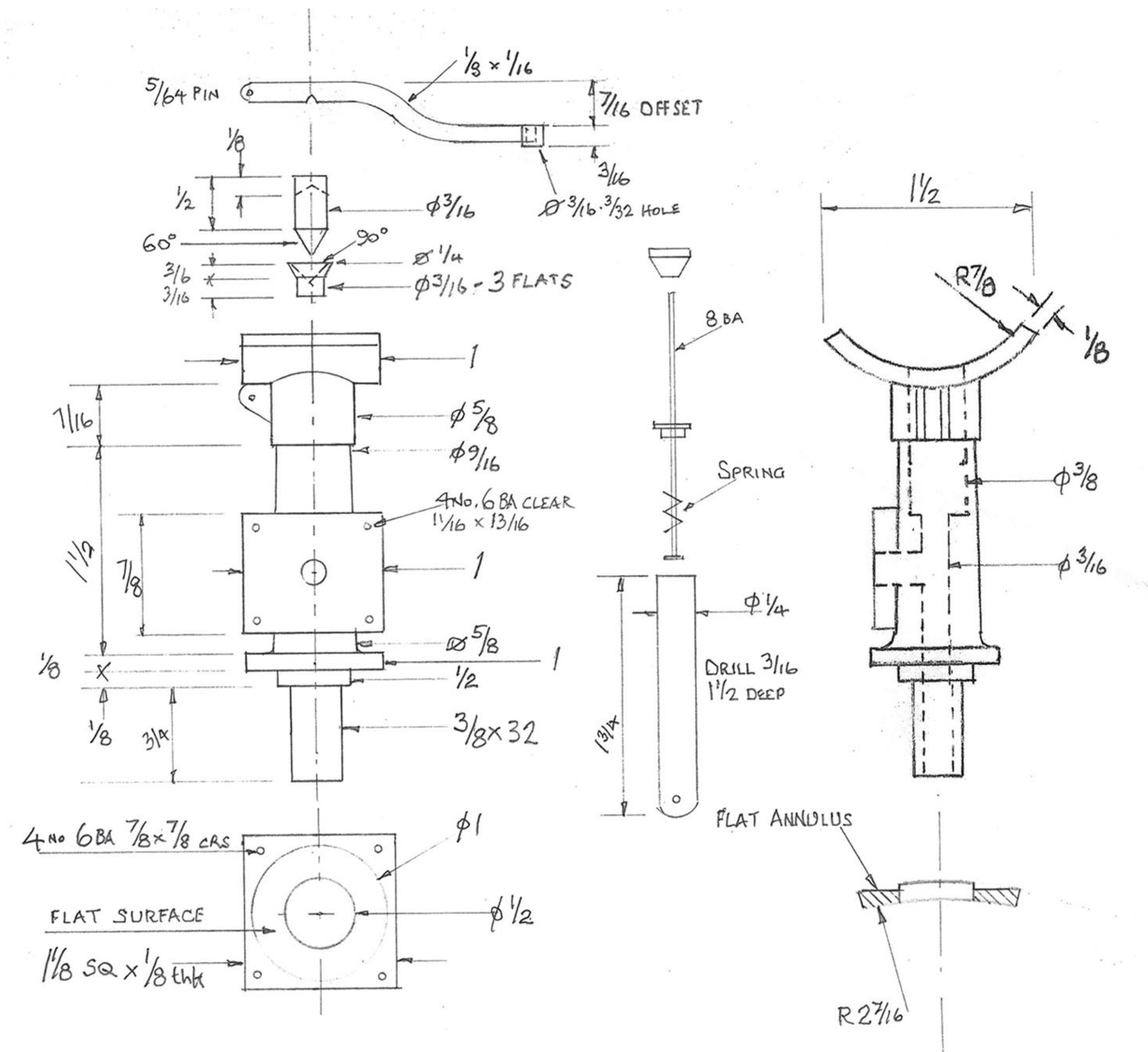

**Drawing 032 Smokebox Door**

## SAFETY VALVE

The safety valve is a straightforward turning job. It can be made from 1in diameter gunmetal or phosphor bronze, or you can use 5⁄8 in diameter and silver solder a 1in diameter flange at the bottom. This acts like a thick washer and could be of brass. Skim the bottom face true afterwards. The square flange must be vertical, so file the taper a little at the bottom.

Silver solder the ‘ear’ at the top and, using two new blades in your hacksaw, cut the slot for the lever. The curved pad for the chimney is silver soldered afterwards. Both this and the square flange at the bottom have a flat annulus machined on to accept the flat flange surfaces. Note that the bottom flange is not attached to the body and is bolted to the dummy firebox top with four 6BA brass screws with brass nuts at the top. This allows the safety valve to be screwed into the boiler bush and the regulator chamber slid in last and fixed with the same studs as the safety valve outlet flange.

The valve itself is brass or stainless steel and is filed triangular to slide in the 3/16 in diameter passage. Turn to 3/16 in diameter first;if you use hexagon bar it is easy to index round to three places. If you have a miller, concave sides can be made that are less restrictive to the passage of steam.




