BAHAN BACAAN

MATA KULIAH
TEKNOLOGI FABRIKASI I

BAGIAN TUGAS
AKTA V BARU

oleh
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PADANG

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introduction

IGURE I. A shop or service center, when properly rranged, can help eliminate the problem of mis-laced tools.

How many times have you been faced with a job to do and you could not find your tools (Figure 1), or you were discouraged because you did not have an adequate space to work?

Most individuals need a shop or service center. The size of the area and the arrangement of the tools and equipment will vary, however. This depends on the scope of your enterprise.

Most business and farm enterprises have numerous pieces of equipment. Some of them are powered by electric motors. Some are powered by gasoline and diesel engines. The equipment requires regular maintenance and repairs. An adequate service area is necessary to do maintenance and repair jobs (Figure 2).

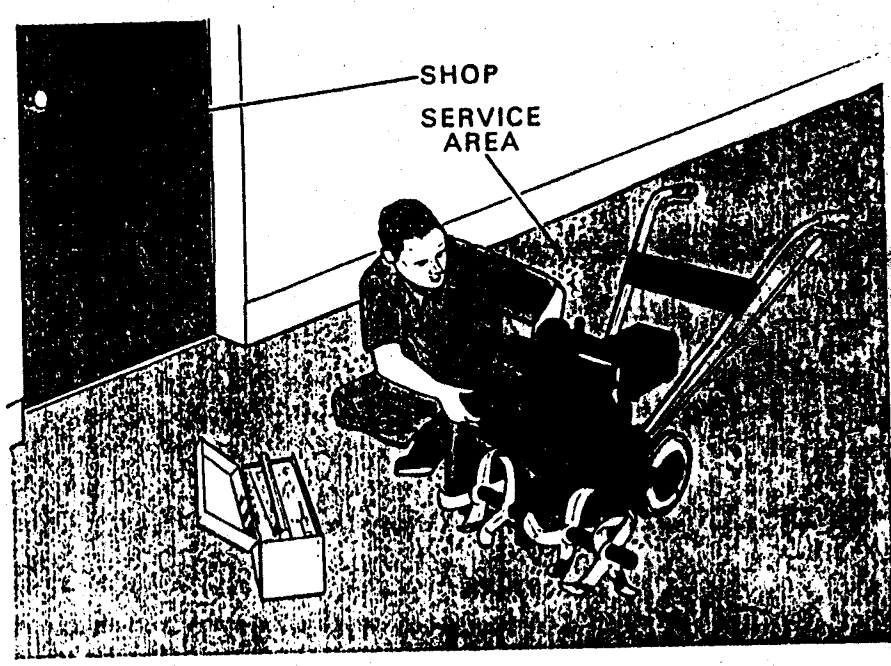


FIGURE 2. A shop or service center is necessary if you are going to repair machinery and equipment.

In addition to the aintenance and pair of power uipment, a shop ovides space for aintaining plumb- g and wiring, for arpening tools, finishing furni- re, painting uipment, and ny other useful rvices (Figure 3).

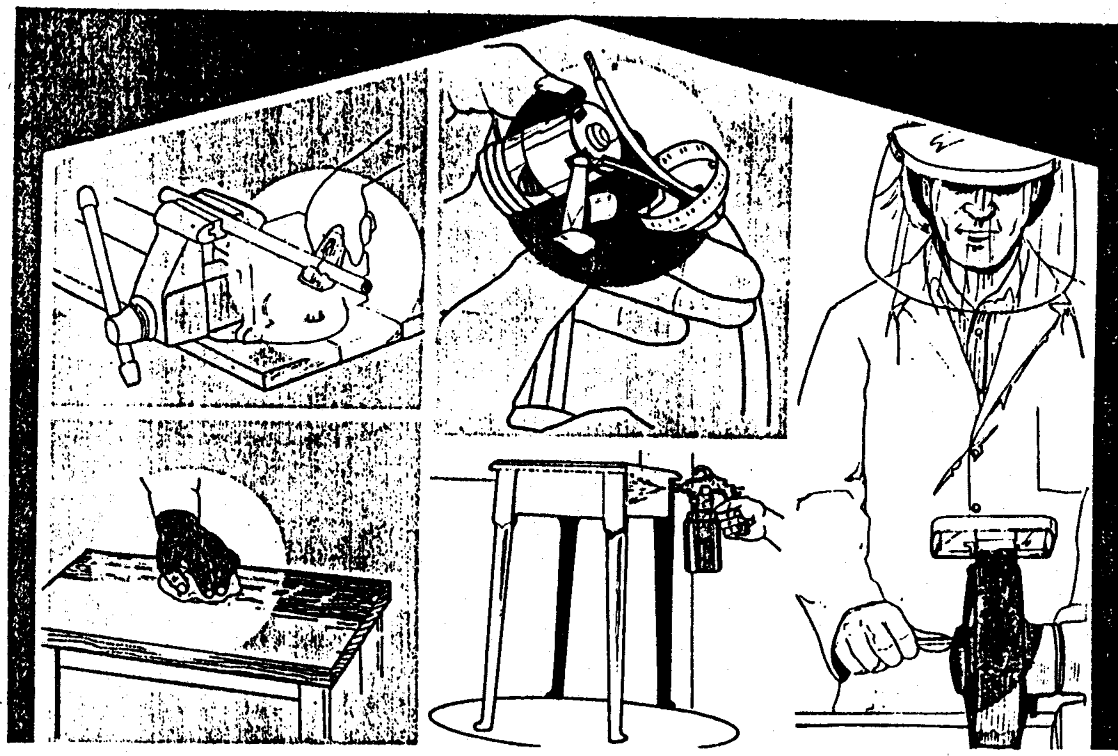
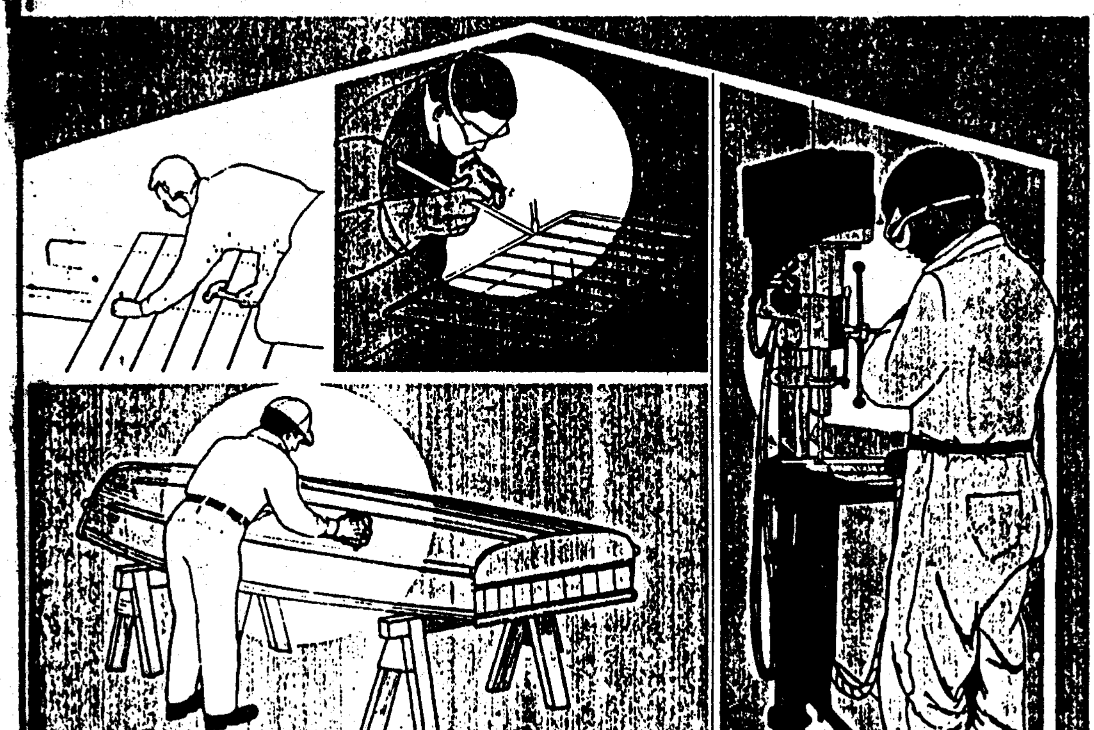


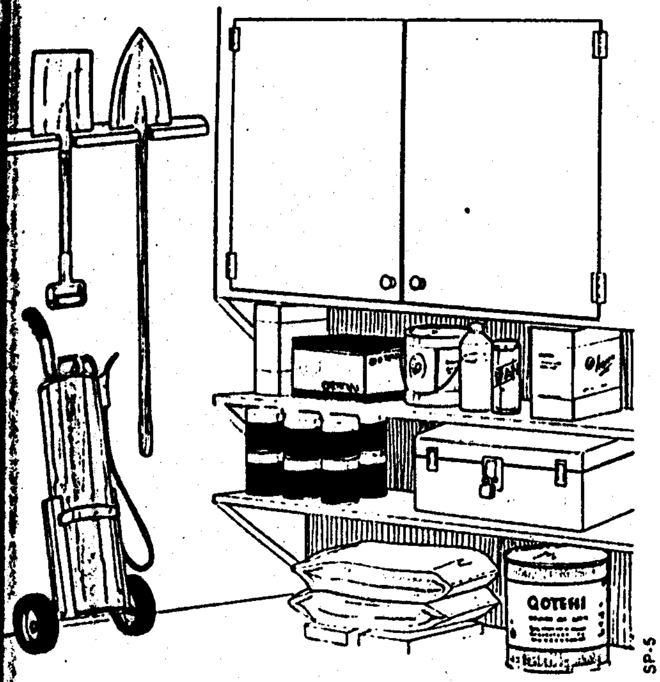
FIGURE 3. Shops provide for maintenance and repair of plumbing, wiring, sharpening tools, refinishing furniture and painting.

Most homeown- s do at least some the maintenance d repairs required und the home. equently, you n do the job as ll as a trained hnician. It is es- tial, however, t you have an equate place to rk and the proper ls.

New construction may include building such things a boat, furniture, a trailer, barbeque grill and spe- l equipment (Figure 4).



URE 4. Shops provide for making such things as boats, trailers, grills, and special ipment.



URE 5. A shop may provide storage space for ols, equipment and supplies.

The shop may also provide storage space for such ngs as tools, equipment and supplies (Figure 5).

So you see how the term "shop," as referred to in this publication, includes several types of facilities. It includes areas for storage and facilities for service and repair. Facilities for fabrication and assembly may also be a part of the shop.

The arrangement of a shop may look something like the one shown in Figure 6.

Shop planning and basic design are discussed under the following headings:

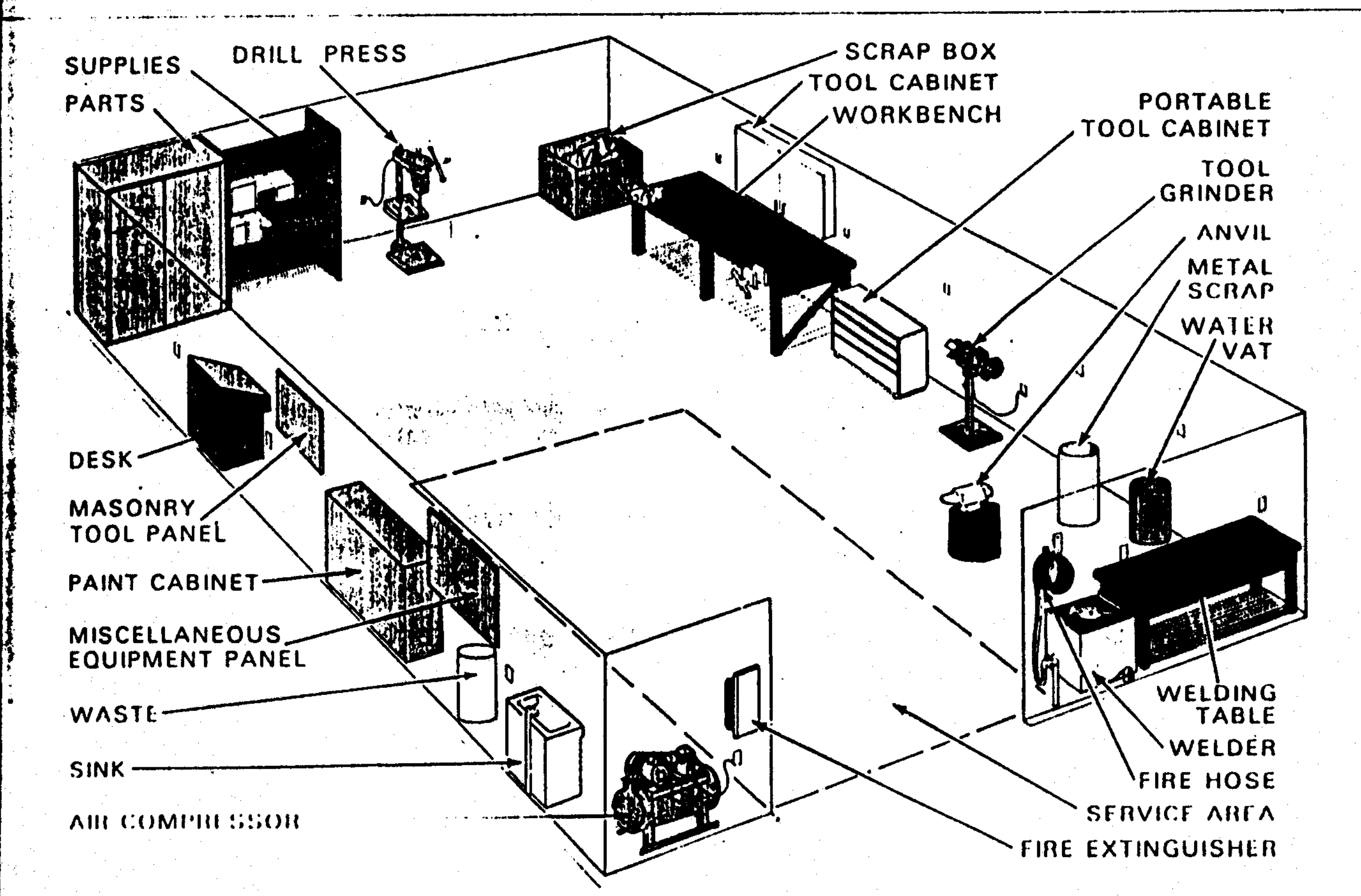
I. Determining If a Shop or Service Center is Needed.

II. Determining Space Needed in the Shop or Service Center.

III. Determining Size and Type of Shop or Service Center Needed.

IV. Determining Heating and Ventilating Needed.

V. Determining Lighting and Wiring Needed.



GURE 6. An example of how a small shop might be arranged.

Determining if a **shop or service center** is **needed**

Many commercial operations have me provision for tool storage and a rvice area (Figure 7).

In the home, the service center may nsist of little more than a corner of a ichen cabinet, or a part of the iveway. Many home building plans w provide for a work bench and a orage area (Figure 8). A basement y provide enough space for a siza- shop. On the other hand, a com- ete new structure may be the ans- er to your needs.

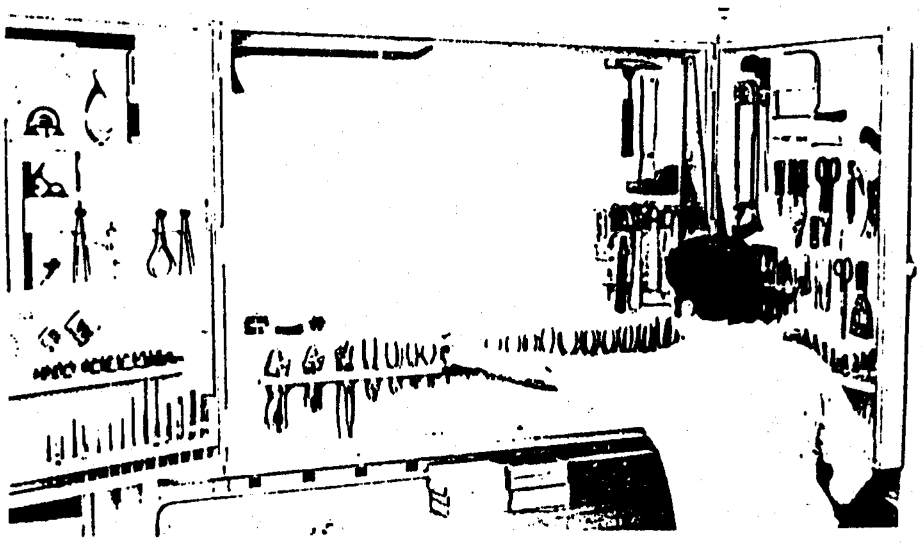


FIGURE 8. A garage or basement in the home may have space for workbench and tool cabinet.

IGURE 7. A commercial shop or service center.

Determining whether a shop is needed is discussed as follows:

A. What Uses Can Be Made of a Shop or Service Center.

B. What Uses Can You Make of a Shop or Service Center.

. What Uses Can Be Made of a Shop or Service Center

GURE 9. Examples of businesses or operations which usually need a shop or service center are (a) farms,) landscaping firms, and (c) golf courses.

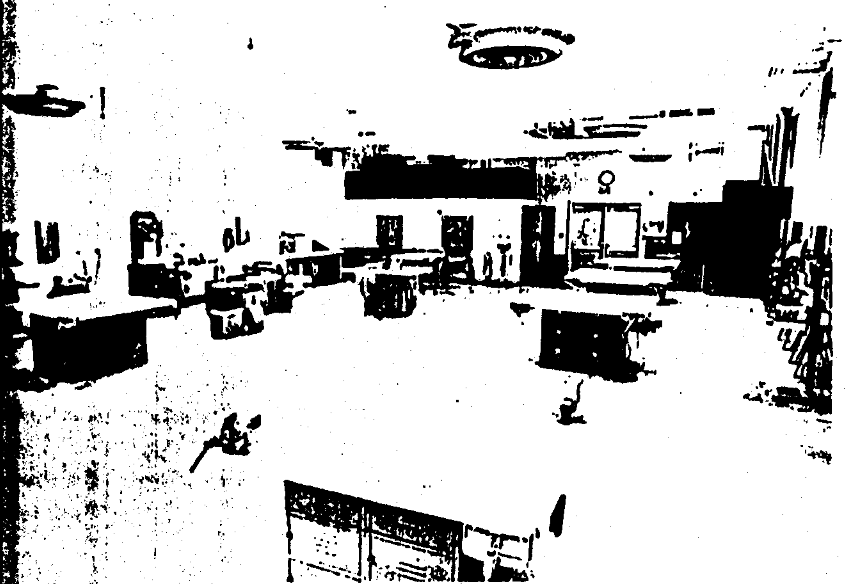
The uses of a shop vary widely. They depend upon e needs and desires of the owner. The hobby shop ay be used primarily for the relaxation and enjoy- ent of the owner.

There are many enterprises for which one may find shop profitable (Figure 9). Some of them are as llows:

- Farms.
- Ranches.
- Groves.
- Schools.
- Instructional laboratories.
- Manufacturing plants.
- Auto and equipment dealers.
- Earth moving and grading.
- Landscaping.
- Plant nurseries.
- Golf courses.
- Park maintenance.
- Grounds keeping.

Many small and medium shops are used by homeowners, or small businessmen and skilled tradesmen. Shop jobs may include repairing or building equipment.

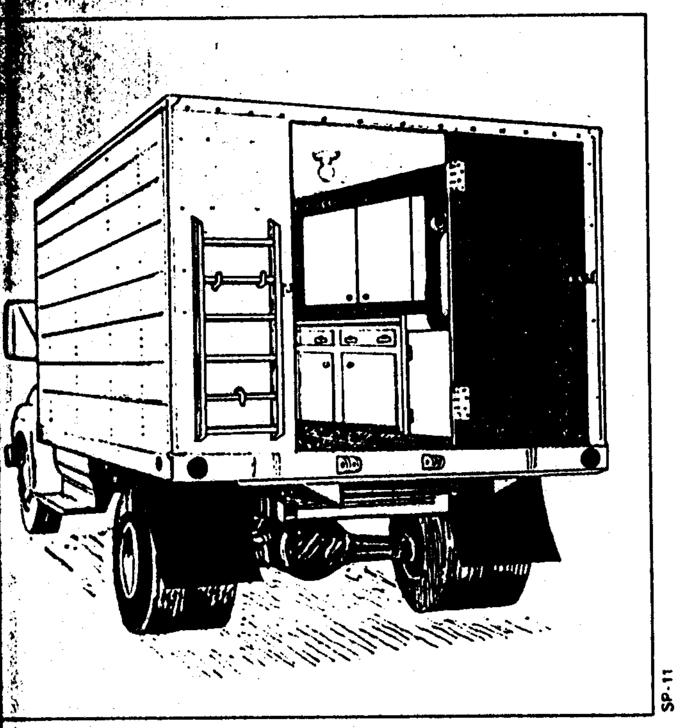
A large service center used by a commercial farmer, rancher, grower, landscape contractor, or manufacturer may often be used to make emergency repairs of mobile and/or stationary equipment.



GURE 10. An Instructional laboratory for teaching op skills.

Schools have instructional laboratories for teach- shop skills (Figure 10).

Some businesses or individuals have need of a l-equipped portable shop. It may be mounted on a k or trailer. Such a shop can go directly to the ipment (Figure 11).



GURE 11. A portable shop may be well equipped.

Upon completion of this section, you will be able to **name many uses for a shop or service center**. What uses can be made of a shop are discussed under the following headings.

1. Provisions for Service and Repair.
2. Provisions for Storage.
3. Provisions for Other Uses.

1. PROVISIONS FOR SERVICE AND REPAIR

Farmers, ranchers, businessmen and individuals depend more and more on the ability of machines to do work rapidly. Emergency repairs are important.

Being able to make **emergency repairs** may result in sizable savings. An emergency repair is often a matter of being able to drill the right size hole, cut threads on a fitting, or weld a broken part. You may save a trip to the hardware store or a long wait for repairs or parts.

Service and repair are the major uses made of most shops. Included in servicing is preventive maintenance.

Your shop may allow you to service and maintain the following:

a. Mechanical Equipment.

b. Electrical Equipment.

c. Buildings.

a. Mechanical Equipment

Maintenance is necessary to keep machinery and other mechanical equipment operating properly (Figure 12). Longer life is assured. With regular maintenance and minor repairs, a major breakdown may be prevented.

FIGURE 12. Maintenance of equipment is an important use of many shops.

b. Electrical Equipment

Maintenance of electrical equipment has further strengthened the need for a shop. Many items of electrical equipment need minor repair occasionally (Figure 13).

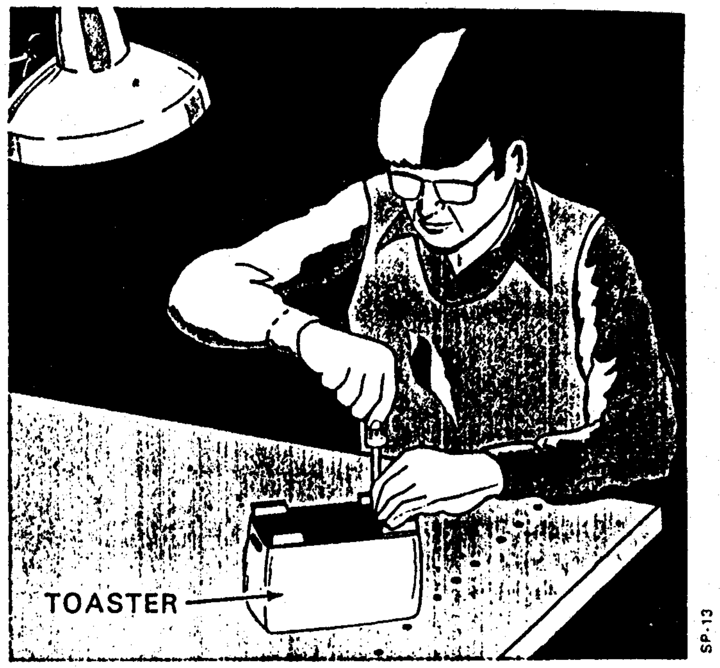


FIGURE 13. Electrical equipment can be repaired easily in a well-equipped service area.

c. Buildings

Maintenance of the homestead and commercial buildings is less likely to be of an emergency nature than mechanical or electrical equipment. A building does not "break down" the way a machine does. Proper up-keep of buildings, however, is important. A well-equipped shop can help you maintain your buildings (Figure 14).

