METAL AIRCRAFT FOR THE MECHANIC

A PRACTICAL TEXTBOOK FOR METAL RIGGERS,
GROUND ENGINEERS, TECHNICAL SCHOOL
INSTRUCTORS AND STUDENTS

BY

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EXAMINER, CENTRAL TRADE TEST BOARD, ROYAL AIR FORCE

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PREFACE

In this work, the author has endeavoured to present a clear account of modern operations and processes dealing with work on metal aircraft.

The methods of explanation and illustration are original in their presentation, and they should serve to enlighten the reader on this subject, without the usual drudgery of reading books which are too involved to be of any use to the practical man.

For the metal rigger, the ground engineer, the technical instructor and the student, this book should prove invaluable.

The nature of the author's experience in conjunction with an intimate knowledge of the psychological effect that this subject can have on students if not put into plain and straightforward terms, has made the compilation of this book possible.

J. HEALEY, A.R.Ae.S.I.

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METAL AIRCRAFT FOR THE MECHANIC

CHAPTER I

THE MAKING OF FITTINGS FOR METAL AIRCRAFT BY HAND

For special purposes it is sometimes found necessary to make an aircraft fitting from sheet metal, the process being done entirely by hand. This is also found to be good practice for an aircraft worker with a view to improving his skill of hand, as certain fittings are designed to include features which call for the application of the various principles involved in the trades concerned with metal aircraft.

If the reader can practise until he can make a complicated aircraft fitting by hand from the directions which are usually contained on a blue print, it may be safely assumed that he is sufficiently skilled to carry out the repair to metal aircraft no matter what class of repair is called for.

However, experience is a necessity, and practice makes perfect. The fault often made by the beginner is to attempt the more difficult and complicated jobs before trying the easier ones—this is, of course, akin to trying to run before one can walk, and it may have the disastrous effect of producing a lack of self-confidence in the craftsman.

Working drawings and blue prints appear to awe most beginners, and this tendency must be guarded against by all concerned. After all, if the prints are properly scrutinized, no difficulty should be experienced in working from them, and the most complicated blue print will very soon lose its terrors if the reader tries to *visualize the job* before going into further details which are given on the print.

The following pages will be found both interesting and useful if closely studied and the instructions carefully considered, and to many aircraft workers they will also lift the veil from a lot of puzzling features which no doubt they have encountered during their experience.

Blue-print Reading

Failure to read the blue print correctly has always the consequences of producing a job that is inaccurate; a few extra minutes spent in reading the print is worth hours in the long run. The blue print gives you your instructions, so treat it with the greatest respect.

First angle projection is the standard method employed in this country and the one which chiefly concerns us. It is described thus: "Where each view is so placed that it represents the side of the object, remote from it, in the adjacent view" (Fig. 1).

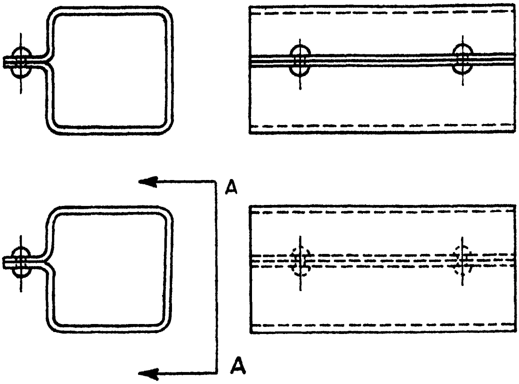


Fig. 1. Above: 1st Angle Projection
Below: 3rd Angle Projection

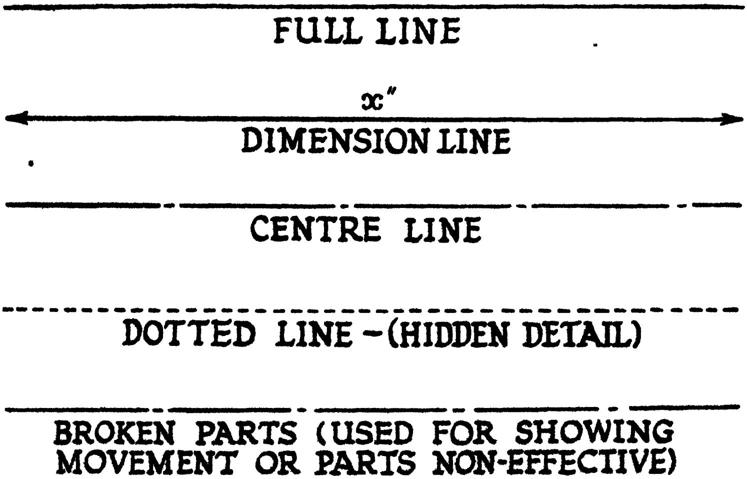


Fig. 2. Lines Used in Drawings

The above definition of first angle projection must be understood, to enable the craftsman to read his blue print correctly. The various types of lines and their meanings are given in Fig. 2.

Normally, blue prints are drawn to scale, but if this procedure is departed from for any reason, the letters N.T.S. (not to scale) are shown on the print, unless the print is for examination purposes, when the above procedure is omitted. In any case, *never use the blue print as a templet*. This is a most unsatisfactory method. Develop the job in the flat from the dimensions, etc., which are given, and above all, *understand your blue print*.

Most jobs are shown by three separate views, namely—

(1) *The Front Elevation*, which is the view looking at the front of the object.

(2) *The End Elevation*, which is the view looking at one of the ends of the object.

(3) *The Plan View*, which is the view looking vertically down upon the object.

In certain cases, *Sectional Views* are required to be shown. These are views showing the object cut into two parts to expose some part of its internal construction. (Fig. 3.)

Bastard Sections are sometimes employed. These are sectional views which are a combination of longitudinal and transverse sections, or one of either of these sections in two or more different planes. A bastard section is usually denoted by the letters *XX* with a dot-and-dash line corresponding to the position at which the object is supposed to be cut.

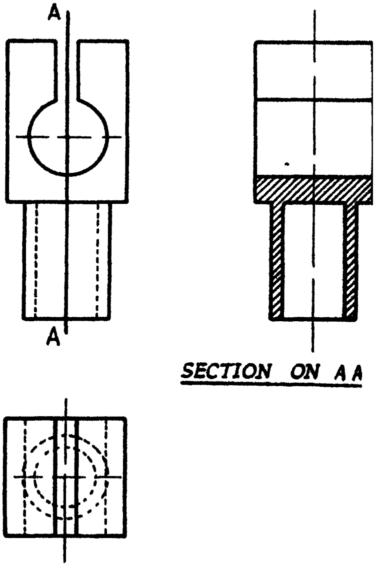
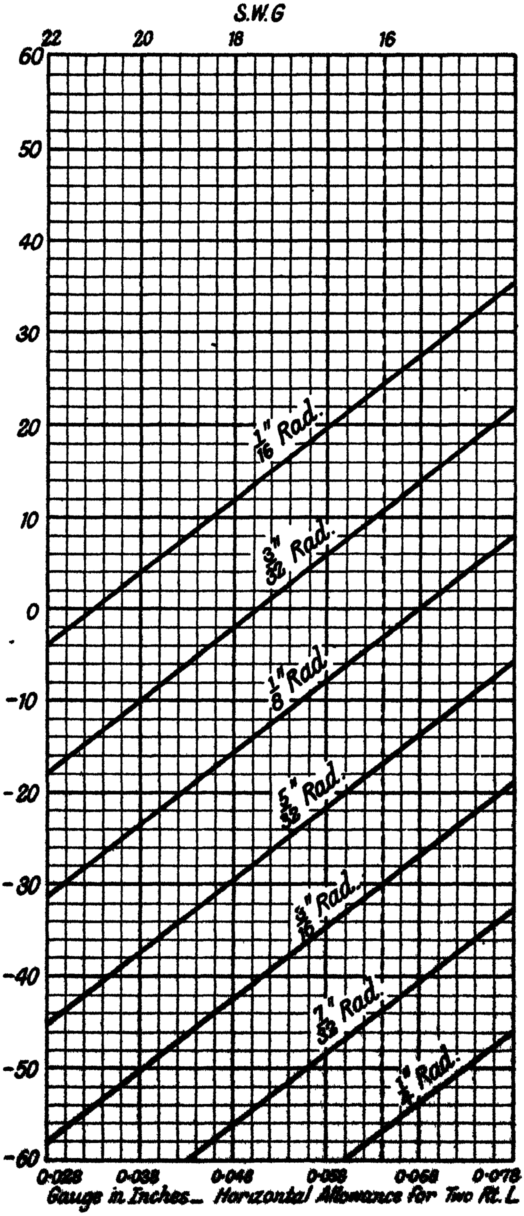


FIG. 3. THE VIEWS REQUIRED ON A BLUE PRINT, WHEN SHOWING A SECTION

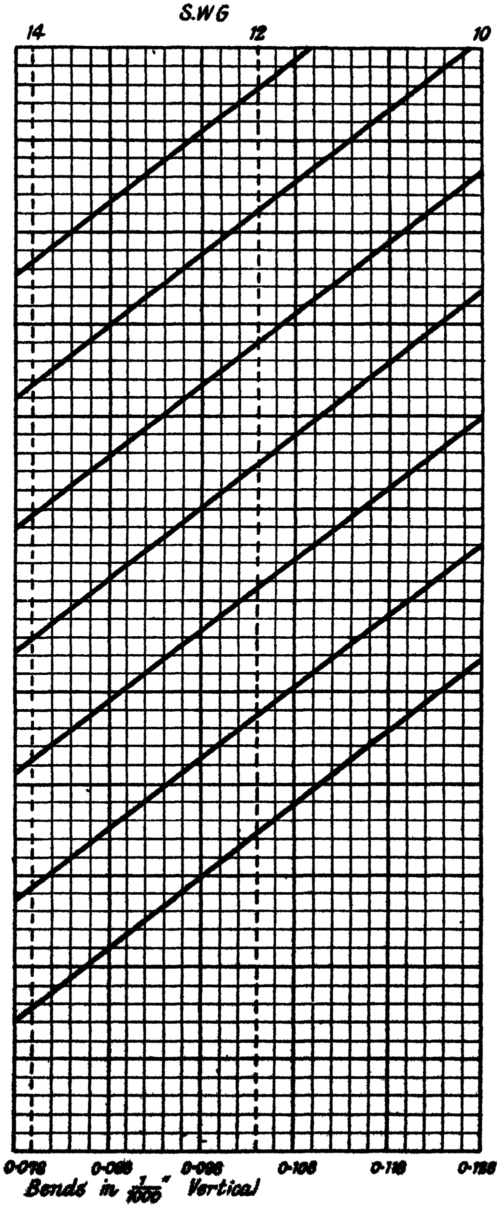
The various fits and their meanings which are frequently used in blue prints will be found under the heading "Useful Practical Information," which is given in a later chapter of this book.

The Bending of Sheet Metal

Let us imagine the piece of metal we are going to use is composed of three laminæ. We bend our metal to an angle of 90°; now what



GRAPH FOR OBTAINING

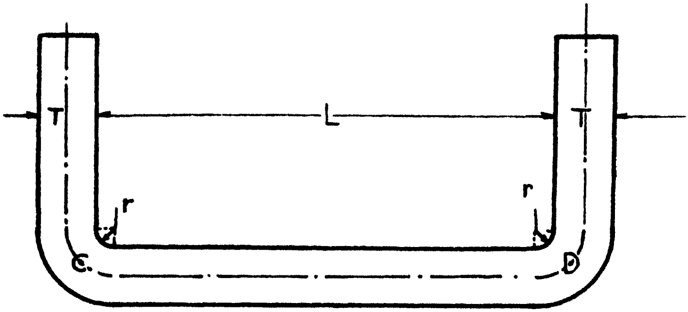


BEND ALLOWANCES

has happened to it? The first lamina, which we will assume is the inside of the bend, has compressed; the second, or centre, lamina has not changed, whilst the third, or outer, lamina has stretched.

In view of the above, if we mark two lines a certain distance apart on our metal and bend, with the lines on the inside, the distance between the lines is going to decrease owing to the compression of the first or inside lamina, therefore causing inaccuracy in our measurements unless we allow for this compressive action taking place. This allowance is called Bend Allowance.

However, it is found in practice that the above change is negligible for 16 S.W.G. mild steel sheet where the radius of bend is $\frac{3}{32}$ in., and the number of bends in one section of the fitting does not exceed two.



$$\textit{Length } CD = L - 2r + \frac{\pi}{2}\left(r + \frac{T}{2}\right)$$

The difference between L and CD is $-\ 2r + \frac{\pi}{2}\left(r + \frac{T}{2}\right)$.

This is the reading on the graph. (*See pages* 4 *and* 5.)

FIG. 4. DEVELOPMENT OF A BENDING LINE

This data has been proved when all the bend lines coincide with the top surface of 90° bend bars. Therefore, to sum up, we can safely say that bend allowance depends upon—

Gauge of metal; radius of bend; angle of bend; and number of bends (in the case of 16 S.W.G. mild steel sheet).

Fig. 4 gives an example of how the bend allowance for 90° bends is worked out. It will also be observed that all calculations are taken from the mean line of the metal.

Bend allowance is a subject ridiculed by many, but it is found to be very necessary, especially where the metal is of a thick gauge and the bends have a large radius.

To simplify the working of bend allowances, a graph has been introduced (see pages 4 and 5). By the graph it is possible to obtain the bend allowance required for your job by a quick glance. For example, a job made of 16 S.W.G. material having $\frac{3}{32}$ in. radius and 90° bends, would require 0·010 in. for two right-angle bends. To arrive at this figure, we have observed the point at which the 16 S.W.G. line cuts the $\frac{3}{32}$ in. radius line, then taken the vertical reading opposite this point.

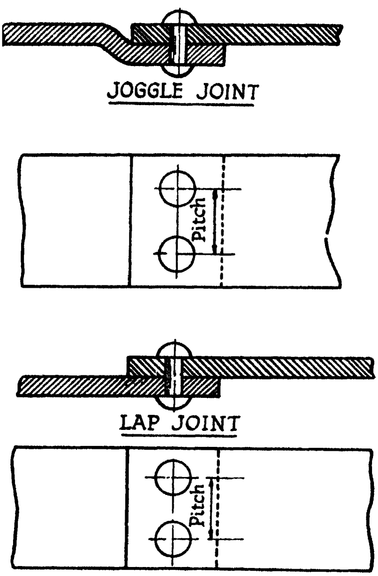


Fig. 5. Riveted Joints

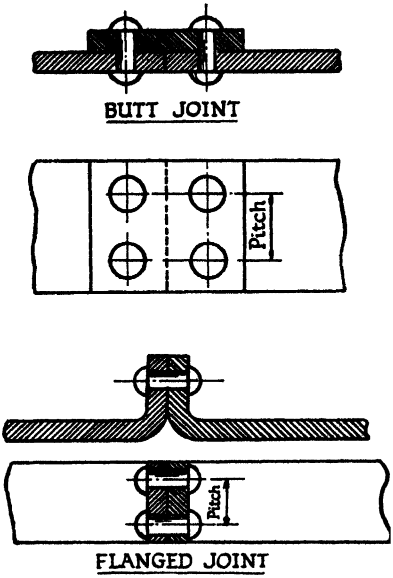


Fig. 6. Riveted Joints

The point often overlooked when once having obtained this measurement is the fact that the allowance is for two right-angle bends, and not for one only, so that we require 0·005 in. each side of the bend line for one bend. The developed jobs given later in this book will clearly show the application of this allowance.

So far, we have only dealt with 90° bends, but it is advisable to obtain a sound knowledge of bending metal before attempting the other various angles, so we will deal with angles from 0° to 90° at a later stage in this book. By doing this we will avoid confusion, which in turn kills our interest.

However, the bending of sheet metal is apt to be very complicated unless the craftsman knows something about the allowances that must be made. It is generally assumed that one must be a good mathematician to work out bend allowances, but this is not the case, as the reader will notice as he studies the explanations in this book.

Types of Joints used on Metal Fittings

Joggled Lap Joint. This joint is used to give a flush surface to the inside of a job where a lap joint is employed (Fig. 5).

Plain Lap Joint. When one plate overlaps another at a joint (Fig. 5).

Flanged Joint. Where two plates are bent at an angle and are joined together as shown in Fig. 6.

Butt Joint. Where two plates are placed together with their inner edges parallel and a plate riveted over the joint as shown in Fig. 6.

CHAPTER II

PREPARING FOR THE FIRST JOB

In view of the knowledge gained from Chapter I we can now attempt our first job. A few hints on preparations will be found useful, and will no doubt save time if followed.

The bench you have selected should be in a position where full advantage of light can be taken; the vice should be in good working order and at the correct height. A test for this latter is as follows—

Stand erect with one arm bent closely to your side and the elbow of the bent arm should just touch the highest point of the vice. The vice should also be positioned so that the face of the inner jaw lies parallel to, or slightly forward of, the edge of the bench. Lead or aluminium sheets should also be available for fitting in the jaws to avoid damage to the metal.

Now for the tools. Needless to say, these must be in sound condition—the steel rule must be clean and easy to read, the scriber sharp, and the spring dividers properly ground; rivets, snaps, and dollies should be inspected for wear by placing the head of a correct size rivet in the face of the tool; files should be clean and in good condition, the handles being fitted before use.

Any special tools, etc., which are likely to be required are obtained and placed ready for use. Bend bars should have the correct radius and must be perfectly parallel.

It is a good plan to have plenty of hardwood blocks ready for use when bending over the metal. This prevents marking the metal with a hammer and gives an even bend when positioned over the full width of the metal in the bend bars.

For our first job we will use 16 S.W.G. mild steel plate and make a simple 1 in. box fitting—all bend radii being $\frac{3}{32}$ in. and bend angles 90°. This job will be found an easy introduction to this class of work.

From the blue print obtain the approximate amount of metal required. File the edges of the metal so that you have a long and short face-edge to work from, also making certain that the metal is flat and free from defects. Then clean off so that a good background is obtained for scriber lines. In certain cases it is found better to clean off all the scale and apply copper sulphate to give a coating to show up the lines when scribed.

Having prepared the metal, we now study our blue print very carefully and try to visualize the completed job. To simplify matters it is found good practice to develop the job in the flat on a sheet of paper representing the metal, as this serves as a double check for avoiding mistakes and also gives us the correct measurements for transferring direct on to the sheet of metal we are using for the job.

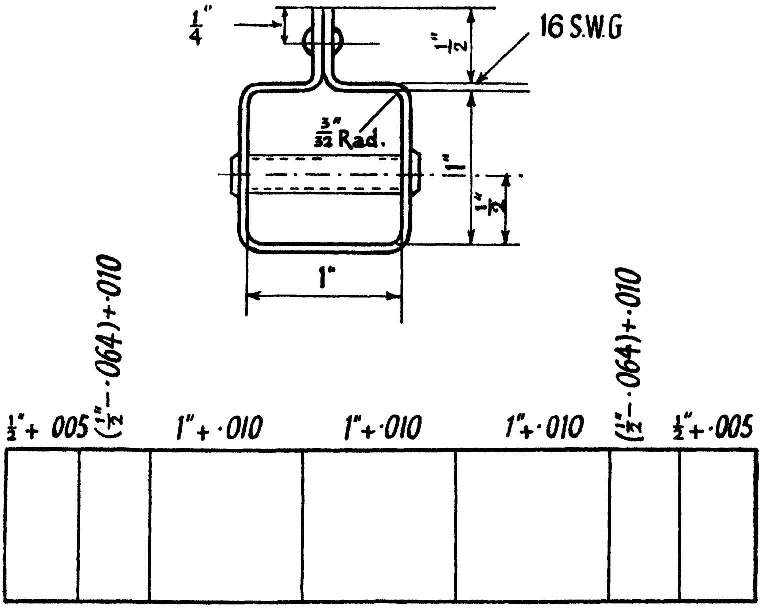


FIG. 7. DEVELOPMENT OF A 1 IN. BOX FITTING

Transferring the Measurements from the Development to the Metal

Place the metal on the marking-off table, face downwards, and, with the scriber on a scribing block, proceed to mark off according to settings obtained and set from the steel rule previously. Avoid wide or deep scriber lines and always use V-blocks for support, as these obviate the possibility of the metal leaning from the vertical.

Use a magnifying glass to set the measurements from the steel rule and ensure that the light is good, otherwise inaccurate settings of the scriber are likely to take place.

Take your time, do not hurry, and so avoid spoiling the job.

Fig. 7 shows the job and the development in the flat.

Use the magnifying glass for positioning centre punch on rivet lines, etc. Drill pilot holes for the rivets.

Before completing the marking-out process, there is one point that must be stressed. That is the exceptional care which marking out calls for when accuracy is demanded. Always use a magnifying glass where possible, especially for positioning the centre punch on rivet lines. The reader is advised to try this out on a piece of scrap metal. Make several lines intersecting, place the centre punch at the intersection of two lines and pop-mark the metal at this point. Look through the magnifying glass and you will invariably find that the mark is anywhere but at the intersection of the two lines where you intended it to be. But, using the magnifying glass, place centre punch on the intersection of another two lines, pop-mark, and the mark at the intersection will be exact if no movement of the punch has taken place since positioning by the aid of the magnifying glass.