**Drawing 033 Safety Valve 1 off**

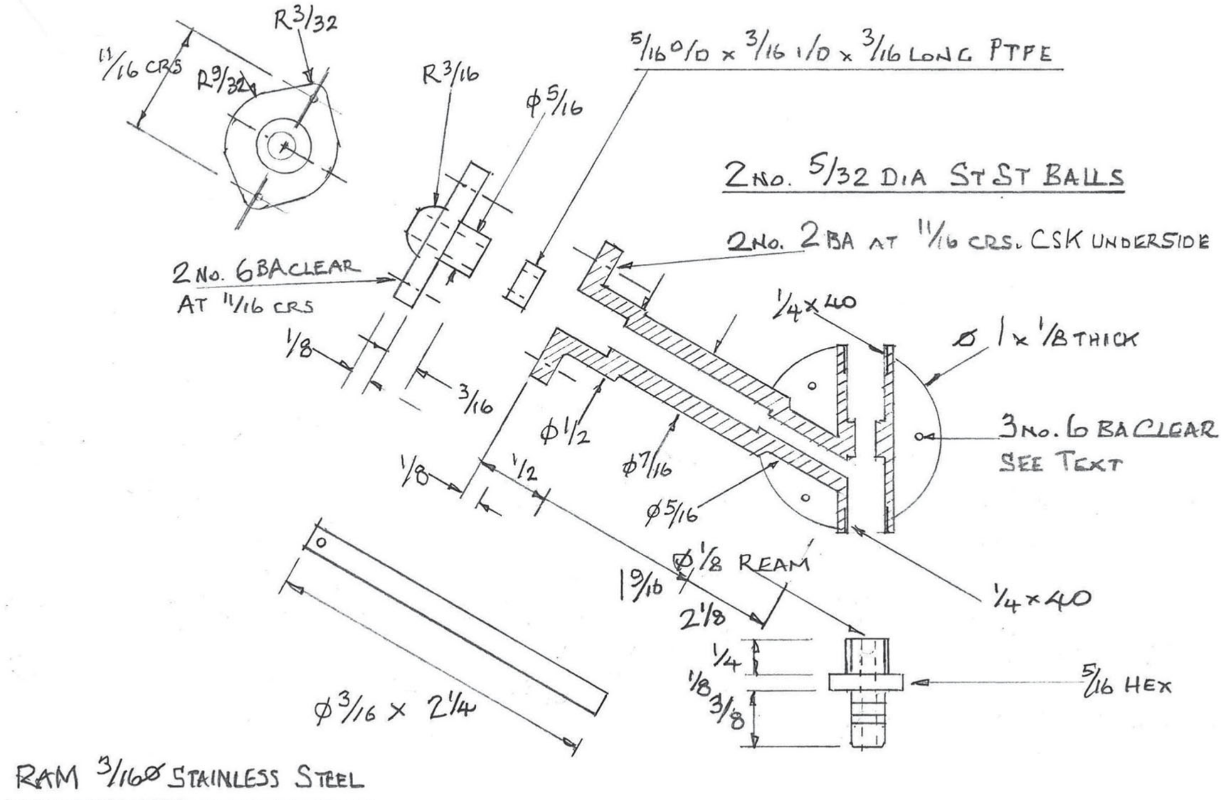
## BOILER WATER FEED PUMP

The boiler water feed pump is driven by an eccentric, much like the steam valve eccentric except that it has a rib in the centre to stop the eccentric strap from working off to one side. If you are not confident about making both sides of the eccentric exactly the same size, the alternative is to bore the eccentric strap straight through, turn the eccentric from side to side and add a 1/16 in wide flange on each side to keep the strap in place. The eccentric rod is also like the valve eccentric rod, except for its length and that it is straight.

The pump itself is fabricated from brass, with a stainless steel ram. Start with the cylinder, or body, which is made from ½in diameter brass. This should be secured in the three-jaw chuck with about 2¼in projecting. Reduce the end 1/8 in by about 15 thou, leave ¼in at full size, and reduce the next 1¼in to 7/16 in diameter. The next 3/8 in goes down to 5/16 in diameter, which will need a couple of cuts. Centre and drill 3/16 in diameter. A better idea would be to drill slightly less and use a machine reamer.

A machine reamer is made with a Morse taper shank and will be the marked size to the end. A hand reamer has a parallel shank with a square on the end, and has a lead or slight taper at the working end. If you have to use a hand reamer, the end of the ram could be reduced by a few thou to maintain clearance. The model engineer's option is to use a 'D' bit made from 3⁄16 in diameter silver steel. Beyond the 3⁄16 in hole is a 1⁄8 in hole to the full depth of 2in. Part or cut off at 2in, and file the end at an angle with a 5⁄16 in diameter round file.

*Pump components.*




**Drawing 034 Pump Body & Gland Brass 1 off**

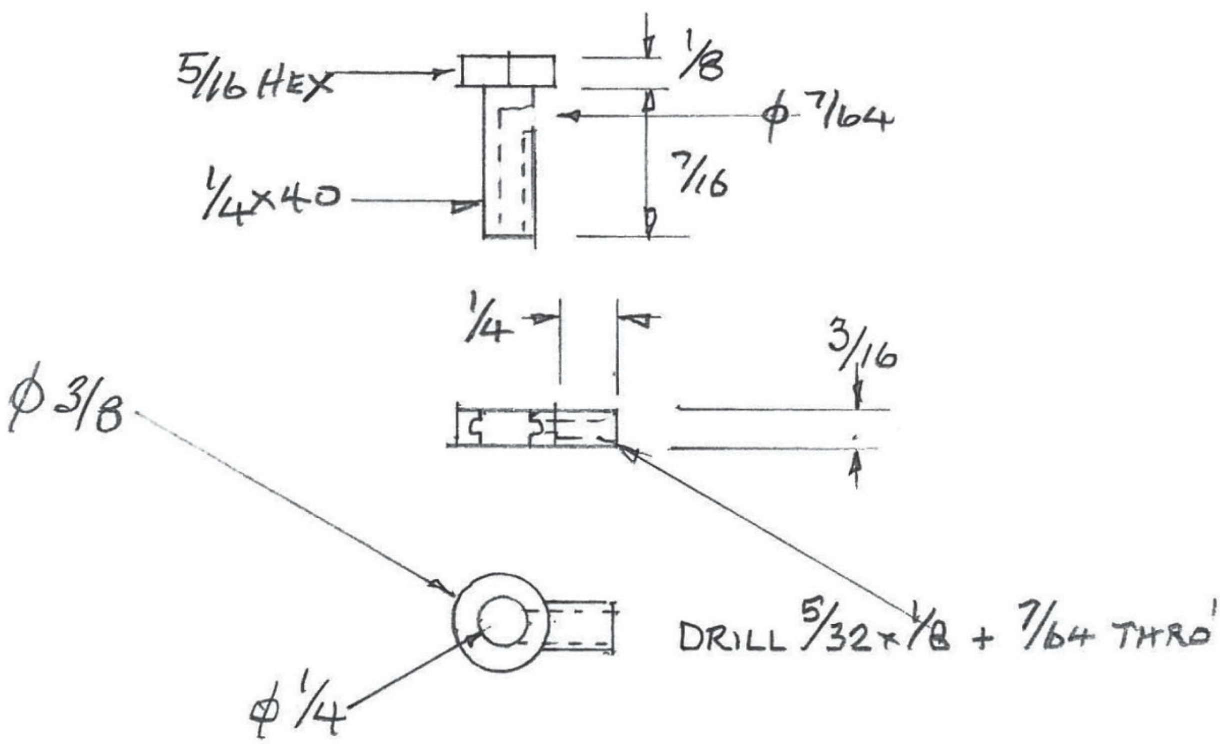
*Pump gland components.*

The end flange and gland are made from 1/8 in thick brass bar or sheet. Mark and cut out two flanges roughly to size. Mark out one and centre dot for the centre hole and mark an arc across a centre line at 11/32 in each side with dividers. Clamp the two together and drill them tapping size for 6BA. Thread one and open out the other one to 7/64 in diameter (2.8mm), the clearance size for 6BA. Screw them together and file them both to the correct outline. If you unscrew them and turn one around, you will see how accurate your filing is. Screw them together, and mark the edges to identify the best way round.

Once these have been screwed together with steel screws (for strength), chuck the threaded one in the four-jaw chuck with the screw heads outwards, centred on the centre dot in the middle. Use a small centre drill to start the hole in the middle. Go carefully as there is not much holding it all together.

When used in brass, new drills tend to snatch and pull in. A 5/16 in drill may also be too much for those 6BA screws. The answer is to bore out to 5/16 in diameter. Now unscrew the outer flange, which will make the gland, and bore out the remaining flange to fit the ‘15 thou below ½in’ at the top end of the pump body. Make it a tight fit if you can. Go carefully as there is not much of it. Remove from the lathe and countersink the tapped holes on the underside and deburr both flanges.