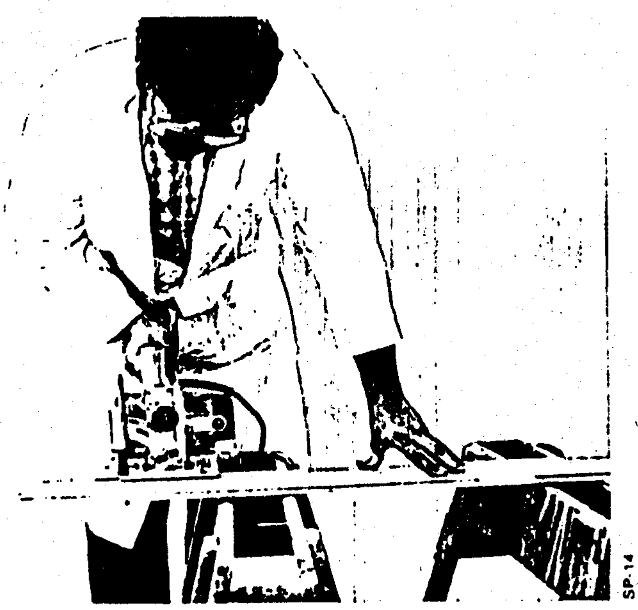


FIGURE 14. A well-equipped shop can help you maintain your buildings.

Provision For Storage

Providing for space always seems to be a problem. A shop large enough to allow for some storage will greatly increase its usefulness and convenience (Figure 15).

Space in your shop can provide for storage of the following:

a. Tools and Equipment.

b. Spare Parts.

c. Supplies.

FIGURE 15. Storage space in the shop increases its usefulness and convenience.

a. Tools and Equipment

The first need for storage is space for tools and equipment used for service and repair.

b. Spare Parts

Space to store spare parts is often needed.

c. Supplies

You can store such **supplies** as lumber, bolts, screws, nails, pipe and miscellaneous materials.

If you desire, you can provide storage **space for** such **tools** as a shovel, axe, step ladder, hedge clippers and lawn and garden tools. Having all this equipment together means that it is kept in better condition. For example, if you have a tool grinder handy, you will find it easier to sharpen an axe before you use it than to worry with a dull one.

The **time you save** in getting ready to do a job is your best reason for storing all these things in one place. Your materials and tools are all together (Figure 16). After you have finished, you can return them all to the same place. This makes for orderly procedure and saves time and trouble.

It is desirable to provide space for such things as **pesticides** and **garden supplies**. Paint and brushes are sometimes stored in the shop, but they increase your fire hazard, unless provisions are made to prevent it. Paint thinners and other volatile material should be stored in a separate building.

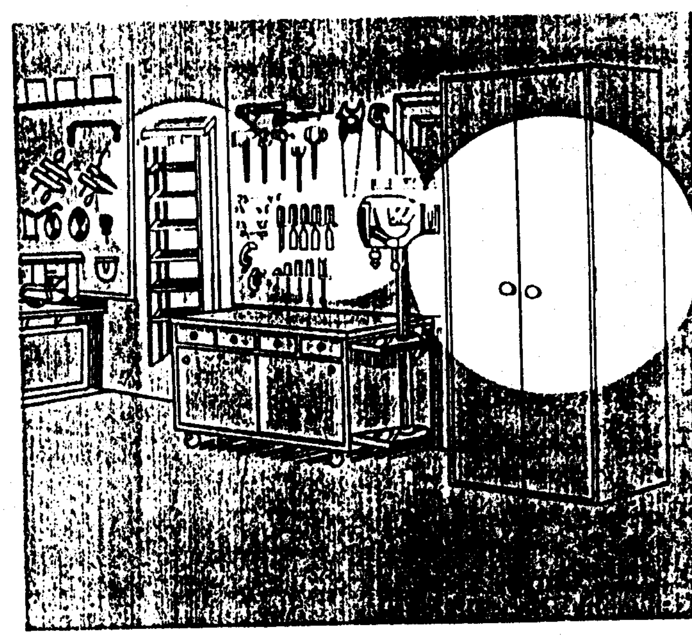


FIGURE 16. Store tools, equipment and supplies in one area for greater convenience.

PROVISION FOR OTHER USES

Shops and service centers may be used for pur-ses other than service, repair and storage. Many ople use them for construction or fabrication of ecial items. These may be used in a business, on farm, or in the home (Figure 17). Boats, furniture, l trailers are examples of items which may be built the shop.

A pleasant way to use the shop is for a hobby of some kind. This may take a variety of forms from pottery making to clock repair and furniture building (Figure 18).

GURE 17. Shops are often used to construct or bricate useful items.

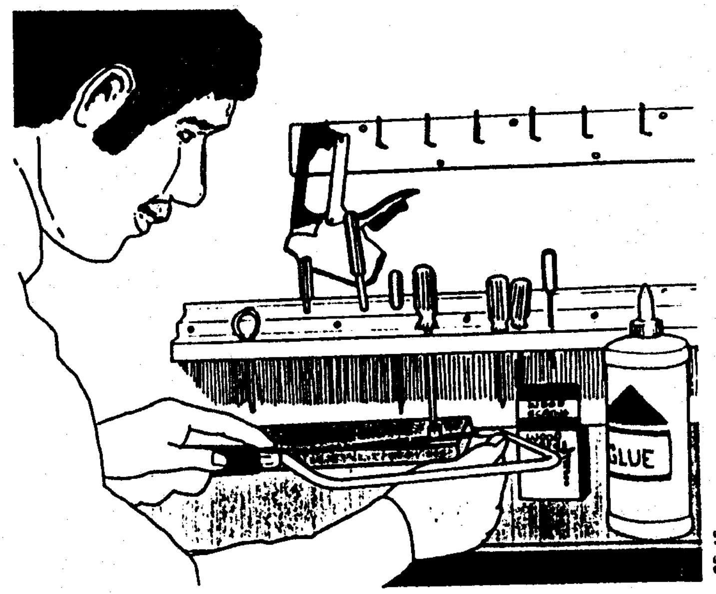


FIGURE 18. Pursuit of a hobby may be another use of the shop.

What Uses Can You Make of a Shop or Service Center

The most important consideration in deciding hether a shop or service center is needed is to etermine the uses you can make of it. These may ary greatly. They depend upon whether you are onsidering a shop for personal use at home, as a ervice center for a farm, or as an aid to your busi-ess.

Upon completion of this section, you will be able decide what uses you can make of a shop. In order to elp you reach a decision you will consider the fol-owing factors:

1. Skills You (or Your Employees) Possess.
2. Tools and Equipment You Have Available.
3. Time You have Available.
4. Amount of Money You Can Invest.

SKILLS YOU POSSESS

onsider your ability to use tools. uses you make of a shop will de- on your interest and ability to do work.

me individuals have little skill in g tools. Most people can develop e skills, but a few dislike doing k of this type and take little in- t in learning. They may damage r tools and equipment. They are y to injure themselves. If this is r case, of course, a large shop ld be of little value—unless you e employees who could make d use of it. A few simple tools, a k bench and a small work area y be sufficient for your needs.

f you enjoy technical work and are ly skilled at it, you should plan to e a well-equipped shop (Figure

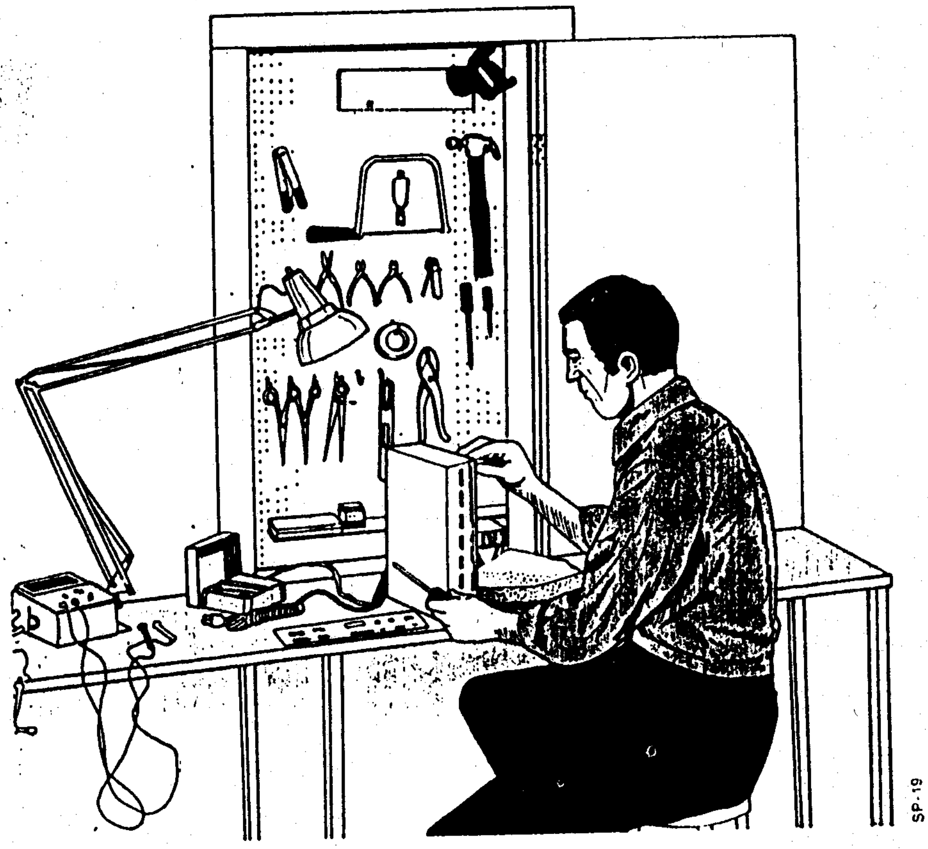


FIGURE 19. A person who is skilled in shopwork will enjoy a well-equipped shop.

TOOLS AND EQUIPMENT YOU HAVE AVAILABLE

The tools you have and their condi- n may influence your type of shop.

The "do-it-yourselfer" who is ac- ustomed to making minor repairs round the home, on his auto, tractor lawnmower may already have a rly good stock of tools.

For business enterprises, a similar ituation may be found unless you are tarting a new facility. A good inven- ory of hand tools and portable electric quipment is needed (Figure 20). Make a list of the tools you will need. Compare that list with the tools you have on hand.

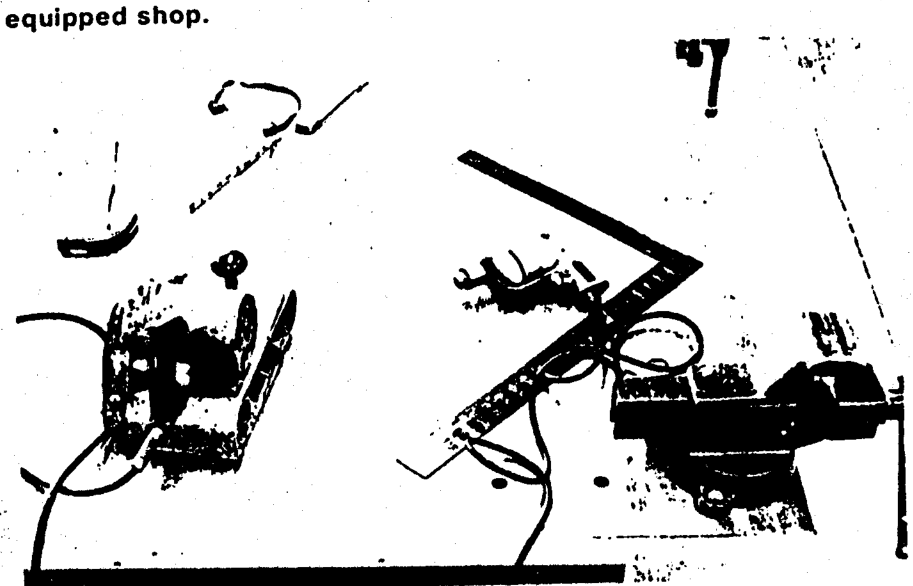


FIGURE 20. Hand tools and portable electrical equipment provide a start toward equipping a shop.

You may be surprised to find how many tools you already have available once you get them all together.

If your hammer is at one place, your socket wrenches at another and your pliers somewhere else, you

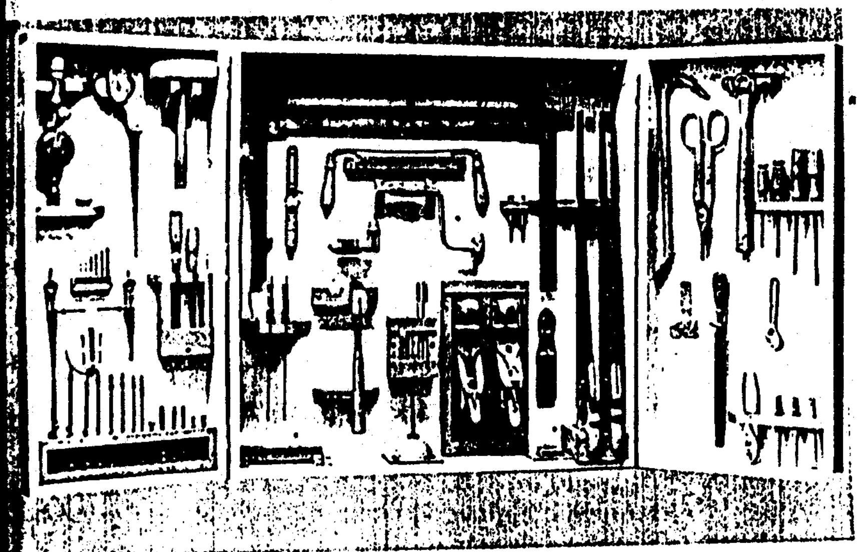


FIGURE 21. A central storage cabinet helps keep hand tools in place and in good condition.

obably do not have a very satisfactory place to ep them. If you see the value of keeping your tools a central place, a shop will help (Figure 21).

Check the condition of your tools. If they are rusted, ey have probably been left out in the weather or are eing kept in a damp, poorly-vented place. A nvenient, well-ventilated shop would keep them in etter condition.

TIME YOU HAVE AVAILABLE

Spare time can often be used to an excellent advange. Time and money saved in repairing and building equipment can be sizable. It is sometimes difficult to arrive at a cash value, however.

A factor to be considered is *whether service and repairs are readily available elsewhere*. If machinery and equipment must be transported considerable distances, much time can be saved by performing the service or repair in your own shop (Figure 22).

The *amount of time you are willing to devote to the shop* will depend on your own priorities. *If the job meets a definite need*, you will likely find the time required to make it worthwhile (Figure 23).

FIGURE 22. Repair jobs that can be done at home or business usually save time and money.

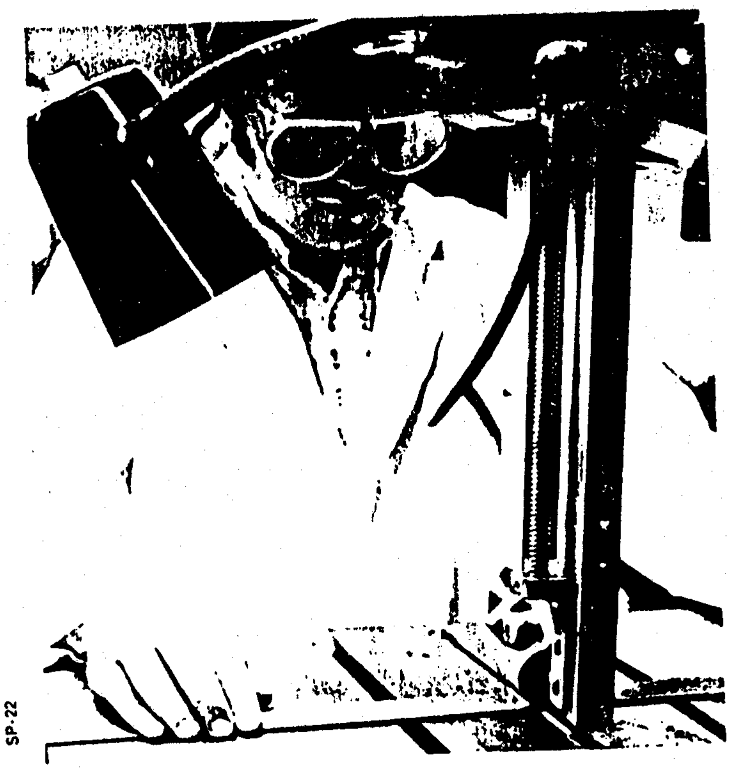


FIGURE 23. A well planned place to work can be profitable and enjoyable.

AMOUNT OF MONEY YOU CAN INVEST

good way to begin this discussion may be to ask ther you can afford not to have a shop. As has ady been pointed out, a shop can be used to uce operating costs for a farm or other business ure 24). It may also be a money saver for the neowner. The hobby shop owner may enjoy bet-health, if the shop provides a way to relax. Also, ny shops that started as a hobby have turned into a t-time or full-time vocation.

o, whether you can afford the cost involved in ding or installing a shop must be weighed against benefits of ownership. *If you can afford the initial* , the chances are good that the benefits derived be worth the cost in the long run. A shop may from a few dollars to several thousand dollars, ending on your needs (Figure 25).

ow much a building will cost, depends on such ngs as:

- How much labor and materials you furnish yourself.
- Type and size of building.
- Number of windows and doors.

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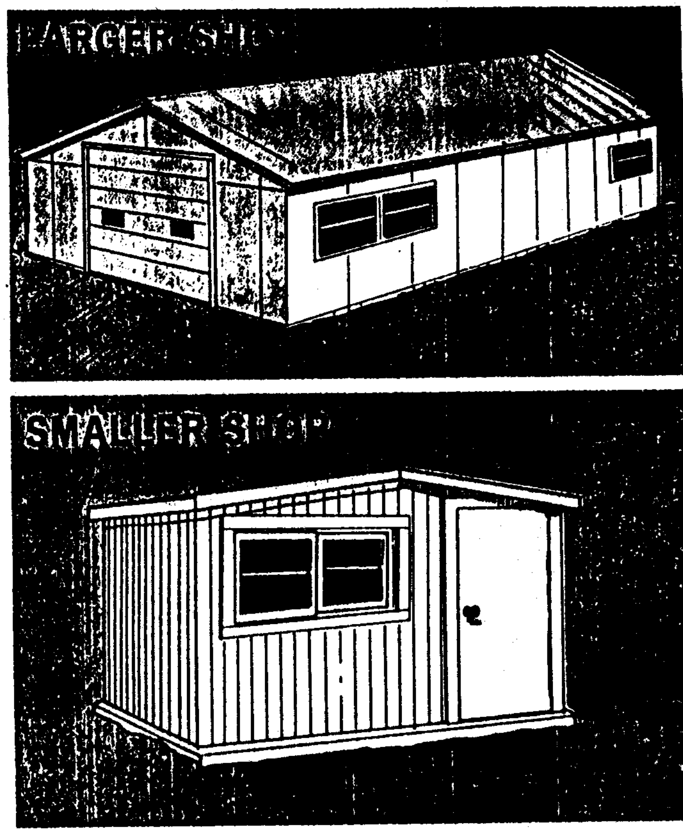
URE 24. Operating costs are reduced through of shop for maintenance and repairs.



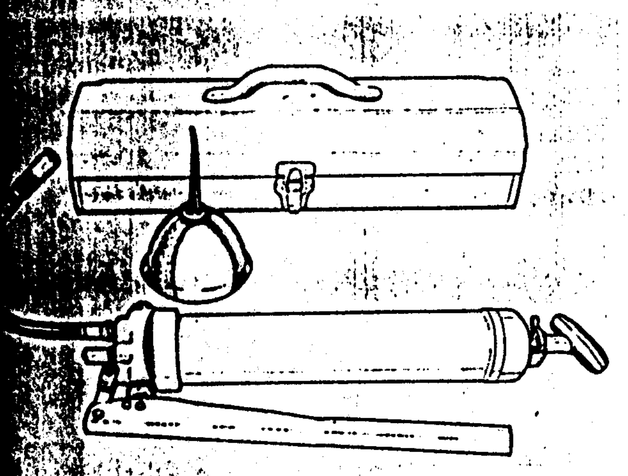
SP-25

FIGURE 25. Shop cost will depend upon size and type of building.

- Kind of floor.
- How complete a wiring job is included.

You can not make a decision based on these factors until you have determined the size and type of structure you need. These are discussed under the headings which follow.

Determining
space needed
in the shop
or service center



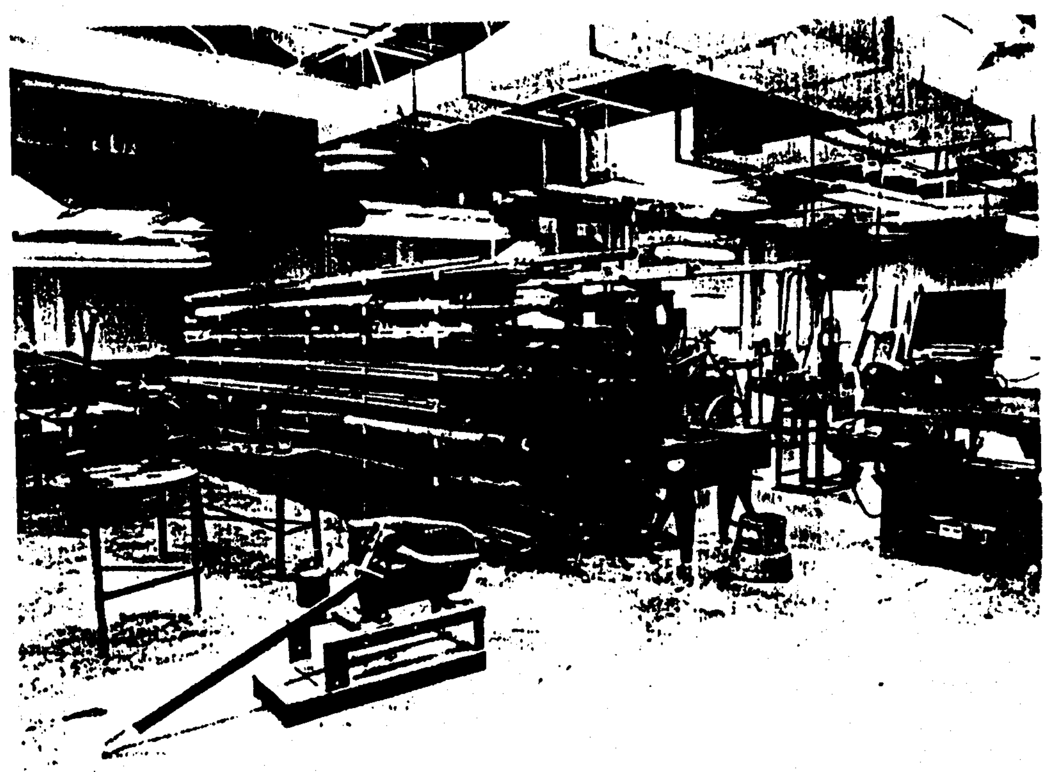
...URE 26. A service center may consist of only a ...kit, grease gun and oil can.

The space required in the shop will vary greatly depending on its uses. One of the simplest forms of a service center may consist basically of a tool kit, a grease gun and an oil can (Figure 26).

At the other end of the scale you may have an elaborate building that is lighted, heated, ventilated, and equipped with a wide variety of hand and power tools, parts, storage bins, and other facilities (Figure 27).

There are many variations between these two extremes. A mobile service facility mounted on a trailer or truck may be taken out to the equipment for emergency repair jobs in case of machine breakdown.

...GURE 27. Shop building ...t is fully equipped, ...hted, heated and venti-...ed.



The outdoor service center may onsist of an open area adjacent to a uilding, paved or unpaved, covered r uncovered (Figure 28).

Regardless of the size, each facility erves a purpose which contributes to he financial success of the farm or usiness. The home shop may conribute to earnings, or savings on reair and construction. Or, it may simly add to the enjoyment of those sing it.

Determining the space needed in he shop is discussed under the folowing headings:

A. What Space is Needed for Service, Repair and Fabrication.

b. What Space is Needed for Storage.

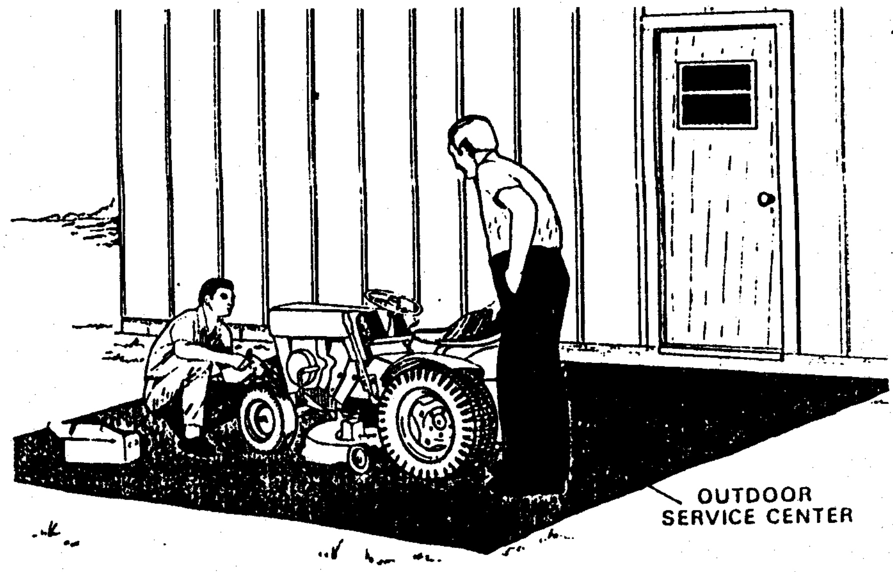


FIGURE 28. Example of outdoor service center.