The First Attempt at Bending

Now for the bending. Place the metal in bend bars which have the correct radius, position the bend line so that it lies coincident with the top of the bend bars, and secure in the vice. Ensure that it lies parallel to avoid twist in the job. A good method of checking this is to use a steel rule laid on the top of the bend bars, and moving the job about until the bottom edge of the steel rule lies coincident with the bend line on each side. Use a magnifying glass for positioning lines.

With as few blows as possible and holding a wood batten against the metal, strike the wood until the bend is completed. Make sure that the wood covers the whole area of metal in the vicinity of the bend to avoid twist. (See Fig. 8.)

It will be appreciated that a certain amount of springing of the metal is unavoidable, and it is not advisable to endeavour to get the metal farther down on the bars by excessive hammering as this only tends to distort the metal.

A practical idea is to relieve the pressure of the vice, slightly raise the metal, place a hacksaw blade underneath the bent metal and bend bars, and tap the metal down evenly on to the blade. Apply pressure slightly, carefully remove the blade and tighten the bend bars and vice. This leaves a small gap between the metal and the top face of the bend bars. Place a wood batten on the metal evenly and tap metal down on to the top surface of the bend bars. This method compensates for the springing which normally occurs in sheet metal, especially of narrow gauge material; the radius is not affected, and the angle does not fall below 90°. The hacksaw blade is exactly the correct thickness for this purpose.

Complete all bends in the same manner for this particular job, taking care not to strain any of the completed bends as you proceed.

During the bending process it is advisable to check each bend for squareness on the marking-off table. This obviates a possible twist in the job. Undoubtedly this takes a little more time, but after all we are endeavouring to produce a 100 per cent job, and a few extra minutes is time well spent to attain this objective.

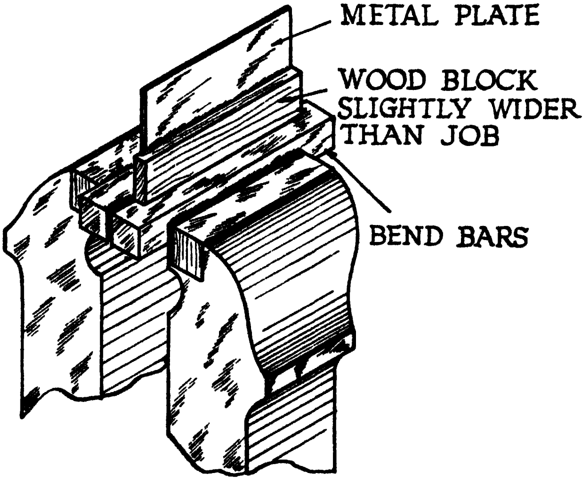


FIG. 8. BENDING METAL IN BEND BARS, SHOWING CORRECT METHOD OF APPLYING WOOD BLOCK

We now have all the bends completed. The next step is to clamp the job together with pilot holes on both flanges of the fitting, coinciding with each other.

Check for size and squareness.

Drill alternate holes for rivets and bolt up temporarily, using washers under the bolt and nut to avoid scratching the metal.

Remove clamps and complete the drilling of remaining rivet holes and bolt up.

Riveting

Good riveting is essential for appearance and a sound mechanical job. First, let us deal with the snap-head rivets. In this case we are using ⅛ in. diameter snap-heads, and we must have a clearance of approximately 0·003 in. to 0·006 in. in the hole to allow the rivet to swell a little. If we did not make this allowance, the metal around the edges of the rivet hole would be distorted, and unnecessary stresses set up. A table of allowances will be found at the end of this chapter which covers the general sizes of rivets.

So much for the rivet clearance. We now have to consider how much we require to leave over on the rivet shank for forming the head of the rivet. The particular size of rivet we are using calls for an allowance of 1½ to 1¾ times the diameter of the rivet.

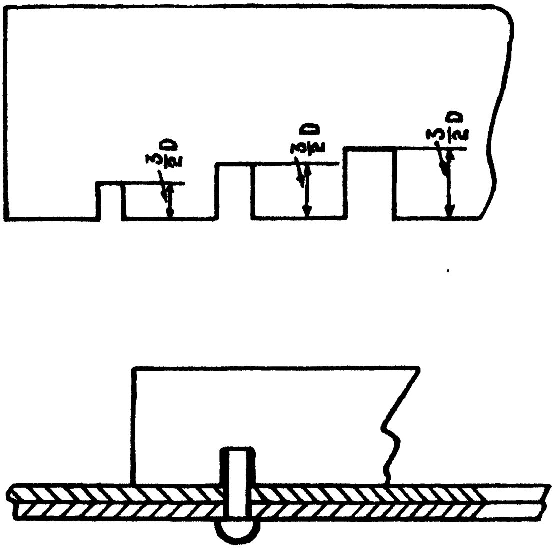


Fig. 9. Gauge for Rivet Allowance

The small variation is due to the conditions of the snap we are using, and it is advisable, if using snaps that are slightly worn, to leave a little more than 1½ times the diameter of the rivet. This avoids ringing the metal with the snap. However, before riveting your job, try out your snaps and ascertain the amount you require to leave over. A simple form of gauge can be made in a few minutes which will give you the same amount for all rivets once you have arrived at the measurement required. (See Fig. 9.)

Another hint for riveting is applying a little oil in the snap. This often prevents the rivet from cracking and also polishes the head when snapping over.

When the rivet is filed to its correct size, a few hammer blows are necessary to swell the shank a little, before finally snapping over. *Use as few blows as possible*, as the more you strike the rivet the harder it becomes. This is a common fault in riveting.

Keep your snaps vertical to avoid getting the rivet in shear.

Having accomplished snap-head riveting, we now come to the tubular rivet.

Tubular rivets are a reamer fit, so having reamered the hole to size, radius the edge of the metal slightly. This avoids an abrupt change of section between the metal and rivet shank.

Again our rivet is made of mild steel, but as it is tubular, the clearance is approximately 0·0003 *max.* The reason for this is that tubular shanks do not expand in the manner of solid rivets and so require little or no clearance.

The amount we leave over for forming the head should be approximately 0·5 times the diameter of the rivet, but in practice it is advisable to allow a little more, as the extra amount is governed by the condition of the snap you are using, as in the case of snap-head rivets or if using a spinning tool to form the head.

Before snapping over, file the shank clean and make a slight radius on the top of the rivet shank. This enables you to form a clean head and minimizes the danger of the head cracking. Use oil on snaps as in the previous case before snapping over and open shank out with a 60° punch supplied for this purpose.

Note. Distance tubes are fitted to tubular rivets—these should be a good fit between the faces of the inside of the job. A loose fit should be avoided.

Having completed all riveting, proceed to clean up the job with a smooth file, checking all flange corners for correct radii and the job for squareness on the marking-off table.

Finishing and Faults

The first job should now be completed within the limits laid down, but it will be clearly noted by the reader that care taken in developing the job is essential, and that slip-shod methods cannot produce an accurate job. To illustrate how mistakes are made, here is a brief summary of faults that have actually been made by craftsmen.

1. Failure or inability to read blue print correctly.
2. Using blue print as a templet.
3. Hurrying the job. (More haste less speed.)
4. Bending in the wrong direction.
5. Too much hammering on metal whilst bending over in bend bars, causing the metal to distort.
6. Wood block too small when bending.

7. Not using magnifying glass.
8. Face edges badly trued up when using that method.
9. Incorrect positioning of bend lines in bend bars.
10. Distorting flanges when riveting.
11. Failing to subtract a thickness when dimension line is so placed as to make this necessary.
12. Taking the result to nearest tenth of an inch instead of working to nearest thousandth when working out dimensions.
13. Failing to check the gauge of the metal for constant thickness with a micrometer—bad rolling of the metal during manufacture causes a variation of gauge in the sheet.
14. Filing distance tubes for tubular rivets to an incorrect size, causing the plates to distort.

Now that the first job is completed, let us ask ourselves what we have gained. Well, if the job conforms to the limits laid down on the blue print, it has proved our ability to—

1. Use our tools correctly.
2. Mark out correctly.
3. Bend metal correctly.
4. Work to fine limits.
5. Work from a blue print.
6. Rivet both solid and tubular rivets correctly.

All the above are necessary qualifications for carrying out most of the general repair schemes which are applicable to metal aircraft, and also to make jigs or templets when required for the manufacture of aircraft fittings.

Although our first job was fairly simple, it has given us a start in the right direction by giving us confidence and ability to carry out further practice on work of this description. We can arrange our practices in the following order, using 16 S.W.G. mild steel sheet, all bends having a $\frac{1}{32}$ in. radius—

1. Simple box fitting with lug. All 90° bends and two tubular rivets with distance pieces.
2. Box fitting with a 45° bend included.
3. Box fitting with semicircle and an inside and outside bend.
4. Box fitting with offset or sliding lug included.
5. Box fitting with lug set at a given angle and bent to a given angle.
6. A fitting including all these characteristics.

All the above complications are explained in the following chapters and illustrations, and as they are likely to be encountered during repairs or constructional work on metal aircraft, jigs or templets, it is essential that we should thoroughly understand them all.

Types of rivets used, riveting faults and forms of riveting are shown prior to dealing with complicated jobs as a guide to the reader if he happens to wish to include the use of various types of rivets and rivet spacing in the job he has chosen from the above list.

Riveting Faults

SNAP-HEAD RIVETS

Shank distorted. Cause: allowing incorrect clearance when drilling rivet holes.

Ringing of metal in vicinity of rivet. Causes: allowing insufficient metal on rivet for forming head, snaps too large, or incorrect use of snaps.

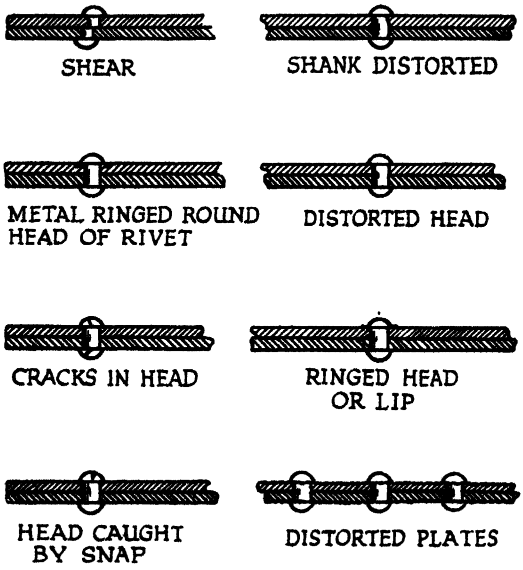


Fig. 10. Snap-head Riveting Faults

Rivet in shear. Cause: bending shank of rivet over from the vertical when riveting shank with hammer before using snap to form head.

Incorrect size of head. Cause: too much or too little allowance being made for forming head.

Cracks in head. Causes: over-hammering when burring over prior to snapping, or incorrect heat treatment in the case of duralumin rivets.

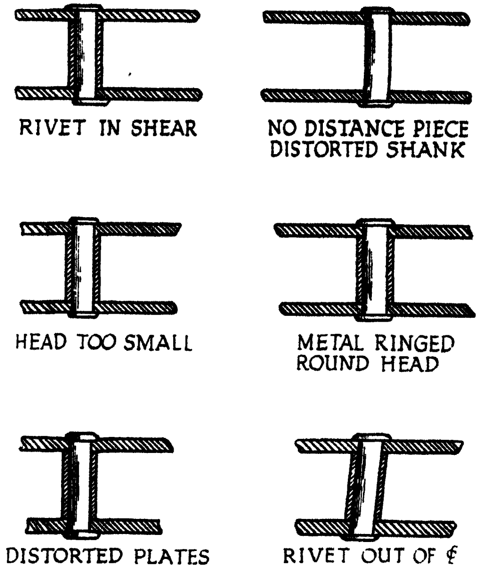
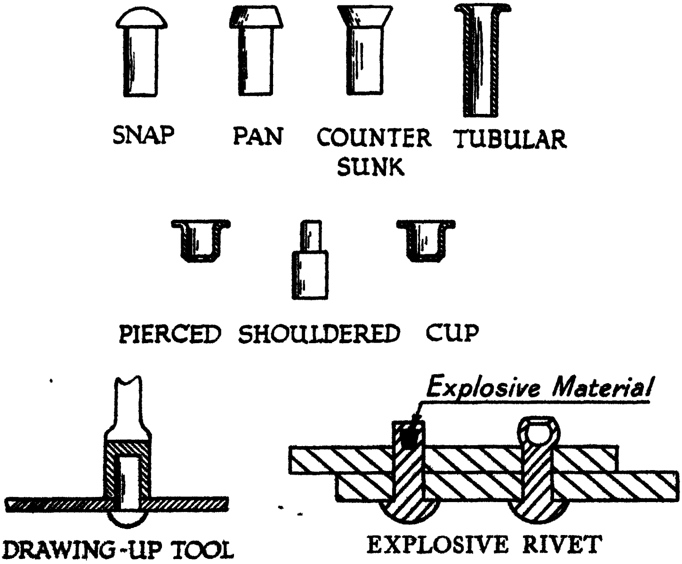

RIVET IN SHEAR
NO DISTANCE PIECE DISTORTED SHANK
HEAD TOO SMALL
METAL RINGED ROUND HEAD
DISTORTED PLATES
RIVET OUT OF ℄

Fig. 11. Tubular Riveting Faults



SNAP
PAN
COUNTER SUNK
TUBULAR
PIERCED
SHOULDERED
CUP
DRAWING-UP TOOL
EXPLOSIVE RIVET

Fig. 12. Types of Rivets

Collar or lip around head of rivet. Causes: allowing too much metal on rivet for snapping over, or using a snap which is undersize.

Distorted flanges. Causes: incorrect holding up on dolly, or snapping over the rivets in rotation instead of alternately.

Rivet head caught by edge of snap. Causes: incorrect holding up, or bouncing of snap due to faulty support of job.

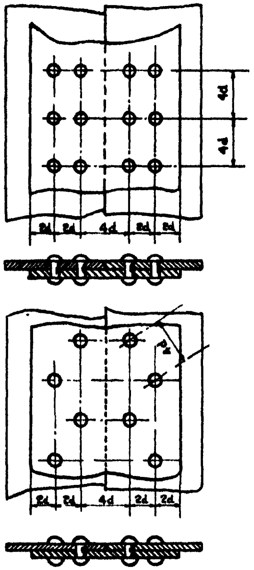


FIG. 13. "DOUBLE-CHAIN" (*above*) AND "ZIG-ZAG" (*below*) RIVETING

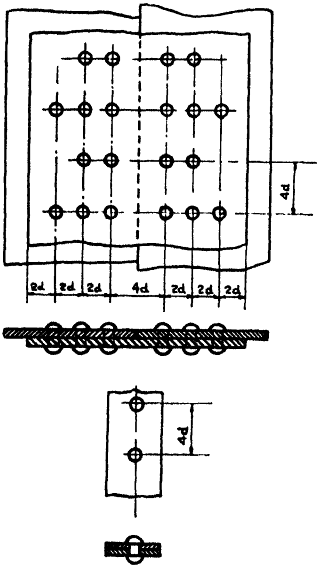


FIG 14. "TREBLE-CHAIN" (*above*) AND SINGLE (*below*) RIVETING

TUBULAR RIVETS

Rivet in shear. Cause: incorrect burring over, as for snap-head.

Distorted shank. Causes: no distance piece fitted or incorrect clearance in hole for rivet.

Rivet head too small. Cause: insufficient allowance for forming head.

Ringing of metal in vicinity of rivet. Cause: as for snap-head.

Distorted plates. Causes: distance piece too small, incorrectly shaped or too much hammering when snapping over.

Rivet at incorrect angle. Cause: faulty lining up when drilling holes for rivets and clearance allowance varying between both holes.

DRILL SIZES FOR RIVETS

Steel Rivets		Light Alloy Rivets	
Drill No.	Rivet size	Drill No.	Rivet size
41	3/32 in.	37	3/32 in.
30	1/8 in.	29	1/8 in.
21	5/32 in.	19	5/32 in.
11	3/16 in.	8	3/16 in.

RIVET CLEARANCES AND ALLOWANCES

Rivet	Clearance in Hole	Allowance for Forming Head	Identification
Mild steel, snap-head	0·003 in. to 0·006 in.	1½ to 1¾ times the diameter of rivet.	Weight; cadmium or zinc coated; magnetic.
Light alloy, snap-head	0·010 in.	1½ to 1¾ times the diameter of rivet	Aluminium rivets have a pop-mark in the head and are non-magnetic; dural. rivets are identified by weight and anodic film; also non-magnetic
Stainless steel, snap-head	0·003 in.	1½ to 1¾ times the diameter of rivet	Very bright finish; copper sulphate will not take
Countersunk	As above, according to material of rivet	¾ the diameter of rivet	As above, according to material
Carbon and mild steel, tubular	Reamer fit	½ the diameter of rivet	One and two flats on head of rivet respectively
Stainless steel, tubular	Reamer fit (Max. 0·003 in.)	½ the diameter of rivet	Bright finish; copper sulphate will not take
Light alloy, tubular	Reamer fit	½ the diameter of rivet	Aluminium rivets, by weight, are non-magnetic and have one flat. Dural. not marked by flats, but identified by their weight; non-magnetic
All tubular rivets		¾ the diameter of rivet when using a spinning tool	

CHAPTER III

THE VARIOUS CHARACTERISTICS INVOLVED IN THE MANUFACTURE OF COMPLICATED METAL FITTINGS

Bending the Metal to Angles up to 90°

HAVING gained a certain amount of experience in the bending of sheet metal, we can now attempt the more difficult problems with which we have to deal when making a more complicated fitting than our first product.

Bending metal to angles up to 90° has caused much controversy with regard to the correct allowance which is required for the various bends other than 90°. When using 90° bend bars, it would obviously prove very expensive and complicated to have different bars for each bend angle, so 90° bend bars are the standard bar used for work of this description.

From a practical point of view the following method will be found very satisfactory, as no intricate formulæ are necessary, only simple calculations well within the scope of the average craftsman being used.

The radius of the bend is the deciding factor and in lieu of a bend allowance being added or subtracted from the length between bend lines, we use what is generally known as a *sighting line.*

The position of the sighting line is always above the normal bend line, the distance varying according to radius and bend angle required. The sighting line is the line which must be coincident with the top surface of bend bars when bending the metal to the required angle for inside bends.

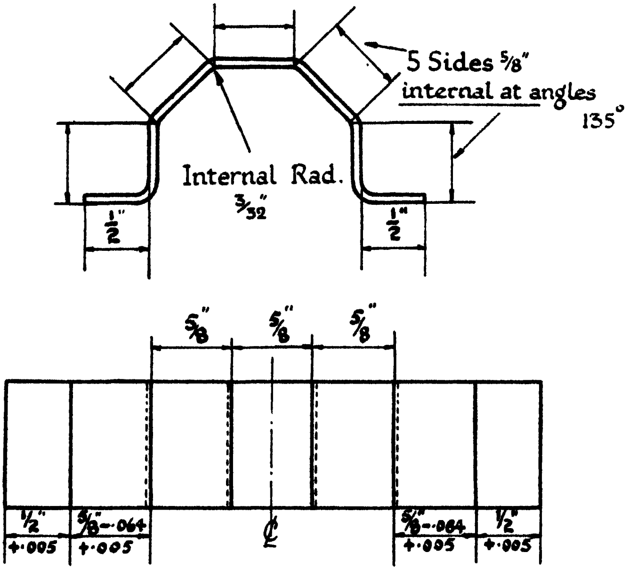
The procedure when marking out in the flat for a fitting which has to be bent at a given angle, apart from 90°, is as follows—

Scribe lines on the metal, no allowance being made for bends. Scribe centre line of plate. Working away from centre line at each side mark sighting lines. It is advisable to mark a dotted line for the sighting line to avoid confusion.

The distance of the sighting line from the normal bend line is arrived at by the following method—

Divide the radius of the bend into nine equal parts, each part being equal to the distance of the sighting line from the normal bend line for angles rising in 10°, until a 45° angle is reached.

At an angle of 45° the peak is reached, so we now decrease the distance between the sighting line and normal bend line, one part being equivalent to 10° angles as before the peak was obtained. This decrease continues until a 90° angle is reached, at which the normal procedure for 90° bends is carried out.



Distance above normal bend line to sighting line = half bend radius for 45° bend.
Dotted lines indicate sighting lines.

FIG. 15. DEVELOPMENT OF A SPAR BOOM FITTING SHOWING POSITION OF SIGHTING LINES

An example of the above when the radius of bend equals $\frac{3}{32}$ in. is as follows—

$\frac{3}{32}$ in. radius equals 0·09375 in.

$$\frac{0{\cdot}09375}{9} \text{ equals } 0{\cdot}010416 \text{ in.}$$

Therefore 0·010416 in. equals the distance of sighting line above normal bend line for an angle of 10°.

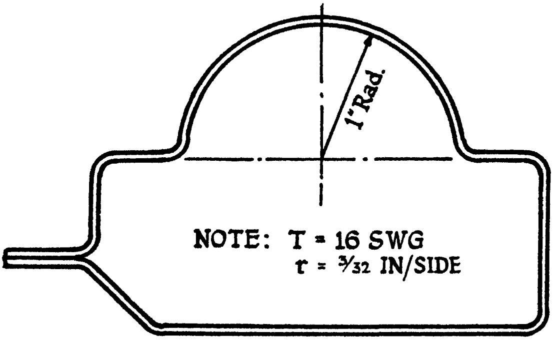
Therefore, at the peak angle, i.e. 45°, the distance of the sighting line from the normal bend line will be equal to half the radius, which is 0·010416 × 4½°.