Make the gland centre from ½in diameter brass, drilled 3/16 in and turned to 5/16 in diameter, and parted off with a tool that makes the hemispherical end like other glands on the engine. Make the 5⁄16 in diameter a good fit in the flange and silver solder them together.




**Drawing 035 Outlet Banjo Brass 1 off**

The valve block is made from 5/16 in diameter brass, drilled tapping size for ¼in × 40 thread. Continue drilling 1/8 in diameter before squaring off the bottom of the tapping size hole with a ‘D’ bit. This will form the outlet valve seat at the top. Do not get them mixed up.

The other end is drilled and tapped in a similar way. The hole should be squared off as before with a ‘D’ bit. The ball valve must not seal against this seat as it would cause a hydraulic lock, but the easiest way of doing the next bit is to have it square.

Make a narrow chisel from 3/16 in diameter silver steel. This is filed or ground to 1/16 in square and the end ground at 20 degrees. It is then hardened and tempered to yellow. The chisel is then poked down the hole and clouted with a hammer to damage the squared-off seat in three places. This will stop the ball valve from sealing and will limit the lift of the ball from its seat on the inlet fitting. The 1/8 in diameter hole should communicate all the way through.

Wire the four parts together with soft iron florists’ wire to silver solder. The wire can pass through the tapped holes in the top flange and round the valve chamber. More wire will be needed through the valve chamber to stop the main body from slipping along its length. The fourth part is a 1in disc of brass, which reinforces this junction and has three 7/64 in holes to fit the bush in the boiler left side.

After silver soldering, the 1/8 in water passage can be continued through the valve block wall. This avoids any worry of misalignment of pre-drilled holes.

*Pump rod.*

Round-headed brass screws may seem to be the best option to secure the pump to the blind bush in the boiler side, but they may shear off if there is a hydraulic lock. Although this might prevent something else from breaking, the broken ends of the screws would be difficult to extract from the boiler bush. Steel screws would be stronger and resist the shearing effect of the ram when pumping water. There is no contact with water so there is little chance of corrosion. Fit a thick gasket between pump and boiler to stop the transmission of heat to the pump.

The top flange has two countersunk brass screws, inserted from underneath to form gland studs. The stuffing in the gland is a short tube of PTFE adjusted by nuts. No packing or ‘O’ ring is needed on the ram.

## BOILER FILLER

To fill the full-size boiler with water there is an elbow on the left of the firebox, capped by a brass plug with a domed top with a square on top. The dome is typical of all such fittings on this engine. The elbow is simply an 8mm copper elbow with a socket at both ends, as used by heating engineers on microbore central heating installations. Most of the bottom socket, however, is cut off where it is silver soldered to the mounting plate, while half the length of the top socket is cut off and a threaded insert is silver soldered in place.

To make the plug from 8mm brass, turn down to ¼in diameter and thread ¼in × 40 tpi. Undercut the thread to make sure that the plug screws fully into the elbow. Use a form tool to form the dome, leaving a 3/16 in diameter stub at the top. Make sure that it is long enough and cut or part off.

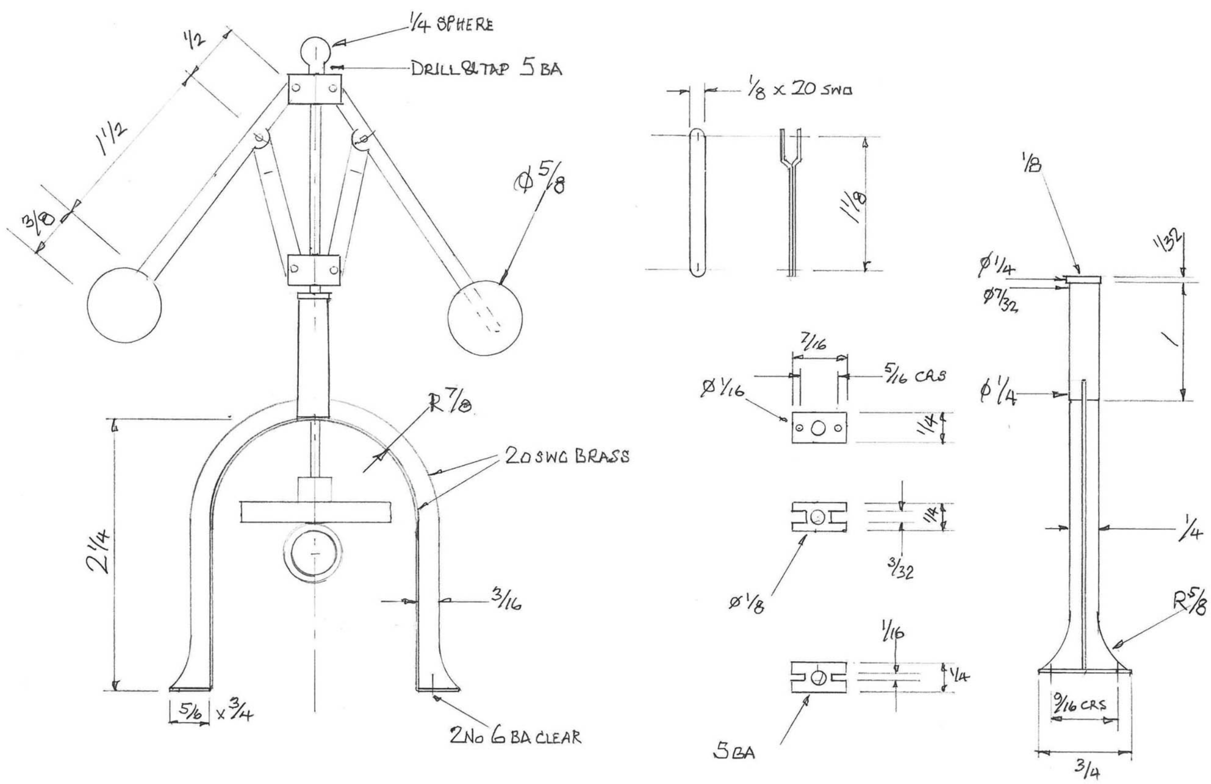
Make the insert by drilling and tapping the end of the bar, but before parting off, screw the plug into the thread. Put a 3/16 in flat washer onto the stub and, using a hand file with a safe edge, file a flat on the stub. Turn the chuck round 180 degrees and file another flat. View the end to make sure that the two flats are parallel. Turn the chuck 90 degrees and file again. View the end again. Turn 180 degrees for the final filing. The finished size does not matter, as long as it looks like a reasonable square. The washer will stop you spoiling the dome shape. Part off and silver solder the insert into the top socket. This end could be soft soldered.

The mounting plate will be slightly curved where it fits at the top of the firebox side. Note that the filler is bolted to the outer dummy firebox and does not connect with the boiler at all.