A. What Space is Needed for Service, Repair and Fabrication

If you are building or installing a home shop, the ize may be predetermined by the space available to ou. Your problem may be deciding how your tools nd equipment can best be fitted into the space. Such paces as part of a garage, store room, or basement may be your only alternative (Figure 29). For many ome shop enthusiasts, however, a separate strucure may be required or desirable.

Upon completion of this section, you will be able determine what space you will need for service, epair and fabrication in your own shop.

What space is needed for service, repair and fabriation is discussed as follows:

1. Uses To Be Made of the Shop or Service Center.

2. Tools and Equipment Needed.

3. Space Needed for Service Area.

4. Space Needed for Metalworking and Machinery Repair.

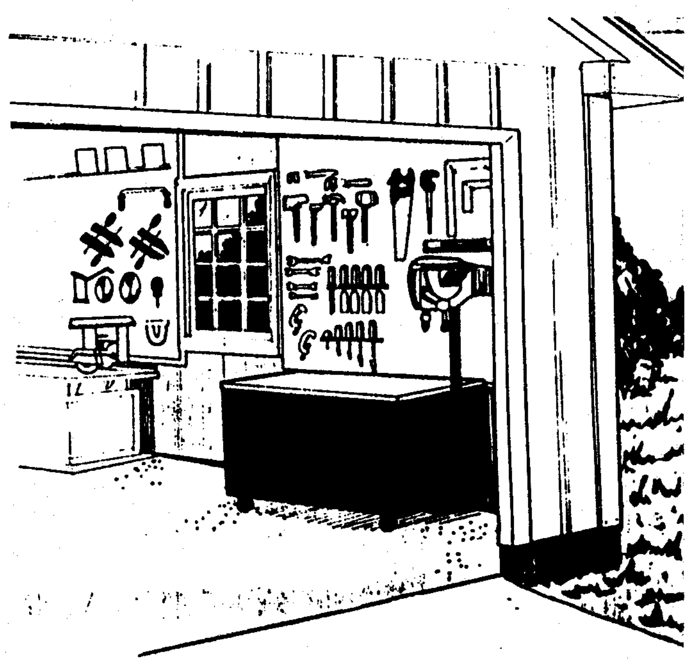


FIGURE 29. The home shop may be located in a pa of the garage.

Space Needed for Woodworking.

Space Needed for Hand Tools.

Space Needed for Miscellaneous Items.

USES TO BE MADE OF THE SHOP OR SERVICE CENTER

In earlier section, the decision was reached as to what uses you will make of the shop. Based on this information, you must now make some decisions which will assist you in determining the space needed for the shop.

For example, you may have decided what your principal uses will be. They may be to do the required maintenance, plus service and repair of your lawn and garden equipment. In this case, your shop probably will be small. However, you must still determine the space requirements for tools and working area (Figure 30).

You may have decided that a separate building is needed to properly house and use the tools and equipment for a farm or industrial shop. In that case a detailed and accurate plan will be required (Figure

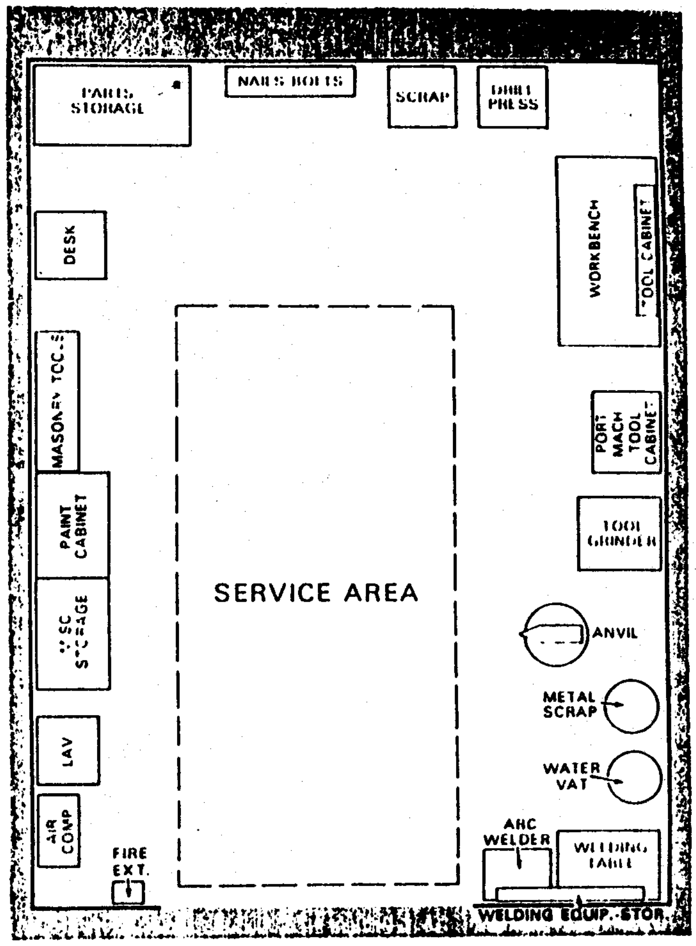


FIGURE 31. Larger shops require detailed plans for several work areas.

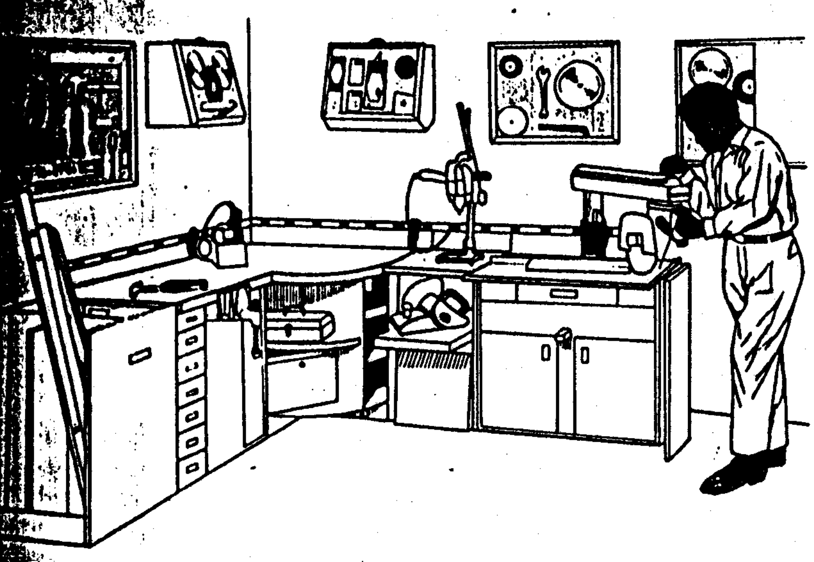


FIGURE 30. A small well-planned shop in an existing building, or a proposed new one, is satisfactory for many purposes.

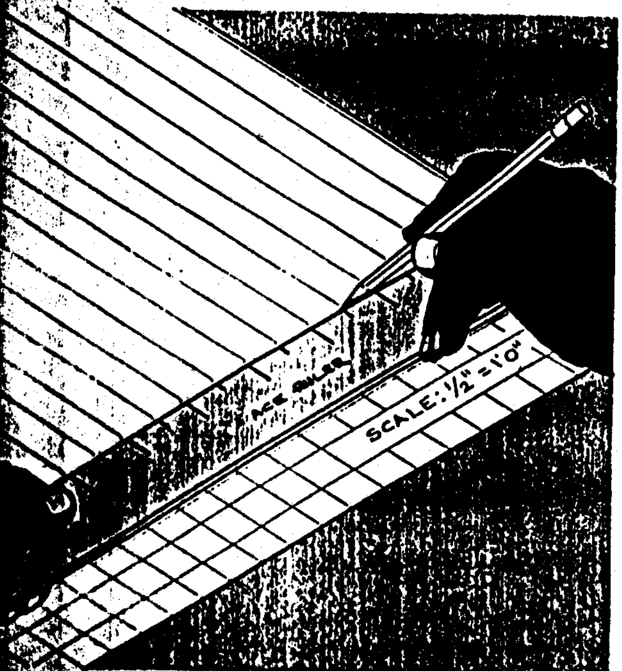
2. TOOLS AND EQUIPMENT NEEDED

In order for your shop to fit your requirements, certain tools and equipment will be needed. If your enterprise is a large farm or business, you may need a full range of tools and equipment. They may include tools for **metalworking, woodworking, machinery repair, plumbing** and **masonry**. For a home shop, a good-sized wall cabinet—well stocked with hand tools and portable drills and saws—may meet your needs.

At this point you should determine what additional tools and equipment you will require. List them by categosuch as woodworking, metalworking, machinery ...ir, plumbing and masonry. Next, think about ...s that you have not listed in a category that you ...uld have in the shop. Examples are fire exting...ers, air compressor, portable hoist and desk. ... these as miscellaneous items.

SPACE NEEDED FOR SERVICE AREA

...fter locating the service area, you are ready to ...n planning the space requirements for the service ... and for each type of equipment.



...RE 32. Mark your plan sheet into ½ inch ...res.

...lanning space for ...ervice area, pro...s follows:

1. *...cure large piece of paper or cardboard for your plan layout.*

 For larger shops, paper or cardboard should be about 20 × 26 inches. For medium- or small-size shops, 14 × 20 inches.

2. *Mark lines across paper ½ inch apart. Then run lines from top to bottom ½ inch apart (Figure 32).* (Graph paper to this scale may be purchased.)

 Each ½" on your paper or cardboard is equal to 1 foot of shop measurement. Write this on the lower right corner of your paper: ½ inch = 1 foot. You will draw all of your measurements to this scale.

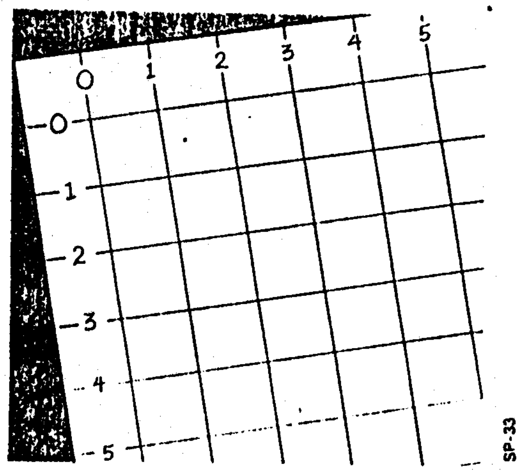


FIGURE 33. Mark every line to show the number of feet it represents.

3. *Mark every line with the number of feet it represents (Figure 33).*

4. *Determine the size of the service area.*

 Measure length and width of the largest equipment you expect to build or repair inside your shop (Figure 34). If you wish to have space for more than one unit, figure the additional space needed in the same manner.

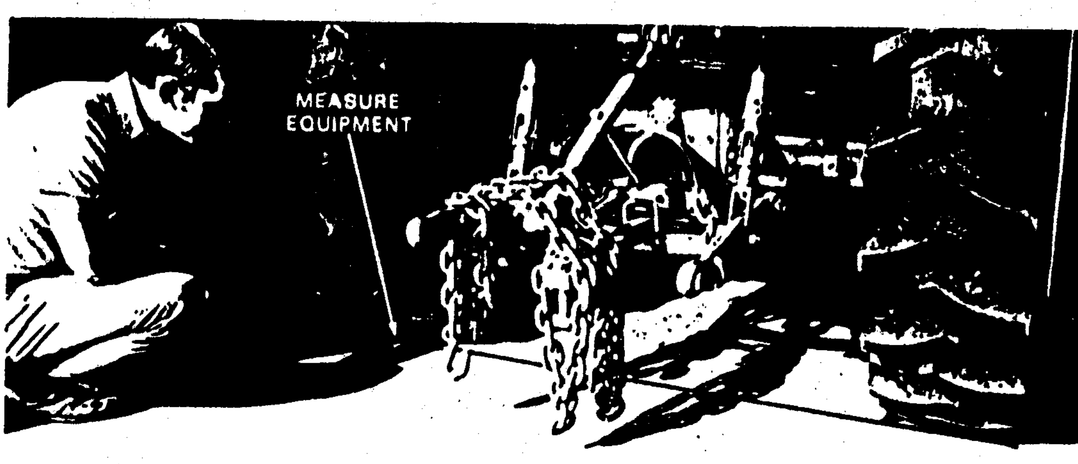


FIGURE 34. Layout of the service area. Measure the largest machine to be serviced in shop.

Label template(s).

A template is a pattern cut to scale to represent the dimensions of an area or the size of equipment representing service area needed (Figure 35). Use scale: ½ inch equals 1 foot. At first, be sure to put arrows on all four sides with "3 feet" marked next to them. This is to keep you reminded of the minimum passageway space needed on each side for servicing machines. As you determine that space is not needed on all sides, you may allow this 3 foot space only on sides that need it.

If you plan to have an additional outside service area, you may reduce the size of your inside service area.

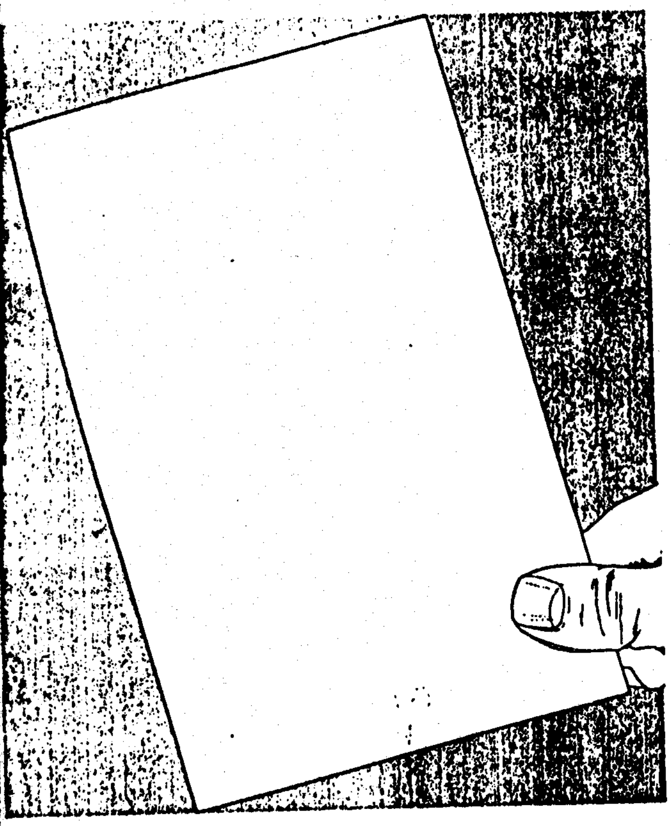


FIGURE 35. Template representing the service area.

4. SPACE NEEDED FOR METALWORKING AND MACHINERY REPAIR

Figure 36 shows the equipment most commonly used in the metalworking area. Note the template shown with each item of equipment. Each template shows the approximate size of the equipment on the same scale as your layout (½ inch equals one foot).

Note in Figure 36 that some of the templates are marked "portable" and "movable." Those not marked are considered stationary. In this discussion, "portable tools" are those mounted on wheels or casters so they can be easily moved from one location to another. To move easily, use 3-inch or larger wheels that will roll readily over small stones, nails, and other small objects on the floor.

"Movable tools" do not have wheels or casters (or are mounted on very small casters). Such equipment is not fastened to the floor; it can be moved but not as easily as portable units.

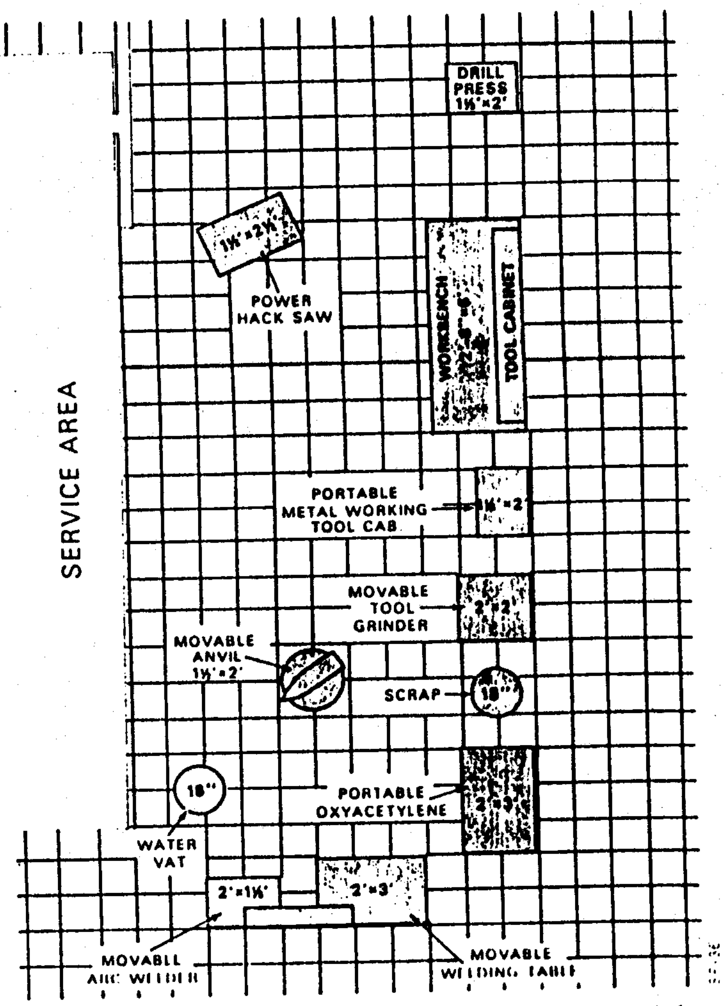


FIGURE 36. Equipment most commonly used in metalworking area. Rectangles represent template size of each unit.

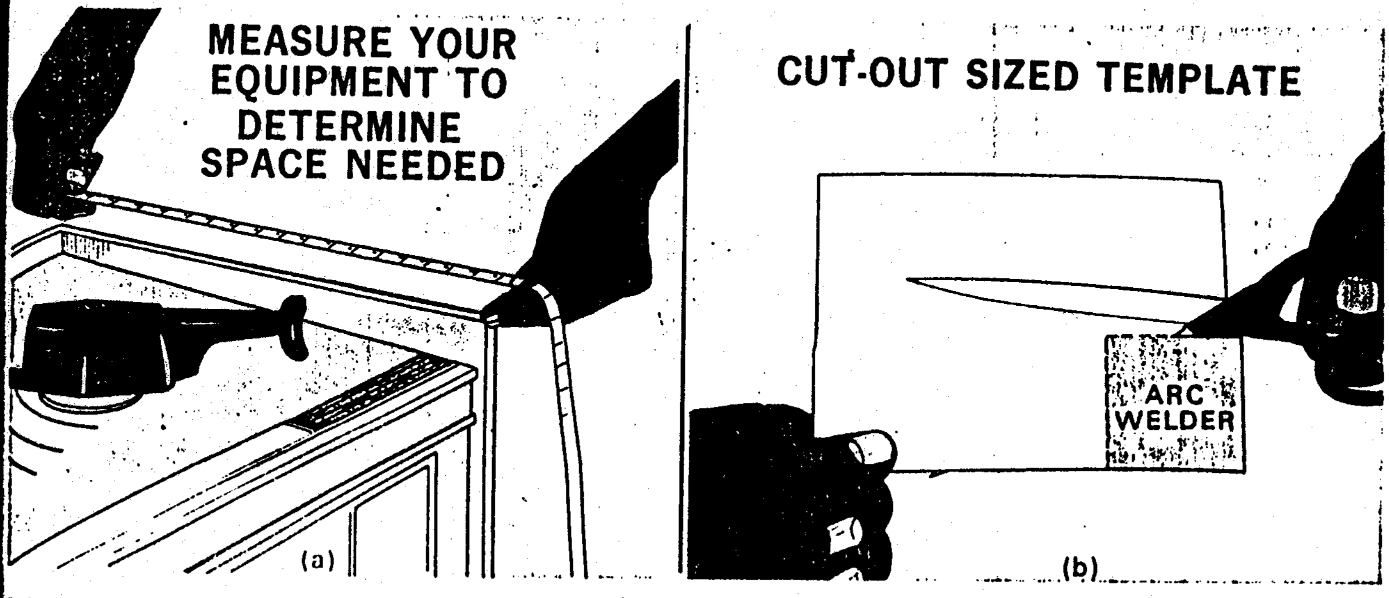


FIGURE 37. (a) Measure space required for each piece of equipment you plan to put in metalworking area. (b) Make a template of each and label it.

In the discussion that follows, you will note that no power equipment is mounted on work benches. This is for two reasons. They are as follows:

- Equipment mounted on a bench takes up valuable space.
- Surrounding bench surface is often in the way of doing some jobs you may want to do with power tools.

It is usually best to mount power equipment, even the bench type, on a separate stand or pedestal. If you prefer that your power equipment be mounted on a bench, lengthen the bench so that you have 6 to 8 feet of bench space left after the equipment is mounted.

Steps to follow in planning your metalworking and machinery repair area are as follows:

1. *Select equipment you plan to use (Figure 36).*
2. *Measure equipment you already have to determine floor space required (Figure 37a).*
3. *Make templates from measurements of present equipment on scale of ½ inch = 1 foot (Figure 37b).*
4. *Copy templates from Figure 36 for equipment you plan to purchase later.*
5. *Label each template and insert clearance measurement (Figure 38).*

Note arrows pointing to sides of some templates, and the figure "3" marked next to arrow (Figure 38). This is a reminder that 3 feet of space should be left on the "arrow" side of equipment for convenient passage. With some equipment, it is not necessary to allow space on all sides. Leave space only when needed.

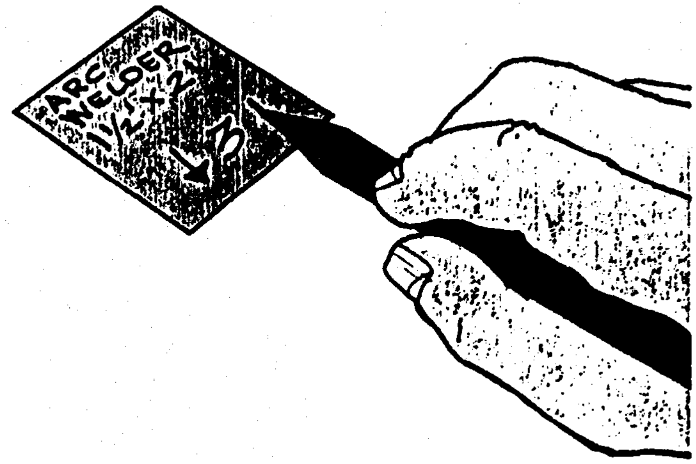


FIGURE 38. Label each template and insert clearance-measurement arrows.

You may have only part of the equipment listed here. This need not change the order of your planning. Leave out those items you do not have, or do not plan to get, and proceed with the others.

SPACE NEEDED FOR WOOD-WORKING

To determine the space required for woodworking tools, use the same procedures as for metal working. Proceed as follows:

1. *Select equipment you plan to use (Figure 39).*

2. *Measure equipment you already have to determine floor space required.*

3. *Prepare templates for equipment you plan to purchase later (Figure 39).*

   Make templates on scale of ½ inch = 1 foot.

4. *Label each template and insert clearance measurement (Figure 39).*

   Figure 39 shows examples of woodworking equipment commonly used along with the templates giving the approximate size and passage way clearances.

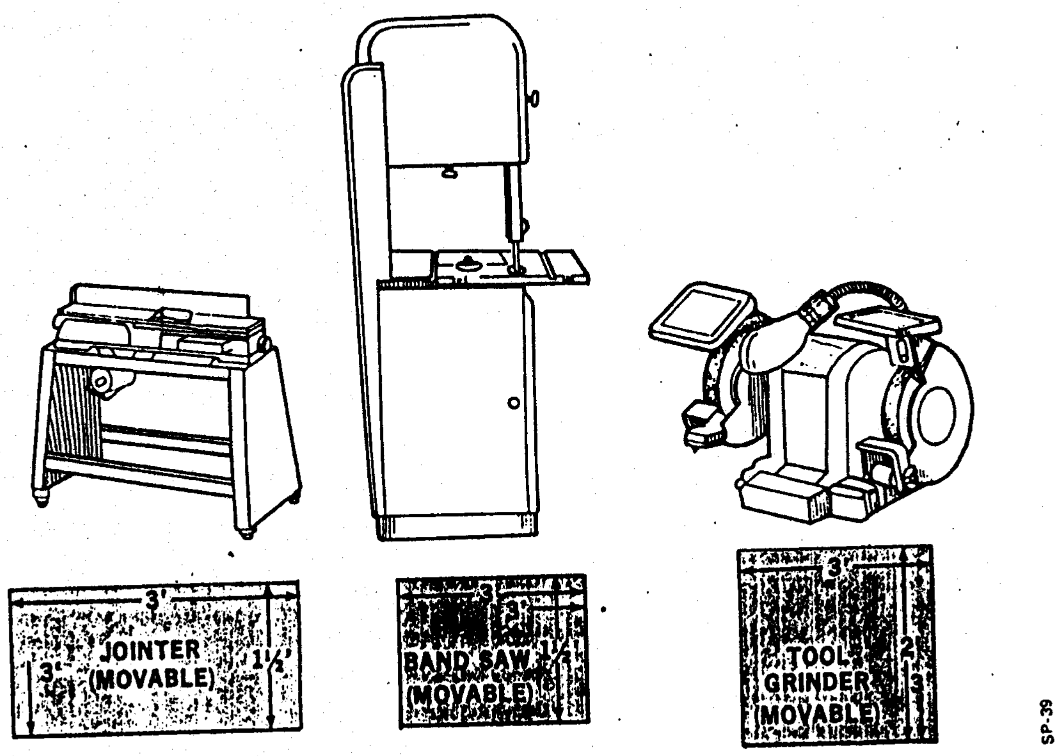


FIGURE 39. Examples of equipment commonly used in woodworking area of shops. Templates indicate approximate size of each unit.