= 0·046 approx., or $\frac{3}{64}$ in.

It is found sufficiently accurate to work to the third decimal figure when using this method.

Developing a Semicircle in the Flat

Simple calculations are necessary before marking out the semicircle in the flat. It will be seen in Fig. 16 that unless these calculations are worked out, serious errors would result, and the reader is advised to study this example closely, with a view to avoiding these errors. The most common mistake that is made is omitting to subtract the two thicknesses of metal from the measurement combining the circumference of the semicircle and bend allowance.



Calculation of ℄ *on semicircle:*

Mean dia. $= 2'' + 0{\cdot}064 = 2{\cdot}064''$.

$\therefore$ *Circumference* $= 2{\cdot}064'' \times \frac{22}{7} = 6{\cdot}487''$

$\therefore$ *Circumference of semicircle* $= 3{\cdot}2435''$

$\therefore$ ℄ $= 3{\cdot}2435 + 0{\cdot}010 - 2T$

$= 3{\cdot}1255''$

FIG. 16. BEND ALLOWANCE FOR A SEMICIRCLE

Having developed the distance in the flat and marked out, we proceed to bend, but after removing from mandrel, as shown in Fig. 17, the metal springs.

To counteract this, no attempt should be made to spring the metal back without a mandrel being placed in the semicircle. This second mandrel should be approximately 0·006 in. smaller than the first. On removing the second mandrel from vice, it will be found that the semicircle fits snugly around the first mandrel, which is, of course, the correct measurement required. It is not advisable to use the smaller mandrel first, as the latter method is a more gradual and effective one in practice.

Developing a Section which has an Inside and Outside Bend

When a piece of metal has an inside and outside bend marked out in the flat to its dead length, it will be found on completing the bends to the required angles that there is a variation in the measurement. This variation is usually a plus measurement.

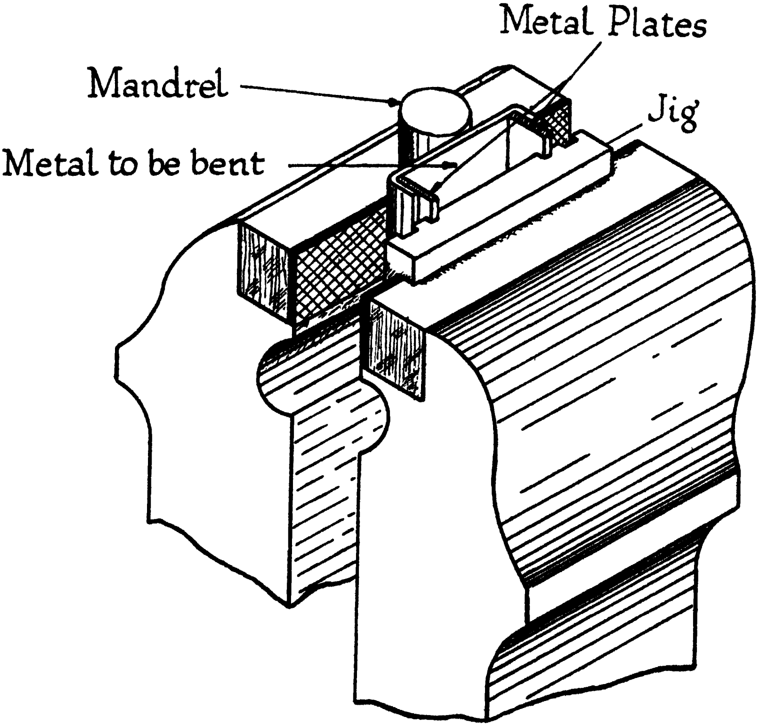


Fig. 17. Using a Mandrel and Vice to Bend Metal to a Semicircle

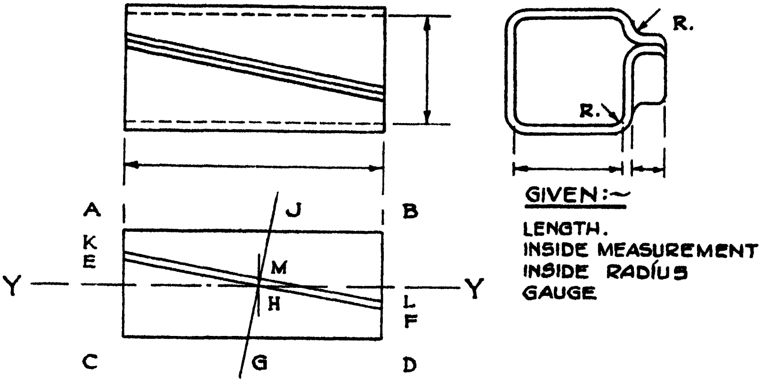
In view of the above, it is advised that the sighting line method be used, the bend line and sighting line being transferred to the opposite side of the metal. In the case of the outside bend, this is, in effect, similar to an inside bend, the normal procedure being carried out as for angles of 0° to 90°.

Where the two bends are of different angles, this method has proved very useful and accurate—90° bend bars being used as in previous examples.

The Sliding Lug

Another complication which confronts us is known as the sliding lug, or sometimes called the step-backed lug. It is one that is often overlooked by craftsmen, but it must be thoroughly understood and allowed for to obtain accuracy in cases where a lug is set off at a given angle from the normal horizontal.

The procedure when marking out in the flat is to mark the centre line of the lug at the angle given; then, as the dimension line is taken from this centre line, it will be found necessary to step back the thickness of the metal, and then to come forward from this new line to add on any bend allowance that is necessary. The main point to watch for is that all measurements from the lug centre line are taken at right angles to this line. Otherwise, if these measurements are taken from the lug centre line along the centre line of the fitting, a discrepancy in measurement arises, and although the

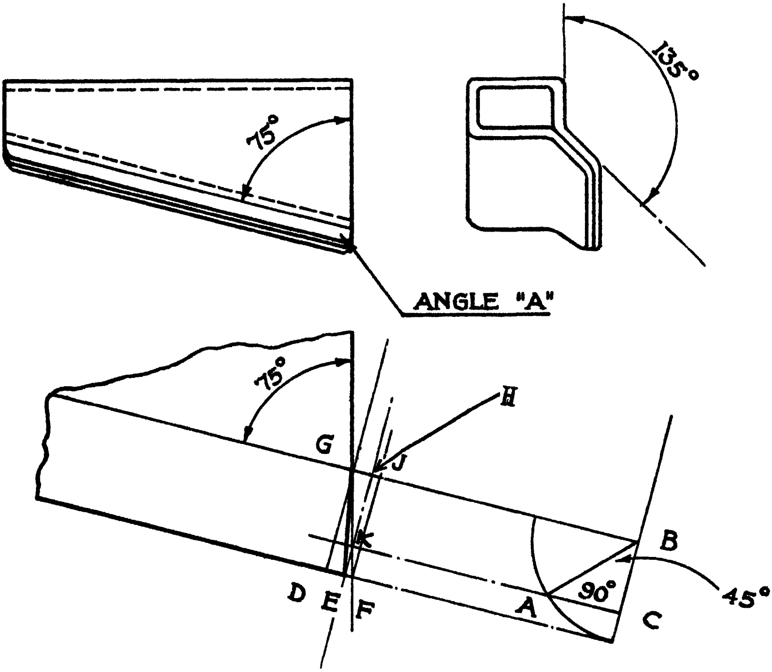


Scribe side ABCD = Inside measurement of fitting.
Scribe ℄ XY.
Through XY draw EF parallel and equal to lug shown above, cutting XY at H.
Draw JG through H at rt. angles to EF.
From H along JG, measure HM = Gauge of metal.
Through M and parallel to EF draw KL.
+ or − allowance from graph, thus giving bending line for lug.

FIG. 18. METHOD OF SCRIBING OUT AN OFF-SET LUG

measurement is small, it will lead to greater inaccuracy if not taken into consideration.

Fig. 18 gives a sketch of the method of marking out, showing how the discrepancy in measurements arises.



Let width of lug $= \cdot 5625 = AB$.

$$BC = \cos 45° = \frac{x}{\cdot 5625} = \cdot 3977 \textit{ in.}$$

$HK = BC$; *angle* $KGH = 75°$.

$$GH = \tan 75 = \frac{\cdot 3977}{GH} = \cdot 1065 \textit{ in.}$$

$DE = GH$.

$GD = AB$.

$$\therefore \textit{angle } GED = \tan GED = \frac{\cdot 5625}{\cdot 1065} = 5\cdot 283$$

Tan $5\cdot 283 = 79° - 18'$ (*approx.*)

$\therefore$ *Angle "A" in the flat* $= 79° - 18'$.

FIG. 19. DEVELOPMENT OF AN ANGLE IN THE FLAT WHEN THE LUG IS SET AT AN ANGLE TO THE HORIZONTAL (75°) AND BENT UP (45°)

Lugs Set at Angles and Bent at an Angle

It will be observed in Fig. 19 that although the lug is bent to an angle of 45° and set at an angle of 75° on the fitting, that a continuous line is shown on the drawing in side elevation.

Now, unless this is taken into consideration, there will be a deficiency of metal on one side and a surplus on the other side, when the lug is bent up to the required angle.

In practice the usual procedure is to leave a surplus of metal on the other side to allow for the deficiency of metal which occurs. By this method, care must be taken to scribe rivet lines after bending and squaring up the lug, otherwise errors are likely to occur in rivet position.

Calculations for this allowance may be carried out as in the accompanying drawing. This method is, of course, very useful, but is much more involved, and it is a matter of conjecture as to which method is applied.

Positioning a Strengthening Plate over a Bend

It has been found in practice that when positioning strengthening plates along the outside of a bend, and if both plates are bent to the same radius, a good fit cannot be obtained at the bend, especially where the plates are of differing thicknesses. To counteract this discrepancy the following allowance is made to the radius of the outside plate.

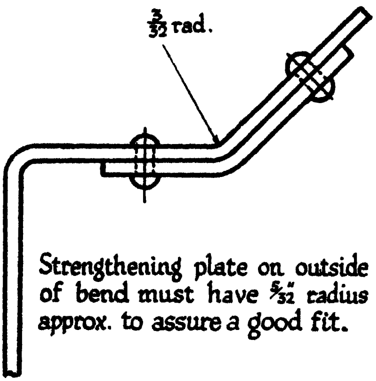


FIG. 20. POSITIONING OF A STRENGTHENING PLATE ON A BEND (16 S.W.G.)

One thickness of the metal of the outside plate is added to the radius of the bend required, and the outside plate is bent to this new radius. For example—

Radius required for both plates $= \frac{3}{32}$ in.

Thickness of outside plate $= \frac{1}{16}$ in. approx.

New radius for outside plate $= \frac{3}{32} + 0{\cdot}064 = \frac{5}{32}$ in. approx. Radius for inside plate remains the same.

CHAPTER IV

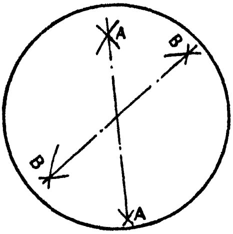
MARKING OUT

It cannot be sufficiently stressed how important it is for a metal rigger to be efficient in marking out. A sound knowledge of this subject is essential when carrying out most of the repairs to metal aircraft.

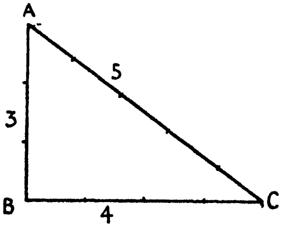
The accompanying drawings and explanations deal with methods which are generally used, and also some that will enlighten the reader as to how some of the more difficult methods are carried out.

Common sense plays a very important part in marking out, and the ability to adapt oneself to circumstances is essential. The basis of all marking out is the finding of the centre line first, before proceeding further. Thus is a foundation provided on which to build the more complicated marking out.

Accuracy is the keynote in marking out—guesswork only leads to waste of material and, in aircraft work, the safety of the aircraft may be involved. So, in view of the importance of this subject, the reader is strongly advised to *practise marking out until perfect.*



FINDING CENTRE OF CIRCLE



METHOD OF DRAWING Rt ANGLE

Fig. 21

Finding the Centre of a Circle

Set dividers at a little more than the radius and scribe arcs at *AA* from outer circumference.

Keeping the same setting on the dividers, scribe arcs from the opposite side of the circle again at *AA*, the arcs intersecting at these points.

Keeping the same setting, repeat this operation at a convenient distance along the circumference of the circle from where you first commenced and scribe arcs at *BB*.

Having completed the scribing of the eight arcs, connect up by two lines cutting the points of intersection of the arcs.

The point of intersection of the two lines will be the centre of the circle.

Method of Drawing a Right Angle

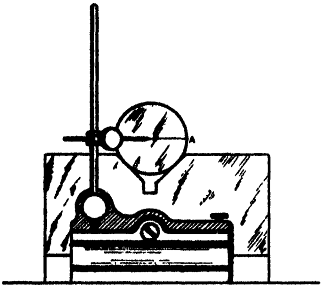
Mark off three units of length to equal a line *AB*.

Mark off four of these units to equal a line *BC*.

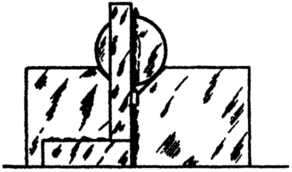
Connect the extreme points of these lines by the line *AC*. This line should equal five of the same units, dividing lines *AB* and *BC*, when the angle will be a true 90°.

Marking out a Round Tube for Positioning Rivets at an Angle of 90° to each other

Method I. This operation can be carried out in several ways, but the most accurate methods are gained by use of the surface plate, V-blocks and scribing block.



OPERATION 1
Scribing ℄



OPERATION 2
Using fitters' square to find 2nd line at 90° to 1st line

Fig. 22. Marking out a Round Tube for the Positioning of Rivets at an Angle of 90° to each other

The tube is placed horizontally on V-blocks and the scriber is adjusted to as near the centre line of the tube as possible. A mark is scribed each side, then the tube is rotated through 180° until the opposite centre line mark comes round to the scriber setting. Again check the opposite side and then divide any error on this side by four, reset the scriber and mark the tube at what is now the correct height of the centre line from the surface plate. This is known as the "trial and error" method.

The centre line having been found, we now require a line at 90° to this. We obtain this line by placing the fitter's square up against the tube whilst the tube remains on the V-block in its original position. Rotate the tube until the centre line marks coincide with the edge of the square, and proceed to mark the horizontal centre lines with the same scriber setting used for the first centre line marks.

You will now have four lines around the edge of the tube, and these can be continued along the side of the tube with the scriber.

The required distances that rivets are to be positioned along these lines can now be marked. (See Figs. 22 and 23.)

Method II. Using the surface plate, place the tube horizontally on V-blocks.

Obtain the total vertical distance from the surface plate to the top of the tube (outside diameter).

Deduct from this measurement half of the outside diameter of the tube.

Set the scriber to this new measurement which conforms to the horizontal centre line of the tube. (See Fig. 24.)

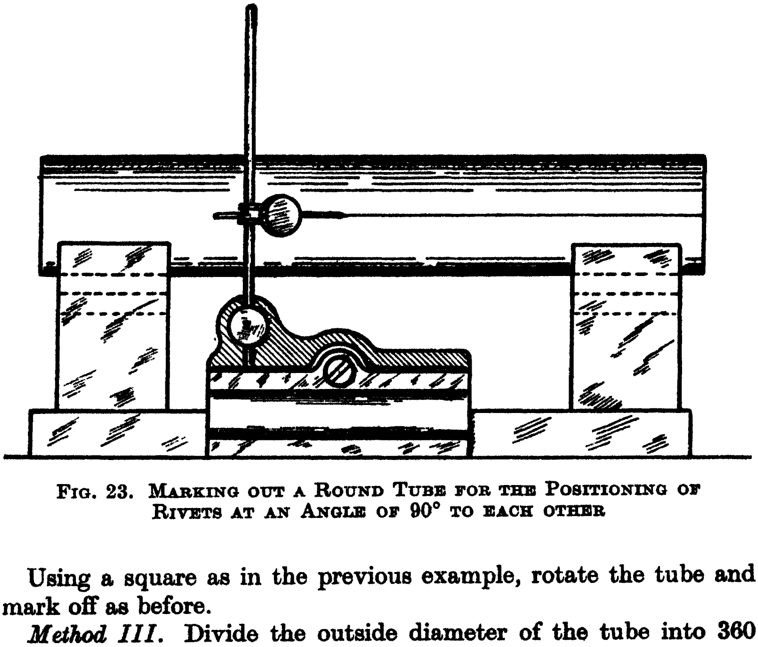


FIG. 23. MARKING OUT A ROUND TUBE FOR THE POSITIONING OF RIVETS AT AN ANGLE OF 90° TO EACH OTHER

Using a square as in the previous example, rotate the tube and mark off as before.

Method III. Divide the outside diameter of the tube into 360 equal parts. Set a pair of spring dividers to the measurement obtained. Smear the end of the tube with chalk and, using spring dividers, lightly mark the tube edge into 360 divisions. Taking marks diametrically opposite and 180 divisions apart, transfer the lines to the side of the tube—this will cut the tube centre line. Ninety divisions each way from the centre line marks will give the points for transferring to the tube side, to form the 90° angle with the centre line. Lines from the tube edge to the tube sides may be transferred by the use of a box square.

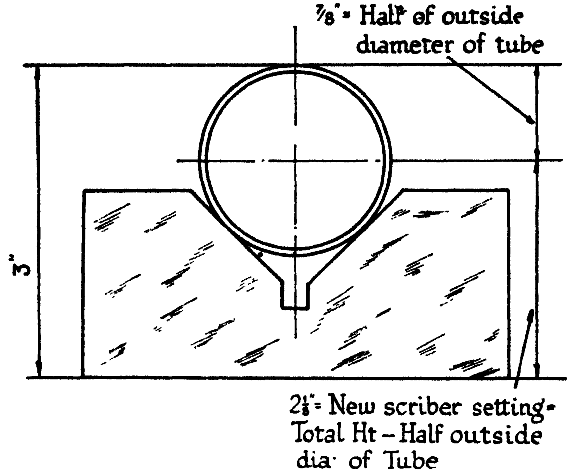


FIG. 24. METHOD OF FINDING THE CENTRE LINE OF A TUBE

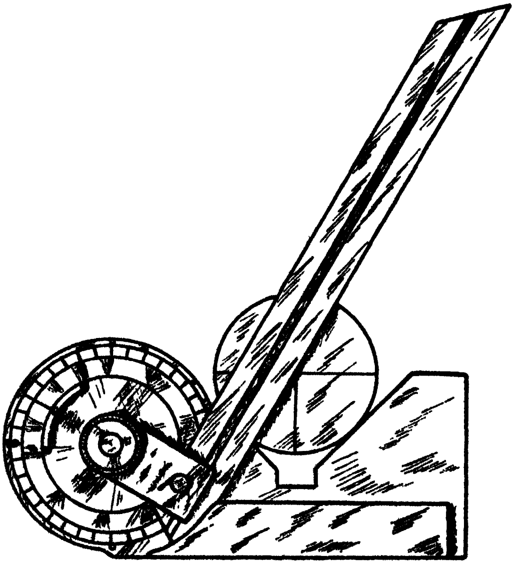


FIG. 25. MARKING OUT A ROUND TUBE FOR RIVETS SET AT A GIVEN ANGLE FROM CENTRE LINE OF THE TUBE

Marking Out a Round Tube for Rivets set at a Given Angle from the Centre Line

The centre of the tube is marked first. This may be found by blocking the end of the tube and scribing arcs (as shown in Fig. 21).

Mark the horizontal centre line of the tube.

Set a bevel protractor to the required angle—the edge of the protractor should just cut the centre of the tube.

Mark points on the tube and transfer to the sides.

Mark distances between rivets along the tube as required.

The above method is carried out with the aid of V-blocks and a surface plate. (See Fig. 25.)

Marking Out a Round Bar for an Odd Number of Sides

Support the bar in V-blocks. Mark a centre line across the face of the bar with the aid of a scribing gauge. Set the bevel protractor to the required angle, e.g. if the number of sides has to be 9, the angle would be—

$$360/9 = 40°$$

Place the protractor on the face of the bar so that the blade cuts the centre of the centre line. Rotate the bar until the marked centre line lies parallel with the blade of the protractor. With the original scriber setting mark another centre line, taking care to hold the protractor parallel with the original centre line. Repeat this operation, marking new centre lines each time until the nine divisions are marked on the face of the bar. Scribe straight lines to connect each division round edge of bar. Transfer the end of each division along the sides of the bar with a box square or scriber, and the bar is ready for the machining operations, etc.

Marking Out a Round-sectioned Longeron which is in Service on an Aircraft

It may be found necessary during a modification to position a fitting on a longeron with the rivets positioned at an angle from the plan centre line of the longeron. In this case, the normal methods of marking out would be found difficult in their application on account of the longeron being a fixture, with the ends inaccessible.