## GOVERNOR

At the time when our portable engine was in service, every handful of corn, wheat, barley or oats would have been cut with a sickle and a few lengths of straw used to bind it together into a sheaf. Six or eight of these would have been stood up, leaning against each other, to form a stook, which allowed the air to blow through and dry out the crop.

With the introduction of the reaper and binder, the corn was cut and tied into sheaves with binder twine, but it still needed to be dried in a stook. The stooks would be gathered and stacked in a rick in the farmyard, awaiting the arrival of the threshing machine driven by a portable engine. Later a self-moving engine, or traction engine, would pull the threshing machine and other equipment from farm to farm. Horses were no longer needed.




**Drawing 036 Governor in 2 in. Scale Brass**

The next development was the combine harvester, which cut and threshed the corn in one operation. These came to England after the Second World War and the Massey Harris 726 combine initially dominated the scene. The combine harvester is used at a later stage in the corn’s growth when the crop has dried out while still standing.

*Governor components.*

Threshing machines could be driven by a portable or traction engine, eventually superseded by a tractor powered by tractor vaporizing oil (TVO). When a sheaf of corn was fed into the drum, the power requirement would rise quickly and the drum speed of 1000rpm would drop. This would be sensed by the governor, which would open the regulator, or throttle, to counter this demand and thus maintain a constant speed. A good feeder would spread the sheaf out into a continuous flow, thus reducing the sudden demand on power.

As the speed increases, the centrifugal force created by the round weights spinning around in the governor moves the weights out and linkage is arranged to close the regulator. An improved design used a cross-arm pattern, which controlled the speed more evenly. The weights for our small engine are made from brass, which is drilled and tapped 4BA and shaped with a form tool. Shape the end of the bar first, followed by the chuck side, and try to get a true sphere before the ball is parted off. The arm is best made from 2mm stainless steel, the end of which is driven into the thread of the ball and silver soldered.

The links are forked where they connect to the arms. This can be done by making each link from two pieces of 22swg (0.5mm) thick stainless steel and bending a dogleg in each. The dogleg is easily made by making a saw-cut across a strip of similar thickness steel, bending one side up a little and placing the link at right angles to the saw-cut. Squeeze in the vice, using soft jaws, to straighten the steel and the link will be doglegged from one side of the sheet to the other via the saw-cut.

*Governor bracket silver soldered.*

The arms are pivoted to a block screwed to the top of the central spindle. The links connect to a similar block, which has a plain bore and is free to rise and fall as the speed changes. All pivot holes are 1/16 in diameter.

Drive to the governor spindle is provided by a pair of bevel gears, which give a 2 to 1 speed reduction. The drive gear on the crankshaft needs to be ¾in diameter and the spindle gear 1½in diameter. The drive ‘gear’ could be a piece of thick-wall rubber tube and the driven gear a disc of steel with a rim on the underside to limit the width of contact area with the rubber.

The whole governor is supported by an arched bracket with feet that attach it to the back and front flanges of the crankshaft bearing bracket. The section is T-shaped and the upright of the T is marked out on 24swg brass.

After the top of the T has been shaped to fit the arch and the feet bent out, it is then silver soldered together. It may be preferable to silver solder it together before adding the spindle bush at the top. Several wire ties will be needed to hold it together for silver soldering. Use four 6BA hexagon head screws into tapped holes to secure the governor to the bearing bracket, making sure that the balls allow the chimney to be folded down. Do not turn the engine when the chimney is in the transport position.

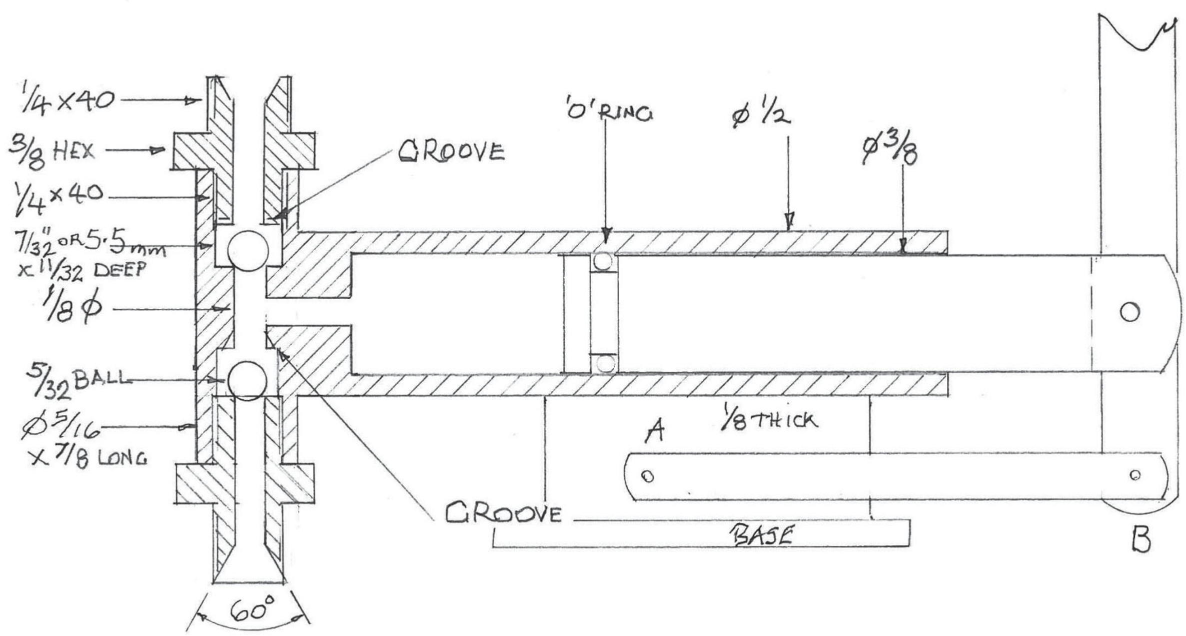
*Governor, down, with bracket material.*

*Governor, up, with bracket.*

## SECOND OR EMERGENCY BOILER WATER FEED PUMP

It is essential to have a second means of getting water into the boiler. If the engine-driven pump fails because there is a small piece of dirt in one of the valves, there must be a second pump. In some cases an injector can be installed, but it would not be appropriate in our case. A boiler inspector will always want to see two methods of pumping water into the boiler. On a traction engine or railway locomotive it is usually possible to fit one in the tender, under the coal or in the water tank. A portable engine does not have a tender and the water tank will be a wooden barrel squeezed in between the wheels. It is possible to fit a pump into the barrel with a detachable handle emerging from the water. It could be a vertical pump but the valve block must be vertical to ensure that the ball valves fall onto their seats.

The accompanying drawing shows a basic pump. The inlet pipe could be plastic or rubber, providing that it does not collapse on the suction stroke. The delivery pipe must be a properly fitted copper pipe as it will have to resist full boiler pressure. This may be the test pressure for the boiler test. The body of the pump may be fabricated or a casting may be obtained from a model engineers' supplier. The ram is slotted to take the handle and there are two links, either side of the foot and handle. Pivot pins should be at least 1/8 in diameter, but larger pivots and their holes will weaken the links, especially the handle.