SPACE NEEDED FOR HAND TOOLS

Many of the hand tools could be listed with either [me]talworking and machinery repair, or woodwork[in]g. However, since wall space is required for most [of] them, they are listed here separately. Some people [pr]efer a tool dolly which does require floor space [(F]igure 40).

In most shops, hand tools are kept either on a wall [mo]unted tool panel (Figure 41a) or in a wall mounted [to]ol cabinet (Figure 41b).

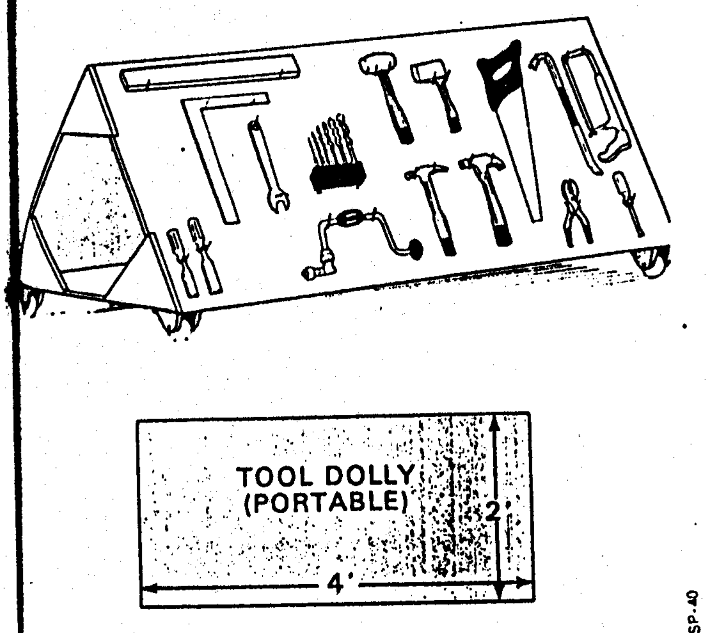


FIGURE 40. Tool dolly requires floor space.

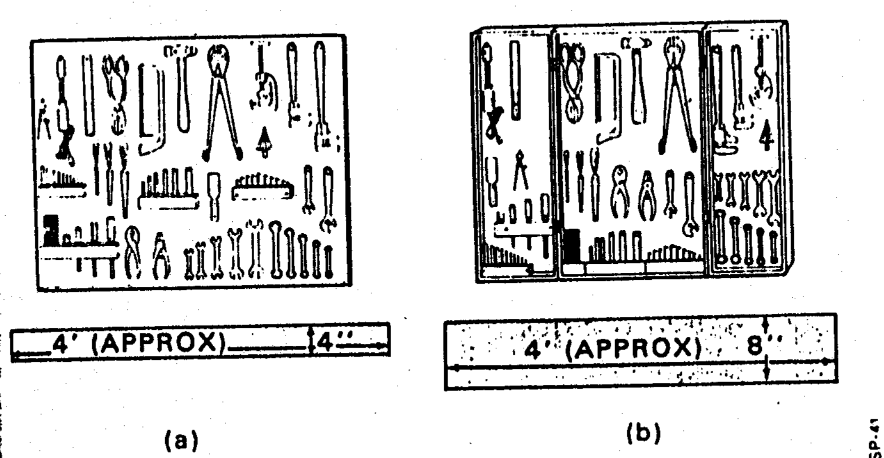


FIGURE 41. (a) Wall-mounted tool panel, and (b) wall-mounted tool cabinet (with templates). Types commonly used in metalworking area.

7. SPACE NEEDED FOR MISCELLANEOUS ITEMS

You may find there are some items you want to include in your planning that have not been previously listed. Examples are a desk, file cabinet, fire extinguisher, portable hoist, sink and air compressor. These and any others required may be grouped as miscellaneous and space assigned as with the other sections.

To determine the space needed for **miscellaneous items**, proceed as follows:

1. *Select equipment you plan to use.*
2. *Take measurements of equipment you now own and make templates to scale (½ inch = 1 foot).*
3. *Copy templates from Figure 42 of any equipment you hope to purchase later.*
4. *Label templates and insert clearance dimensions (Figure 42).*

   In some large shops, a separate office may be included to provide for the desk and file cabinet.

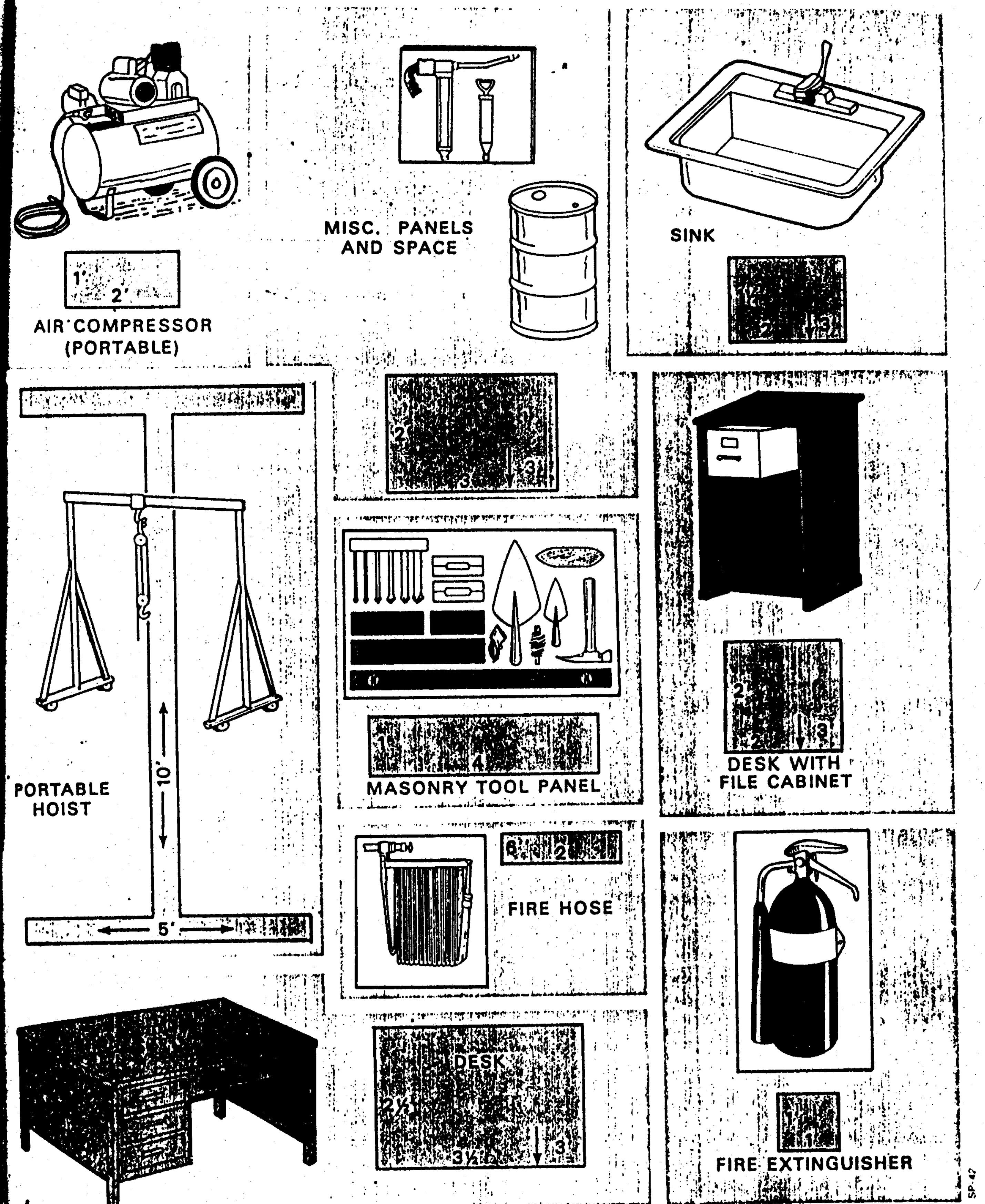


FIGURE 42. Miscellaneous equipment commonly included in shops and templates scaled to approximate size.

8. What Space Is Needed for Storage

Some storage space is desirable even in a small shop or service center. A well-planned shop will provide maximum storage using a minimum of floor space.

Upon completion of this section, you will be able to determine what space is needed for storage in your shop.

What space is needed for storage is discussed under the following headings:

1. Items to Be Stored.

2. Space Needed for Storage.

1. ITEMS TO BE STORED

Space for lumber and plywood storage is a major need in most shops. Other requirements may be storage areas for metal, machinery and electrical parts, nuts, bolts, nails, garden tools, lawn equipment and ladders. Paint thinner, gasoline and other volatile materials should not be stored in the shop, but in a separate building (Figure 43).

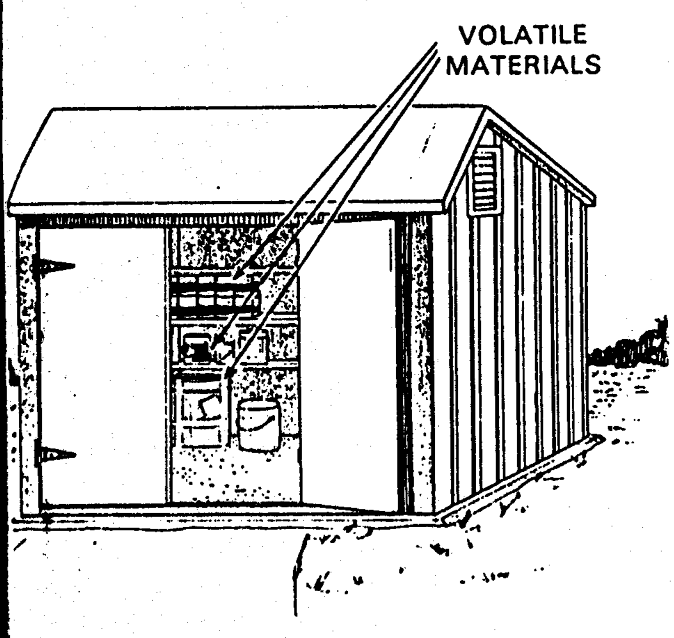


FIGURE 43. Store paint thinner, gasoline and other volatile materials in a separate building.

2. SPACE NEEDED FOR STORAGE

You can cut your space requirements by storing part of your bulky supplies—such as lumber—in your machinery shed or in a building close by, if available. However, it is usually better to provide for most or all of your present storage needs within your shop (Figure 44). Later, you may want to provide space in your shop for more equipment—some you have not considered in your present shop plans. Then, you can remove some storage racks or bins to get the needed space. Figure 44 shows common types of storage along with the templates that give the approximate and suggested sizes. Study them carefully to see if they meet your needs. If you already have some storage cabinets, or racks, take your template measurements from them.

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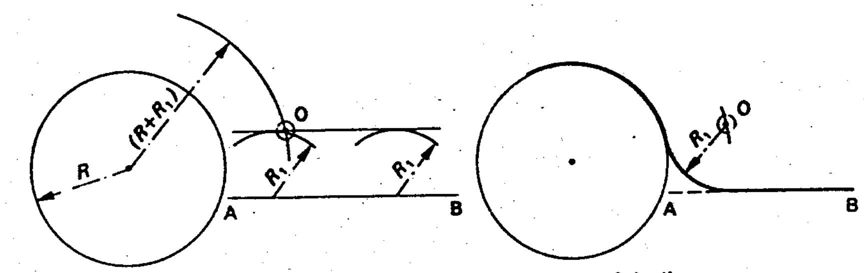
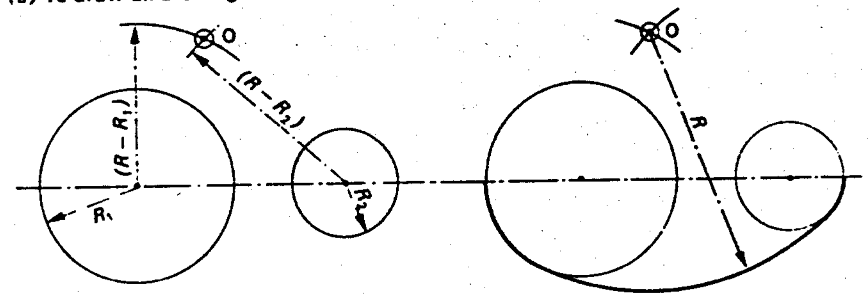
Figure 2.50(b) shows the construction of an external, tangential arc. Let R represent the radius of the given arc, and R_1 and R_2 the radii of the circles it is required to touch. Subtract the circle radii from the given radius of the arc, in turn, and from the respective centres of the circles draw arcs to intersect at point O. *With O as centre and radius R draw the required arc to touch the circles externally.*

Figure 2.50(c) shows the construction of an internal, tangential arc.

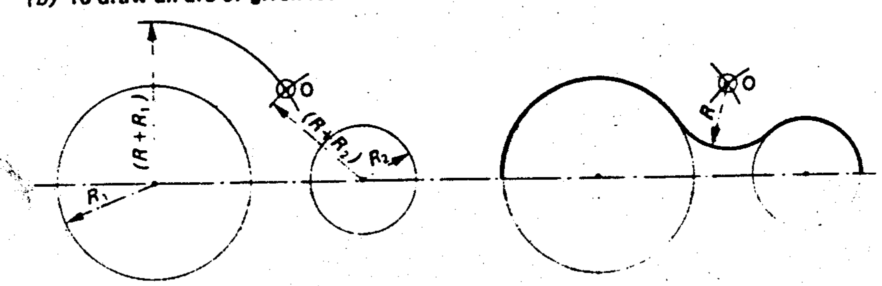
Add the circle radii to the given radius of the arc R. From the respective centres of the circles draw arcs to intersect at a point O. *With O as centre and radius R draw the required arc to touch the circles internally.*



(a) To draw an arc of given radius to touch a circle and a straight line



(b) To draw an arc of given radius to touch two circles externally



(c) To draw an arc of given radius to touch two circles internally

Fig. 2.50 Tangential arcs

2.15 Development of surfaces

The three basic methods used in pattern development are:

1. The PARALLEL LINE method.
2. The RADIAL LINE method.
3. The TRIANGULATION method.

In this book the principles of these methods will be explained, and the examples used will be limited to right prisms, right pyramids, the right cylinder, and right cone, and their frustums between parallel planes. *The development of a surface is the unrolling or unfolding of that surface so that it lies in one plane.*

The faces of *Prisms* are planes with their edges parallel. The unfolding of these faces will produce a development which takes the form of a simple rectangle.

A cylinder is developed by unrolling its surface, thus producing a *rectangle* having *one side equal in length to the 'circumference' of the cylinder*, the other side being equal to the *length or height of the cylinder.*

A pyramid, when its surface is unfolded, forms a development which consists basically of a number of triangles. *The base of each triangle is equal to the length of the base of the pyramid. The sides of each triangle are equal in length to the 'slant' edges of the pyramid.*

A cone, is developed by unrolling its surface. The circular base of the cone unrolls around a point, which is the apex of the cone, for a distance equal to its circumference. *The radius of the arc producing the base of the development is equal to the 'slant height' of the cone.*

In practice a complete cone is rarely required, except perhaps 'flat cones' which are used as 'caps', for example, on stove pipes. However, in the fabrication industry conical sections are constantly required to be manufactured. These components are part cones, often referred to as TRUNCATED CONES. When the cone is cut off parallel with its base, i.e. the top portion removed, the remaining portion is called the FRUSTUM.

2.16 Parallel line developments

The 'parallel line method' of pattern development depends upon a principle of locating the shape of the pattern on a series of parallel lines. All articles or components which belong to the class of PRISMS, *which have a constant 'cross-section' throughout their length, may be developed by the parallel line method.*

Elementary examples of parallel line development are illustrated in Fig. 2.51 to 2.53 inclusive.

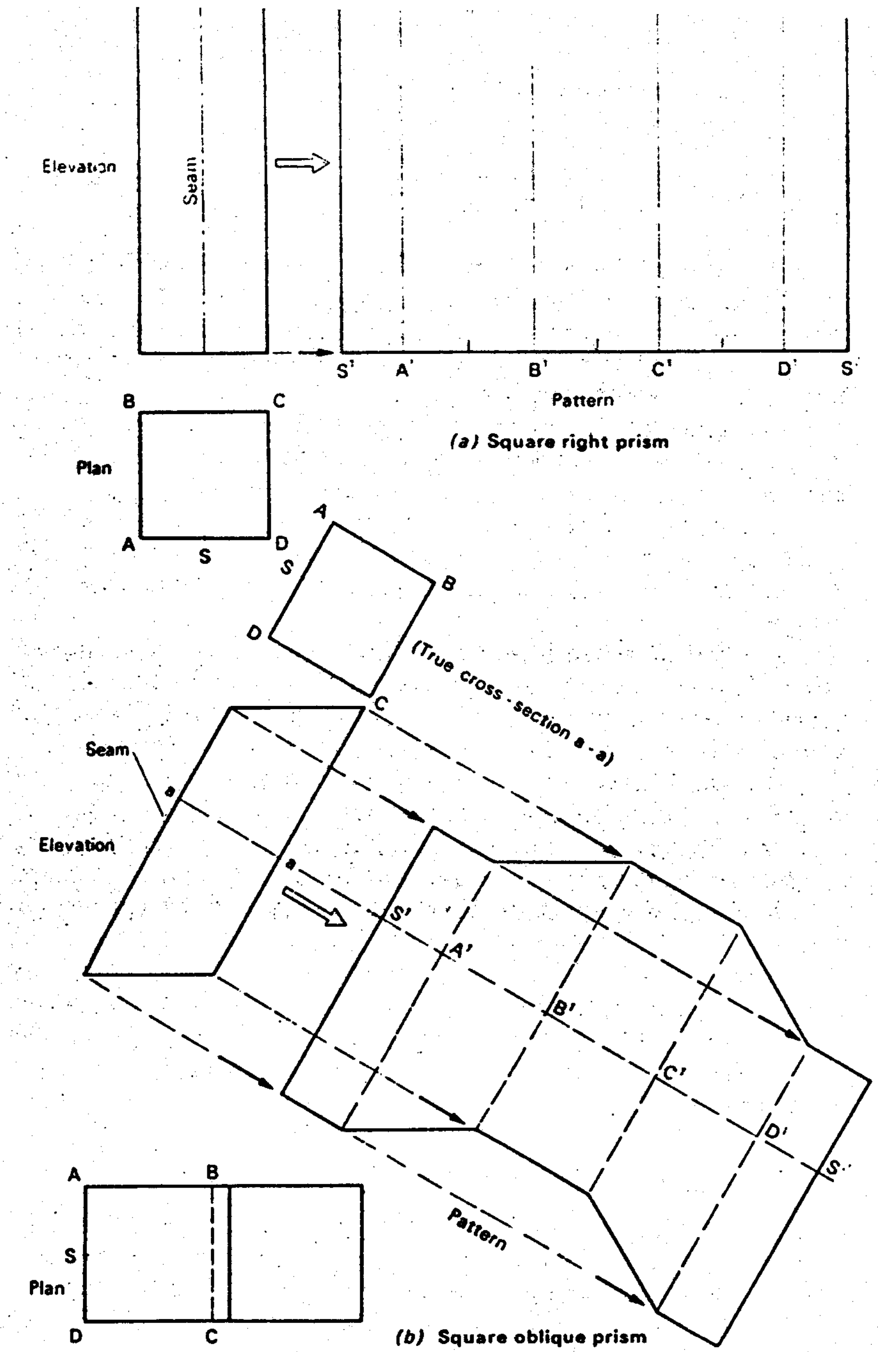


Fig. 2.51 Developments of square prisms (parallel line)

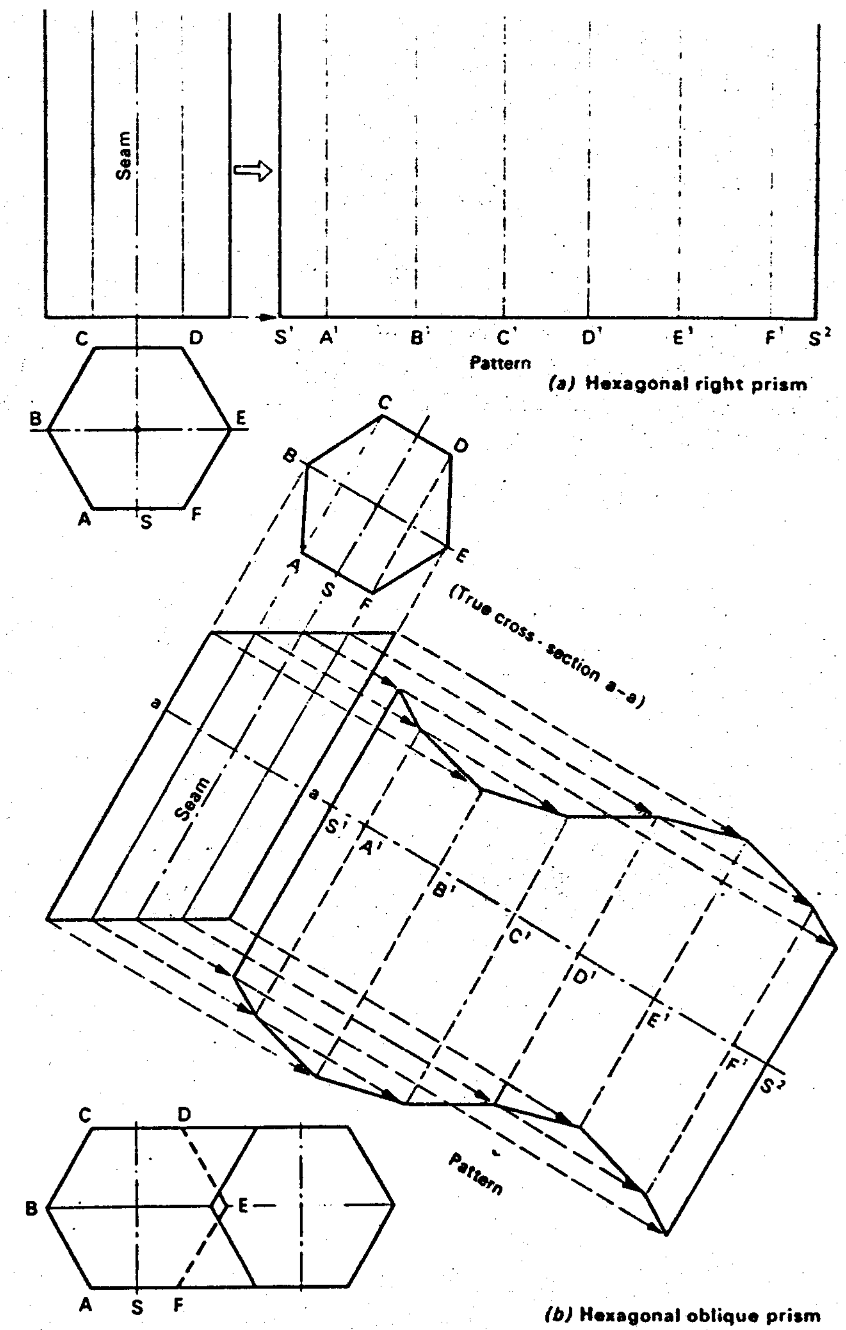


Fig. 2.52 Developments of hexagonal prisms (parallel line)

Fig. 2.53 De

In order to distinguish the basic difference between a 'right prism' and an 'oblique prism' it is essential to apply the basic rule:

IF THE CROSS-SECTION OF THE ENDS BETWEEN PARALLEL PLANES IS AT 90° TO THE AXIS, THE COMPONENT IS A RIGHT PRISM.

IF THE CROSS-SECTION OF THE ENDS BETWEEN PARALLEL PLANES IS NOT NORMAL TO THE AXIS, THE COMPONENT IS AN OBLIQUE PRISM.

Therefore in order to develop the correct 'stretch-out' for the length of the pattern the distance around the TRUE CROSS-SECTION *must be used.* The examples illustrated should be self-explanatory.