Again, several methods are available, but only the more general ones will be dealt with here.

One method is to place two squares or straightedges vertically up against the longerons, so that their inner edges are parallel and positioned firmly against the longerons.

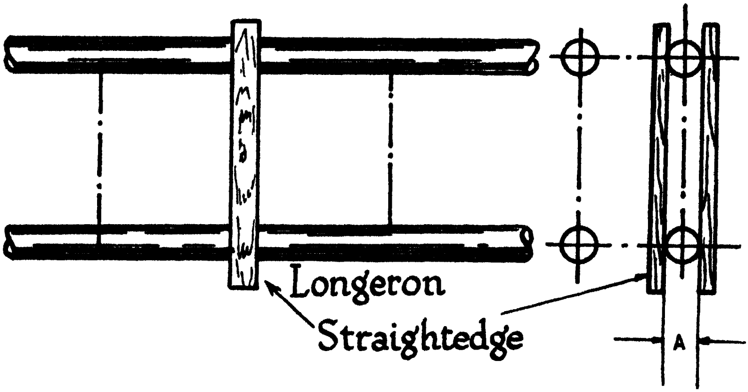
The distance between the inner edges of the straightedges is then measured. This will be equal to the outside diameter of the longeron at this point.

Holding a steel rule square across the face of the longeron, mark off half the distance from the inner edge of one straightedge. This gives you the position of the centre line of the longeron.

The straightedges are then re-positioned at right angles to their first position, and the same procedure is carried out as above.

The longeron is now marked to position rivets, etc., at 90° to each other. (See Fig. 26.)

In some cases it is possible to find the centre line of the longeron by marking a line coincident with the centre line of a strut bolt-head which is positioned about the longeron centre line.



Distance A = outside diameter of longeron.
The straightedges are then re-positioned to find the line
at 90° to the ℄.

FIG. 26. MARKING OUT A ROUND-SECTIONED LONGERON WHICH IS IN SERVICE ON AN AIRCRAFT

Another method similar to the above is by the use of fitters' squares with a straightedge as a base for the square.

When the angle varies from 90° another method can be adopted. First, mark the plan centre line of the longeron by either of the methods already described.

Obtain a flat piece of thin gauge aluminium and file the edges at true right angles to each other. Mark out on the aluminium the outside circumference of the longeron in the flat. Next mark lines dividing the length into quarters.

If the aluminium was at this stage bent around the longeron (with the narrow line which forms the joint between the two edges of the metal coincident with the marked centre line on the longeron), we would then have marks situated at 90° to each other, having, of course, bent the metal with the lines on the outside. It will easily be seen from this that if the length of the circumference which you have marked on the aluminium is divided into 360 equal parts, any angle can be marked by this method, e.g. dividing the length into four equal parts gives us 90° angles; dividing into eight equal parts gives us 45° angles, and so on.

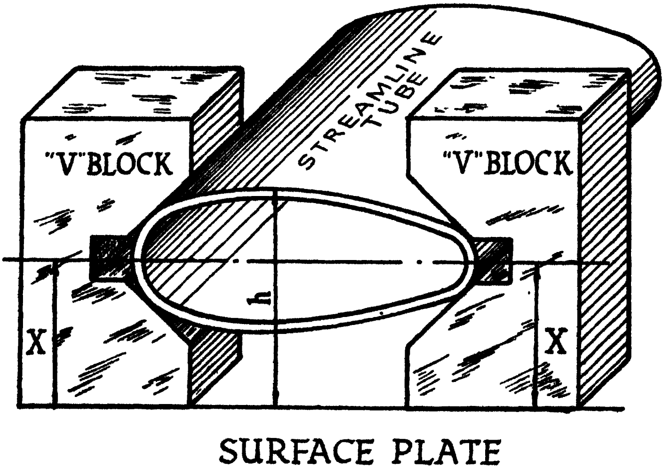
A good stiff paper could be used in place of aluminium, but great care must be taken to ensure that the edges are true and at right angles to obtain accuracy.

Avoid deep scriber marks when marking out and always restore the anti-corrosive film on completing the job.

Accuracy is essential. A complete longeron may easily be rendered useless through careless marking out on jobs of this description.

Marking Out a Streamline-sectioned Strut for Positioning the Fork-end Attachment

Method I. Streamline struts are superseding the round-section ones, and the alteration in design brings with it a new marking-out procedure. As the streamline section is usually supplied in long lengths, this means that the lengths have to be cut to size and drilled to take the rivets for the fork-end attachment fitting.



Height of major axis XX to be equal.
Vertical distance h = highest point where dial indicator will touch—this point gives position of the minor axis.
The opposite side is treated in a similar manner.

FIG. 27. MARKING OUT A STREAMLINE STRUT (METHOD I)

Several methods are used, the most common being to clamp the tube in V-blocks on a surface or marking-off table, with its major axis horizontal. Then, by trial and error method using the scribing block, the position of the major axis is marked. A check can then be made to ensure that the major axis lies horizontal with the surface table.

With a Dial Test Indicator, adjust until the needle just touches the highest point on the streamline tube (which is lying horizontal), run the D.T.I. along the surface of the tube as a check and then mark the point of contact. Reverse the tube complete with V-blocks and repeat this operation, checking for movement of the tube by checking the distance from the surface table to each side of the major axis—this should correspond with the previous setting of the scriber. (See Fig. 27.)

From the points marking the minor axis, set the scriber and mark lines along the side faces of the tube, keeping the job in the V-blocks and on the surface table.

Obtain fork-end socket, transfer the position of pilot holes to scribe lines on the strut. With the under edge of the socket-lip bedding down evenly on the face-edge of the streamline tube, mark a line coincident with the centre line of the pilot holes on each side of the socket-lip. (*N.B.* This is a guide for getting holes in line with a socket and streamline tube.)

Now screw the adjustable fork-end into the socket until the amount of threaded portion below the inspection hole is equal to the amount above the top face of the socket. This can be measured by counting the number of threads on the fork-end before fitting and calculating the distance from the top face of the socket to the centre of the inspection hole, taking that distance away from the number of threads and dividing the remainder into two equal numbers of threads on the fork-end. This will give you the number of threads required above the top face of the socket. This method allows for adjustment which may be found necessary during service and ensures that adjustments will not take the threaded portion out of safety.

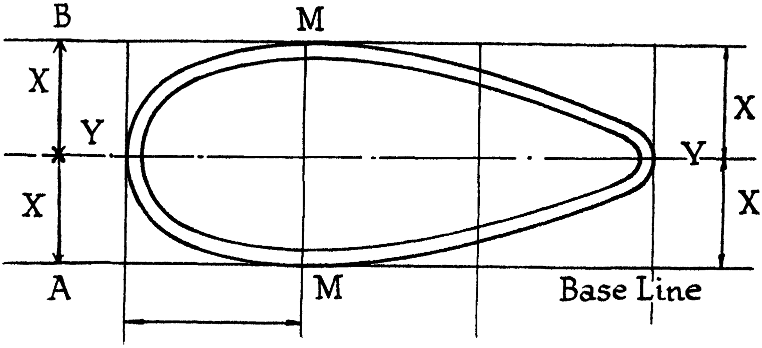
Method II. Square the end and mark the metal with ink at the end which you have squared.

Using the strut as a stamp, transfer the outline on to paper. Mark a base line *A* horizontally so that it just touches the widest part of the strut.

Draw another line parallel to the base line, touching the widest part of the strut at the top side at *B*.

Halve the distance between the two lines and draw a parallel line to coincide with the major axis.

Now, to find the minor axis, draw a line at right angles to the base line just touching the leading edge of the strut. Draw another line parallel to this line running through the points where the base and top lines touch the side of the strut. This line coincides with the minor axis. (See Fig. 28.)



⅓ of chord back from leading edge is the point of fineness ratio.

Distances XX to be equal. Line YY major axis. Line MM minor axis.

FIG. 28. MARKING OUT A STREAMLINE STRUT (METHOD II)

Now place the strut on the drawing so that the squared edge fits the stamped outline of the strut.

Using a fitter's square and a scriber, transfer the lines up the sides of the strut and proceed to fit the fork-end.

(*N.B.* To obtain accuracy when using this method it is advisable to use a surface plate or a good flat surface for your paper to rest upon.)

The minor axis is at the point of fineness ratio which is one-third of the strut's chord measured back from the outer face of the leading edge; so, by drawing another line and completing the rectangle, a double check can be obtained by measuring back from the leading edge line one-third of the distance between lines.

Method III. Another method of marking out a streamline-sectioned tube for the correct position of the rivets securing the fork-end sockets is as follows—

Carefully block the end of the tube with wood so that the surface of the wood lies flush with the edge of the tube.

Scribe the wood at the leading and trailing edges of the tube to complete circle as shown on the drawing (Fig. 29).

Scribe a line through the centres of the circles. This line corresponds to the major axis. The minor axis is obtained by the following method—

Find the maximum diameter of the tube by the aid of Vernier calipers or common calipers, checking the calipers during this operation to ensure squareness when applied to the job. Having found the maximum diameter of the tube, scribe a line at this point at right angles to the major axis line. This line corresponds to the minor axis. The position of the major and minor axes can now be transferred along the sides of the tube and the rivets placed as required. (See Fig. 29.)

Marking Out a Streamline-sectioned Tube when in Position on an Airframe

Streamline struts may be marked out whilst in position on the airframe, this method being found most useful in the saving of time and labour. Assuming that we had the job of fitting a wrapper plate which carried an instrument bracket on to a strut of the above section, we would obviously position the rivets or bolts securing the

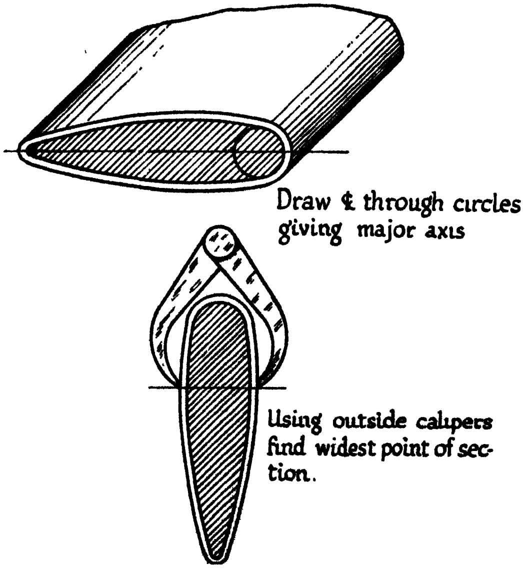


FIG. 29. MARKING OUT A STREAMLINE STRUT (METHOD III)

wrapper plate through the minor axis of the strut, as any other position would no doubt reduce the strength of that member.

The first operation would be to mark the centre lines of the bolts or rivets, securing the strut sockets or fork-end fitting. Then connect these points by the aid of a straightedge. This would give a line cutting the minor axis, as the securing bolts or rivets are positioned through the minor axis and are a safe guide.

The distance down the strut would be obtained from the drawing. This could be measured along the line connecting the centre points of the securing rivets or bolts.

Having marked both sides of the strut, drill pilot holes. Check for alignment of the holes, and finally drill and reamer to the finished size.

Marking Out Tubes for Cutting Off at Various Angles

Several methods are available.

1. Using a jig cut at the required angle and having a case-hardened surface.
2. Marking out by use of an angle plate, surface plate and scribing block.
3. Using a bevel protractor, V-block, surface plate and scribing block.
4. Using thin gauge soft metal or stiff paper as a templet, having developed in the flat the tube cut off at the angle required.
5. Making a mitre box marked out and slotted at the required angle. By this method large numbers of tubes may be cut, no resetting of scribers, etc., being required. (A periodical check of the condition and accuracy of the mitre box is recommended, as constant use causes the angle grooves to become worn.)

Development in the Flat of a Tube Cut Off at a Given Angle

Scribe a line *EE* to represent the outside circumference of the tube.

Scribe vertical lines at right angles to this line at equal distances apart.

These vertical lines will be marked *A* to *E*, each side of the centre line which is marked *A*.

Now scribe the circle representing the tube and divide into an equal number of parts.

Mark the line *AE* to just touch the outside diameter of the tube. The line must be parallel to the centre line of the tube.

Mark off the angle required at *E*.

Connect up the divisions marked off on the top half of the tube by lines at right angles to line *AE*. These lines will cut the angle already marked off. Transfer the vertical distances *Aa, Bb, Cc, Dd,* to the lines at right angles to the line *EE*, *Aa* being marked on the centre line and *Bb*, *Cc*, *Dd* being marked on the lines each side of the centre line respectively.

The marked points are then connected up in a fair curve.

Fig. 30 represents a tube cut off at an angle of 45°. When using a development of this description as a templet, the lines *Zz* must be at perfect right angles to the line *EE*, and when bent around the tube their inner edges must be flush and parallel. The angle can then be scribed around the edge of the templet.

Using a Scribed Base Line instead of Filing Face Edges on Flat Plates

Much time can be saved by using the method shown in Fig. 31. This method also obviates any possible errors caused by an incorrectly trued face edge.

When scribing the base line, allow a minimum for facing up by filing; it will be noticed that a more accurate width measurement is obtained by filing up to the scribed line after bending owing to the metal spreading at the bend radii—as occurs when using the face edge method.

It is essential when using a flat square to mark out lines at right angles to the base line to ensure that the square is correctly positioned about the base line before scribing the line at right angles to it. When using spring dividers for this operation instead of a square, ensure that the line connecting the arcs makes contact on the centres of intersection points. It is not necessary to scribe arcs deeply.

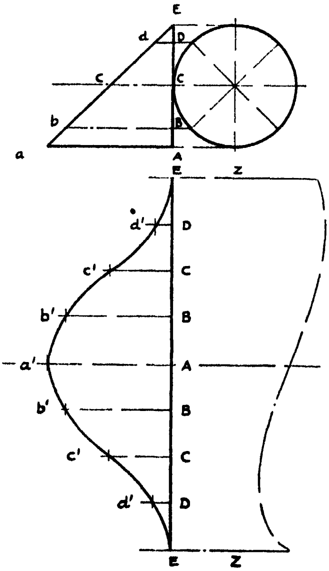


FIG. 30. METHOD OF DEVELOPING A TEMPLET FOR TESTING THE ANGLE OF A TUBE

Marking out an Ellipse

Scribe two lines equal to the lengths of the major and minor axes and at right angles to each other, intersecting at their centres.

Form rectangles by connecting up all four points of the lines as shown on the drawing. Now divide each of these rectangles as follows.

Divide the line parallel to the major axis in each small rectangle into an equal number of parts, lettering or numbering them from the end of the line. Divide the line parallel to the minor axis in the rectangles into the same equal number of parts as for the major axis line, numbering or lettering away from the centres to the end of the lines. Connect up the similar lettered or numbered points by a straight line. Finally scribe a fair curve to cut all outside points of intersections of these lines as shown on the drawing.

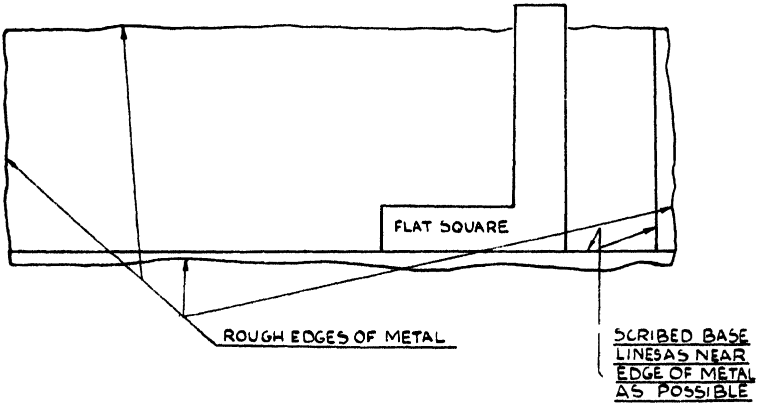


FIG. 31. MARKING OUT FROM A SCRIBED LINE INSTEAD OF FILING A TRUE EDGE FOR USE AS A BASE LINE

Marking Out Rivet Lines near the Edges of Flat Plates

A true face edge is essential, so we will assume that we have trued up the face edge of our plate in all cases. The most accurate method is:

Position the plate face edge to the surface plate and scribe a thin line the required distance from the edge of the plate by the use of a scribing block.

Other methods are—

Using odd-leg calipers set at the required distance from face edge, taking care to keep calipers square on the job whilst scribing lines. (See Fig. 33.)

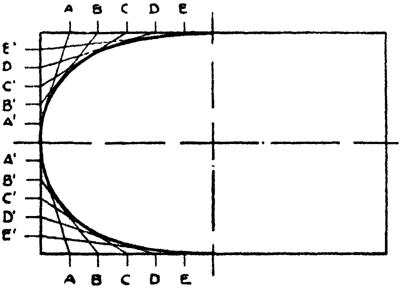


FIG. 32. MARKING OUT AN ELLIPSE

Using spring dividers to scribe arcs from the face edge to the required distance, finally connecting these arcs by a thin line.

Using a carpenter's marking gauge.

Marking several points with a steel rule and finally connecting all points with a thin scribed line.

Having obtained the rivet line, proceed to mark along the line the correct position of rivets, with the aid of spring dividers and steel rule.

To Divide an Angle into Two Equal Parts

Let *bac* be the angle. Then, with *a* as centre and any radius, draw arcs at *d* and *e*. With *d* and *e* as centres and the radius greater than one half the angle, draw arcs at *f*.

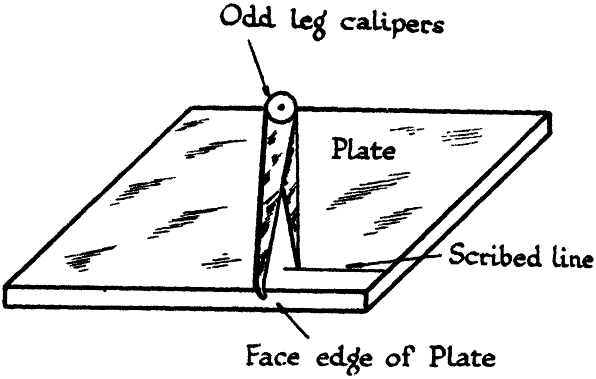


FIG. 33. SCRIBING LINES ON A FLAT PLATE TO POSITION RIVETS, ETC.

A line drawn through the intersection at *f* to *a* divides the angle into two equal parts. (See Fig. 34.)

To Draw a Line Parallel to a Given Line at a Given Distance

Let *ab* represent the line. From any points, *cd*, draw arcs with the given distance as the radius. A line just touching the arcs is parallel to *ab*. (See Fig. 35.)

To Find the Centre of the Arc of the Segment of a Circle

From points *a* and *b*, with length *ab*, draw arcs at *c*.

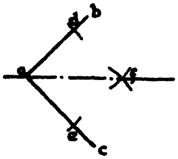
The point of intersection will be the centre of the arc. (See Fig. 36.)

To Inscribe a Hexagon in a Circle

Draw diameter *ab* with *c* as the centre. With radius *ac* mark off points intersecting at *d*, *e*, *b*, *g*, *f*. Then join *ad*, *eb*, *bg*, *gf*, and *fa* to form the hexagon. (See Fig. 37.)

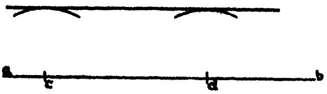
To Inscribe a Circle in a Triangle

Bisect the two angles at *a* and *b*, and the point of intersection is the centre of the circle. (See Fig. 38.)



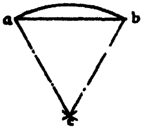
To divide an angle into two equal parts

FIG. 34



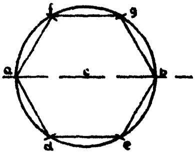
To draw a line parallel to a given line at a given distance

FIG. 35



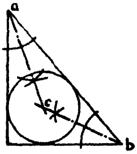
To find the centre of the arc of the segment of a circle

FIG. 36



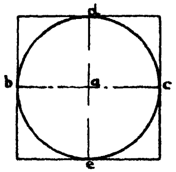
To inscribe a hexagon in a circle

FIG. 37



To inscribe a circle in a triangle

FIG. 38



To describe a square about a circle

FIG. 39

To Describe a Square About a Circle.

Draw a line *bc* through the centre *a* of a circle. Draw lines parallel to *bc* at *d*, and *e*, and also lines at right angles at *c* and *b*. (See Fig. 39.)

CHAPTER V

GENERAL NOTES ON REPAIRS TO METAL AIRCRAFT

DETAILED instructions for particular types are found in the various makers' notes, which are normally available, but a sound knowledge of the general practices connected with repair schemes will be found very useful to those concerned.

Inspection after Damage

Always make your motto "Safety First." Thoroughly inspect in a good light, and don't be afraid to roll the fabric well back. The transmission of damage is very prevalent in metal aircraft, so inspect the damaged member at all joints for drawn bolt or rivet holes and bent plates. *Never assume, always make certain.*

General Classification of Damage

1. Negligible damage.
2. Damage necessitating repair by patching.
3. Damage necessitating repair by insertion.
4. Damage necessitating replacement.