**Drawing 037 Second or Emergency Boiler Water Feed Pump Twice full size Brass**

Make the valve chamber first by drilling 7/32 in or 5.5mm, which is tapping size for ¼in × 40, followed by 1/8 in diameter. Do this while there is a centre to follow from the 5.5mm drill. Use a ‘D’ bit to square off the bottom of the hole, to make the valve seat, and tap the hole ¼in × 40 tpi. Do not damage the seat with the tap. If you do, use the ‘D’ bit again to clean up the seat. It is usually recommended to put a reamer through the 1/8 in hole to sharpen up the valve seat. This can be done later. Cut or part off. Reverse in the chuck, face, centre, drill and tap as before and square off the bottom of the hole. This should break into the 1/8 in hole.

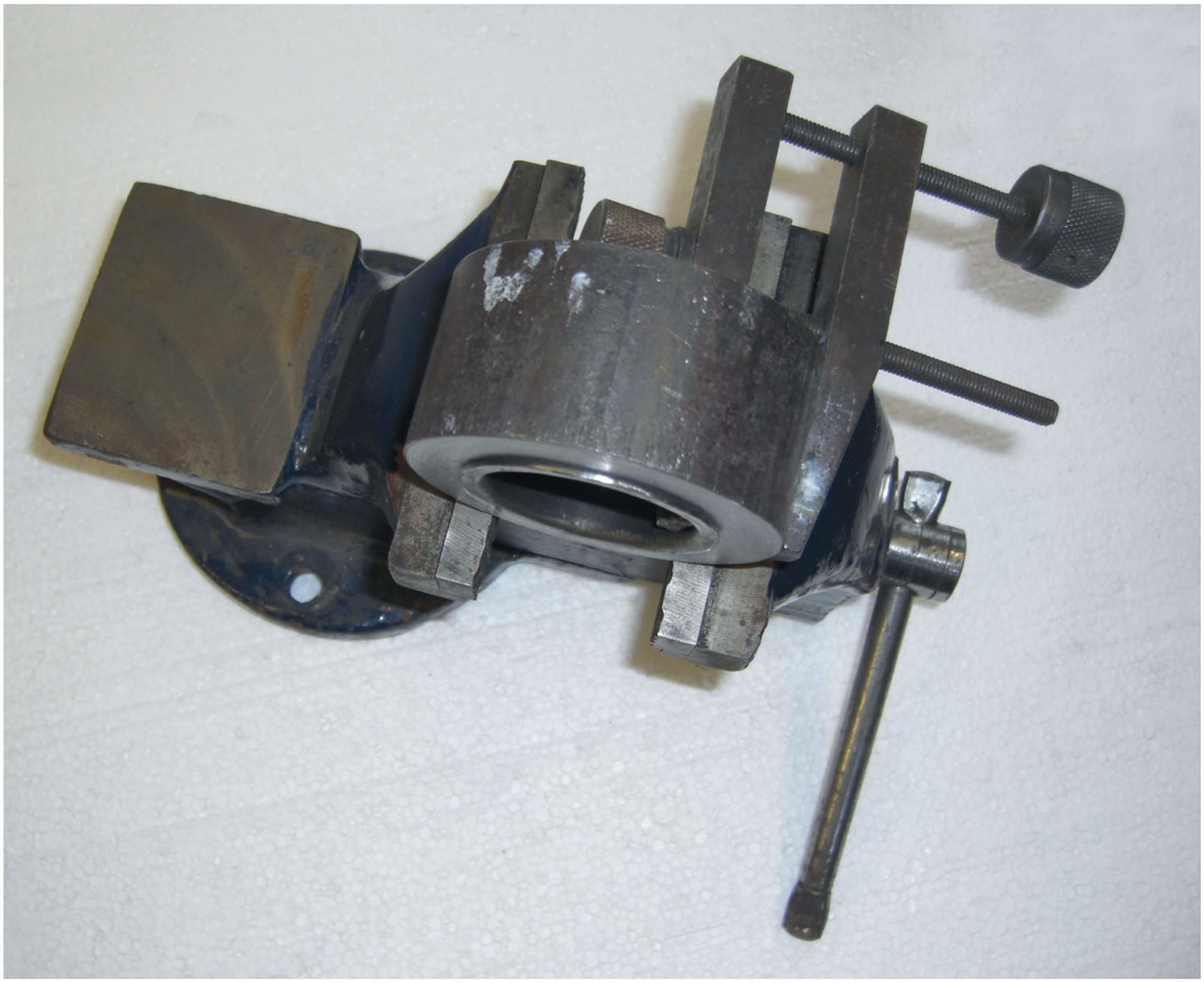
Make the barrel nipples from 3/8 in or 5/16 in hexagon brass, turn down to ¼in diameter and thread ¼in × 40 tpi. Drill deeply with a combination centre drill to make the 60-degree countersink and follow this with a 1/8 in drill. Cut or part off and make two. Re-chuck the valve chamber and screw the barrel nipple into the thread. A flat washer spacer will be needed as it will not screw up to the hexagon. Turn to ¼in diameter and thread ¼in × 40 tpi. Centre and drill if the hole is not long enough from the other end.

It is always a good idea to drill the 60-degree countersink and thread for the nut at the same time to ensure concentricity.

The flat end of one of these barrel nipples will become the seat on which the inlet ball valve sits. The internal shoulder in the valve chamber at the lower end must not act as a valve seat or a hydraulic lock will be created. The shoulder must be damaged with a special punch, or chisel, to allow the water to pass and the shoulder prevents the valve from lifting more than 15 thou (0.015in).

The punch is made from 1/8 in or 3mm silver steel, ground into a 2mm square and the end ground off at about 20 degrees. Harden and temper and gently chisel four grooves into the shoulder. At the top end, or delivery end, the valve seat in the chamber is preserved and the barrel nipple gets two grooves across the flat end with a Swiss file, which is smooth on the sides and has teeth only on the edge. Do not try using a hacksaw as it is far too coarse.

To achieve the desired 15 thou lift, make the barrel nipples a little long, insert a 5/32 in diameter ball and screw in the nipple. If it does not screw in to the hexagon, measure the gap with feeler gauges and remove that amount from the flat end of the nipple. Assemble again and the ball should be just trapped. Dismantle and remove another 15 thou and on assembling the ball will be found to rattle when shaken. To hold the nipples for machining, put the valve chamber in the three-jaw chuck and screw the nipple in. Repeat at the other end but turn the chamber round and make sure that everything is tried at its correct end.



*Internal flange of fire-hole door.*

Drill and bore the barrel and wire it to the middle of the valve block with an ‘M’ wire. Silver solder at the same time as the mounting plate and pivot. Reaming the main bore is best left until after silver soldering in case the heating distorts the barrel;and don’t forget to drill the 1/8 in water passage through the valve block side by passing the drill down through the barrel.