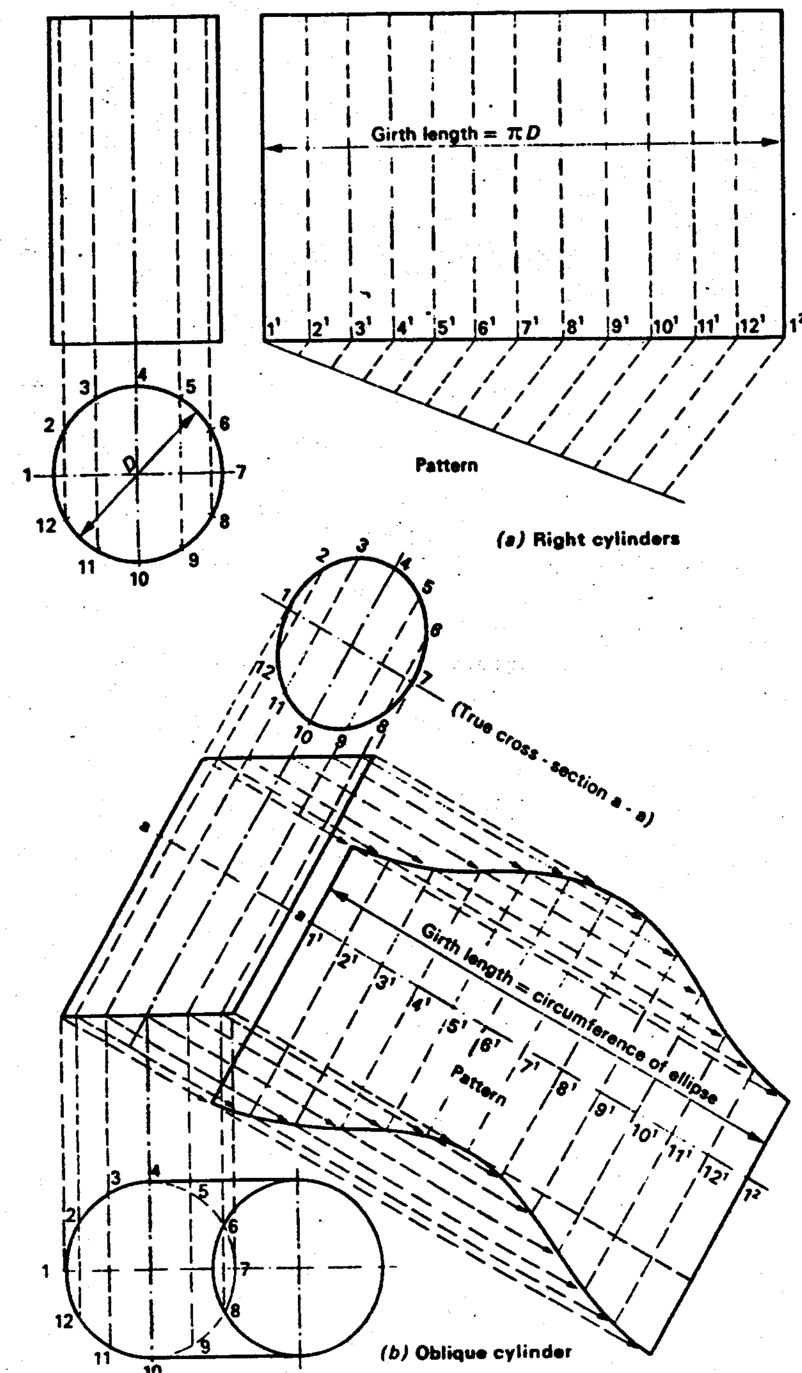


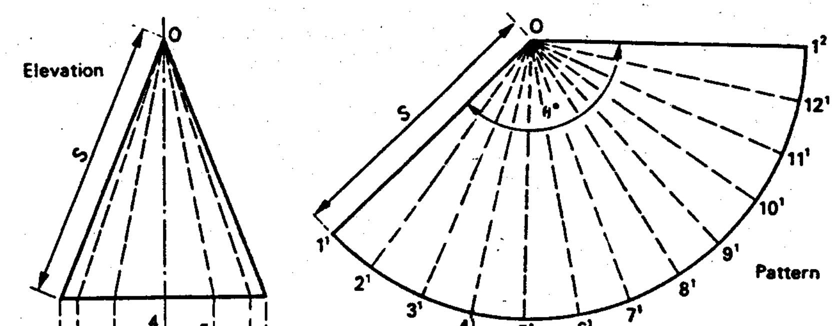
Fig. 2.53 Developments of cylinders (parallel line)

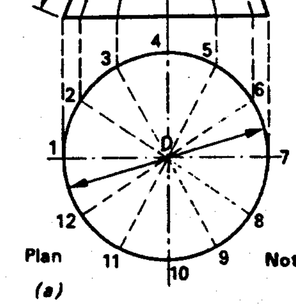
2.17 Radial line development

The 'radial line method' may be applied for developing the pattern of any article or component which *tapers to an Apex.* This method is also adaptable to the development of 'frustums' which would normally *taper to an apex if the sides are produced.*

The principle of radial line development is based on the location of a series of lines which radiate down from the apex along the surface of the component to a base, or an assumed base, from which a curve may be drawn whose perimeter is equal in length to the perimeter of the base.

Elementary examples of radial line development are illustrated in Figs 2.54 to 2.57 inclusive.





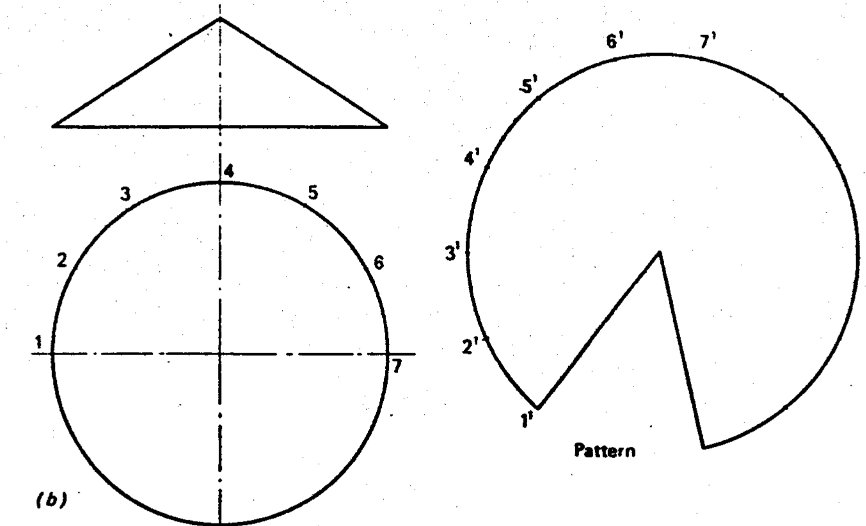
(a)

1. Draw the elevation and plan
2. Divide the plan circle into twelve equal parts using 60°/30° set square and number as shown
3. With centre O and radius equal to the slant height S of the cone draw a circular arc for the circumference of cone pattern and step off the arc distances $1^1 - 1^2$
4. Join the first and last element lines $0 - 1^1$ and $0 - 1^2$. The sector represents the true pattern for the cone

Note: The pattern of a right cone may be checked for accuracy by measuring the included angle $\theta°$

$\theta° = \frac{180D}{S}$ (where D = diameter of base, S = slant height)

e.g. given D = 60mm ⌀ S = 80mm then $\theta = \frac{180 \times 60}{80} = 135°$



(b)
A flat cone

Fig. 2.54 Development of a right cone (radial line)

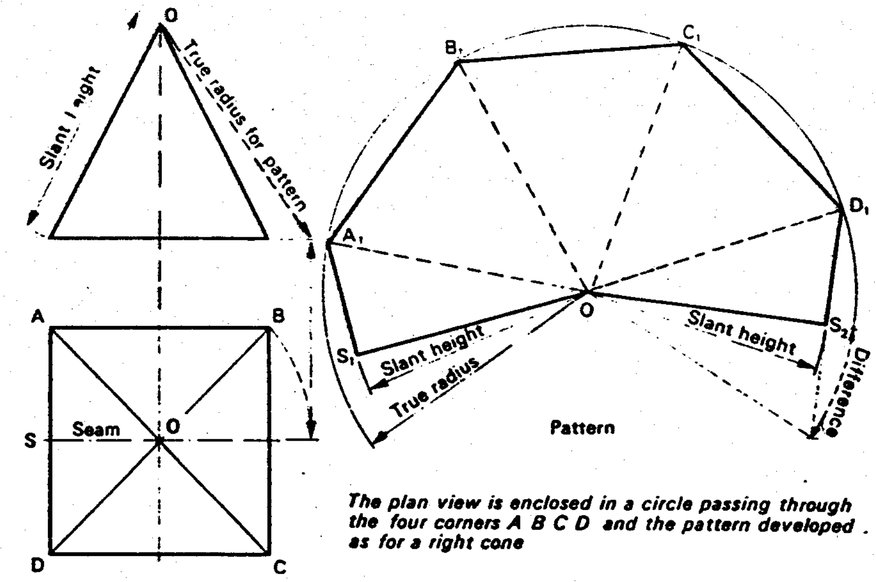
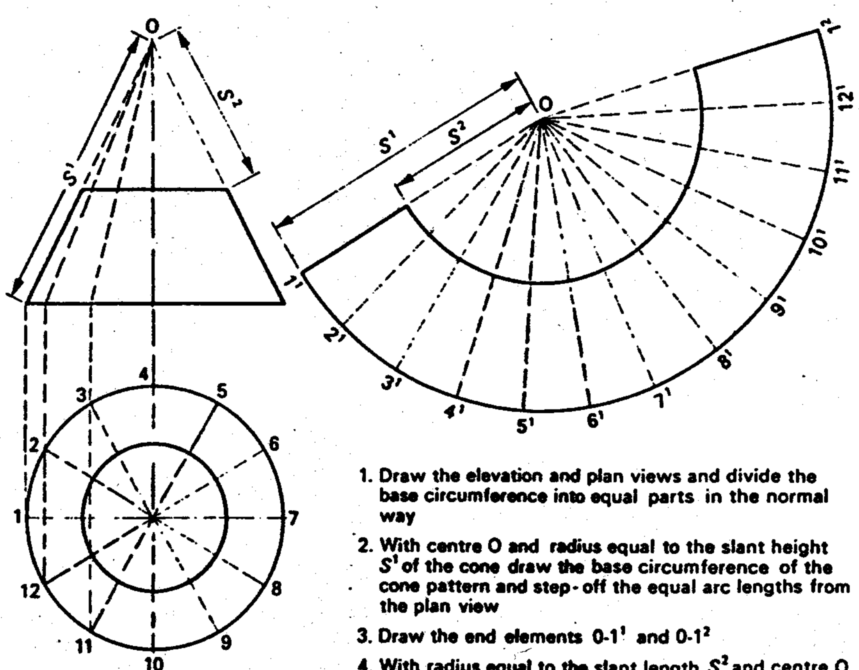


Fig. 2.56 Development of a square - based pyramid (radial line)



1. Draw the elevation and plan views and divide the base circumference into equal parts in the normal way
2. With centre O and radius equal to the slant height S^1 of the cone draw the base circumference of the cone pattern and step-off the equal arc lengths from the plan view
3. Draw the end elements $0\text{-}1^1$ and $0\text{-}1^2$
4. With radius equal to the slant length S^2 and centre O draw the top arc to complete the pattern

Fig. 2.55 Development of a right cone frustum (radial line)

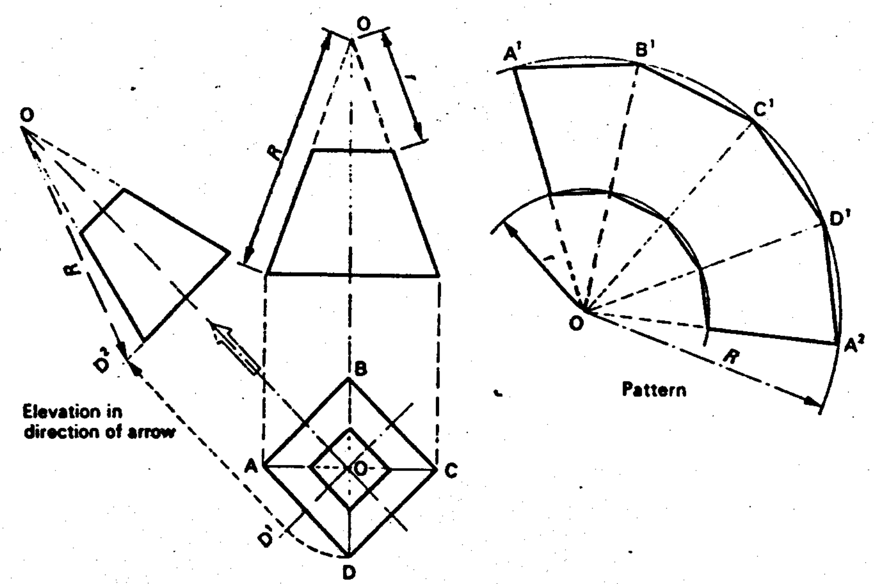


Fig. 2.57 Development of a square - based pyramid frustum (radial line)

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Fig. 2.57.

2.18 D…

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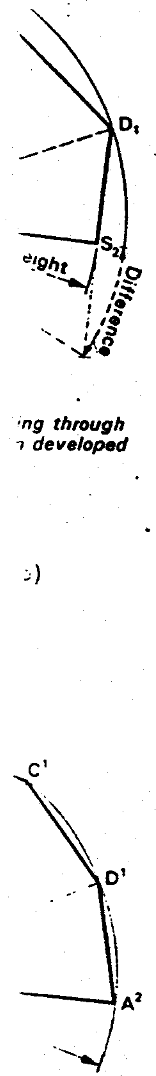


Cones and pyramids are very closely related geometrical shapes. *A pyramid may be considered as 'a cone with a limited number of sides'*. Similarly a cone may be considered as 'a pyramid of an infinite number of sides'. *In practice, many large conical shapes in heavy gauge metal are often formed on the press brake as if they were many-sided pyramids.*

Although cones and pyramids have very similar characteristics, care must be taken when developing patterns for pyramids. It is very important to recognise one specific difference between a cone and a pyramid in order to avoid mistakes in development.

Figure 2.56 shows two views of a right pyramid which completely describe the object. The elevation shows the true slant height of faces of each triangular face which are square to the plan view. However, *the slant corners of the pyramid in the plan view are not normal to the elevation.* In order to establish their true length for the pattern, the plan view would have to be rotated until one slant corner was square to the elevation. This is not possible on the drawing board, but an arc may be drawn in plan as shown in the figure (radius O B) to the centre line and the point projected up to the base of the elevation view. The distance from the apex to this point will provide the true radius for swinging the arc for the basis of the pattern. It will also be noticed, in this example, that the seam is to be along the centre of one face of the pyramid. Therefore the true length of the joint line is equal to the slant height shown in the elevation. The three full sides are marked off along the basis curve in the pattern, in the same manner as for a right cone, an arc is swung each end using centre O and radius equal to the slant height, and the last two triangles are completed by swinging arcs from A and D with a radius equal to half the length of one side in the plan. The fundamental difference between the cone and pyramid is clarified in Fig. 2.57.

2.18 Development by triangulation

Triangulation is by far the most important method of pattern development since a great number of fabricated components transform from one cross-section to another. A typical 'square-to-round' transformer is illustrated in Chapter 5. The basic principle of triangulation is to develop a pattern by dividing the surface of the component into a number of triangles, determine the true size and shape of each, and then lay them down side by side in the correct order to produce a pattern.

To obtain the true size of each triangle, the true length of each side must be determined and then placed in the correct relationship to the other sides.

THE GOLDEN RULE OF TRIANGULATION:

'PLACE THE PLAN LENGTH OF A LINE AT RIGHT ANGLES TO ITS VERTICAL HEIGHT, THE DIAGONAL WILL REPRESENT ITS TRUE LENGTH.'

An elementary example of the method of triangulation is shown in Fig. 2.58.

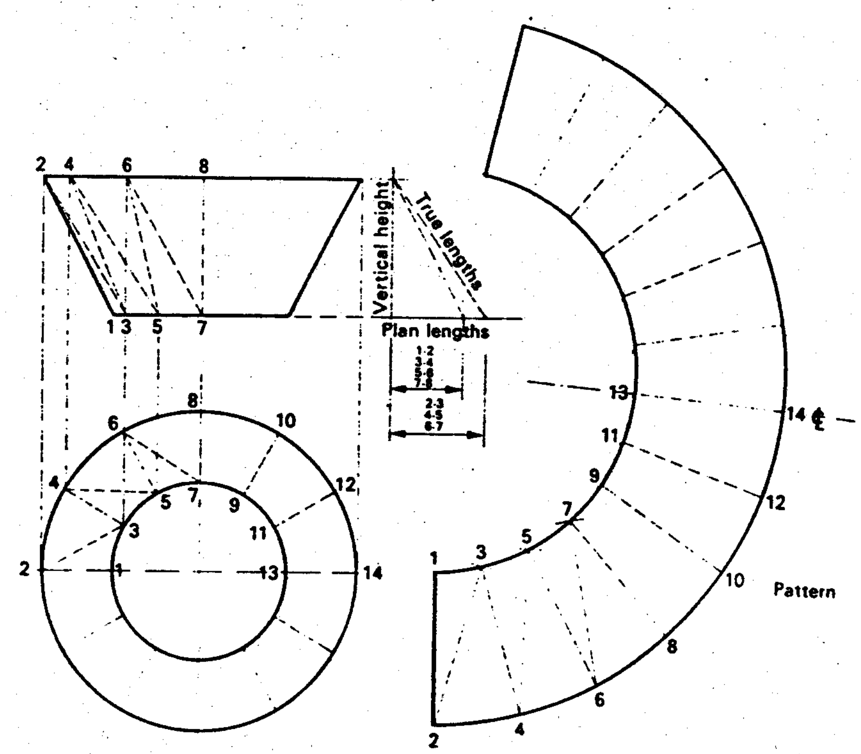


Fig 2.58 Development of a truncated cone (triangulaution)

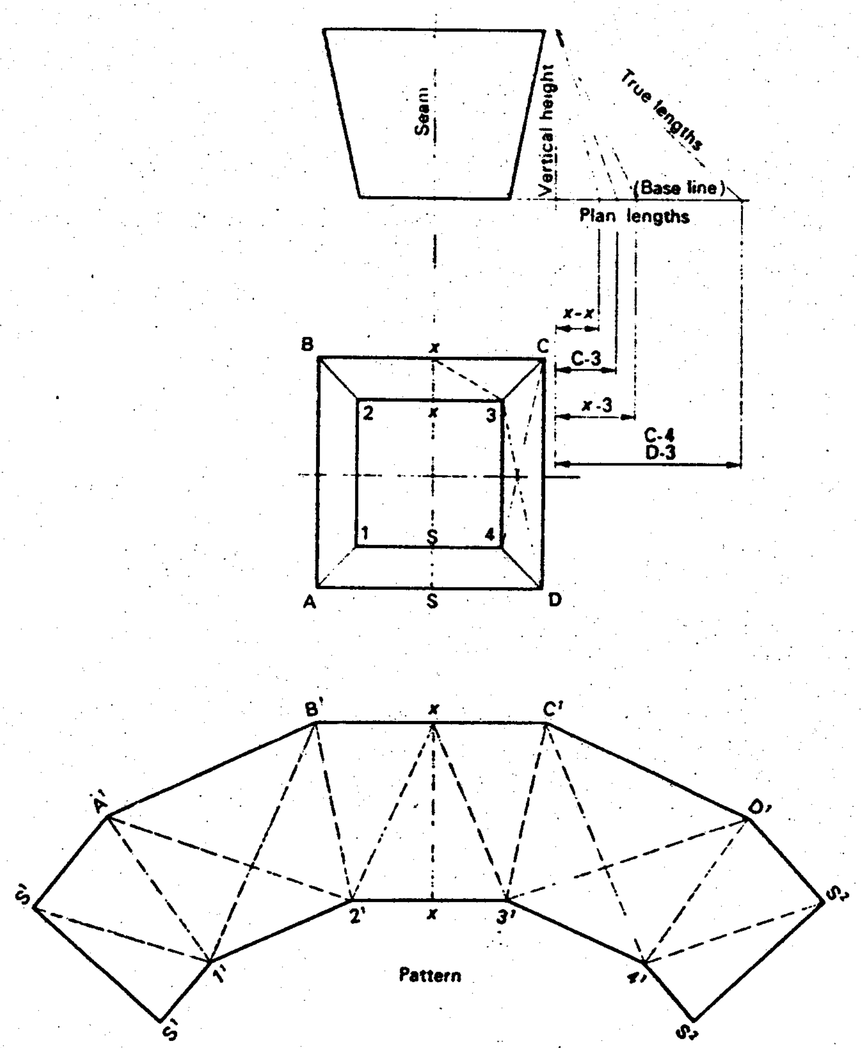


Fig 2.59 Development of a square hopper (triangulation)

A more complex example of triangulation is shown in Fig. 2.59.

1. Draw the elevation and plan views. The corner points in plan are lettered A B C D and numbered 1, 2, 3, 4 and 5,5 denotes the seam.
2. It will be seen that the lengths A B, B C, C D and D A of the large square, and lengths 1,2, 2,3, 3,4 and 4,1 of the small square are TRUE LENGTHS in plan since they lie in the same horizontal plane, and therefore have no vertical height.
3. For the first triangle in the pattern take the true length distance B C (in plan) and mark it in the pattern. Draw a vertical centre line *x,x*. Mark the plan length *x,x* along the base line at 90° to the vertical height, and obtain its TRUE LENGTH and mark it on the pattern. Obtain the true length of diagonal *x*,3 in plan and swing arcs from *x* (on B C) in the pattern. Complete the triangle in the pattern by taking true length *x*,3 (in plan) and swing arcs each side of the centre line to locate 2 and 3.
4. Join B,2 and C,3 in the pattern (this represents one side of the hopper) check these two sides by plotting plan length C—3 against the vertical height.
5. For the next triangle mark true length arc B A. Obtain the true lengths of diagonal 2,A in plan by plotting it against the vertical height and swing an arc from 2 in the pattern to locate point A. Join B,A in the pattern.
6. For the next triangle swing true length arc 2,1 and true length arc B,1 these will intersect to locate point 1 in the pattern. Join A,1 and 2,1 to complete a second side of the hopper.
7. Take 3,1 in plan and swing an arc from 1 in the pattern. Take true length A,S from the plan view and swing an arc from A in the pattern to obtain true length 1,S by plotting its plan length against the vertical height and swing an arc from 1 in the pattern to locate points S. The last triangle S,1,S is completed by swinging an arc from S equal to the true length of the font line. Join A,S, 1,S and S,S.

Note: By commencing the pattern in the middle at *x*—*x* (i.e. opposite the seam). The whole pattern to be obtained by repeating the marking out procedure each side of the centre line.
Check the pattern for symmetry — if drawn correctly the last two triangles are right-angle triangles.

2.19 Comparison of right and oblique cones

Although the development of oblique cones and their frustums is beyond the scope of this book, it is important to be able to recognize the essential differences between these very similar geometrical shapes.

The essential differences between right and oblique cones is explained in Fig. 2.60.

Welding of mild steel, stainless steel, aluminium and copper pipes
Technically, oxy-acetylene welding can be used to join almost any size or thickness of pipe or tube. In practice it is seldom applied to pipe over 150 mm in diameter or 10 mm wall thickness.

With this process it is possible to produce sound welds in mild steel pipe situated in any position and using the minimum of runs. Because the equipment is portable and minimum clearance round the joint is required to allow the blowpipe to be played on the joint, it is widely used for installation and repair work.

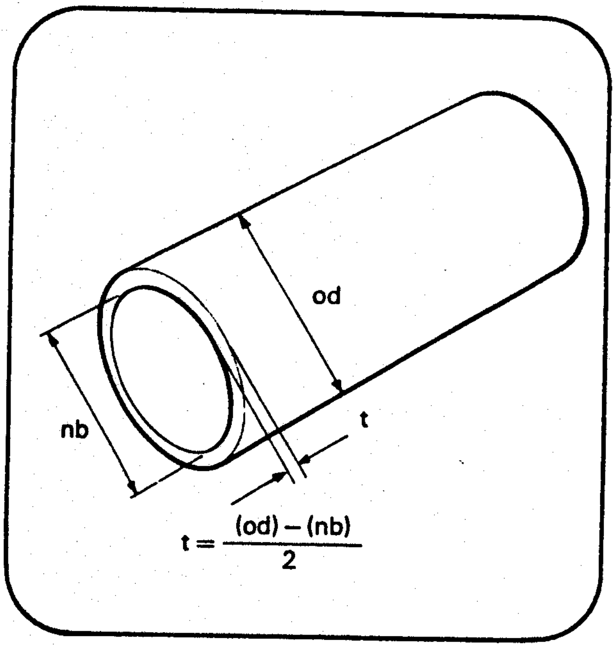
For joining aluminium pipes, tungsten-arc gas shielded or metal-arc gas shielded welding is preferred (if available).

Thin-wall copper pipes may be readily bronze-welded, giving a joint which retains adequate strength even at elevated operating temperatures; again this technique is in wide use for installation and repair work.

When welding stainless steel pipe it is essential to identify the material as there are numerous specifications.

Example procedures—material
Pipe of a nominal bore of 50–100 mm is specified in module F25 Skill and Training specification and should be used for training.

The pieces used in the Example procedures should be long enough to allow a length, either side of the weld, at least equal to 1½–2 times the diameter of the pipe.