General Limits Governing Negligible Damage to Aircraft Tubes

Solid-drawn steel tubes. Smooth dents not exceeding $\frac{1}{50}$th of the tube's outside diameter in depth and having no sharp corners, cracks or fractures. Damage must not be in the middle third of the member's length.

Duralumin Tubes. Smooth dents not exceeding $\frac{1}{30}$th of the tube's outside diameter in depth and having no sharp corners, cracks or fractures. Damage must not be in the middle third of the member's length.

Welded Tubes. Smooth dents not exceeding $\frac{1}{20}$th of the tube's outside diameter in depth and having no sharp corners, cracks or fractures. Damage may be in any part of the member's length, except where specially stated in the maker's notes.

Limits of Bowing Allowed in Members Between the Centres of Points of Support

Axle. 1/100th of the length.

Fuselage. 1/500th of the length.

Main Planes. 1/600th of the length.

Subsidiary Members, e.g. Tail plane struts, etc. 1/600th of the length.

Manufacturers' instructions take precedence when there is any variation between these limits and theirs.

Engine plates, undercarriages, tail skids, inter-plane and tail plane struts are replaced when damaged.

(*N.B.* In some types of structures, duralumin tubes are used for side struts, etc., whilst steel is used for longerons. The reason for this is an endeavour to cut down the weight of the structure as much as possible. Where this method of construction is used, always make certain that steel is replaced by steel, and vice versa. It is quite easy to make a mistake where the whole structure is enamelled in one colour. A glance at the maker's key diagram will dispel any doubts, and, if this is not available, tests must be carried out on the old members to ascertain the kind of metal used.

No heat treatment of any kind is to be carried out without instructions from manufacturers.

The approved methods of repair must be strictly adhered to throughout all repairs to metal aircraft.)

Supporting and Jury Rigging of Fuselages during Extensive Repairs

Unless adequate support is given to a fuselage structure during major repairs, there will be a risk of causing serious distortion.

The deciding factor to be considered when it is found necessary to support the fuselage is how to prevent sagging and twisting due to the removal of a complete component, or a part of one. A good method of arriving at the number and position of trestles required is to imagine the damaged component to be under compression at each end, and studying the likely result if the middle of this component was removed whilst under this force. The trestles can then be positioned to counteract the effect.

A trestle which has to take a load should never be positioned in the middle of a member, but wherever possible it should be placed beneath a strut which is in compression or beneath some reinforced joint as near as possible to the part undergoing repair.

Jury rigging can be adapted to suit the circumstances of the repair. An example is shown in Figs. 40 and 41.

The General Procedure for Carrying Out Major Repairs

Taking for example a damaged longeron in the vicinity of the stern bay—

1. Get the machine under cover.

2. Remove surplus weight.
3. Place where advantage of light can be taken.
4. Place the machine on trestles at a convenient working height.

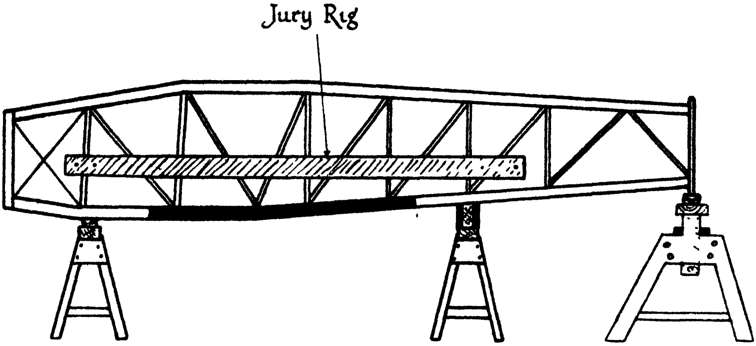


Fig. 40. Supporting a Fuselage During Major Repair (Longeron Repair of an N-braced Fuselage)

5. Remove all cowlings, fairings, etc.
6. Remove tail unit—this is a safe measure where damage may have been transmitted.

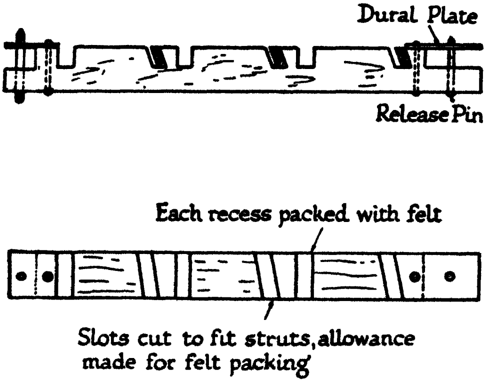


Fig. 41. Jury Rig for Fuselage Repair

7. Get plenty of light and inspect *thoroughly*.
8. Having localized the damage, proceed to jury rig to prevent sag on removal of damaged member. (Circumstances and position of damage will have to be taken into consideration when erecting jury rig.)

9. Obtain length of member to be replaced from adjacent similar member or maker's key diagram. Use a reliable trammel.

10. Release local stresses by slacking any bracing in the vicinity of damage.

11. Remove damaged member and further inspect where bolts or rivets pass through points supporting damaged member.

12. Make up new member to conform to the length previously obtained—the replacement to be of the same diameter, gauge and specification as the old member.

13. Apply anti-corrosive internally.

14. Fit the new member, using new bolts or rivets where necessary.

15. Bolt or rivet up according to original method of attachment.

16. Tension the bracing wires and check by trammel.

17. Check length of new member.

18. Apply final and anti-corrosive treatment.

19. Remove jury rig.

20. Assemble tail unit, replace fairing, bonding, etc.

21. *Look for tools inside of fuselage before finally closing the job up.*

22. Have a general check to see that the aircraft is in a safe and airworthy condition.

During the different stages of the repair always obtain a double check of your work from a senior, as this is only fair to everybody concerned. Two heads are better than one, and do not forget that *safety* comes before *pride* when dealing with aircraft.

Repairing a Welded Structure

In addition to the general procedure for carrying out major repairs to fuselage structures, the following precautions must be observed when dealing with welded structures.

Remove all petrol and inflammable material.

Have the fuselage positioned away from any other aircraft or inflammable materials and take all the normal fire precautions.

Make certain of your welding plant.

Have all patch replacements, etc., ready before welding.

If using a jig, tack-weld the component whilst in the jig, then remove jigs before completing the weld.

Repairs to Steel Strip Structures

In certain types of airframes narrow gauge steel strip is used in built-up form for the rear portion of the fuselage.

This method of construction is a great weight saver, the strip being only a few thousandths of an inch in thickness and made of a nickel-chrome steel.

The tubes are rolled sections drawn together to form the tube and are secured to one another by curling over the edges, rivets being used only at the gusset plate joints.

Owing to the extreme thinness of this material, it is not used where accidental damage due to a blow from an outside source is likely to occur, as in the vicinity of cockpits where the buckle of a safety harness could cause damage. In this latter portion solid-drawn steel tubes are used.

It is permissible in these structures to reinforce the rivet holes if they become elongated. This is done by fitting washers of 20 gauge mild steel over the enlarged hole.

A common fault made during repairs to the tail ends of rear fuselage longerons is fitting the plug ends too tight in the longeron. This sets up a bursting action causing the strip to split. To obviate this danger, thin metal strips of the same material as the longeron are fitted between the lips, enlarging the hole until a push fit is obtained for the plug ends.

The usual precautions, as outlined previously, are carried out for repairs to this type of construction.

Main Plane Rib Repairs

In all cases where damage has occurred to ribs, it is advisable to carry out a thorough examination of all other members in the vicinity, taking into consideration transmission of damage to extreme points of these members.

A common fault is made by not rolling sufficient fabric back, which results in other damages remaining unnoticed. Have a good light on the job and take all the usual precautions for safety. Any damage, however slight, is important.

In some cases of major damage, it is found more convenient to remove the damaged wing.

Where a complete rib is to be fitted, remove the old rib, inspect for elongation of rivet holes and obtain a new rib.

Fit the new rib with the bottom boom off.

Having positioned the top boom, etc., fit the bottom boom.

Apply anti-corrosive treatment.

Carry out a thorough inspection for tools, etc., lying about.

The practice of fitting the bottom boom last makes the job much simpler, as the rib will hang in position without having to be held there whilst riveting, etc.

Reference to makers' notes must be made to obtain the size, etc., of the rib to be fitted. In the case of a rib having to be made up, and where no notes or drawings of the rib are available, a spiling of an adjacent similar rib will have to be taken.

Taking a Spiling of a Main Plane Rib

When a rib is badly damaged and no drawings are available to obtain dimensions for the manufacture of a new one, the following method of obtaining the shape of the rib can be effectively used.

From a similar rib in the opposite side main plane a spiling can be taken as follows—

Obtain two pieces of plywood about 12 in. longer than the chord of the rib and about 6 in. wide, with their inner edges parallel.

Mark vertical ordinates at right angles to the face edges. These ordinates may be equidistant or, if required, the ordinates may be spaced closer together for the quick curve of the rib and wider apart for the slower curve.

These boards are called "spiling" boards.

Fix wood battens on to the spiling boards and clamp the spiling boards in position so that their inner edges just touch the deepest point of the rib on the top and bottom booms, making certain that the inner edges are parallel and the ordinates on both boards coincide with each other.

By the aid of a spiling stick or spring dividers set at a suitable distance, mark points on the ordinates from the top surface of the rib booms keeping the dividers set at the same distance.

Care must be taken to keep the dividers or spiling stick vertical and square with the ordinates to obtain accuracy.

Having marked all points on ordinates, connect up in a fair curve. Then mark in the position of spars, etc., and remove spiling boards from the rib. (See Fig. 42.)

The shape can now be transferred to a jig board.

Making a Jig Board for a Main Plane Rib

The jig board should be made of hard, well-seasoned wood and planed level.

Having prepared the jig board, the spiling can then be transferred, with the position, depth, and shape of spars, etc., marked and blocks made to represent these, fitted by screwing on to the jig board. Grooved blocks are fitted to the board for positioning the webs.

The position of the rib boom blocks or eccentric buttons should be placed so as to allow for the depth of the booms.

Leading and trailing edge blocks should now be fitted and a final overall check of measurements carried out.

Useful Hints Applicable to Repair Schemes

Use the special tools designed for the particular scheme when obtainable. In the case of members that are tackwelded, always replace them by tackwelding.

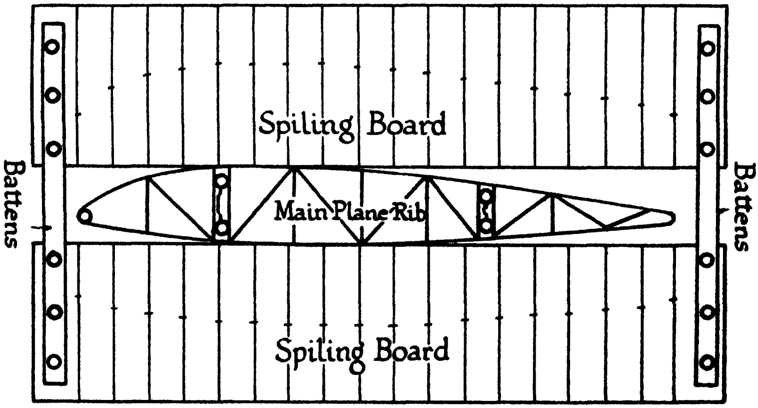


FIG. 42. TAKING A SPILING OF A MAIN PLANE RIB

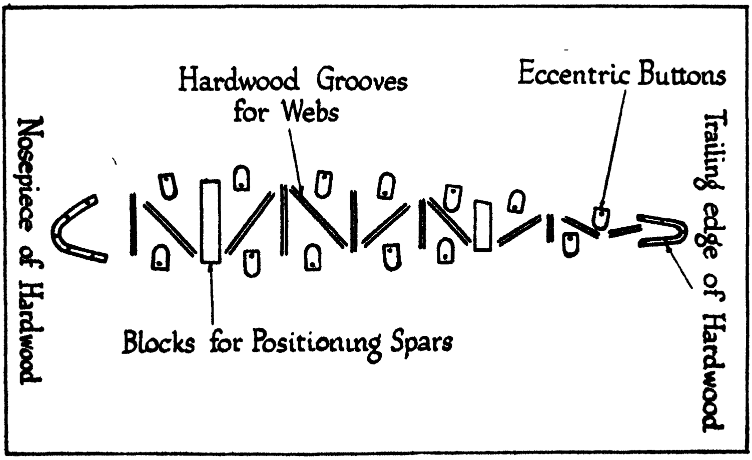


FIG. 43. JIG BOARD FOR MAIN PLANE RIB

When using tube squaring rolls, avoid cracking the member by judicious use of the machine, especially when applying pressure.

See that squared ends of tubes are in correct alignment.

When bending for wing tips, small settings give smoother curves.

Duralumin rivets may be stored after the normalizing process for 150 hours by removing them to a cold chamber and kept at a temperature of — 25° C. by solid carbon dioxide. The removal of the rivets to the cold chamber must take place immediately after washing, following the heat treatment quenching process.

It is not necessary to completely dry off the rivets, but, if attempted, the drying operation must be done as quickly as possible without artificial heat being applied.

The temperature of the cold chamber must not exceed — 15° C. and rivets must be renormalized if storage is required after 150 hours.

Where duralumin rivets are used, normalize and use within one hour of final quenching.

Avoid abrupt change of section where patches or sleeves are employed.

In some types of structures the struts do not butt up to adjacent members. This allows more tolerance when fitting, avoids abrupt change of section and ensures that the stresses are distributed correctly.

When a rear fuselage longeron is very badly damaged it may be easier to replace it with a new one rather than attempt a repair. The operation in this case is as follows—

Before dismantling, a straightedge made of good, hard, well-seasoned wood, longer than the longeron, is fixed against the opposite undamaged longeron by clamping to the stern-post bay, and also at the bay forward of the longeron front joint. Then, with a pencil, draw a line on the board opposite the centre line of each strut in order to correctly position the strut joints on the new longeron upon reassembly.

Light alloy tubes of $\frac{11}{16}$ in. diameter and under are not anodically treated on account of their small diameter. Hot lanoline may be used as an anti-corrosive treatment. The tube is usually plugged at one end, and then filled with hot lanoline. The plug is removed, allowing the lanoline to drain out. This ensures an even coating around the inside of the tube.

When working on repairs with electron metals, a froth fire extinguisher should be handy and in the event of a fire, treat it as a petrol fire.

Use a zinc base paint for the anti-corrosive coating on duralumin repairs.

When metal is suspected of being cracked, soak it in hot oil, clean off with a dry rag, and apply whiting mixed with water. When the whiting dries, oil will show the position of any cracks which were not visible to the naked eye.

Patch plates should be clamped into position before drilling. This avoids elongated holes.

Never fit bolts with the threaded portion in shear stress.

Wire or rod passed through the distance tubes which are used to prevent crushing of longerons in certain repair schemes will prevent the distance tubes from being lost in the longeron. This precaution would often save a lot of time if practised.

Old ferrules may be used if not damaged. These ferrules are sometimes referred to as "Shear Bushes."

The correct way to remove a rivet on an aircraft structure is to—

1. File a flat on the head.
2. Pop-mark the centre of the flat.
3. Drill the head with a drill of the same diameter as the rivet shank to a depth less than the thickness of the rivet head.
4. Use a small chipping chisel to chip off the remaining portion of the rivet head, supporting it with a dolly.
5. Punch out the remaining rivet shank with a punch slightly smaller in diameter than the shank.

Taper pins securing sleeves or sockets to tubes are invariably fitted with the ends facing alternate ways.

It is a common mistake to ream the taper pin holes so that the ends of the pins will all face one way. By making this mistake the holes in the socket or sleeve will differ in size to the holes in the tube—large holes in the tube will face small holes in the socket. As it would be detrimental to the efficiency of the socket to enlarge these holes, the tube would be useless for the job concerned.

To avoid this mistake the letter L, for large, and S, for small, can easily be marked over the respective and correct holes requiring reamering.

When using the Vernier caliper for measuring the inside diameter of a tube, do not forget to add the width of the jaws which is usually stamped on the instrument.

Some Vernier calipers are graduated in inches and fractions of inches on the back of the instrument, which enables the instrument to be used as a depth gauge.

When measuring dents on tubes, any of the following instruments may be used for measuring the depth—

1. Micrometer.
2. Outside calipers.
3. Depth gauge.

Where it is impracticable to use any of the above owing to the nature and position of the dent, plasticine can be used to take an impression of the dent, and the measurement can subsequently be obtained from this impression.

Another method is to have pop-marks on the jaws of outside calipers. Position the calipers in the dent and measure the distance between the pop-marks. Remove the calipers from the tube, and reset them to the measurement between pop-marks as obtained. Measure the gap between the jaws. This measurement, subtracted from the outside diameter of the tube, equals the depth of the dent.

Special orders are now laid down with regard to repairs on mass-balanced components. It is found that the added weight of rivets, patches, etc., was detrimental to the mass balance effect when the repair was carried out in the mass balance area. The various designs have their respective methods of repair but it is usual to fit a complete length of boundary tube to make the joint outside the affected area.

When fitting an old plug-end to a new tube, measure off as accurately as possible the pin holes from those on the old tube. Drill these undersize, fit the plug-ends, and ream out the tube holes to the correct size.

Cracked or disturbed enamel is a good guide for detecting damage to aircraft structures.

Fixed-ended struts are theoretically four times stronger than pin-jointed struts.

CHAPTER VI

USEFUL PRACTICAL INFORMATION

1. V-BLOCKS, surface plates, and marking-off tables are normally made of close-grained cast iron.

2. Use a brass scriber when scribing highly polished metals.

3. Graphite is a good lubricant for threads on duralumin bars.

4. To set a pair of spring dividers to a three-decimal-figure measurement, use the target marks on the Vernier calipers.

5. A set of taps comprises taper, second cut and plug.

6. Odd-leg calipers are useful for marking out rivet lines near the edge of a plate.

7. The minimum distance from the edge of a plate to the centre line of the first rivets is 1½ times the diameter of the rivet used.

8. The following letters refer to different types of fits and lengths—

A—Drill or standard fit.
B—Reamer fit.
A length—overall length of a wire.

9. Cast steel is used extensively for the manufacture of tools.

10. The normal angles for twist drills are—

Clearance angle 10°.
Cutting angle 59° each side of drill axis (118° total).

The clearance angle varies, but it is usually 7° for cast iron and 6° for mild steel, the maximum being 15°.

11. The teeth of a hacksaw blade should slope away from the handle of the frame when fitted correctly.

12. Files are measured for length minus the tang. They are usually made of cast steel.

Order of coarseness: rough, bastard, second cut, smooth and dead smooth.

New files should only be used on soft metals at first, gradually working up to harder metals.

13. Chisels are measured by the width of their cutting edge. The normal cutting angle is 60°, but the harder the metal to be cut the greater the cutting angle—75° being the maximum efficient angle.

14. Types of chisels—

(i) Flat—for chipping all flat and convex surfaces.
(ii) Cross cut—for cutting rectangular sectional grooves.
(iii) Diamond point—for clearing out corners.
(iv) Round nose, curved type—for cutting oil channels along the curved surface of a bearing.
(v) Round nose, straight type—for cutting oil channels along flat or convex surfaces.
(vi) Side—for chipping sides of keyways.
(vii) Cowmouth—for removing projections from interior of cored holes.

15. *Keyseat rule.* Used for marking out lines parallel to axes of tubes on round bars, which are in awkward positions. The accuracy of the tool is tested on a parallel test bar, by scribing lines along the edges of the keyseat rule, then reversing. If the scribed lines agree with the edges, the rule is true.

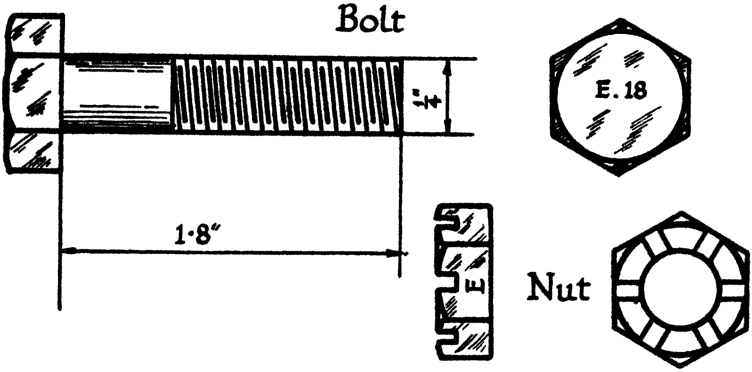


FIG. 44. MARKING ON B.S.F. BOLT AND NUT

16. *Taper Pins.* These may be locked in the following manner—

(i) Split ends opened out.
(ii) When threaded, using a nut and a split pin.
(iii) Burred over at the small end.
(iv) When threaded, using a nut and spring washer.

17. B.S.F. bolts are lettered and numbered for identification purposes. These are positioned on the head of the bolt. (See Fig. 44.) The letter denotes the diameter and the number length in tenths of an inch. The decimal point is omitted for obvious reasons. In this

case the bolt would be ¼ in. dia. and 1·8 in. long. A good method of memorizing the lettering is by the following passage—

Eat	Good	Jam	Leave	None
E	G	J	L	N
¼ in.	$\frac{5}{16}$ in.	⅜ in.	$\frac{7}{16}$ in.	½ in.