Valve lift needs to be only one quarter of the diameter of the port below the valve seat to achieve an open area equal to the area of the port. This applies to the valves in your car engine as well.

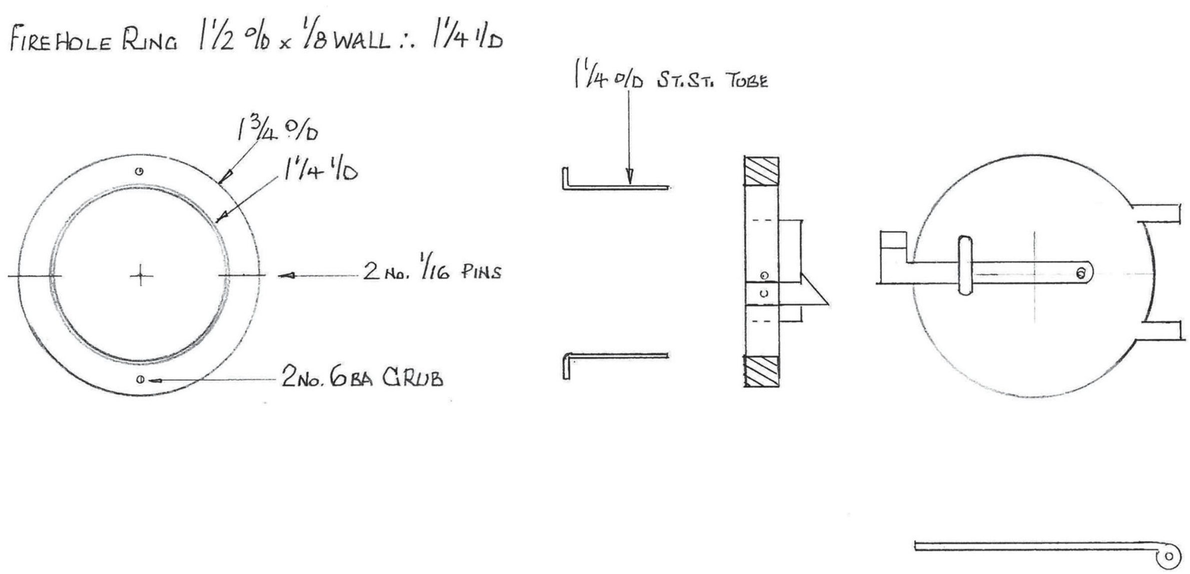
An observation on this design is that the weight of the operator’s hand is supported by the ram in the cylinder. This would be eliminated if the handle is pivoted on the foot, at A, and the links go either side of the cylinder to the end of the ram. This arrangement could be installed inside a water barrel. It is essential that mechanical stresses are all concentrated on the centre line of the cylinder.

If the portable engine is positioned within a diorama, such as a farmyard scene, a thicker base could contain the water supply for both pumps and the emergency pump hidden within. The suction pipes could pass through the barrels. The engine wheels could be secured with screws passing up through the base and into tapped holes in the wheel rims. If a diorama is not used, the pump must be sited in close proximity to the engine.

## FIREHOLE DOOR

The firehole door can create problems in fixing the hinges to the doorplate of the boiler (*see* Drawing 038 below). A solution, which was developed by regular *Model Engineer* contributor John Haining, was to fit the hinges and catch to a detachable ring, located in front of the firehole opening. This consists of a stainless steel tube, which is a close fit in the copper firehole in the boiler and has an external flange at the fire end. This is being created in the photo opposite, where the tube is a snug fit in a substantial tube. The flange is created with the ball peen of a hammer. The clamp stops this process from pulling the tube through. The ring, complete with hinges and catch, slides on the outer end of the tube and is secured there with two pins that are at 180 degrees to each other. At 90 degrees to these pins are two grub screws that press against the end of the copper firehole ring, pulling the inner flange tight against the inner end of the fire-hole ring. The grubscrews and the tube must not project beyond the face of the ring.

This arrangement is especially useful on a traction engine, where access is very restricted. The outer ring can be removed complete with the door and catch and serviced before replacement.



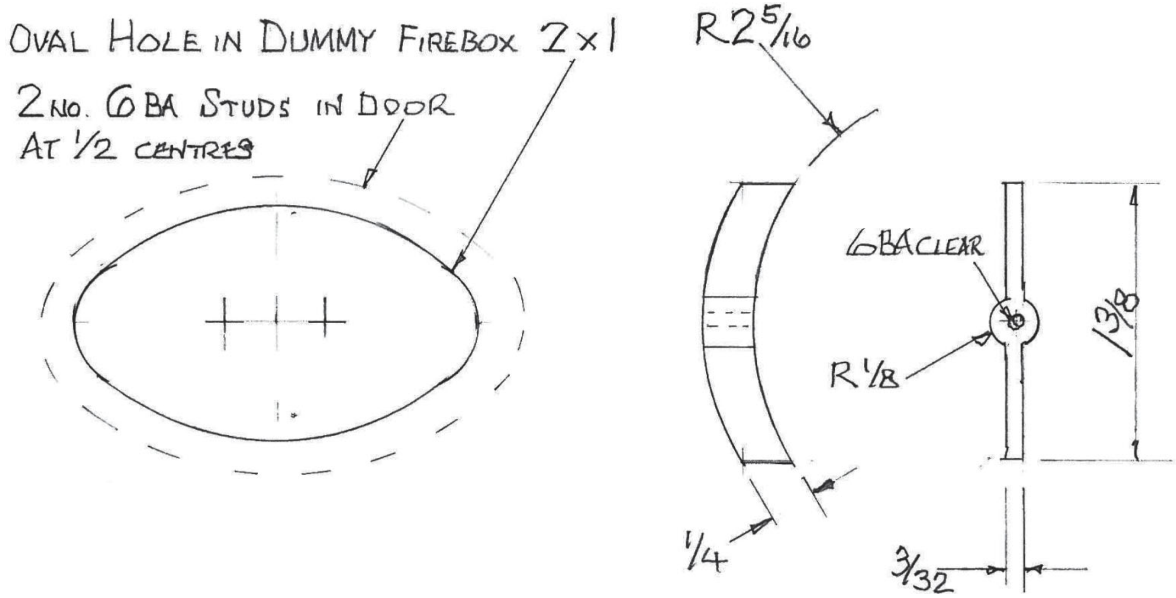

**Drawing 038 Firehole Door Steel 1 off**

## INSPECTION DOOR

Most steam boilers have an inspection door, usually sited over the firebox, to enable the interior of the boiler to be washed out and especially to remove mud from the top of the firebox. Access is by an oval manhole, secured by two bridge pieces, and because of its shape it can be turned and removed through its own hole.

Our copper boiler does not need this fitting, but as access will be needed under the dummy firebox top, a dummy one is fitted in the dummy firebox. Access through this hole will be needed for a ½in A/F spanner to tighten a nut on the safety valve down to the boiler bush. As only a twelfth of a turn can be achieved through this restricted opening, turn the spanner over for the next twelfth. This is why an open-ended spanner has its jaws at an angle of 15 degrees.