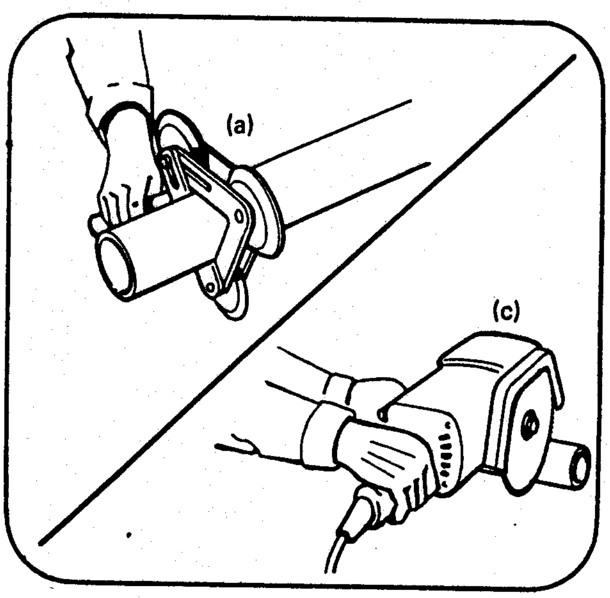


Cutting and bevelling procedure
Before cutting

Identify materials by relevant colour coding and/or stock list reference. Read all instructions on the drawing.

Check:

(a) Specification of material
(b) Nominal bore (nb)
(c) Wall thickness (t)
(d) Length required
(e) End preparation required.

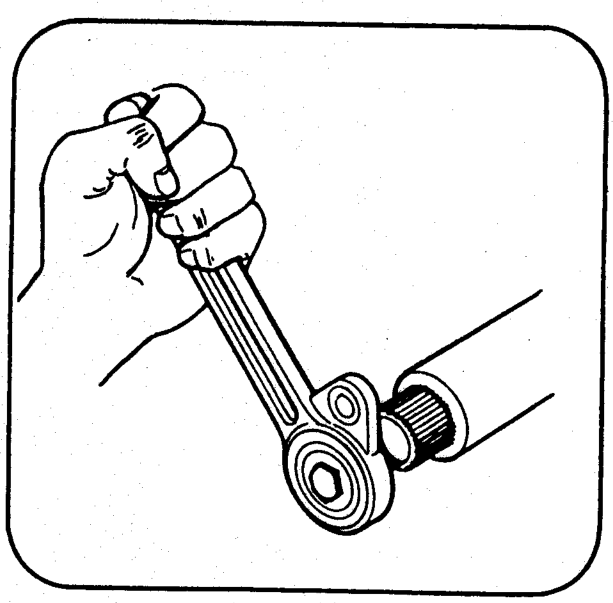


End cutting

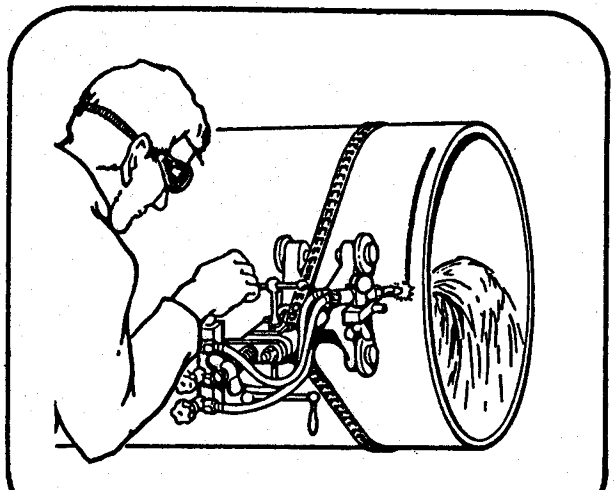
1. Cut small diameter mild steel pipe by:

(a) pipe cutters
(b) hand saw, or
(c) power saw.

Note: When using a hand saw, ensure that the cut is at right angles to the pipe axis.



2. After cutting to length, remove any burrs on the inside of the pipe by reaming or filing.

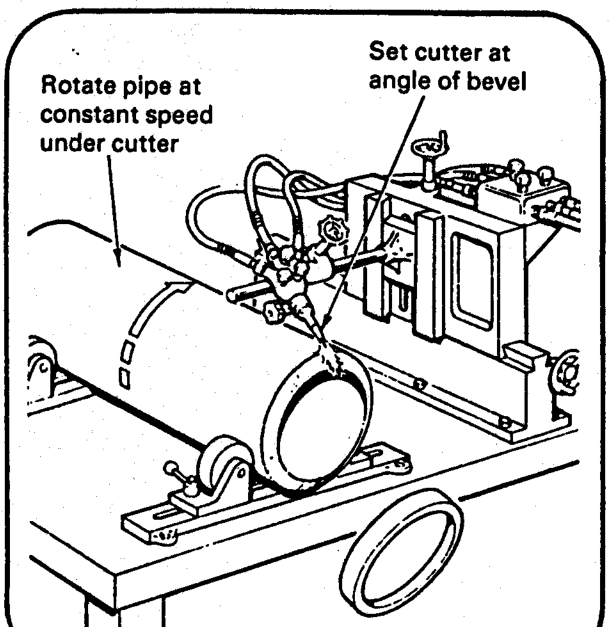


Rotated pipe-cutting head

3. Cut large diameter pipe by:

(a) power saw, or

(b) portable oxy-fuel gas cutting machine, either mechanically or electrically driven.



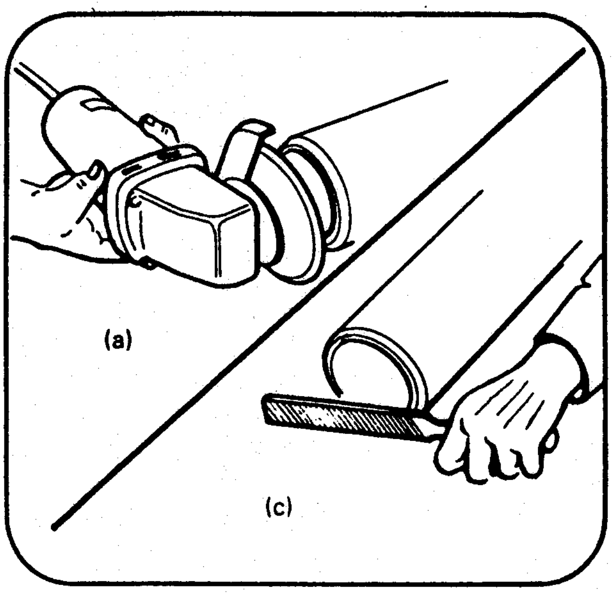
Cutting bevel on pipe

Bevelling

1. Cut the required angle of bevel using:

(a) oxy-fuel gas cutting machine, or

(b) ending machine.

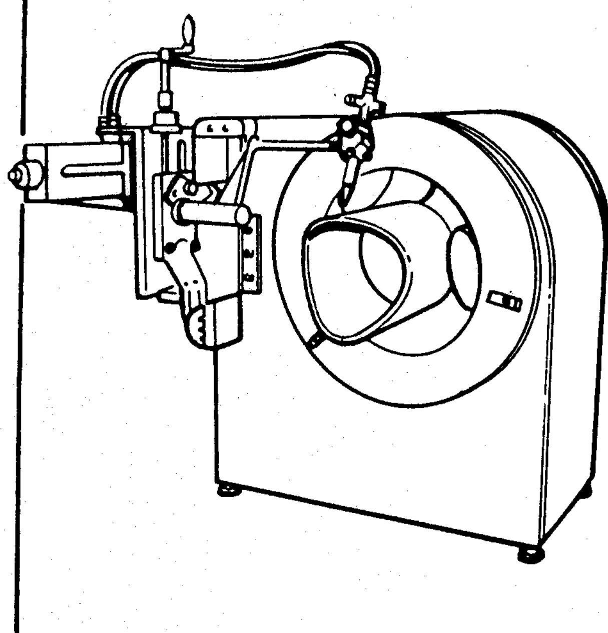


2. Obtain the required root face depth by:

(a) grinding

(b) machining

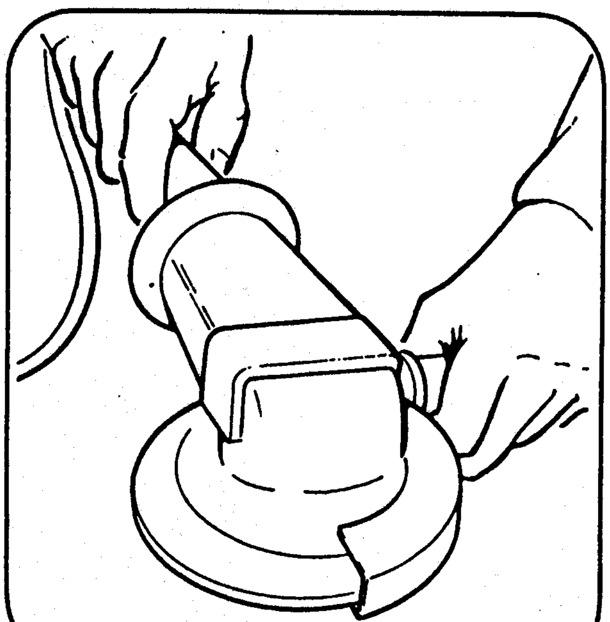
(c) filing.



Profiling machine

Cutting of branch components in mild steel

1. Branch pipes in mild steel may be cut on a special oxy-fuel gas profiling machine. Where such equipment is not available, the branch can be produced by marking the outline using a template and scriber or pointed chalk followed by centre punching. The branch can then be produced by cutting to the marked outline, using manually operated oxy-fuel gas cutting equipment.



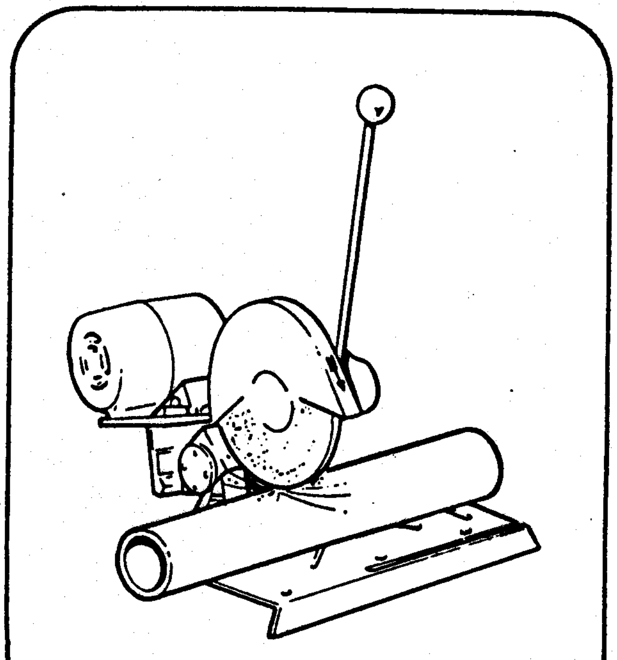
Hand grinder

2. Branch holes may be cut by any of the following methods, depending on the equipment available:

(a) Oxy-fuel gas profiling machines, which cut the holes and produce the required angle for weld preparation.

(b) Cutting manually, using the oxy-fuel gas process; the cut edge being dressed smooth by using a hand grinder or file. With this method, care must be taken to ensure that the cut sections are removed from inside the pipe.

(c) Using trepanning tools for holes up to a maximum of 150 mm diameter. This method is suitable for use with all types of steel pipes.

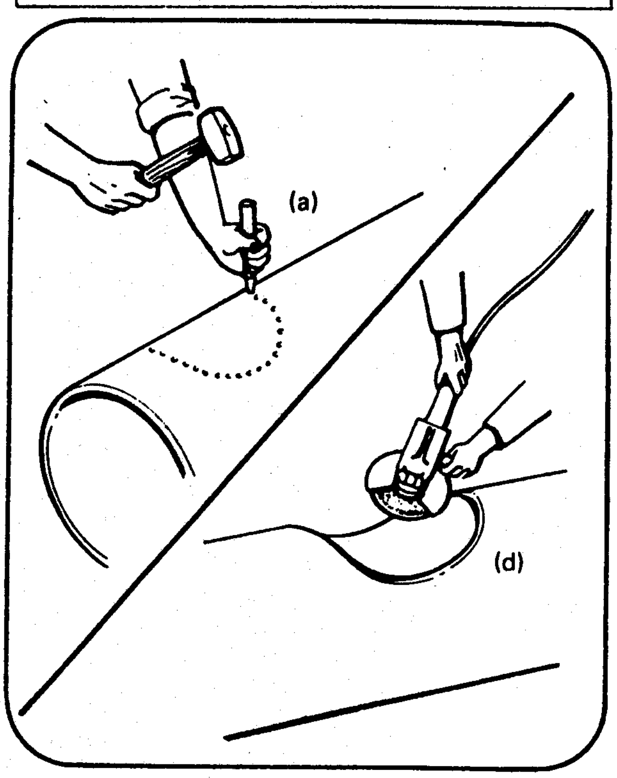


Slitting saw

Avoid

Accidental arcing outside the area to be cut.

There are numerous stainless steel specifications. It is essential to identify the material prior to cutting.



Stainless steel

1. Stainless steel cannot be cut by a conventional oxy-fuel gas process.

Normally, straight end preparations are obtained mechanically by power saw, slitting saw or in the lathe.

2. Bevelling is carried out by grinding, in a lathe or by portable electric bevelling machine.

Cutting of branch components in stainless steel

1. Branch pipes and branch holes can be marked out as described for mild steel. The hole is produced by using the air-arc process. After cutting stainless steel pipe with the air-arc process, it is important to ensure that all iron powder or carbon deposits are removed, otherwise the corrosion resistance of these materials is reduced.

Do not cut to the finished *scribe line;* cut approximately 3 mm inside the line (ie. in the waste area).

The final dimension is obtained by portable grinding.

2. Holes may be pierced by trepanning or the use of an arc cutting process. Take care to protect the surface and inside of the pipe from damage by the cutting action.

3. Where these methods are not applicable, the following procedure may be adopted:

(a) mark out the hole as described for mild steel

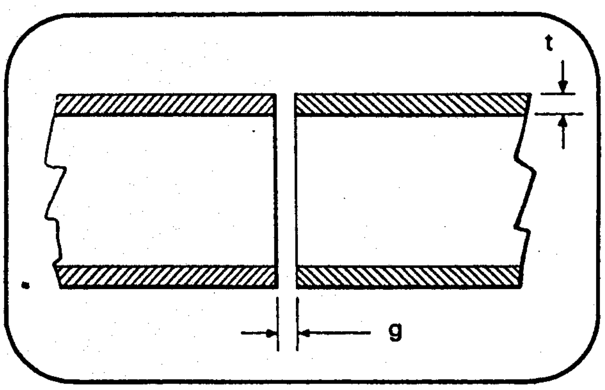
(b) drill a series of overlapping small holes around the scribed line

(c) remove metal between the holes by chipping, using a diamond pointed chisel. Remove the waste metal disc

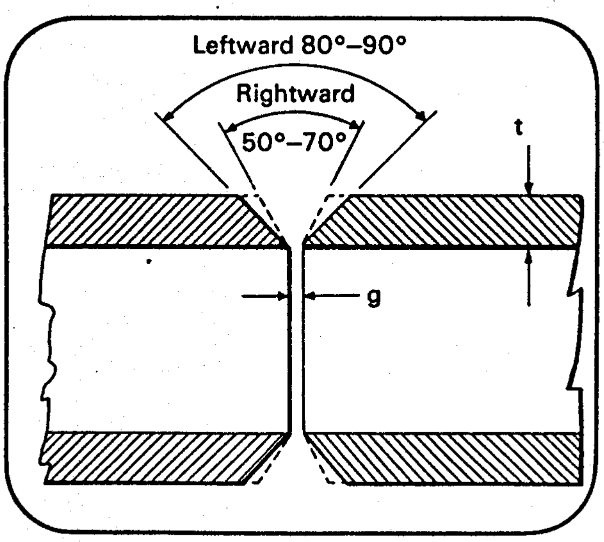
(d) smooth and bevel the hole, using a grinder or file.

Selection of welding technique and pipe end preparation
For blowpipe and filler rod angles see Module F10 Instruction Manual.

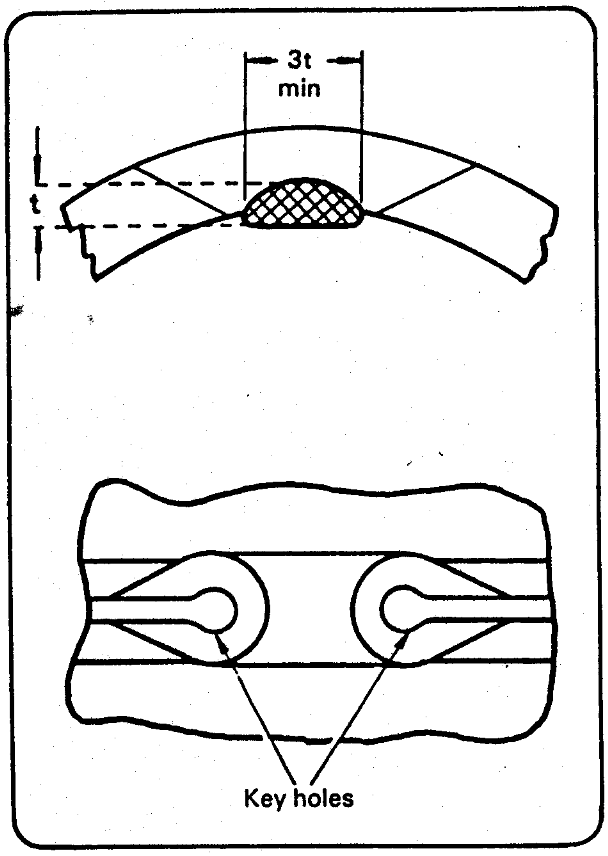
Wall thickness (t)	Pipe preparation	Welding	Joint gap (g)
3 mm or less	Square	Leftward	2·5–3 mm
5 mm or less	Square	Rightward or all-positional rightward	2·5–3 mm
3–5 mm	Bevelled	Leftward	1·5–2·5 mm
5–7 mm	Bevelled	Rightward or all-positional rightward	3–4 mm



Pipe ends square



Pipe ends bevelled



General notes, preparations, tackwelding

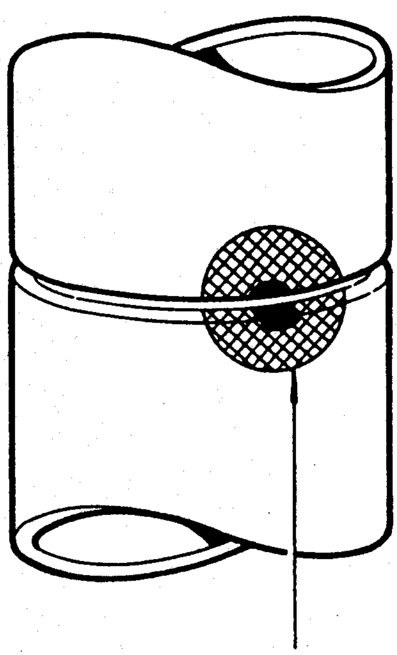
Gaps are those to be left after tackwelding or when set up in a jig.

A pipe alignment jig can eliminate the need for tackwelding.

Oxy-acetylene tackwelds normally form part of the welded joint, so they must be free from defects.

A 'keyhole' is left at both ends of the tackweld which enables a good 'join-up' with the main weld.

> Tackwelds have to hold the pipes in position whilst the main weld is being made. Ensure that they are sound enough to do this.



Area to be red hot. Both edges should be melted through to the bore before filler metal is added.

Making a tackweld

1. Hold the blue cone about 12 to 25 mm away from the tackweld area, and heat until an area of about 25 mm diameter is red hot.

2. Position the nozzle about 6 mm away and direct the cone into the gap and wait for both edges to melt through to the bore of the pipe.

3. Bring the tip of the filler rod (which will be near melting point) into contact with the melting edges and hold under the flame until enough filler rod has been deposited.

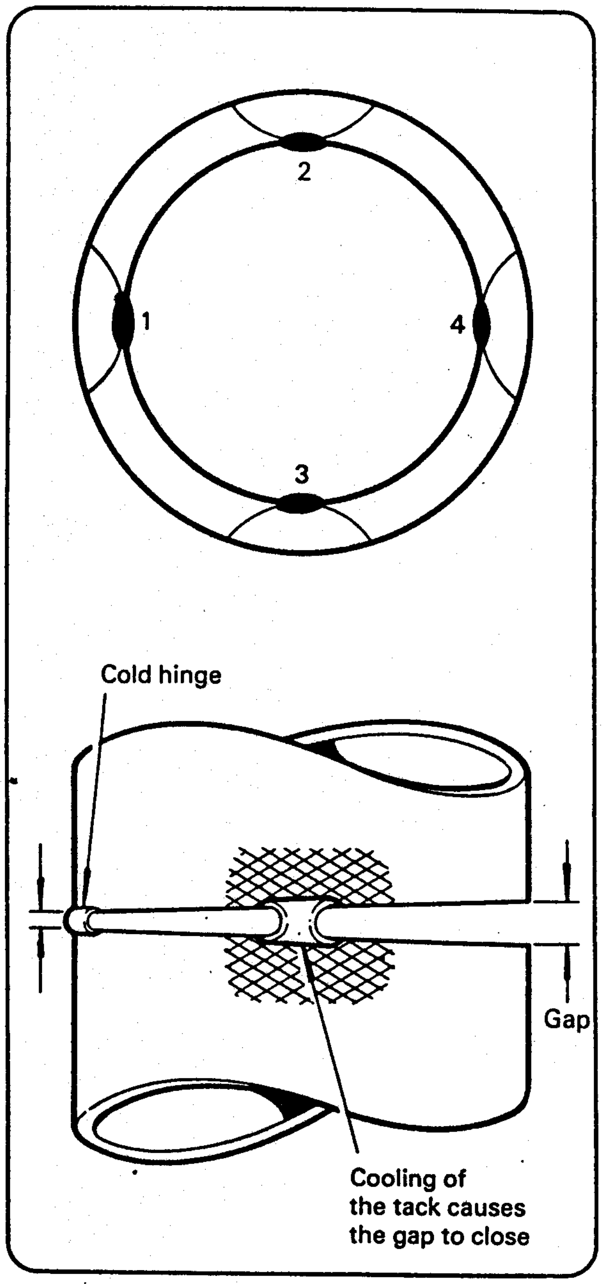
4. Momentarily withdraw the flame to allow the metal to solidify and then (in turn) direct the flame at each end of the tackweld until the keyhole is obtained.

Do not insert a cold filler rod into the weld pool.

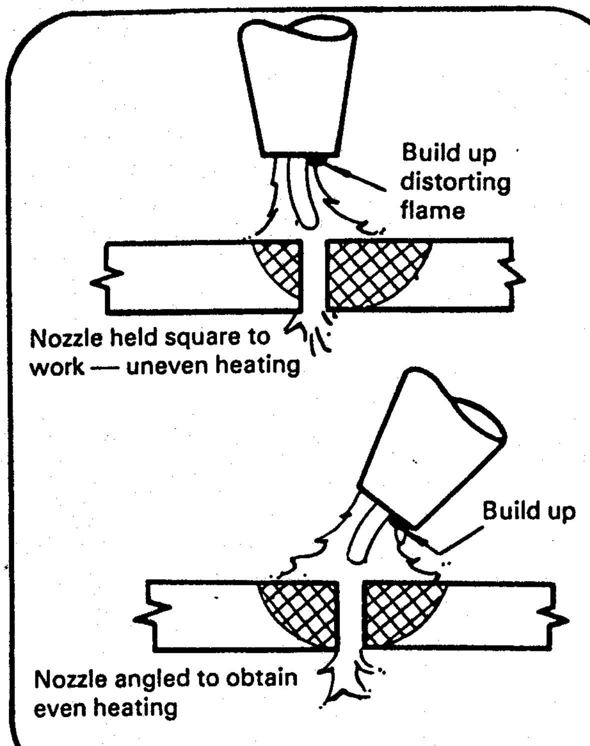
The number and size of tackwelds will depend upon the length and sizes of the pipe.

The position of the tackwelds will depend upon the accessibility and position of the joint.

Diameter of pipe	Number of tackwelds
Up to 30 mm	2
30 to 75 mm	3
75 to 150 mm	4



The sequence shown allows for contraction at each tackweld. The gap before tack welding should be set slightly wide and tapering for this reason.