18. The high-pressure system is chiefly used for welding on account of the mobility and ease of maintenance. The two cylinders are identified by the colour of the release cocks—

Black for oxygen; Red for acetylene.

19. A strut which is difficult to test for suspected bow owing to protruding fittings, etc., may be tested by the use of a three-point trammel (adjustable type).

This operation is a simple matter in normal cases where the strut is in a position to accommodate a straightedge without removal of adjacent components. However, where this is not practicable, the following method may be used—

Obtain a three-point trammel with adjustable points. Set all points equidistant from straightedge to surface plate and lock in position.

Next, place trammel along bowed member and slide the points into positions that are convenient and, as far as possible, equally distributed along straightedge. Lock the slides in position.

With all the points touching the surface of the strut, the member would be straight, variation in truth being shown at the centre point which can be compared with its original length.

20. Examples of the use of threads are found as follows—

Buttress—in vices, for power in one direction.

Square—in aircraft actuating gears, for power and ease of control.

B.S.F.—where bolt is under shear stress.

Whitworth—where bolt or stud is under a tensile load (used in crankcases.)

Acme—in aircraft actuating gears and some types of lathes. Has the advantages of the square and V threads, without their respective disadvantages. (See Fig. 45.)

21. Taper pins are measured by length and the diameter of small end. They are a reamer fit. (The R.A.F. standard taper is 1 in 48. The American or Morse taper is 1 in 20.)

22. A practical method of obtaining drill sizes for tapping holes in

metal blocks is to choose the drill whose shank will be a sliding fit in the nut of the stud required.

23. A *plus thread* is when the thread stands proud of the shank of the stud or bolt.

A *minus thread* is as seen on a normal bolt, the thread being cut into the shank, thereby reducing the core diameter of the bolt or stud.

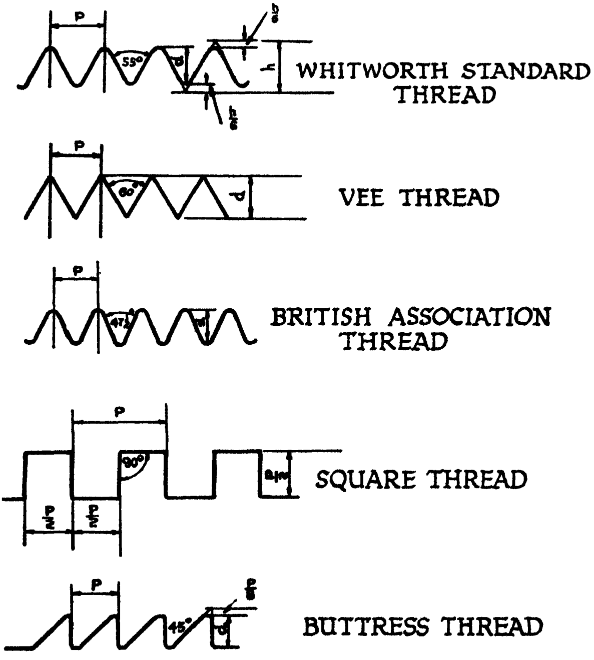


Fig. 45. Screw Threads

24. A metal mitre box will be found useful as a jig when a number of tubes have to be cut off at various angles.

25. The rivet size when riveting plates of unequal thicknesses together is determined by the thickest plate (2 to 2½ times the thickness of the plate equals the diameter of the rivet required).

26. When mating stainless steel threaded parts make sure that they engage freely with each other. It may be necessary to ease the female by use of a tap, the amount of metal which is to be removed being reduced to a minimum.

27. The method of measuring shackle pins is from the underside

of the head to the inner edge of the split-pin hole. The size ranges from ⅛ in. to $\frac{17}{32}$ in., rising in $\frac{1}{32}$ in.

28. A tube end may be squared by—

(i) A rosecutter,
(ii) A case-hardened jig,
(iii) By filing to scribed lines,
(iv) By turning in a lathe.

29. Grade A solder is composed of 2 parts of tin to 1 part of lead, the melting-point being 181° C.

30. Duralumin rivets must be normalized and used within one hour of final quenching.

31. The width of a lap on a lap joint is equal to 7 times the diameter of the rivet used.

32. Drills are numbered and lettered and are made in fractional sizes—

Numbered 1 to 60: No. 1, 0·2280 in.; No. 60, 0·0400 in. Lettered *A* to *Z*: *A*, 0·234 in.; *Z*, 0·413 in.

Fractional: $\frac{1}{32}$ in. to ⅜ in., for hand drills, rising in 64ths of an inch.

33. The letter A after a specification means that it is a forging.

The letter B after a specification means that it is a machined article.

34. *Studs and bolts.* Generally a bolt is screwed down 2½ times its diameter; thus, a ½ in. diameter bolt would be screwed for a distance of 1¼ in.

A tapping hole to receive a stud should be drilled to a depth equal to twice the diameter of the stud and the latter screwed into the metal a distance of 1½ times its diameter.

35. A cold chisel may be hardened and tempered by the "once heating" method as follows—

Obtain a piece of high-carbon steel, i.e. 9 per cent approx. Heat it to a bright cherry-red and forge to shape. Cease hammering at a dull red heat on the final working.

Heat the chisel for about one-third of its length to a medium red heat (750° to 800° C.). Quench about ½ in. of the tip, thereby hardening it.

Clean off the tip immediately, then allow the heat to run down from the body of the tool to the tip. Watch the colours. When a brown-purple colour appears at the tip, quench the whole tool. This results in the tip being hardened and tempered, and the body of the chisel remaining comparatively soft and tough.

When quenching, avoid an abrupt water-line by moving tool up and down slightly in the water.

36. The heat treatment of duralumin is normally carried out in the salt bath, the temperature for normalizing being 490°, plus or minus 10° C., and for annealing 360° to 420° C.

37. Methods of checking the temperature of a salt bath may be by means of a pyrometer, Seager cones or oxide paints.

38. Tubes, bars, etc., may be tested for cracks by application of hot oil followed by cleaning off the oil and smearing with chalk. The hot oil will ooze from the crack and show a thin line on the surface of the chalk.

39. Always make a gradual change of section when fitting patch plates. This avoids a weak spot in the vicinity of the repair.

40. Taps can be sharpened by grinding the cutting face of the groove on a small emery wheel.

41. Repeated grinding of a tap will result in the tap cutting a smaller thread, but within certain limits no harm is done.

42. The main precaution in tapping is to ensure that the tap enters the hole squarely—check this by means of a fitter's square.

43. It is advisable to countersink a hole slightly before tapping as the action of tapping causes a swelling around the hole.

44. A good hint when using dies is to slightly taper the end of the bolt or rod. This prevents what is commonly known as a "drunken" or "twist" thread. Hob taps are used for recutting solid or adjustable dies. The long tap is used first and the smaller one to finish the threads off to correct size.

45. When a thread has to cut up to the head of a bolt it will be necessary to turn the die over to finish the last few turns.

46. Always remove the anti-corrosive coating from a rod or bolt on the portion you are to cut the thread on. This avoids clogging of the dies.

47. Locking nuts on aircraft bracing wires are made of cast iron or brass. Landplanes may use either, but only brass is used for marine craft.

48. The reason for making these of the above materials is to avoid damage to the threaded portion of the wire in the event of overtightening the locknut, and in the case of brass, it resists corrosion. Locknuts are normally half the thickness of ordinary nuts.

49. The size of a U-shackle is governed by the size of the cotter pin used.

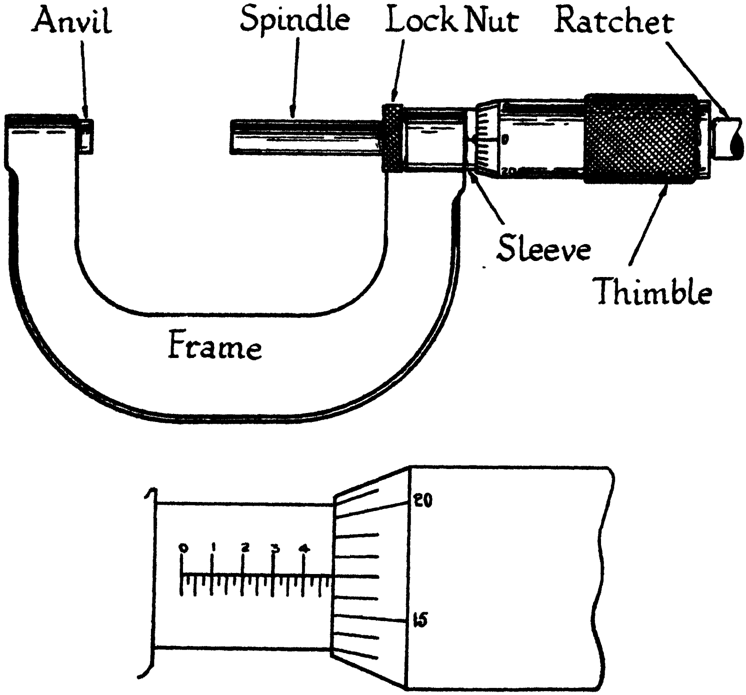
50. Stainless steel fork-joint fittings for aircraft bracing wires are identified by their bright finish, having no shoulder and the letters S.S. after the part number.

High-tensile steel fork-ends are marked by a groove cut around periphery of shoulder and part number.

High-tensile steel (stainless) is marked similar to stainless steel, but also has a groove where the shoulder should be.

51. Calcined borax makes a good flux for brazing.

52. Lamp-black should be smeared on parts not requiring brazing when using a brazing bath.



READING ·492″

Fig. 46. The 0 to 1″ Micrometer

53. Radial scratch lines running from the centre of the job assist the spelter to run into it.

54. The principle of a micrometer is: The spindle has 40 threads to the inch and the thimble is divided into 25 equal parts around the circumference of its bevelled edge. The sleeve is divided into tenths, each being subdivided into four. Thus, rotation through one thimble division produces an axial movement of the spindle of

1/25th of 1/40th, which equals 0·001 in. along the sleeve. (See Fig. 46.)

55. A micrometer is used for defining accurate measurements to 0·001 in. *It is a precision instrument.*

56. *Soldering fluxes.* Non-acid fluxes are to be used when carrying out any soft soldering or sweating operations on aircraft. This is to avoid any subsequent corrosion of the part at or near the soldered joint due to the action of mineral acid.

The following test should be carried out where any doubt exists as to the purity of the flux:

First, dilute with an equal volume of water and dip methyl orange paper into the solution. If the paper turns pink in colour

CUTTING LUBRICANTS

Metal	*Lubricants used*	*Remarks*
Ordinary steels	(*a*) Soluble oil mixture (*b*) Soft soap and water mixture	(*a*) Often referred to as "Economy mixture" (*b*) Referred to as "Slurry"
Air-hardening steels	Turpentine and engine oil mixture—borax and lard oil mixture	
Stainless steels	Soluble oil mixture or thin engine oil	Austenitic stainless steel requires great care when being cut owing to work-hardening tendencies in the vicinity of the cut
Cast steel	Lard oil—soapy water solution	
Cast iron	None	Self-lubricating
Copper	Crude petroleum and lard oil mixture—soapy water mixture	Milk is sometimes used for fine work
Brass	None	A tool lubricant is sometimes required to prevent blueing. Soluble oil mixture is recommended
Bronze	None	
Magnesium alloys	None	A large cut at a fast speed is recommended
Light alloys	Turpentine	Paraffin may be used if fire precautions are taken

the presence of acid is indicated and the flux must not be used for aircraft parts.

57. *Tightening of Locknuts and Nuts on Aircraft.* Great care must be taken when tightening nuts or locknuts on aircraft to avoid distortion, etc., and subsequent failure of the part concerned.

The correct size of spanner should be used to avoid over-leverage and for normal use the following table, giving the length of spanner for the various diameters of bolts, will be found useful.

Diameter of Bolt	Length of Single-ended Spanner	
	B.S.W.	B.S.F.
¼ in.	5 in.	3½ in.
⅜ in.	6 in.	5 in.
½ in.	8 in.	6 in.
⅝ in.	9 in.	8 in.
¾ in.	10 in.	9 in.
1 in.	15 in.	12 in.

Avoid the use of box or tube spanners wherever possible as these permit the imposition of bending loads.

58. *Exploded View.* This is a view of a component which has several internal parts. The internal parts are shown exploded outwards from the main external component, in their correct order of assembly. This type of view is very useful in saving explanatory detail, the view itself giving the sequence of assembly.

59. *Fretting Corrosion.* This type of corrosion is found in ball races and on airscrew shafts, etc. It is a mutual corrosion and deterioration of metal surfaces which are in close-fitting contact with each other, and at the same time are subject to vibration. The vibration is an essential condition in the cause of this corrosion. The pressures between the two surfaces are sometimes increased with a view to preventing this type of corrosion.

60. *Engine-driven Instruments.* Where engine-driven instruments are used on aircraft, as in the modern monoplane, trouble is often experienced with the separator box throwing out excess oil. This trouble can be overcome by detaching the outlet pipe and cleaning the small gauze filter. The filter is very small, and it may be necessary to pierce the mesh with a fine needle, but care must be taken not to enlarge the mesh.

CHAPTER VII

METALS AND EXPLANATIONS

METALLURGY, as a subject, is so complicated and extensive that it is obviously a matter for endless study; therefore, unless the would-be metal fitter is warned, he will probably find himself the owner of a number of expensive books without the slightest hope of gaining any knowledge from them which will be directly useful to him in his trade.

As an elementary knowledge of this subject is really all that is necessary, it is only intended to touch on the points that are essential and useful.

How Steel is Obtained

For aircraft steels, a good class of *iron ore* is obtained, placed in a blast furnace and smelted. This process gives us pig iron, which is the base for making steel.

Pig iron is of little use from the mechanical point of view owing to the presence of numerous impurities. These impurities are removed by various processes, the most popular being known as the "Bessemer." This is a method by which air is blown through a molten mass of pig iron, burning out the carbon, silicon, and manganese which are present, and maintaining sufficient heat to keep the metal in a molten state, thus enabling it to be poured into ingots. After the metal is completely decarbonized, Spiegel and ferro-manganese are added according to the quality of steel required.

A straight carbon steel is one which owes its main properties to its carbon content and is a compound of iron and carbon.

Carbon steels are graded as follows—

(0·25 per cent carbon content)—*low* carbon, or mild steel.
(0·25 per cent to 0·7 per cent carbon)—*medium* carbon steel.
(0·7 per cent to 1·5 per cent carbon)—*high* carbon steel.

Heat Treatment of Steels

By careful heat treatment the mechanical and physical properties of a steel may be varied considerably and it is largely because of this property that steel is used more extensively than any other material or alloy for engineering purposes.

During heating or cooling of a steel, certain temperatures, known as "critical" temperatures, are observed. This denotes change points in the condition of the steel and on these points depends the success and operation of the heat treatment.

There are three general heat-treatment operations—

1. Hardening.
2. Tempering.
3. Annealing.

Normalizing, which is akin to annealing, and case-hardening are also important. The object sought in each of these operations is to change the existing properties of the steel to meet a particular requirement. The controlling factor in each case is temperature, and there is a definite temperature for each particular steel which gives the best result for any one heat treatment.

Hardening. Steel possesses the property of becoming very hard when quenched from a suitable temperature. In straight carbon steels such hardening is only effective if the carbon content is above 0·25 per cent and the degree of hardness attainable increases as the carbon content increases above this value. In practice, hardening is usually confined to steels having a carbon content between about 0·4 per cent and 1·2 per cent.

The first operation is to heat to the required temperature for this particular steel. Care must be taken not to keep the steel too long at this temperature, otherwise a coarse structure will result. Furthermore, uniformity of temperature must be secured, since irregular temperatures produce irregular hardening, and, on quenching, cracking will occur. The rate of quenching controls the degree of hardness attained in a particular steel. When maximum hardness is required, cold water or brine solutions, both of which give a rapid rate of cooling, are used. When maximum hardness has to be sacrificed with a view to avoiding brittleness, the steel is quenched in oil.

Large pieces of steel cannot be cooled very rapidly by quenching, and in certain cases the rate of cooling is not sufficient to secure the hardening of straight carbon steels. This difficulty is overcome by the use of special steels, some of which possess self- or air-hardening properties.

The hardening treatment produces in the steel—

(*a*) Small grain size.
(*b*) Maximum hardness.
(*c*) Maximum tensile strength.
(*d*) Minimum ductility.
(*e*) Internal strains.

Tempering. In order to release the strains mentioned above, and decrease the brittleness whilst still preserving sufficient hardness and strength, the metal is generally tempered.

The tempering operation consists in heating the hardened steel to a temperature just below its lower critical point, depending upon the use to which the finished article is to be put.

By tempering at about 200° C. brittleness is considerably reduced; at 300° C. the hardness is considerably affected, and above this temperature, softening of the steel begins to take place rapidly.

The well-known temper colours on the surface of hardened steel, which has been tempered in air, are due to the formation of an oxide film. These colours indicate approximately the amount of temper a hardened steel has received.

In the case of carbon steels, the rate of cooling from the tempering temperature has little influence on the resulting properties of the steel, provided it does not cause internal stresses by irregularity or rapidity of cooling.

Temper Colour Chart

The following colours are caused by the formation of a thin film of oxide produced by the action of the oxygen in the air and the heat and carbon in the metal—

Colour	*Degrees C.*	
Very light straw	220	
Light straw	225	
Pale straw	230	
Straw	235	
Dark straw	240	
Dark yellow	245	
Very dark yellow	250	
Yellow-brown	255	
Yellowish-brown	260	
Reddish-brown	265	
Brown purple	270	
Light purple	275	
Full purple	280	
Dark purple	285	
Very dark purple	290	
Full blue	295	
Dark blue	300	
Red	582	Film-colouring ceases after Dark Blue, when the appearance of Black Oxide signifies the approach of red heat.
Dark red	704	
Cherry-red	788	
Bright cherry	982	
Light orange	1093	
White	1316	
Brilliant white	1399	
Dazzling white	1499	

Annealing. In general, to anneal means to soften or toughen by heating, but in the case of steel, annealing has several specialized meanings in order to distinguish it from tempering.

Its properties may be

(1) to increase the ductility of the material before further drastic mechanical work;

(2) to relieve internal stresses caused by such work, in which cases the maximum temperature may be arbitrarily chosen;

(3) to refine the crystallized structure, in addition to (1) and (2), in which case the temperature must exceed the upper critical range.

Normalizing. When a steel is heated (however previously treated) to a temperature exceeding the upper limit of the critical range, and allowed to cool freely in the air, it is said to have been normalized. The object of normalizing is to relieve the internal stresses and strains which have taken place while working the metal. Normalizing restores the crystalline structure to its normal condition. Note that for steels containing more than 0·9 per cent carbon, the maximum temperature should only just exceed the lower critical point.

The higher rate of cooling used in normalizing results in a structure which differs from an annealed structure in that—

(1) the grain size is smaller than in the annealed condition; and

(2) the character of the pearlite is known as "sorbitic pearlite," which confers on the steel a high elastic limit and considerable hardness.

Case-hardening. This treatment is applied to give a low carbon steel a higher carbon content on the surface with a tough mild steel core. The case resists abrasion and wear, whilst the core provides the necessary strength and toughness to resist shock (e.g. gudgeon pins, gears, etc.).

The first operation is to carbonize the surface of the material by heating it to redness surrounded by some carbonizing medium. The nature of this medium controls the amount of carbon absorbed. A well-known medium is made up of 60 per cent wood charcoal and 40 per cent barium carbonate.

Case-hardening by the nitrogen process. In this process the steels are case-hardened by exposure to the action of dry ammonia gas at a temperature of 500° C. The steels used in this form of case-hardening are known as nitro-alloy steels and contain aluminium or chromium, or both.

The articles are first heat-treated to produce the mechanical properties in the core, and then machined to finished dimensions.

They are then thoroughly washed to remove grease and packed in a gas-tight chamber. The articles rest on wires or netting to expose the whole surface to the action of the gases, and any part which is not desired to be hardened is tinned with a solder of 80 per cent lead and 20 per cent tin.

When packed, the box is placed in the furnace and its temperature raised to 500° C. A steady stream of gas is passed through the box from the commencement of heating and is continued until the temperature falls to 150° C. on completion of the process. A temperature of 500° C. is maintained for a period of from ten to ninety hours, for producing a case thickness of from 0·006 in. to 0·030 in.

The steel is refined automatically and there is no final quenching—consequently no distortion. The case is harder than that of a steel case-hardened in the usual method.

Alloy Steels

These are steels containing carbon and, in addition, one or more other elements. The addition of these elements confers special physical properties such as increased strength in nickel steels, increased hardness in nickel-chrome steels, and resistance to corrosion in chromium and high nickel-chrome steels. The carbon content in these steels is usually low.

Nickel Steel. The nickel steels used in engineering practice contain from 3 per cent to 5 per cent of nickel. The addition of nickel to ordinary low carbon steel has the effect of increasing the toughness, and consequently such steels are extensively used for work which requires to be case-hardened. The presence of 27 per cent nickel leads to non-magnetic steel and is almost non-corrodible.