The opening is an oval 2 × 1in and the curved door 2.5 × 1.5in. This is placed on the left shoulder of the boiler offset 2in to the left, measured around the surface of the curved top of the dummy firebox




**Drawing 039 Boiler Inspection Door 1 off Bridges: 2 off Steel**

# 8 Running a Steam Engine

The following basic rules apply to railway locomotives, traction engines and stationary engines, as well as to our own Lampitt portable engine.

## WATER LEVEL

With all steam engines it is imperative that the water level is kept *above* the firebox.

The water level is shown in the water gauge glass (tube) on the back-head of the boiler. Aim to keep the water level at about 'half glass'. This ensures that the fire-box, the hottest part of the boiler, is always kept covered in water.

If the water level does drop out of sight, *stop* the engine. Close the fire-hole door and damper, and wait for things to cool down. *Do not add water* to the boiler. The hot firebox will instantly turn the water into steam and the pressure will go off the scale – making it very dangerous.

## MATERIALS AND EQUIPMENT

Before lighting the fire, make sure that you have everything to hand:

- Firelighters (Zip white or grey)
- Lumpwood charcoal (not briquettes)
- Charcoal lighting fluid (not gel)
- Wood sticks (greengrocer's boxes, etc.)
- Coal (small, anthracite beans)
- 'Blower' and battery
- Shovel and coal chute

- Water

Despite its name, the ‘blower’ actually sucks air through the fire to make it burn brightly. It is electrically driven, 12 volts, and is used when lighting the fire.

Check that the water tanks are full of water.

When a steam engine is working, the exhaust is directed up the chimney. This is why a steam engine ‘chuffs’. The harder it is worked, the more it chuffs and the more it pulls air through the fire to keep the fire bright and make more steam.

## LIGHTING THE FIRE

Remove all traces of the old fire and refit the ash-pan and grate. Open the fire-hole door and push through firelighter cubes, sticks and charcoal, to which lighting fluid has been applied.

Check that the water level is at ‘half glass’. Fit the electric ‘blower’ onto the chimney and be ready to connect the battery. Push a lighted taper into the ash-pan from the back. This should light the contents of the fire-box above the fire-grate. Connect the blower to pull air through the boiler. (Do not try to light from the fire-hole door as this will not be at the bottom of the fire.) Close the fire-hole door.

Check that the cylinder drain-cocks are open.

As the fire takes hold, add coal to the fire. Keep adding coal, but give the first lot a chance to light. The easiest way to add coal is to use a coal chute and push the coal in with the poker. The poker is also used to open and close the fire-hole door. Keep the fire-hole door closed as much as possible.

## MAINTAINING THE PRESSURE

Continue to keep an eye on the water level. If a bubble appears in the glass (tube), clear it by opening the blow-down valve.

Keep adding coal and the pressure will start to rise. The electric blower can be used until the working pressure is reached. When the gauge reads about 80psi (pounds per square inch).

It should not be possible to raise the pressure by more than 10 per cent over the working pressure. This makes sure that the safety valve is big enough.

Make sure that the cylinder drain cocks are opened before starting the engine. These valves are there to remove condensate (water) from the steam cylinder. If left there, the condensate could damage the cylinders.

There is a boiler water feed pump built into the engine and this pumps water all the time. When the water level is reached (half glass), the bypass valve is opened and the water is returned to the tank. Remember to close it again after a couple of minutes. Sometimes it is possible to adjust the bypass valve to bypass a little and balance the water used against the water pumped.

When starting up, the bypass valve should be opened (with the engine running) to let the pipe fill with water. Close the valve. (If there is air in a long delivery pipe, the air can be compressed and released by the pump without putting any water into the boiler.) You will probably hear the ball valves rattling as the water is forced through the pump. This indicates that all is well and water is going into the boiler.

If more water is needed to maintain the water level, the hand pump can be used. The hand pump may be needed when standing in the station.

If too much water is fed to the boiler and the level rises too high, there is a danger that water is carried over with the steam and into the cylinders where damage could result. There may be a change to the sound of the ‘chuff’ and water may spray out of the chimney. Open the drain cock immediately and open the bypass valve to stop the feed to the boiler.

Remember to stay safe and enjoy yourself.

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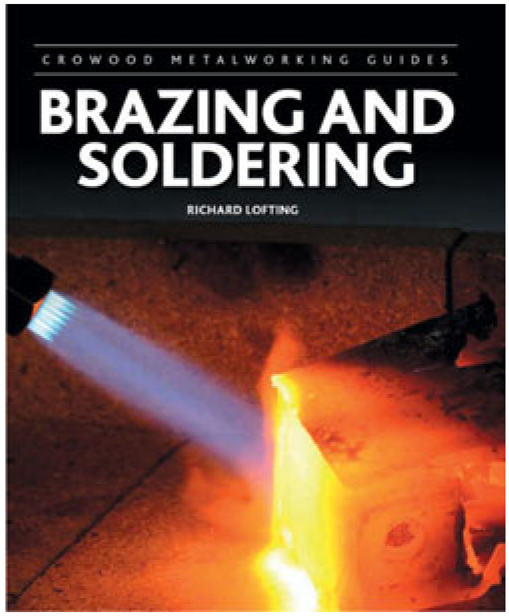


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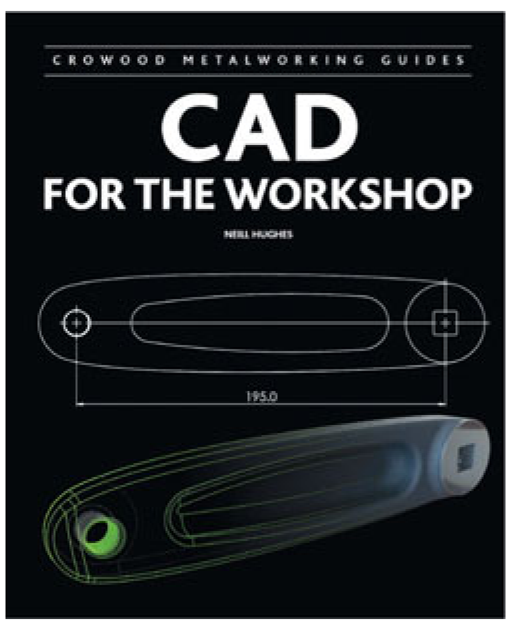

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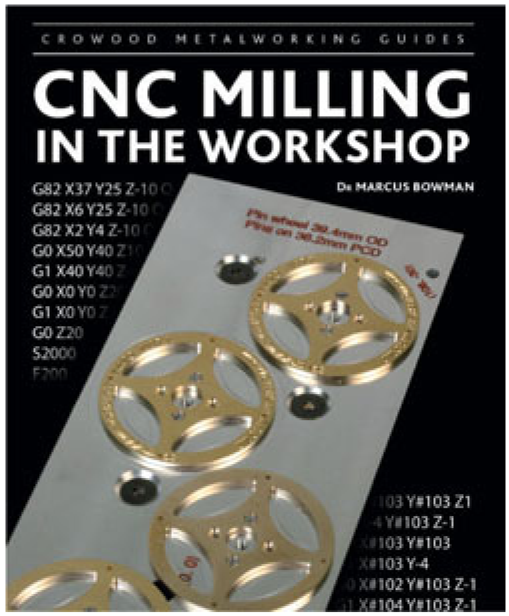