Effect of spatter on nozzle

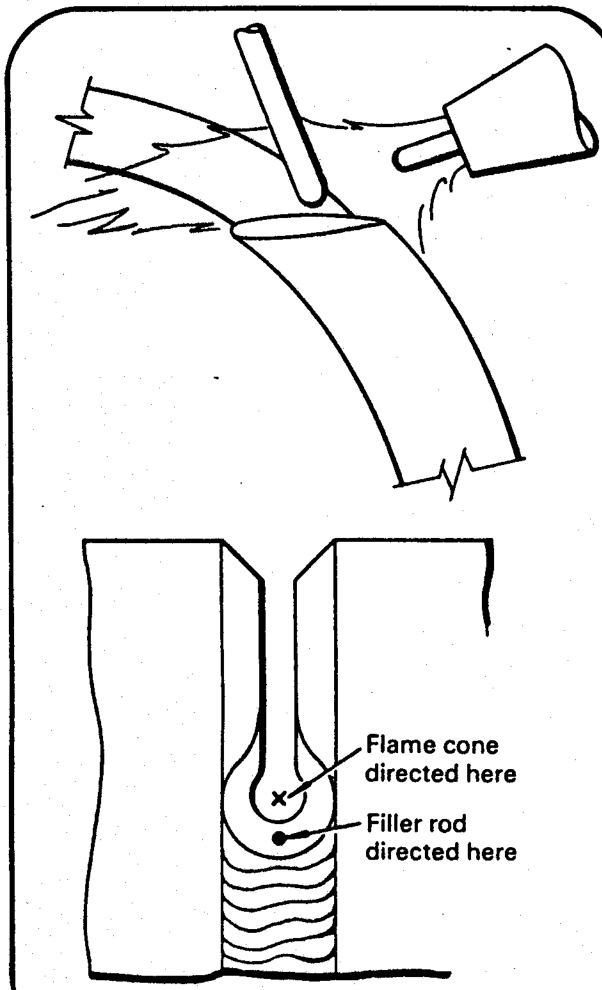
Welding torch (blowpipes)

(i) Blowpipes for tube and pipe welding are almost exclusively of the high-pressure type, ie. for use with acetylene gas cylinders.

(ii) Recommended pressures are higher than for general welding, longer hoses normally being required.

(iii) A build-up of metal particles on the tip of the nozzle is inevitable when welding mild steel pipe. A certain amount of build-up can be tolerated and counteracted by altering the angle of the nozzle. (See illustration.)

If the build-up cannot be brushed off with a welding rod then the flame will need to be turned off and the gas way cleaned out with the appropriate cleaning tool.

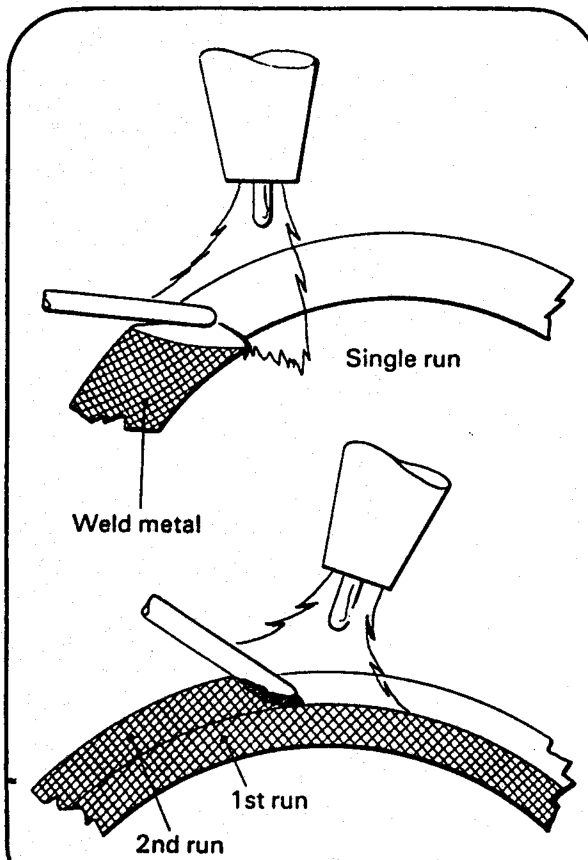


Leftward welding

Welding techniques

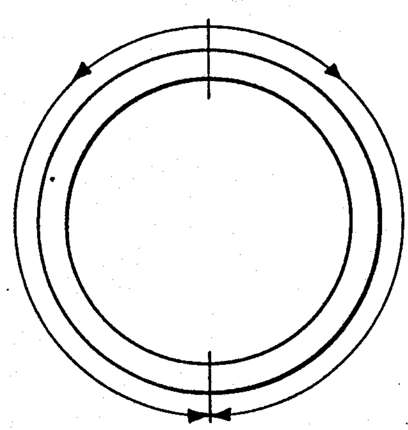
1. Leftward welding.

This technique can be used to make welded joints in all positions, for all thicknesses and sizes of pipe. It is a slow technique for positional work and often requires more edge preparation and runs than the rightward technique. It is generally used for thin-wall pipe.



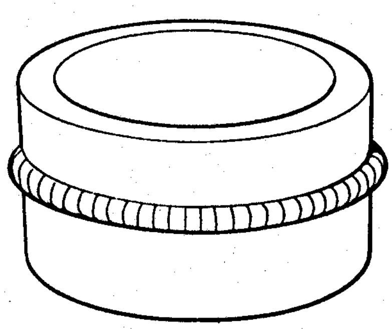
Two runs

2. Rightward welding.
The filler rod is nearly always given a circular, or side-to-side motion to place the molten metal into the required position.
This technique is mainly applied to:
(a) the top sections of a pipe


(b) Vertical down

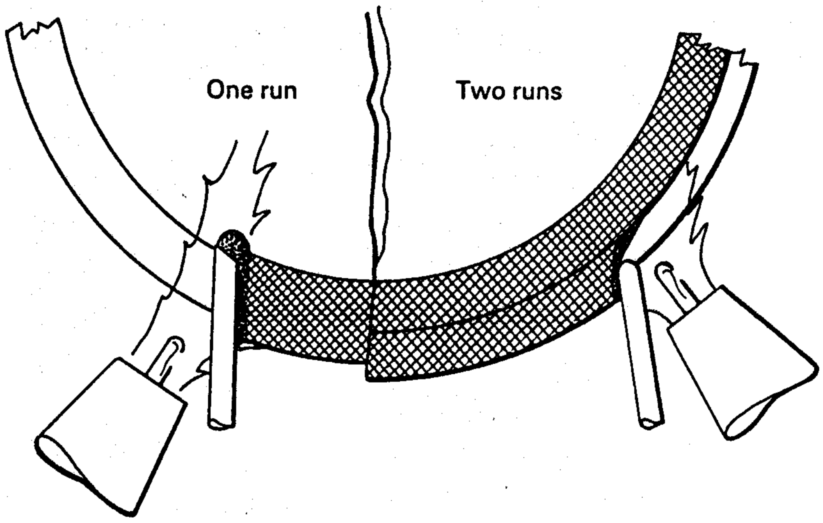
(b) the first run for vertical down welding.

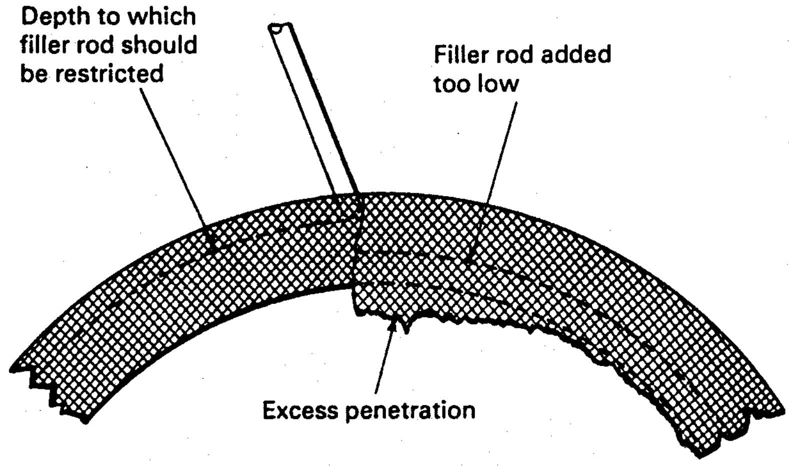
Note: The welding position will actually change from flat at the top of the pipe to vertical at the side and finally to overhead at the bottom; it is, however, referred to as vertical welding of pipe.


(c) Horizontal-vertical

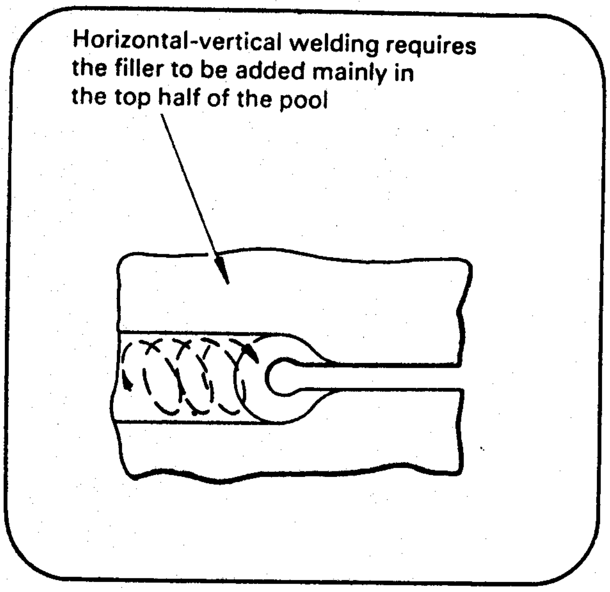
(c) a single-pass weld in the horizontal-vertical position (butt weld in a vertical pipe).

3. All positional rightward welding.
This technique is applied mainly to joints in the overhead and vertical positions.





Filler rod additions — Flat position



Filler rod manipulation and weld pool control
When welding pipe the method of adding the filler rod must be adjusted to suit the position of welding.

When welding in the flat position, the metal will be pulled downwards into the pipe bore.

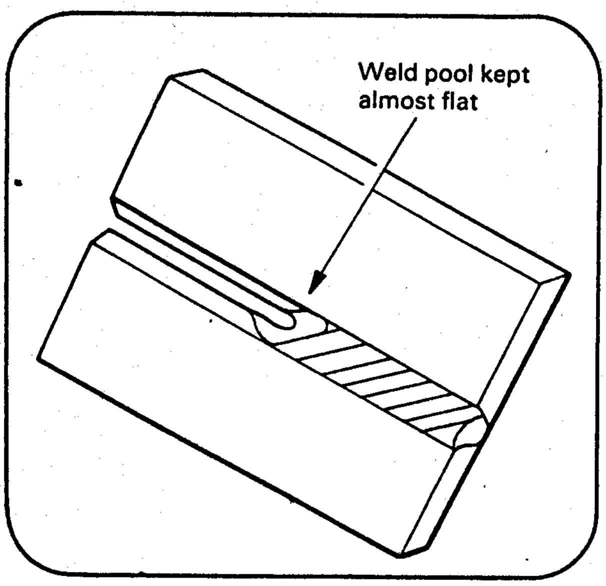
To help avoid this, the filler rod is added to the top of the pool and the weld metal is allowed to solidify when it has run down into the correct position.

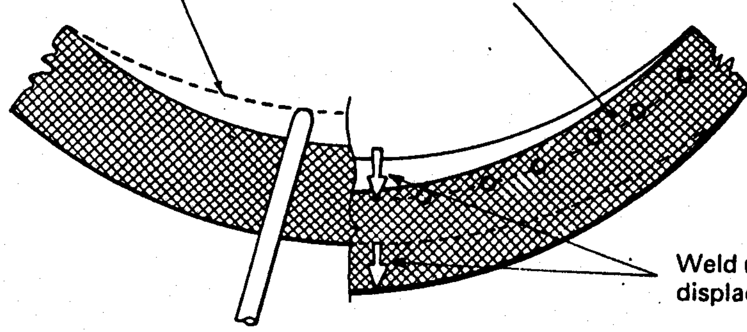
Vertical welding does not present any problems, provided the filler rod is regularly moved into position.

Horizontal-vertical welding requires the filler rod to be added mainly in the top half of the pool.

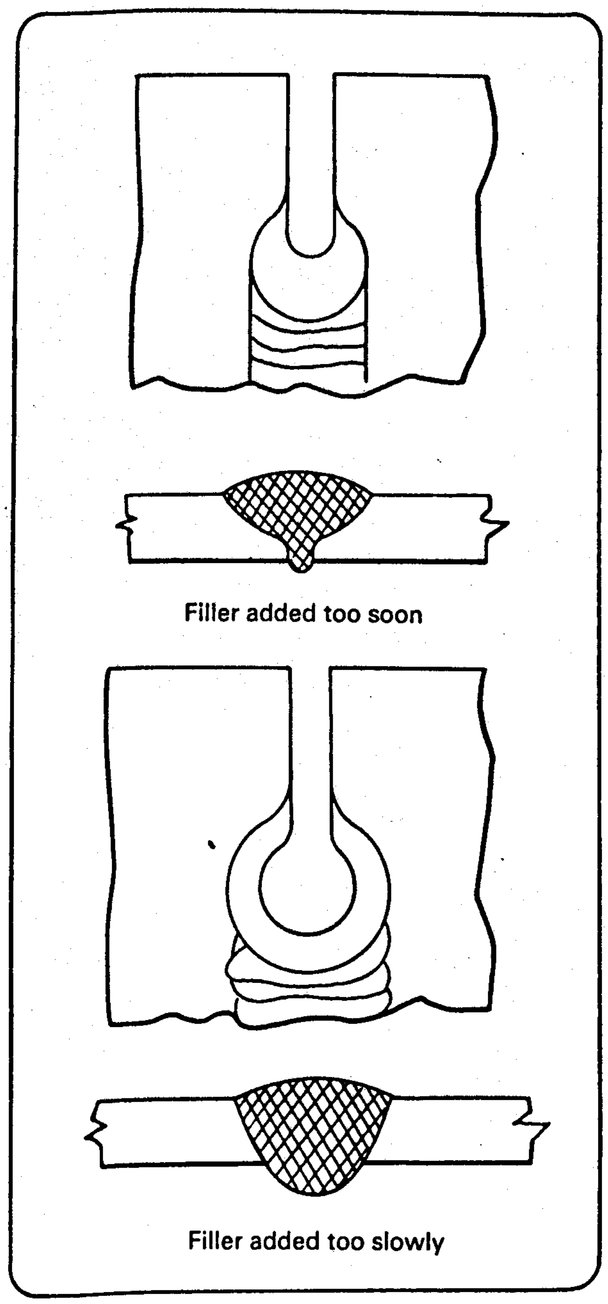
Overhead welding has the opposite effect to the flat position.

It is often necessary to keep the weld pool as flat as possible.



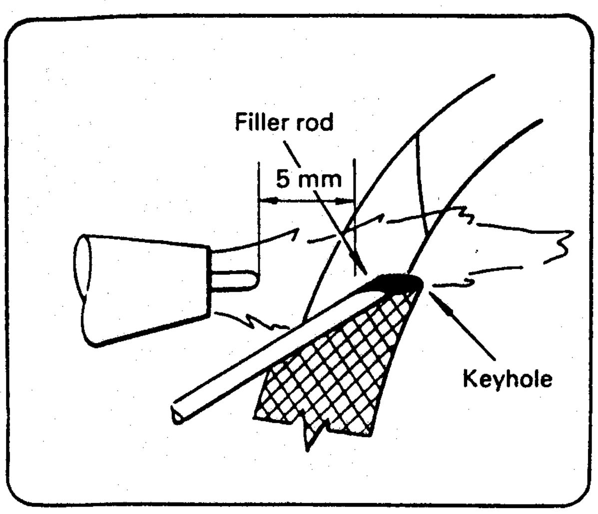


Filler rod additions — Overhead position



Unless the filler rod has to be pushed through the keyhole, always add the filler as soon as the keyhole has been obtained.

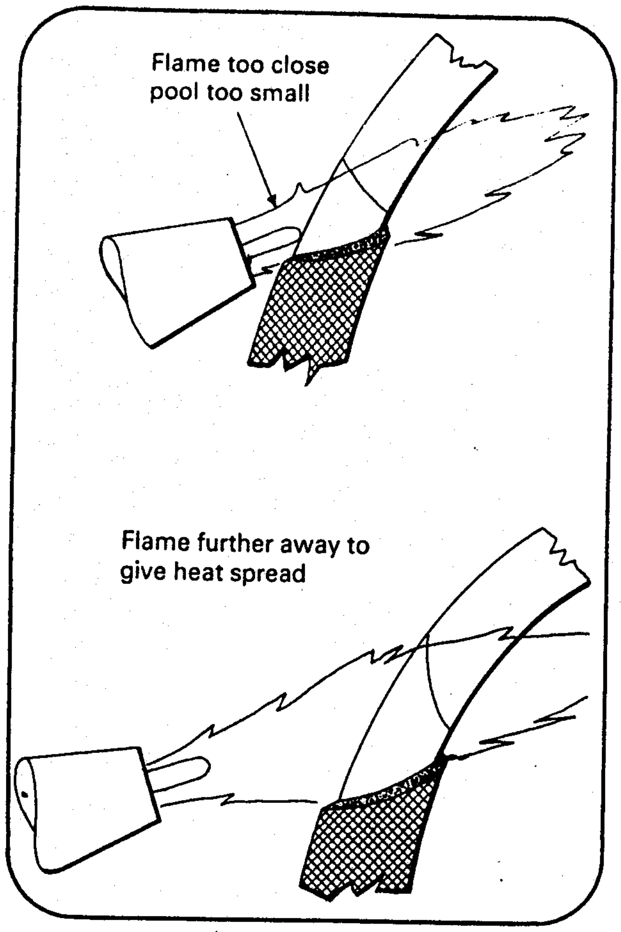
Control the size of the keyhole by the rate at which filler rod is added.



When adding filler rod bring the end of the rod into the hottest part of the flame. (Approximately 5 mm in front of the blue cone). The filler rod should be brought into the hot part of the flame when the keyhole is correct.

Keep the side-to-side movement of the nozzle to a minimum.

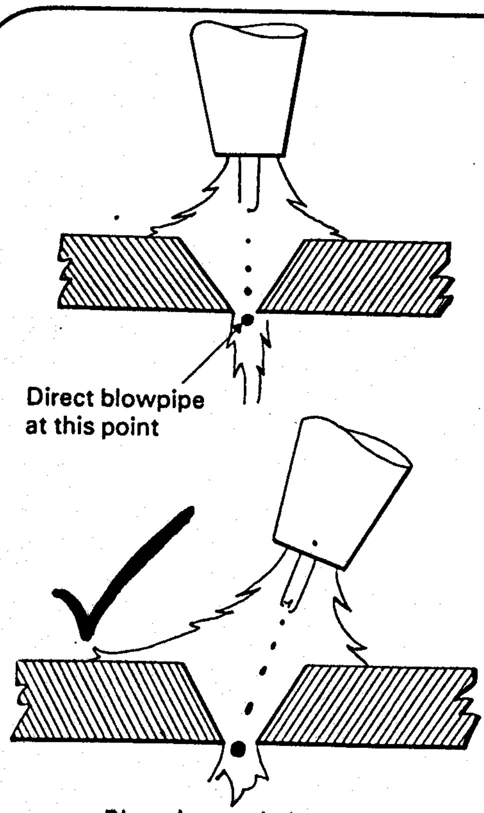
If the weld pool is not fluid enough or big enough, draw the flame away to spread the heat.



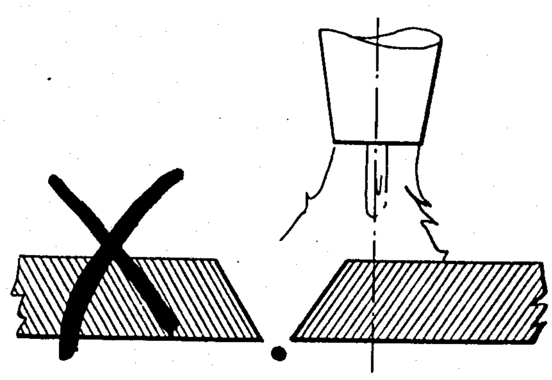
In most cases direct the flame at and along the centre line of the weld. If one side is getting hotter than the other, angle the blowpipe.

Do not move the blowpipe over. Keep it pointing at the centre line of the joint.

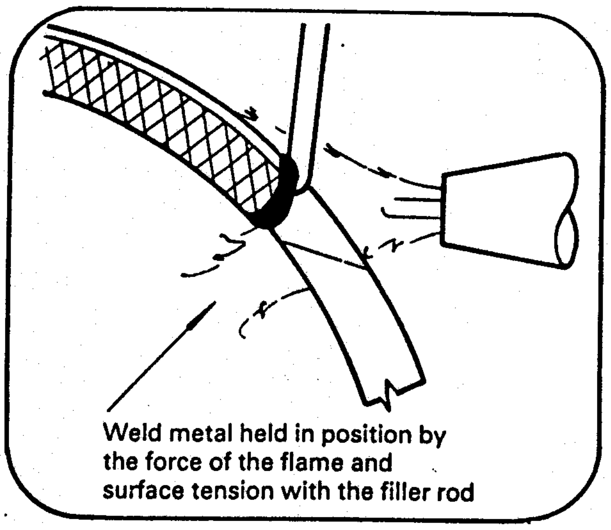
Once a pipe joint has been started endeavour to complete it without stopping.

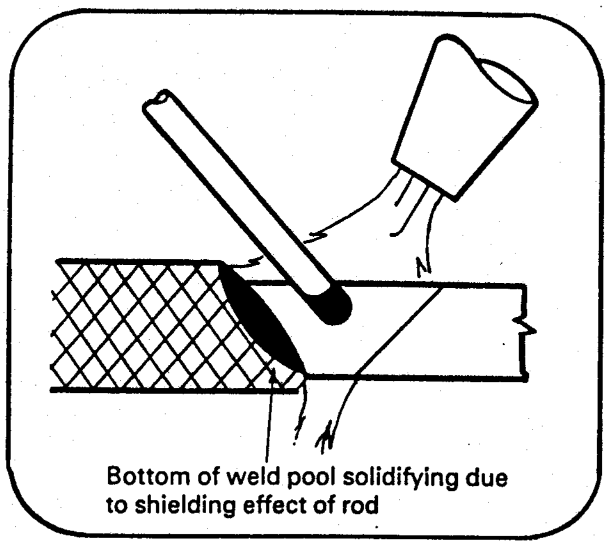


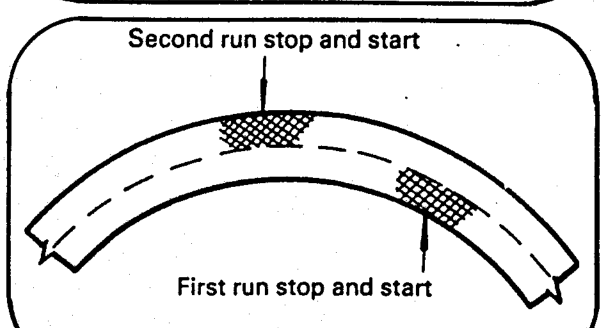
Blowpipe angled to rectify uneven heating



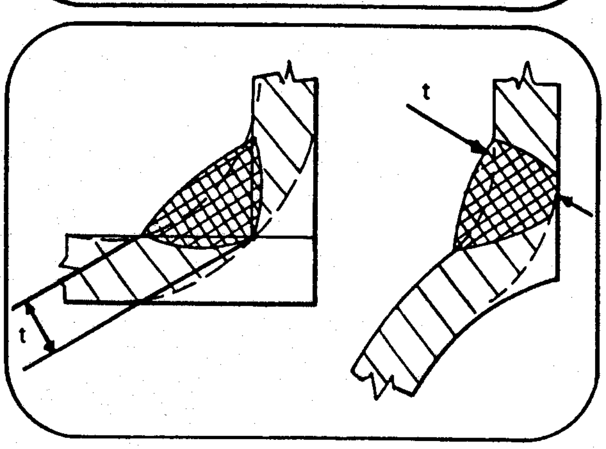
Do not move the blowpipe over







Staggering stop and start positions



Stopping the weld

On mild steel, up to 1·5 mm thick, the speed of taking the flame away from the weld pool has little if any adverse effect.

Above this thickness and depending upon the weld position, it is advisable to withdraw the flame slowly to allow the liquid weld metal to solidify before it it exposed to the air. In some cases the force of the flame is used to help control the liquid metal. Then it is essential to withdraw the flame slowly to prevent the liquid metal running over the melted parent metal.

Restarting the weld

Restart welds as quickly as possible:

1. Maintain the flame slightly further away than for welding, but directed at the centre of the keyhole.

2. When the area is red hot, position the flame for welding and wait until the weld pool is molten through to the bore or root.