Nickel-chrome Steels. Chromium confers a fine grain structure and strengthens the nickel steel, especially against shock loading. In case-hardening steels, the chromium increases the penetration and gives greater hardness. The high-tensile steels used in aircraft normally contain 3 per cent to 5 per cent nickel and from 0·5 per cent to 1·5 per cent chromium. Air-hardening steels have a fairly high percentage of chromium, usually about 1 per cent and up to 1·5 per cent. Chromium is non-magnetic and when present in steel above 12 per cent, the alloy is known as Stainless Steel.

Tungsten, Vanadium, Cobalt and Molybdenum Steels. The addition of tungsten to carbon steel and other alloy steels enables them to be hardened to a high degree. Most of the *high speed steels* contain tungsten, from which they obtain their exceptional cutting properties.

When cobalt and chromium are alloyed with carbon steel, special characteristics are imparted, such as non-scaling at high temperatures, non-corrodibility and air-hardening. This alloy is therefore often used for the manufacture of exhaust valves, cutters, dies, etc. The addition of cobalt to a high carbon steel produces an alloy which has exceptional magnetic properties.

Molybdenum has an influence on the physical properties and on the structure of steel similar to that of tungsten, but the influence is more intense.

Vanadium is added in smaller quantities to impart fatigue-resisting characteristics. *Spring Steel* is usually a straight carbon steel of 0·9 per cent carbon content, containing about 0·2 per cent of vanadium so as to resist the high alternating stresses and such shocks to which it may be subjected.

Manganese Weldable Steel. Steel containing approximately 1·5 per cent manganese with a mild steel base is used extensively for aircraft *welded* structures. The manganese content causes the steel to lend itself easily to fusion welding and in effect is self-normalizing by refining the grain of the metal on the solidification of the weld.

The strength of the metal never falls below 66 per cent of its original, previous to the operation of welding.

Heavy Alloy

This alloy is one of the more modern introductions to the metallurgy side of aviation.

It is of the Powdered Metallurgy class, and the development of this class of metallurgy should give impetus to the progress of metal aircraft design, where materials of construction need to possess so many important qualities.

The alloy contains 90 per cent tungsten, 4 per cent copper, and 6 per cent nickel. It is highly resistant to salt water and atmospheric corrosion, and is used for balance weights on variable-pitch airscrews, etc. It has a high density, and thus less bulk is required; it does not have the tendency to creep the same as lead, and its tensile strength is much higher (40 tons per square inch).

Machining of this metal can be carried out by the use of the ordinary cutting tools, and therefore no special tools are required. Brazing and silver soldering can also be carried out without detrimental effects. Soft soldering, however, is very unsatisfactory, but this difficulty is now being overcome with the aid of special methods.

Non-ferrous Metals and Alloys

Brass is an alloy of copper and zinc, with generally small percentages of tin and nickel. Muntz metal—60 per cent copper and 40 per cent zinc—is a typical example.

Bronze is an alloy of copper and tin. The strongest alloy contains 9 per cent tin, and the bronzes used in general engineering contain 8 to 11 per cent tin and 2 per cent antimony, when they are known as "Gunmetal."

Phosphor Bronze is an alloy of copper and tin with about 1 per cent phosphorus. This addition produces an alloy much stronger than ordinary bronze and is used for bushes and high duty bearings.

Nickel (*Ni*). Silver-white in colour; specific gravity 8·0 and melting-point 1450° C. It is a hard, ductile metal which does not show tarnish in dry air. Nickel is somewhat similar to iron in that it is magnetic, weldable and influenced by carbon.

Chromium (*Cr*). A hard, grey metal; specific gravity 6·5 and melting-point 1615° C. It is non-magnetic. Confers air-hardening properties on alloy steels.

Zinc (*Zn*). Bluish-white in colour; specific gravity 7 and melting-point 419° C. It is ductile and malleable, and is much used in the formation of brasses and for coating iron and steel (galvanized iron).

Soft Solders. These are alloys chiefly consisting of tin and lead, but sometimes other metals, such as bismuth, are added to reduce the melting-point. The solder can be classed into three groups—common, medium and fine—according to the tin content. The quality is improved by the increased percentage of tin. Grade "A" is used extensively for aircraft. This contains 2 parts tin to 1 part lead, and its melting-point is 181° C.

Brazing spelter. The alloys used for brazing are composed of copper and zinc. A common brazing spelter is made up of 50 per cent copper, and 50 per cent zinc, having a melting-point of 880° C.

Aluminium Alloys

Duralumin. Composition: copper, 3·4–4·5 per cent; magnesium, 0·5–1·0 per cent.; manganese, 0·5 per cent; and silicon, 0·5 per cent—present as an impurity.

This important aircraft alloy is composed of an aluminium base with copper, manganese, magnesium and silicon. The tensile strength is about 28 tons per sq. in. and it has a specific gravity of

2·85. This alloy is generally used in the worked condition. It can be hardened by quenching, but it is a peculiarity of this and other aluminium alloys that the hardness that develops on quenching is not final. There is a gradual increase which goes on for an indefinite period, but which, for practical purposes, reaches a maximum in four or five days.

Duralumin offers a marked resistance to corrosion when in the fully age-hardened condition and this useful characteristic can be intensified by the process known as Anodizing. It is malleable and ductile, and can be forged at a temperature of from 400° to 450° C.

Alclad. The aluminium coated duralumin sheet, first produced commercially under the name of Alclad, consists of a sheet of duralumin, each surface of which is covered with a coating of aluminium firmly alloyed to the underlying duralumin. The tensile strength of the coated sheet is, as would be expected, somewhat less than that of a normal duralumin sheet of similar thickness.

Sheet aluminium is hot-rolled on the duralumin during the manufacture of this alloy.

Y Alloy. This contains 4 per cent copper, 2 per cent nickel, and 1·5 per cent magnesium, the remainder aluminium. It was first developed as a casting alloy, but is now used for rolling and forging. The alloy can be heat-treated to give properties practically equal to those of duralumin and has been found to show considerable resistance to corrosion.

Duralumin and Alclad—Heat Treatment and Working

1. The name "Duralumin" refers to certain alloys of aluminium, e.g. Alclad, which is subjected to the same conditions of working.

2. To ensure the best and most consistent results in parts made of duralumin, the following procedure must be carefully observed in respect of its manipulation and heat treatment.

3. All material for service use is supplied finally heat-treated—that is in the normalized and aged condition—and in this condition is suitable for machining, cutting, drilling and, to a limited extent, bending.

4. The following table shows the minimum radius of bending which will be permitted for sheet and scrap material of various gauges in different conditions of heat treatment.

Condition	Minimum Radius of Bending			
	18 S.W.G. and thinner; radius of bend		Thicker than 18 S.W.G.; radius of bend	
	Through 120° or less	Over 120°	Through 120° or less	Over 120°
Fully annealed . .	½ T	1 T	½ T	1 T
Normalized within 1 hour after quenching . .	½ T	1½ T	1½ T	2 T
Normalized and aged .	2 T	3 T	2½ T	3 T

5. The method of re-normalizing and carrying out bending within one hour after quenching should be adopted only for simple one-operation bending. For more severe work the parts must be annealed, and it is most important that mechanical work be done as soon as practicable after annealing as annealed parts will harden slightly during the course of time, especially when the annealing temperature is over 350° C.

6. The heat treatment of duralumin can be carried out conveniently in a bath of suitable molten salt, or in muffles or other furnaces.

7. The most convenient liquid bath is produced by a suitable fusible mixture of salts, and a very satisfactory bath for the immersion of duralumin can be made by mixing together equal portions of sodium nitrate and potassium nitrate.

(8) *Annealing.* The duralumin must be heated uniformly to a temperature between 350° and 420° C. When the material attains the required temperature, it should be cooled slowly or quenched in water or oil, whichever is the most suitable for the work.

(9) *Final heat treatment or normalizing.* To secure maximum results in strength and ductility, *parts which have been annealed must be normalized.* The temperature of the bath, muffle or furnace must be maintained at 490° C. (± 10° C.). When this temperature is attained uniformly throughout, the parts are removed and immediately quenched in cold water. They are in a soft condition, but gradually harden up and after a period of four days, the maximum properties are attained. This is called ageing. The normalizing temperature must be carefully controlled owing to the danger of overheating the material and rendering it brittle.

(10) *Periods of soaking for normalizing.* When a salt bath is used it must be heated to a temperature of 490° C. (± 10° C.) previous

to the immersion of work. The parts must be suspended and completely submerged. If they are too small to be suspended individually (e.g. rivets), they must be put in a container, the sides of which are perforated to obtain a free flow of the salt. The time of soaking must be such that the whole of the material reaches the desired temperature.

The actual time varies according to the thickness of section, but the following table may be taken as a guide—

Sheet and strip . .	Not less than 15 min.
Rivets	,, ,, ,, 15 ,,
Bars and thick sections .	,, ,, ,, 30 ,,
Heavy forgings . .	,, ,, ,, 3 hr.

(11) *Rivets.* The rivets must be normalized and riveting carried out within one hour after quenching.

(12) *Washing after treatment.* The material, after heat treatment in a salt bath, must be washed and scrubbed in a bath of running water, preferably hot, to ensure the removal of the salt. Failure to carry out thorough washing will result in the subsequent corrosion of the work. After washing, the material must be dried thoroughly.

Alpax. This is an aluminium base alloy containing 10 per cent to 14 per cent silicon which greatly assists fluidity when making castings.

Copper (*Cu*). Copper is reddish-brown in colour, with a specific gravity of 8·9 and a melting-point of 1085° C. It is ductile, malleable and very tough. The tensile strength is about 15 tons per sq. in., but this may be increased by cold working, though the metal is rendered hard and brittle. After work-hardening, copper may be restored to its original toughness by annealing. This is done by heating to 650° C. and either cooling in air or quenching in water.

Aluminium (*Al*). Tin-white in colour; specific gravity 2·67 and melting-point 657° C. It is the greatest of all useful metals with the exception of magnesium. It is soft, ductile, malleable, and when pure, is practically resistant to corrosion. Commercially, pure aluminium has found only restricted use in aircraft on account of its relatively low strength compared with that of aluminium alloys. On account of its useful working properties it has been used for engine cowlings, fuel tanks, instrument cases, etc.

Although aluminium can be soldered effectively, the use of solders for joining aluminium has been restricted by the relatively poor resistance to corrosion of the soldered joints. Welding has proved a more suitable method; there is no marked tendency towards corrosion and the art of welding aluminium in the aircraft industry has attained a very high standard.

Tin (*Sn*). White in colour; specific gravity 7·3 and melting-point 232° C. Is very malleable and can be rolled into very thin sheets. Used for coating iron and steel plates (tin plates) and in the manufacture of alloys.

IDENTIFICATION OF LIGHT ALLOYS

Metal	*Test and Effect*
Duralumin.	Turns black on application of caustic soda solution.
Alclad.	Shows a black core in section on application of caustic soda solution.
Aluminium.	Turns white and powdery on application of caustic soda solution.
Magnesium Base alloys.	Test by placing shavings of the metal in the fire—these shavings give an orange flash similar to a wing-tip flare flame.

The Salt Bath

The primary use of this bath is for the heat treatment of duralumin. By this method, a uniform temperature can be maintained by immersing the job in a bath of molten salts. Normally, these salts consist of 50 per cent sodium nitrate and 50 per cent potassium nitrate.

Small baths are made of cast iron, whilst large ones are made of mild steel welded plates.

The method of heating the salts is by oil, gas or electrical furnace.

Pyrometers are used to determine the temperature. These have readings of 0° to 600° C.

The bath should be cleaned out once a working month, and should be kept about three-quarters full of the salts.

When re-heating the nitrates, the crust must be broken up to avoid volcanic explosion.

Safety Precautions

1. The plant is highly dangerous—remember that when working it.
2. On no account must the salts come into contact with the skin, as although these salts look like ordinary warm water, their temperature is probably 480°.
3. In the event of the blower failing, turn off the oil immediately.
4. If a fire occurs in the shop where a salt bath is in use, the shop should be vacated immediately and the fire dealt with from the outside of the building.
5. All jobs must be thoroughly clean and dry before being placed in the bath.
6. Leave a clear exit in case of accidents.

7. Do not inhale the fumes.
8. Keep your eyes protected against any possibility of a splash causing the salts to enter your eyes.

The Age-hardening of Duralumin

The hardening of this alloy is due to the presence of copper, magnesium and silicon.

The operation necessary to effect this change is called normalizing, which consists of heating the alloy to a temperature of 490° C. (± 10° C.) and then quenching in water immediately. It will be found that, on quenching, the metal is soft and easily workable. It does *not* remain in this condition, however, but becomes harder and increases in strength. This change continues for an indefinite period, but for practical purposes, the required hardness and strength is reached three to four days after final quenching, hence the term age-hardening, the metal hardening as it ages after being normalized. It is usually in this condition that the sheets of duralumin or alclad are issued for normal use. The sheets are stamped with an N to verify this.

We know now what the term age-hardening means and when it takes place; but what happens to the structure of the metal to bring about this change?

The alloy was made up with a certain excess of copper and magnesium. The amount of copper that can normally be held in aluminium when in solid solution is between 1 to 2 per cent. However, on being heated to certain higher temperatures, 4 to 5 per cent can be absorbed and also retained in solid solution on quenching. This surplus is subsequently precipitated in very fine particles around the crystal boundaries in the form of a chemical compound, therefore giving hardness by resisting any plastic deformation by slip.

So much for the copper. We now turn our attention to the magnesium. In aluminium, an element known as Silicon is present. The excess of magnesium (approximately 3 per cent), combines with the silicon and forms a compound—the same phenomenon taking place in the case of the copper. It must be clearly understood that this change only takes place when the metal is heated to the normalizing temperature, which must be uniform and not exceeded, otherwise there will be a grave risk of ruining the metal.

Air-hardening Steels

These steels are now used very extensively in aircraft construction. Their outstanding advantage is that there is no distortion due to final quenching, which would occur in normal steel. It will be appreciated that this is a great asset when considering such components as main plane spars, where distortion on a long length of spar would be very detrimental to the efficiency of that member.

Air-hardening is brought about by adding alloying elements to steel; these alloys affect the position of the critical points during heat treatment. In air-hardening steels the recalescence point is retarded and occurs at such a low temperature that, on cooling through this point, the steel is too cool and too rigid for the soft constituents to form, and consequently the steel is hard.

Austenitic Steel

Here we have a steel which appears to confuse the average student, and after a thorough investigation as to the cause of the confusion, the following conclusion has been reached.

An austenitic steel must not be confused with the austenitic *condition* of a straight carbon steel.

Austenitic steel is a stainless alloy steel, and is brought about by the addition of large quantities of alloying elements. The recalescence point is retarded to well below atmospheric temperature and the steel is in an austenitic condition. Therefore it is fairly soft and can only be hardened by cold work.

It is a steel which is highly resistant to corrosion and is used for planing bottoms of flying-boats and aircraft fittings.

This steel contains 12 per cent (min.) chromium and 6 per cent (min.) nickel.

One feature about the steel is that ordinary acids do not affect it.

Heat treatment is by annealing only—by heating to 1000° C., and air cooling or quenching, which leaves the metal soft and tough.

Temper Brittleness

Nickel-chrome steels are subject to a phenomenon known as "Temper Brittleness." This is found when the steels are heated to their respective tempering temperatures and *cooled too slowly* from these temperatures.

When specimen test pieces are tested they give low impact figures, if temper brittleness is present, but if the steels are cooled quickly, their impact value is not depreciated. In recent years, manufacturers have added varying quantities of molybdenum which counteracts this phenomenon and also increases the resistance to corrosion of the steel.

The reader is advised to avoid confusing the above with ordinary tempering of straight carbon steel.

Corrosion

One of the greatest enemies of metal aircraft is corrosion and an infallible remedy has yet to be found for the majority of ordinary metals.

Materials used on aircraft which demand the greatest care from the aspect of corrosion are ordinary steels and light alloys. Steels are used in much thinner gauges than other materials on account of their greater tensile strength, and are therefore more susceptible owing to this cause.

Light alloys which have as a base either aluminium or magnesium are inherently unstable metals and, given an opportunity, corrode very quickly. The corrosion which occurs in these materials is not always attributable to exterior causes, but it may be due to the interaction between impurities in the metal.

In both steels and light alloys, the basic principle of protection against corrosion is to exclude the air from contact with the metal. If, therefore, corrosion is to be avoided, it is imperative that the protective covering should remain intact.

The types of corrosion which occur are surface corrosion and that due to an electrolytic interaction (called intercrystalline corrosion) between dissimilar constituents of the metal.

Surface corrosion is usually easily recognizable as a visible form of oxidation and is mainly produced by external conditions, such as humidity or the presence of sea air or water.

The intercrystalline form of corrosion, however, is not easily recognized in its early stages as it affects the internal structure of the material, but as surface corrosion or pitting usually accompanies intercrystalline corrosion, some indication is afforded.

Protection of Steel Parts of Aircraft

Stainless Steels. It is now recognized that the high form of resistance of these steels to corrosion is due to the protective effect of the films which form under normal conditions of use upon the exposed surface and to the rapidity with which such films form again at places where the rupture of the original film occurs by reason of chemical attack or mechanical breakdown.

The addition of special elements to a steel, notably chromium, produces a high degree of resistance to corrosion, and so this may be regarded as the application of a method of protection.

Steel. Stoving enamels have found extensive application and have been found satisfactory when good quality enamel is applied under appropriate conditions and properly stoved.

Pigmented oil varnishes have been used with satisfactory results except in cases of exposure to severe conditions. Good adhesion, however, is difficult to attain except with sand blasting, but this produces an open surface much more susceptible to corrosion than a machined surface and so reduces the protective effect of the enamel.

Lanoline solutions afford protection to steel parts not exposed to severe influences.

For protection of steel parts, zinc or cadmium coatings are extensively used in British aircraft.

Cadmium Plating. Electro deposits of cadmium on steel parts have been found to be capable of affording a high degree of corrosion resistance, particularly when mechanical abrasion or severe exposure and other influences of the weather do not occur.

The process consists in the electrolytic oxidation of the surface of the steel by treatment in a solution of potassium and cadmium cyanide. The part to be treated forms the cathode, the anode being of good quality cast cadmium.

All parts must be thoroughly cleaned prior to dipping by means of sand blast, hot caustic baths, etc.

Zinc Plating. The electro deposits of zinc are usually harder than those of cadmium and are slightly more durable under normal conditions of use.

Heating Processes. Zinc coatings can be produced by the hot diffusion or "Sherardizing" method. The treatment consists of heating the parts for several hours in sealed containers filled with a mixture composed essentially of zinc oxide and finely divided metallic zinc. A coating of metallic zinc is deposited on the steel and actual diffusion of the zinc into the steel occurs.

The protection by this means is not quite so good as that afforded by electro-deposited zinc coatings.

Calorizing Process (protection against oxidation at high temperatures). The steel parts are thoroughly cleaned by sand blasting or other suitable means, and are placed in a sealed container with a mixture consisting of aluminium powder, aluminium and ammonium chloride. This is heated to approximately 680° C. for one to two hours, when an aluminium alloy layer is formed on the surface of the steel.

The prevention of scaling of exhaust pipes and manifolds, etc., can also be effected by means of aluminium dipping or nickel plating.

Protection of Aluminium and Aluminium Alloys

A process which has been found capable of affording considerable protection to aluminium alloys against corrosion is that of anodic oxidation.

The degree of protection is greatly enhanced by an additional covering, depending on the conditions, of non-acid oil or grease such as lanoline, or by a coat of cellulose enamel.

Anodic Treatment—Duralumin. The process consists of the electrolytic oxidation of the surface of the alloy by treatment in a solution of chromic acid. A bath is prepared consisting of 3 per cent chromic acid with distilled water. The part to be treated forms the anode, the cathode usually being of graphite.

The bath is raised to a temperature of 40° C., with parts ready in position and all electrical connections made, and the current is gradually raised to 40 volts in 15 minutes. This voltage is maintained for 35 minutes, then gradually raised to 50 volts for 5 minutes. The current density should be from 3 to 4 amps. per sq. ft. of treated surface.

Summary of Anti-corrosive Processes

Ferrous Alloys. Cadmium plating, zinc plating, stove enamelling and air-drying enamels.

Magnesium Alloys. Chromate immersion, followed by cellulose enamel.

Aluminium and Aluminium Alloys. Anodic treatment, stove enamelling and air-drying enamel.

Brass and Bronze Alloys. Cadmium plating, stove enamelling and air-drying enamel.

Note. The cadmium bath differs from the anodic bath in that the centre brass rail is the cathode, and also in the constituents, for the film is not extracted out of the job, as is the case with anodic treatment, but is a " plating "-process.

Zinc plating is similar to cadmium and differs only in the constituents of the bath and the current. Its constituents are Zinc Cyanide (12 oz.), Sodium Cyanide (6 oz.), and Caustic Soda (4 oz.), to each gallon of *distilled water*.

The anode should be of good quality zinc and the current density should be 2 to 4 amps. per sq. ft. of cathode, with a voltage from 3 to 5.

Definitions

Decalescence Point is the magnetic loss point of steel. Whilst heating the steel, it is observed to suddenly glow less brightly and if held by a magnet, the steel would drop at this point. It is also known as the Upper Critical Point.

Recalescence Point is the point on cooling when the steel regains its magnetism and is observed suddenly to glow more brightly. It is also known as the Lower Critical Point.