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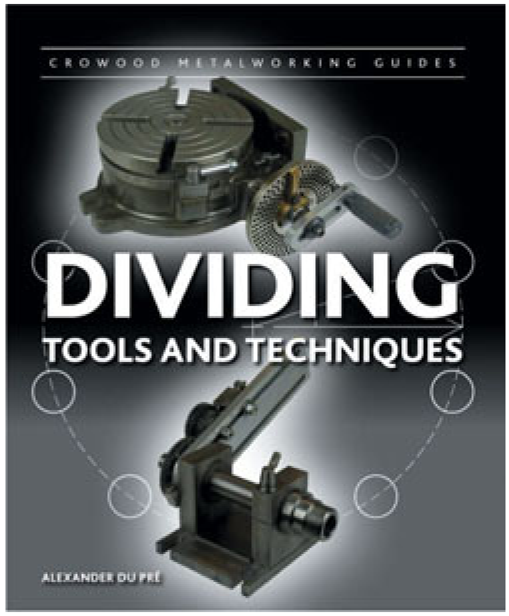


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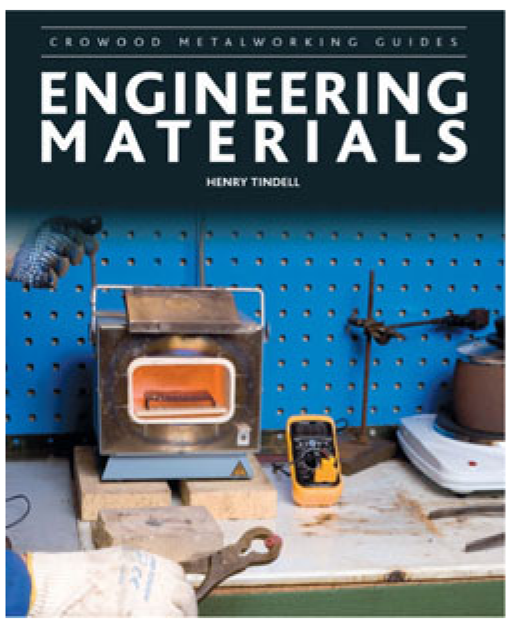


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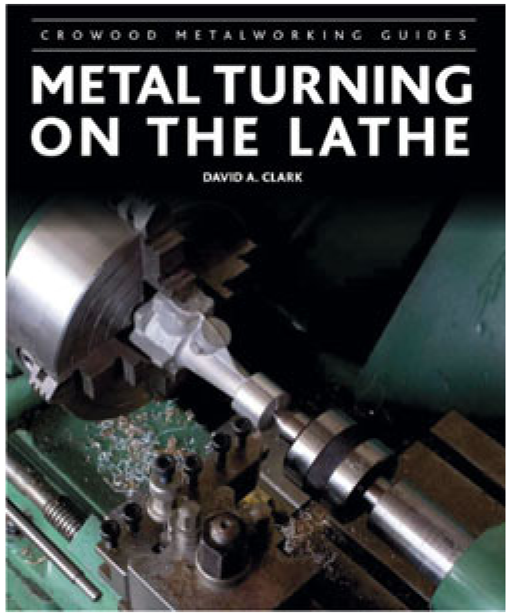


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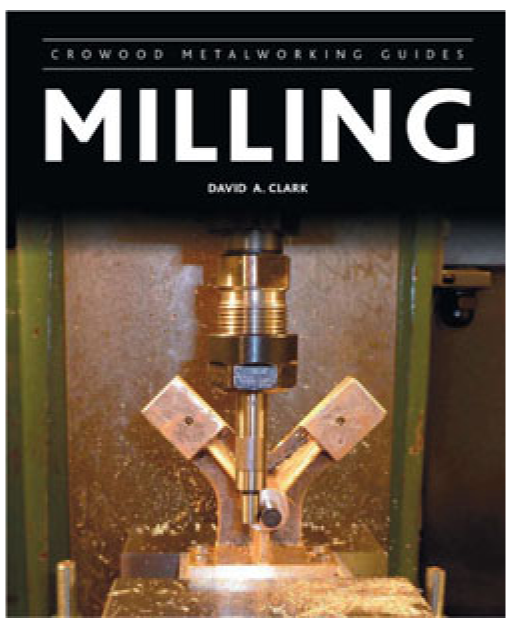


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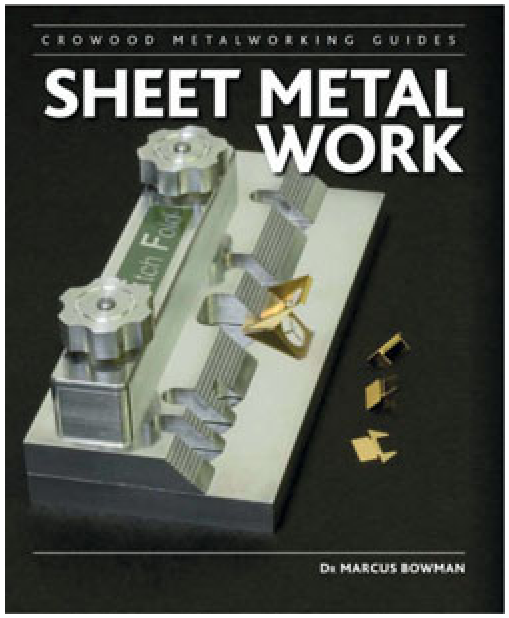


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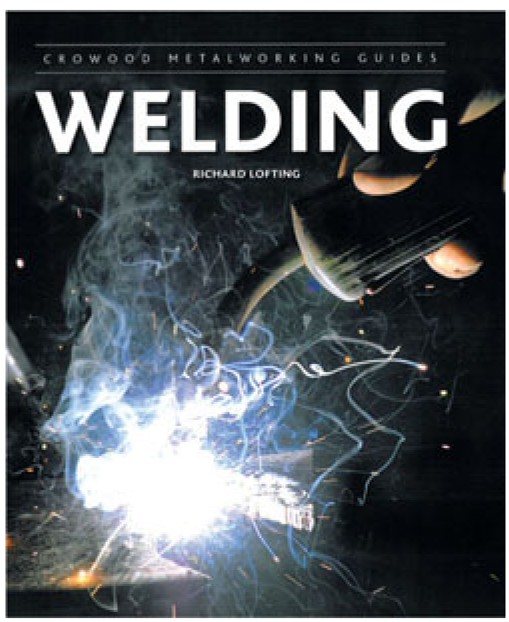


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