Critical Range. The range of temperatures between upper and lower critical points of any steel.

Austenitic Condition is when the structure of the steel goes into solid solution on reaching its upper critical point.

(*N.B.* When heating, this must not be confused with Austenitic stainless steel.)

Pearlite. A constituent in steel consisting of alternate laminæ of iron and iron carbide. A very pure steel contains 0·9 per cent. Known also as softening carbon.

Cementite. The structure of a high-carbon steel consists of pearlite with an excess of carbon. This excess is known as cementite or hardening carbon.

Martensite. Steel which has been *suddenly* quenched from the austenitic condition at a temperature well above the decalescence point. It is a hard and brittle metal, very magnetic.

Sorbite. A constituent of steel, very strong and tough. It is obtained by quenching a pearlite steel in warm oil and by other methods.

Refining. An operation necessary after case-hardening. Prolonged heating at the carburizing temperature (approximately 900° C.) causes the mild steel core to have a coarse structure. Also, the high-carbon skin requires hardening. A double treatment is therefore necessary—one to refine the mild steel core and the other to harden the high-carbon steel skin.

This treatment usually consists of heating to 860° C., air cooling or quenching to refine and toughen the core, then finally heating to 750° C. or 800° C. and quenching to harden the case.

Spiegel and Ferro-manganese. These elements are added to the steels during manufacture by the Bessemer process. After the metal is fully decarbonized, these elements are added to give the required carbon and manganese content.

Spiegel is added in a molten state; ferro-manganese is added cold or at a red heat.

Eutectoid. A 0·9 per cent carbon content steel is a good example of a eutectoid steel. It is the absorption point of one element into another at room temperature. Sometimes referred to as the Saturation Point.

Eutectic. An alloy which has the lowest melting-point of any of its series. A good example is Grade "A" solder, which melts at 181° C. Tin, one of its alloys, melts at 230° C. Lead, another of its alloys, melts at 325° C.

Ductility. The property of being permanently extended by a tensile or stretching force.

Tenacity. The property of resisting fracture when under the application of a tensile force.

Malleability. The property of being permanently extended or flattened when worked under the hammer or rolls.

Toughness. The power to resist fracture when subjected to bending, torsion, or impact.

Brittleness. The tendency of the metal to fracture on receiving a blow or shock. Brittleness implies lack of toughness.

Softness. This is a relative expression for the property of permanently yielding to pressure without fracture.

Hardness. A measure of the property in virtue of which a material is able to cut, scratch or indent another material, or it may be described as the capability of resisting wear by abrasion, or the resistance to penetration.

Elasticity. The capacity of a material to return to its original size and shape on removal of distorting forces.

Fusibility. The capability of being melted. All metals are fusible. A substance that does not easily melt is termed "refractory."

Conductivity. The ability or capacity of a metal to conduct heat (Thermal conductivity) or electricity (Electrical conductivity).

Fatigue. The diminishing resistance to fracture caused by the continued application of alternating or varying stresses.

Electrolyte. A liquid capable of conveying an electric current and becoming decomposed in the process. A liquid that does not convey an electric current is called a Non-electrolyte.

Elastic Limit. The maximum load a metal will withstand without appreciable permanent set.

Yield Point. The load in tons per square inch at which the test specimen extends without increasing load.

Proof Stress is defined as that stress at which the stress/strain curve deviates by 1 per cent of the gauge's length from the straight line of proportionality. (Used when yield point is not clearly defined.)

Galvanic Action. A current flowing between two dissimilar metals during the presence of an electrolyte.

NOTES ON AIRCRAFT FUSION WELDING

As stated in the metallurgy notes, no further heat treatment is necessary on account of the high manganese content of the steel.

The high-pressure oxy-acetylene system is chiefly used.

A neutral flame is the ideal flame required.

A test for the purity of the acetylene gas is by soaking a piece of blotting paper in silver nitrate and holding it over the nozzle with

the gas turned on. The paper turns brown, and the deeper the colour the more impurities are present.

When a piece of metal is joined by actually melting its parts, or by melting a second piece of metal and running it into a joint raised to the same temperature, then fusion welding has taken place.

The electric arc and the oxy-acetylene torch are chiefly used for providing the necessary heat.

Experience has shown that certain high-tensile alloy steels should not be welded, as their full strength cannot be developed after welding by heat treatment or any other process. All parts expand and contract considerably during welding operations, and therefore precautions must be taken to avoid, where possible, the troubles which ensue due to distortion and cracks.

Preparation for Welding. Surfaces should be free from oil, grease and oxide. If dealing with a thickness greater than ⅛ in., the edges must be bevelled.

FAULTS IN FUSION WELDING

Lack of Penetration. Failure to fuse the metal throughout the depth of the weld. It can be detected by inspecting the underside of the weld which will show both edges in an unfused condition.

Adhesion. Adhesion is said to exist when the added metal adheres, without fusion, to the sides of the weld. It is caused by the molten metal being allowed to flow on the sides of the U previous to bringing the sides of the latter to a state of fusion.

Craters. Conical depressions may form in the molten metal, especially when filling in the bottom of the weld. These are due to the metal being insufficiently heated or fluxed.

Oxide Trapping. The embedding in the weld of particles of oxide and slag is generally due to lack of heat, or the surface of the molten metal crusting over.

Channelling. This consists of a groove or trough below the surface of the metal, thus causing a weak joint. It is caused by insufficient addition of metal from the welding rod.

Burning. By burning is meant the degeneration of the physical properties of the metal. This is apparently caused by oxidation of the crystal boundaries through the use of too small a blowpipe.

Oxidation. An excess of oxygen causes the weld to lack homogeneity due to the large amount of oxide trapped in the metal.

Carbonization. An excess of acetylene causes carbon to enter into the chemical combination with the metal, making it hard and brittle.

CHAPTER VIII

MISCELLANEOUS

Bracing Wires

Bracing wires used in aeroplanes are indicated in terms of the purpose for which they are used, e.g. lift wires are so called because the principal function of these wires is to transfer the lift of the wings to the body or other part of the aeroplane.

Flying and landing wires are usually made of a medium carbon steel with approximately 0·9 per cent manganese content.

Their lengths are referred to as—

A length, which is the overall length.
B length, measured from shoulder to shoulder.
Cropping length, which is the exact length before rolling.

The anti-corrosive treatment is cadmium plating.

After being plated, they are boiled for approximately half an hour to remove any surface brittleness and acid.

The correct method of cleaning these wires is by the use of a paraffin-soaked rag, drying thoroughly afterwards and applying a coating of thin oil or sozzle mixture.

Streamline wires have a B.S.F. thread. As one pitch is made to serve more than one diameter, it is therefore sometimes possible to screw a larger size of a female threaded part along a male part.

For example, take a streamline wire with a $\frac{3}{8}$ in. thread screwed into a $\frac{13}{32}$ in. threaded fork-end. The slackness is not apparent when the wire is sprung in, so it is always good practice to make certain of the diameters, etc., before fitting these wires.

The table of B.S.F. threads used in streamline wires and other aircraft parts is as follows—

Outside diameter . . .	$\frac{7}{32}$	$\frac{1}{4}$	$\frac{9}{32}$	$\frac{5}{16}$	$\frac{11}{32}$	$\frac{3}{8}$	$\frac{13}{32}$	$\frac{7}{16}$	$\frac{15}{32}$
Number of threads per inch .	28	26	26	22	22	20	20	18	18

General Notes on Doping

Modern schemes allow for application under adverse conditions. Doping may be carried out at a temperature as low as 32° F. However, the usual precautions must be taken against cold winds to avoid blushing of the doped surface.

The procedure when doping a newly-covered component is as follows—

> Rub the first coat well in with a stiff brush. A second coat may then be sprayed or brushed in. Now either brush or spray the aluminium dope on.

The normal coatings are two coats of red dope and one or two coats of aluminium dope according to requirements.

100 sq. yds. of fabric take 7 gal. of red dope and 6 gal. of aluminium dope.

Only the thinners specified by the makers is to be used for spraying purposes. Twenty-five per cent by volume of dope to be thinned is the maximum amount of thinners that may be used.

Dope-resisting white paint must be used where fabric parts come into contact with the metal.

Pigments in dope are added to form a barrier to the ultra-violet rays.

Weight of the fabric is increased by 2½ to 3 oz. per sq. yd. on completion of doping.

The *warp* of fabric is the length.

The *weft* of fabric is the width.

Defects in fabric are marked by means of red thread sewn in the selvedge opposite the fault. Any one piece of fabric containing more than six faults is not to be used for aircraft material.

When covering wood or plywood with fabric, the method of attaching the fabric depends upon the final covering which has to be applied to the fabric.

Where the final coating is dope or cellulose lacquer, proceed as follows—

> Sand-paper the surfaces of component. Apply thin coating of dope. Stretch fabric over the surface of the component. Remove any excess of dope with a pad. Overlap joints of the fabric. Leave to harden and dry for about two hours. Apply the dope or lacquer.

Where the final coating is an oil-bare paint or varnish—

> Thoroughly wash the fabric and sand-paper the surface of component. Apply thin coating of glue. Stretch the fabric over the surface of the component. Remove any excess of the adhesive, using a pad soaked in hot water. Overlap the joints of the fabric. Leave to dry for twenty-four hours. Apply paint or varnish as required.

When fixing frayed edging to a curved component, such as a wing tip—

> Obtain total length of frayed edging in one piece. Crease down the centre of the length. Dope on to wing tip so that the crease coincides with the centre of wing tip sweep. Stretch the fabric during doping on to wing tip.

This method of attachment allows the fabric to be fixed in one piece.

Identification markings are to be applied with a softer brush, and the normal precautions must be taken. They should not be applied for about six hours after final doping of the component.

Identification markings are not to be applied to control surfaces as their added weight has a tendency to affect the mass balance of these surfaces, especially after repeated application of the markings.

Willesden Green canvas must on no account be used for the manufacture of airscrew covers for light alloy airscrews on account of the dye having a detrimental effect on the metal. White duck canvas must be used instead.

When an aircraft wing has been doped there is an explosive mixture in the plane for approximately three days which renders the dusting of the planes extremely dangerous, especially in warm, dry atmospheres. It is due to the action of static electricity. To avoid risk of explosion due to this, the metal components of the plane are connected to a common earth such as a water pipe, etc., whilst dusting of the component is being carried out.

Lubrication of Aircraft Parts

Type A anti-freezing oil. This is used throughout the control system other than ball or roller bearings. It is also used as an admixture with thick oil, as used for lubricating moving parts of steam-engines, throughout the control system of flying-boats which are operating in tropical climes, when no anti-freezing grease is available.

Type B anti-freezing oil. This is used for the lubrication of remote controls.

Grease and general-purpose thick oil. These are mixed for use on axles.

Brake oil. This is used for landplanes fitted with hydraulic brake systems and oleo legs—oil and air types. It is also used as a lubricant for the pneumatic type of undercarriage legs.

Fitting of Shims

When side play occurs on bushes fitted to aeroplane wheels it is permissible to fit 20 S.W.G. hard sheet brass shims. The maximum number which may be fitted is five.

For wheels fitted with brakes and having plain bearings the order of fitting the shims is as follows—

First shim on the outside of wheel. Second shim on the inside of wheel, and so on alternately.

For unbraked wheels with plain bearings all shims are fitted on the outside of the wheel.

For braked wheels with roller bearings all shims are fitted to the outside of the wheel.

General Notes on Hydraulic Brakes

Special brake oil or the maker's oil should be used. Paraffin or mineral oils are detrimental to the system. The maker's oil is dyed a greenish tinge to distinguish it.

The reservoir should be kept half-full.

Leakages from the reservoir may be remedied by adjusting the central rod with the aid of a screw-driver, care being taken not to crack the glass by over-tightening.

Dirt under the valve seatings in pedal units makes the brake sluggish and weak in operation, and the oil rises in the reservoir. To remedy this defect, remove the valve housing and clean; then replace carefully and prime.

Special rubber bands behind the brake blocks are designed to take up wear and increase braking efficiency.

Hydraulic Brakes fitted to Dual-controlled Aircraft. In this system a master control is fitted to the instructor's cockpit, by which he can cut out the pupil's control of the brakes when occasion demands. A large capacity reservoir into which fluid from the pupil's pedals is passed when cut out, is also incorporated in the system.

At the first movement of the pupil's pedals the valves in the connections to the reservoir close, and further pressure causes the fluid to travel down the pipe lines through the instructor's pedals to the brake. The cut-out, when operated, provides a free passage from both brake pipe lines to the reservoir, all the fluid in the front pedal and the brake rushing up to the reservoir, when the pressure in the system drops to zero. If the instructor now operates his pedals, the first movement of them closes the valves in the connections to the reservoir, further pressure forces fluid into the brakes from which it cannot escape until pressure on his pedals is released.

After the cut-out has been operated and the front pedal depressed, it is advisable to allow the pedals to return fully before the cut-out is closed again, otherwise their recharging with fluid will be incomplete.

Priming instructions. Remove pedals from the machine's rudder bar so that the orifices are uppermost.

Connect the delivery nozzle to the priming apparatus, operating the pedal as a pump three or four times, then couple the pedals in the pipe line and prime the system as a whole, as follows—

The priming nozzle of one brake is attached to the filling apparatus. Fluid is then forced into the system, and this being the lowest point, it drives the air out before it as it rises towards the reservoir. When the reservoir is filled, the fluid should be allowed to run back by gravity into the filling apparatus again, until within about half an inch off the bottom of the reservoir, when it should be again forced to the top. This procedure should be repeated about three or four times, till no further bubbles of air are seen rising through the fluid in the reservoir. Now remove the priming apparatus and quickly insert the nozzle plug. The same procedure should now be repeated at the other wheel. The simplest form of filling apparatus and one which has proved most satisfactory in service consists of a motor-horn bulb to which is attached a length of rubber hose. This should be completely filled with fluid in the first instance, so that bubbles of air are not forced into the system behind the fluid. It is advisable to hold the bulb in an inverted position as this prevents any air which may enter the bulb being pumped into the system.

Adjusting mechanically-operated steering wheel brakes of the floating shoe type. In this type, the brakes are applied by means of hand levers in the cockpits of the aircraft, the steering being controlled by the rudder bar movement. The operation of adjusting for wear, etc., is as follows—

Jack up the machine with the wheels clear of the ground, and rollers may be placed under the wheels, the surface of the wheel just touching the rollers and taking the weight of the wheel only, whilst the jacking apparatus takes the weight of the machine.

Clamp the rudder bar in the neutral position.

See that the brake levers are in the "Off" position.

Adjust on the serrated disc which is situated through the slot in the torque plates by the aid of a screw-driver until both wheels are braked.

Slacken off the serrated disc until the brakes are just off and the wheels spin freely.

Never adjust on brake cables until rudder bar is clamped in neutral position. Cables should be in equal tension when the rudder bar is central.

Eccentric adjustment is not provided on brakes of 10 in. diameter and below, otherwise the method of adjustment is as above.

Where eccentric adjustment is provided, the clearance between shoes and drum should be 0·008 in. at the anchor pin end of the shoe and 0·015 in. at the star wheel end.

Do not forget the locknut when making any adjustments on the eccentric.

Inspections of Aircraft

A good system for memorizing the order of inspection for aircraft is as follows—

Undercarriage	U
Cockpits	Can't
Fuselage	Fool
Tail unit	The
Planes	Pilot
Airscrew	And
General	Grin
Automatic controls	At
Lubrication	Liberty

A between-flight inspection carried out conscientiously has often been the means of saving a disaster.

Do you inspect the upper main planes during a daily inspection? The answer should be *Yes*.

Every inspection is an *important* one.

"Safety first" should always be your motto whatever type of inspection you are carrying out.

Instruments

Air Speed Indicator. Never blow down the pitot tube to test air-speed indicator, as damage to the instrument will result from this practice.

Use a calibrater or a rubber tube, rolling the tube up from the bottom to increase the pressure, and obtain a reading on the instrument when testing for correct readings and leaks.

Avoid acute bends in pipe lines during the fitting of an A.S.I.

Check the position of the pressure head and see that it conforms to instructions laid down by the makers of the particular type of aircraft to which it is fitted.

Renew rubbers in metal connections even though only slightly perished.

See that the Bezel Ring is tight.

Make certain that the holes in the static tube are clear, especially after repainting operations.

Turn Indicator. Always fit with the machine in rigging position, making certain that the venturi head is in its correct position with the small aperture forward, and side slip needle reading zero.

Check joints for airtightness.

Clean air filter approximately every twenty flying hours to maintain true and correct functioning of the instrument.

Check the bracket holding the venturi head for fracture during service.

Fore and Aft Level. Machine to be in rigging position during fitting.

During service watch the liquid for discoloration and periodically check for any alteration of position.

Compass. This should be fitted with the machine in rigging position.

Lubber line should be parallel to the longitudinal axis of the aircraft.

The word "Aft," which is marked on the compass, should point aft.

Watch for leaks or air bubbles.

Non-ferrous attachment bolts or screws should be used.

See that the corrector-box is in its correct position and its attachment secure.

After a compass has been fitted or disturbed in any way it should be checked on a compass base for correct reading. This should be done periodically during service to maintain accuracy.

APPENDIX I

FRACTIONS AND DECIMAL EQUIVALENTS

1/64	0·015625	33/64	0·515625
1/32	0·03125	17/32	0·53125
3/64	0·046875	35/64	0·546875
1/16	0·0625	9/16	0·5625
5/64	0·078125	37/64	0·578125
3/32	0·09375	19/32	0·59375
7/64	0·109375	39/64	0·609375
1/8	0·125	5/8	0·625
9/64	0·140625	41/64	0·640625
5/32	0·15625	21/32	0·65625
11/64	0·171875	43/64	0·671875
3/16	0·1875	11/16	0·6875
13/64	0·203125	45/64	0·703125
7/32	0·21875	23/32	0·71875
15/64	0·234375	47/64	0·734375
1/4	0·25	3/4	0·75
17/64	0·265625	49/64	0·765625
9/32	0·28125	25/32	0·78125
19/64	0·296875	51/64	0·796875
5/16	0·3125	13/16	0·8125
21/64	0·328125	53/64	0·828125
11/32	0·34375	27/32	0·84375
3/8	0·375	7/8	0·875
25/64	0·390625	57/64	0·890625
13/32	0·40625	29/32	0·90625
27/64	0·421875	59/64	0·921875
7/16	0·4375	15/16	0·9375
29/64	0·453125	61/64	0·953125
15/32	0·46875	31/32	0·96875
31/64	0·484375	63/64	0·984375
1/2	0·5	1	1·0

APPENDIX II

STRAIGHT CARBON STEEL

CARBON PERCENTAGE APPLICATION TABLE

Temper	Approx. Carbon Content	Use
—	0·10—0·20%	Bolts and nuts, rivets, pins, aircraft plate fittings, case-hardening steels
—	0·20—0·40%	Drop forgings, pressings, stampings, castings
—	0·40—0·70%	Aero-engine cylinders, streamline wire, solid-drawn tubing, and general aircraft serviceable work
Die	0·70—0·75%	Dies for deep stampings and pressings
Smith's tool	0·80—0·85%	Large punches, hammers, scrapers, cold chisels
Shear blade	0·85—0·90%	Punches, taps, screwing dies, shear blades, cutlery, saws, springs
General purposes	0·90—0·95%	Taps, small punches, needles, general purposes
Axe	0·95—1·00%	Axes, carpenters' chisels, small taps, miners' drills, plane irons
Cutlery	1·00—1·10%	Milling cutters, hammers, woodworking tools
Tool	1·20—1·30%	Turning, planing, shaping, slotting tools, twist-drills, files, metal saws (unweldable)
Razor	1·30—1·40%	Hand-boring bits, razors (unweldable)

APPENDIX III

WORKSHOP METHODS OF IDENTIFYING VARIOUS METALS

Spark	Cooled in air from a red heat	Quenched from red heat	Fracture	Magnetic	When magnetism is regained on cooling	Copper sulphate	Metal
Bright yellow, non-bursting	Soft and tough	Soft and tough	Very coarse and fibrous (Greenstick)	Yes	Dull red heat	Affected	**Wrought iron**
Bright yellow, few bursting	Soft and tough	Soft and tough; will not harden by heat	Fairly fine, crystalline structure	Yes	Dull red	Affected	**Mild steel**
Bright yellow, all bursting	Soft and fairly tough	Hard and brittle	Very fine light grey crystals	Yes	Dull red	Affected	**High carbon steel**
Blood-red, non-bursting	Hard and brittle	Hard and brittle	Bluish-grey, very silky	*Very* Magnetic	Black heat (Air-hardened 200° C., very low)	Affected	**Tungsten high-speed steel**
Bright yellow, few bursting	Hard and brittle	Hard and brittle	Very fine and silky—not as much as tungsten	Yes	Black heat	Affected	**Air-hardening Nickel-chrome steel**
Bright yellow, few bursting	Hard and brittle	Hard and brittle	As above	Yes	Black heat	Not affected	**High-chromium stainless steel**
Bright yellow, few bursting	Soft and tough	Soft and tough	As above	Only when cold worked		Not affected	**Chrome-nickel (Austenitic)**

MADE IN GREAT BRITAIN AT THE PITMAN PRESS, BATH