3. Draw the flame away slightly and heat the end of the filler rod to almost melting point.

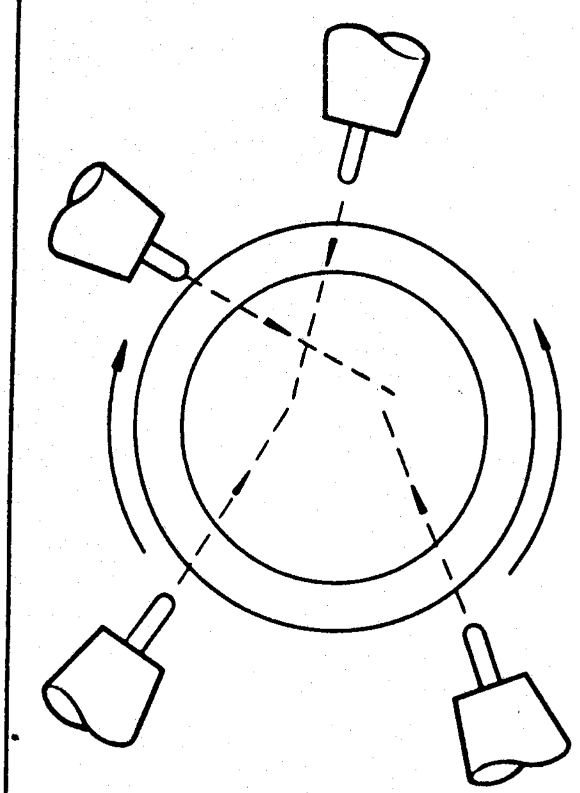
4. When the pool and the end of the welding rod are molten insert the filler rod into the pool and continue welding.

Do not insert a cold filler rod end into the weld pool.

5. When adding the filler rod do not shield the pool from the flame. When making multi-run welds stagger stop and restarts.

Weld size

Unless otherwise stated the throat thickness 't' of the weld (or the combined throat thickness of more than one weld) should be equal to, or slightly larger than the wall thickness of the thinnest section.



Torch or blowpipe positions when welding butt joints

Butt joints

As a general rule the blowpipe is directed a few degrees to one side of the pipe axis.

This means that, when welding small diameter pipes, the nozzle has to be angled more rapidly.

Inspection and testing

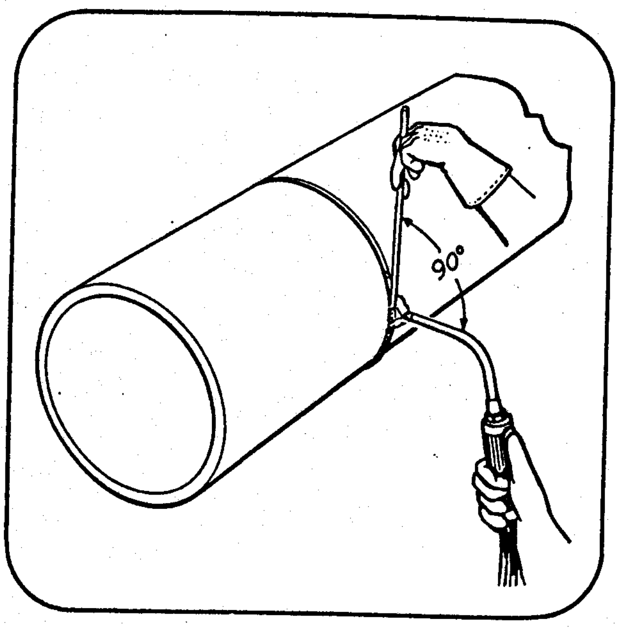
After visual examination cut three 12 mm wide bend specimens from the positions of each joint as shown in the table below.

Pipe axis	Position of specimen in welded joint
(a) Horizontal	(i) Bottom (ii) Side (iii) Top
(b) Vertical	Three specimens at 120° apart
(c) 45° Inclined	(i) Bottom (ii) Side (iii) Top

When prepared, make 180° root bends over a former of diameter four times the wall thickness.

Normally there are more bend test failures taken from the top position than from the overhead and vertical positions. This is often due to the gap closing up during welding.

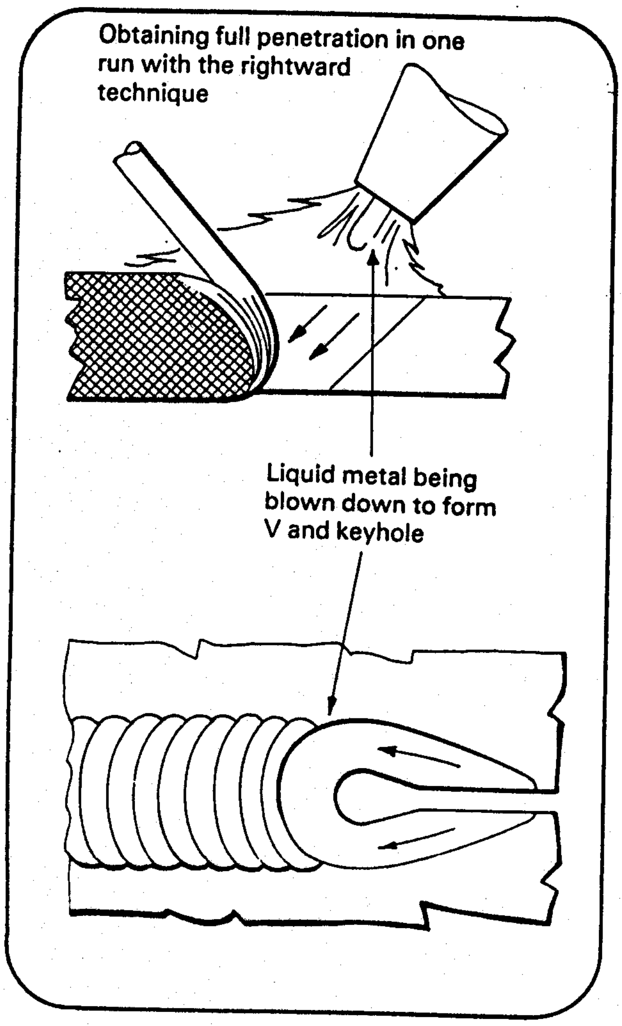
The top section is the most difficult part to weld if the gap closes up. It is recommended that this section should be welded first.



Mild steel pipe—butt joint
Welding position: Vertical
Pipe fixed with its axis: Horizontal
Technique: Leftward
Example procedure EP/OA/30

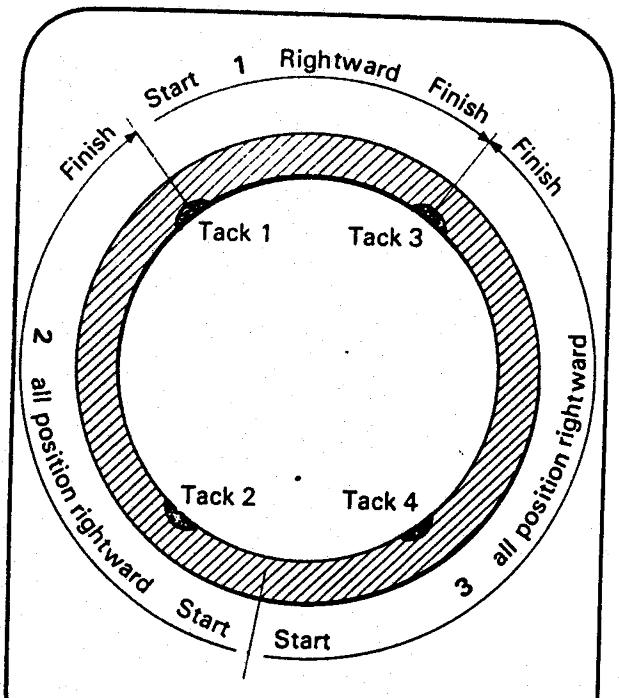
Material	Two pieces of mild steel pipe, 50–100 mm diameter, 2 mm wall thickness
Preparation	Square end
Assembly	2·5–3 mm gap. Tack as shown on pages 39 and 40, leaving the 6 and 12 o'clock positions clear of tacks
Nozzle size	5 (140 litres/hr)
Regulators	Each 0·14 bar
Filler rod	2·4 mm

Weld up each side of the pipe in turn from the 6 o'clock to the 12 o'clock positions.



Mild steel pipe—butt joint
Welding position: Vertical
Pipe fixed with its axis: Horizontal
Technique: Rightward and all-position rightward
Example procedure EP/OA/31

Material	Two pieces of mild steel pipe, 50–100 mm diameter, 5 mm wall thickness
Preparation	Square end
Assembly	2·5–3 mm gap tack as for EP/OA/30
Nozzle size	18 (520 litres/hr)
Regulators	Each 0·28 bar
Filler rod	3·2 mm



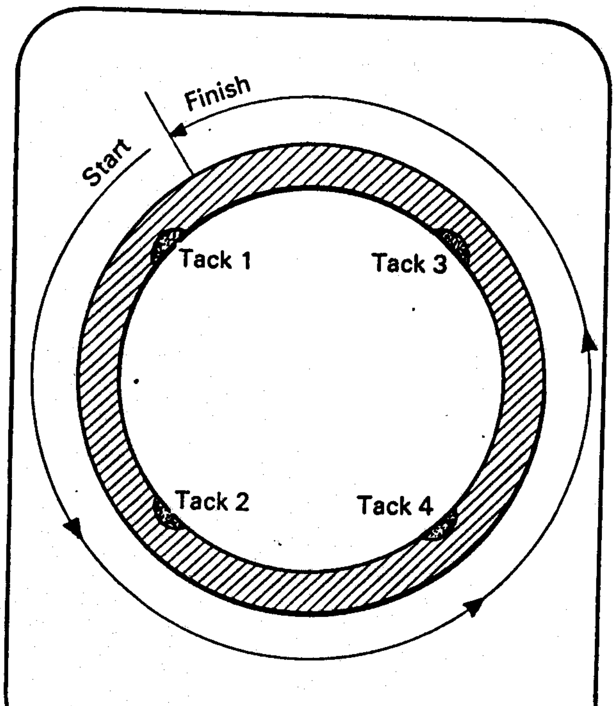
Welding sequence

Deposit the weld in one run, divided into three sections:

1. Start on the first tackweld and progress through the 12 o'clock position to the next tack weld (rightward technique).

2. Start the next section at the point slightly above the 6 o'clock position and progress upwards. Ensure that the tackweld is fused into the weld run (all position rightward).

3. Complete the joint by depositing the third section, welding upwards from the start of the second section (all position rightward).



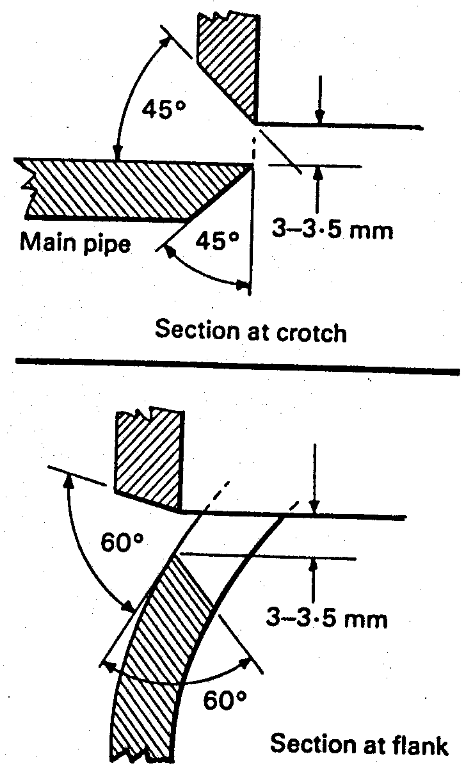
Rightward technique

Mild steel pipe—butt joint
Welding position: Horizontal-vertical
Pipe fixed with its axis: Vertical
Technique: Rightward
Example procedure EP/OA/32
Materials etc. as for EP/OA/31 except:

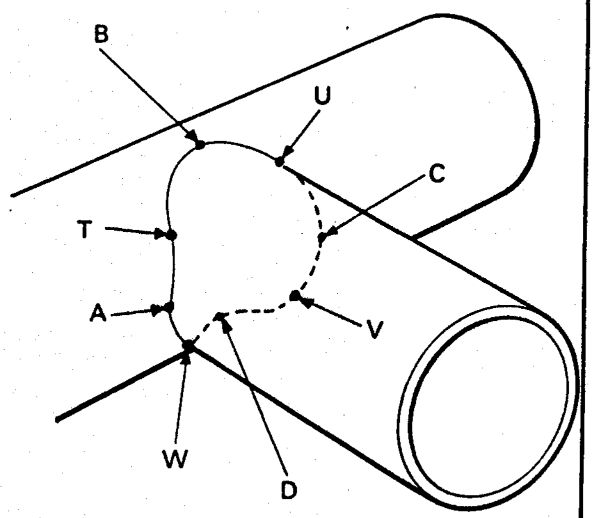
Nozzle size	13 (370 litres/hr)
Regulators	Each 0·22 bar

Deposit the weld in one continuous run as illustrated.

Mild steel pipe—butt joint
Welding position: Inclined
Pipe fixed with its axis: at 45° to the horizontal
Technique: Rightward
Example procedure EP/OA/33
Proceed similarly to Example procedure EP/OA/32.



Preparation



Welding sequence

Mild steel pipe—branch joint 90° set-on
Welding position:
Vertical to Horizontal-vertical
Pipe axes: Horizontal, assembly turned over during welding
Technique: All-position rightward
Example procedure EP/OA/34

Material	Two pieces of mild steel pipe, 50–100 mm equal diameter, 5 mm wall thickness
Preparation	Shape the end of the branch pipe to fit the main pipe. Cut a hole in the main pipe to equal the bore of the branch pipe. Prepare the edges by bevelling (see bevelled edges as shown in the illustration)
Assembly	Root gap 3–3·5 mm. Four tacks at points T, U, V, W
Nozzle size	13 (370 litres/hr)
Regulators	Each 0·22 bar
Filler rod	3·2 mm

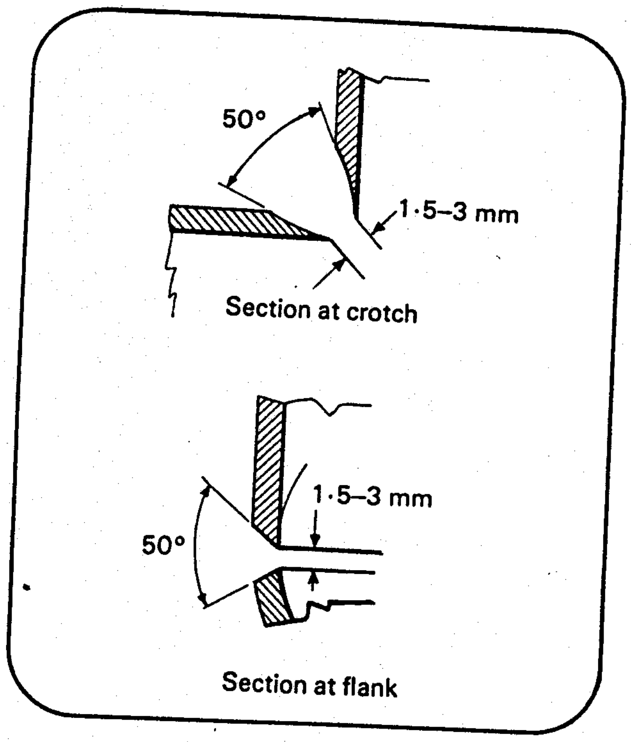
1. Weld in one run from the tack at T to the tack at U.

2. Turn the assembly over so that D is on top, and weld from V to W.

3. Complete the job by welding from U to V and from T to W.

Visual examination
Check for: uniformity of weld size and penetration; smooth face.

Cut and etch sections from flank and crotch.



Mild steel pipe—branch joint 90° set-in
Welding position: Vertical to horizontal-vertical
Pipe axes: Horizontal, assembly turned over during welding
Technique: Leftward
Example procedure EP/OA/35

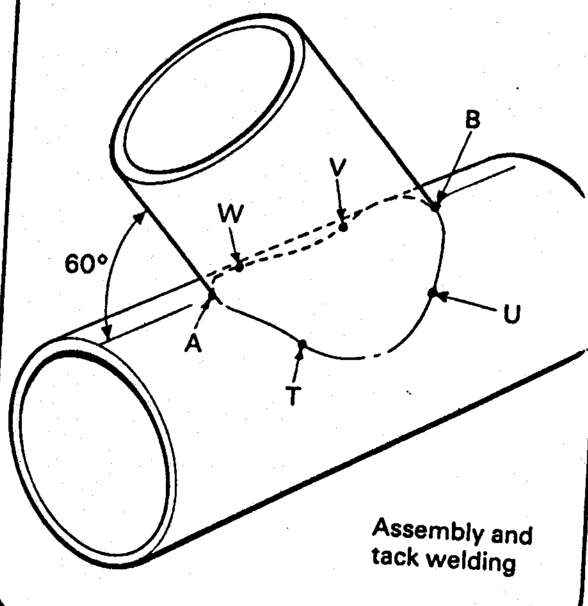
Material	Two pieces of mild steel pipe, 50–100 mm equal diameter, 2 mm wall thickness.
Preparation	Shape the end of the branch pipe, cut a hole in the main pipe and prepare the edges as shown in the illustrations.
Assembly	Root gap 1·5–3 mm. Four small tackwelds, located as for EP/OA/34
Nozzle size	5 (140 litres/hr)
Regulators	Each 0·14 bar
Filler rod	2·4 mm

Weld in the same sequence as EP/OA/34, paying special attention to obtaining consistent penetration at the crotches.

Mild steel pipe—branch joint 90° ~~set-on~~
Welding position: Horizontal-vertical
Pipes fixed with their axes:
Main pipe—Horizontal
Branch pipe—Vertical, above main pipe
Technique: All-position rightward
Example procedure EP/OA/36

Material, preparation etc.	As for EP/OA/34

Proceed as in EP/OA/34, except that the assembly should remain fixed in the position described above.



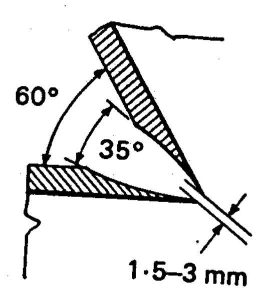
Assembly and tack welding

Mild steel pipe—branch joint 60° set-in
Welding position: Horizontal-vertical
Pipes fixed with their axes:
Main pipe—Horizontal
Branch pipe—in same vertical plane at 60° to main pipe
Technique: All-position rightward
Example procedure EP/OA/37

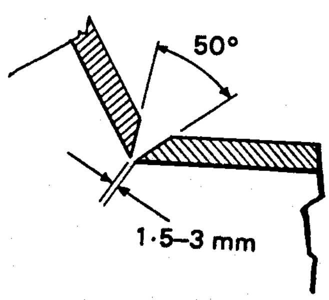
Materials, etc.	As for EP/OA/34 except that preparation and assembly are as shown in the illustrations.

1. Tack at points T, U, V and W.
2. Weld sections TU, VW and UV, in this order.
3. Complete the job by welding section WT without interruption.

Note: Practise manipulating the torch and filler rod first to ensure that the joint can be reached.



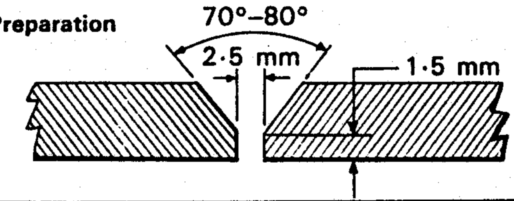
Section at crotch, A

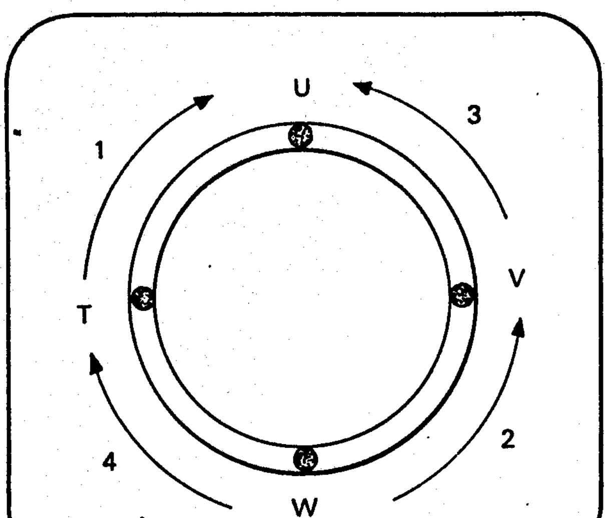


Section at back, B

Sections at flank as for EP/OA/34

Mild steel pipe—butt joint: root run only
Welding position: Vertical
Pipe fixed with its axis: Horizontal
Technique: All-position rightward
Example procedure EP/OA/38

Material	Two pieces of thick-walled mild steel pipe, eg. 100 mm dia. × 10 mm wall thickness.
Preparation	
Assembly	2·5 mm gap. Four tacks at points T, U, V and W of minimum length 10 mm and with complete penetration.
Nozzle size	7 or 10 (200 or 280 litres/hr)
Regulators	Each 0·14 or 0·18 bar
Filler rod	2·4 mm



Welding sequence

Deposit the root run in the sequence shown. The weld will be completed by another process.

Visual examination
Uniform penetration; weld face free from irregularities large enough to trap slag in subsequent runs.

Low alloy or stainless steel pipe—
butt joint: root run only
Welding position: Vertical
Pipe fixed with its axis: Horizontal
Technique: All-position rightward
Example procedure EP/OA/39

Material, etc., as for EP/OA/38, except that either low-alloy steel parent material and appropriate filler should be selected, or stainless steel parent and filler material with a suitable flux.

Proceed as in EP/OA/38
The weld will be completed by another process.

11.2 Oxygen and acetylene cylinders

The differences between an oxygen cylinder and an acetylene cylinder are clearly illustrated in Fig. 11.2.

Oxygen

This is supplied to the welding torch from a solid drawn steel cylinder where it is contained in compressed form. Oxygen cylinders are usually supplied in capacities of 3·4 m^3, 5 m^3, and 6·8 m^3. Mild steel cylinders are charged to a pressure of 13 660 kN/m^2 (136·6 bar) and alloy steel cylinders to 17 240 kN/m^2 (172 bar).

The oxygen volume in a cylinder is directly proportional to its pressure, and the consumption for a welding job can, therefore, be found by noting the pressure drop during the welding operation. For example, if it were noted that the original pressure of a full oxygen cylinder had dropped 5% during a welding operation, then 1/20 of the cylinder contents would have been consumed.

THE VALVE OUTLET ON AN OXYGEN CYLINDER HAS A RIGHT-HAND SCREW THREAD.

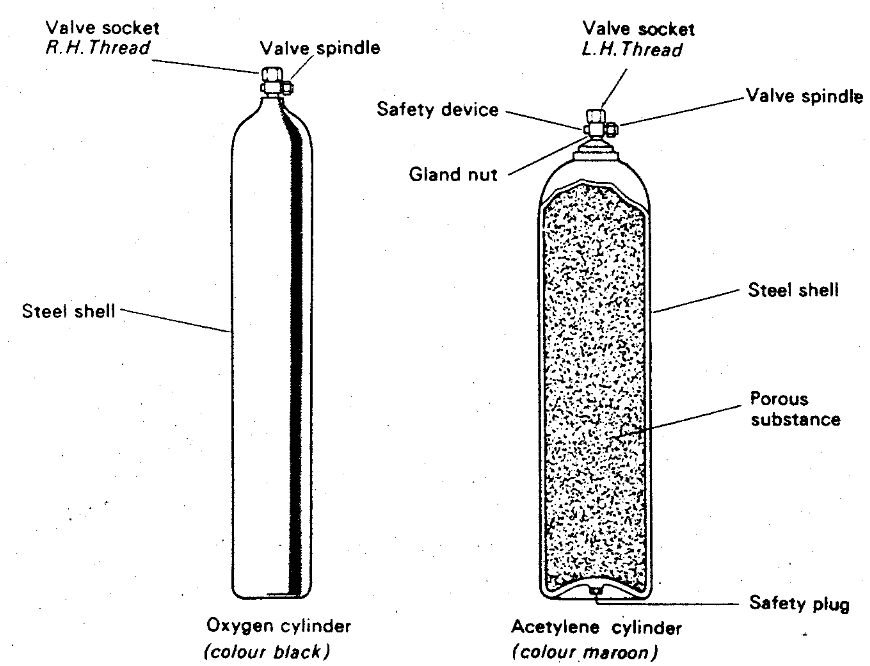


Fig. 11.2 Acetylene and oxygen cylinders

Acetylene

For high pressure welding is supplied in a solid drawn steel cylinders as shown in Fig. 11.2. *High pressure acetylene is not stable and for this reason it is dissolved in* acetone, *which has the ability to absorb a large volume of the gas and release it as the pressure falls.* One volume of acetone at atmospheric pressure and at a temperature of 15°C is capable of dissolving about 25 volumes of acetylene. *This dissolving capacity can be increased in proportion to the pressure.* Acetylene cylinders are charged to a pressure of 1 552 kN/m^2 (15·5 bar), and as one atmosphere is equivalent to one bar it follows that, at the same temperature, one volume of acetone absorbs approximately 25 x 15 = 375 times its own volume of acetylene at a pressure of 15 bar.

Because of the danger of explosions to which compressed acetylene is susceptible, the steel cylinder is filled with a porous substance, and the construction of the cylinder, its filling and testing, are all strictly controlled by the manufacturers in the interests of safety. The pores in the filling material divide the space into a large number of very small compartments which are completely filled with 'dissolved acetylene'. *These small compartments prevent the sudden decomposition of the acetylene throughout the mass, should it be started by local heating or other causes.*

THE VALVE OUTLET ON ACETYLENE CYLINDERS IS FITTED WITH A LEFT-HAND SCREW THREAD.

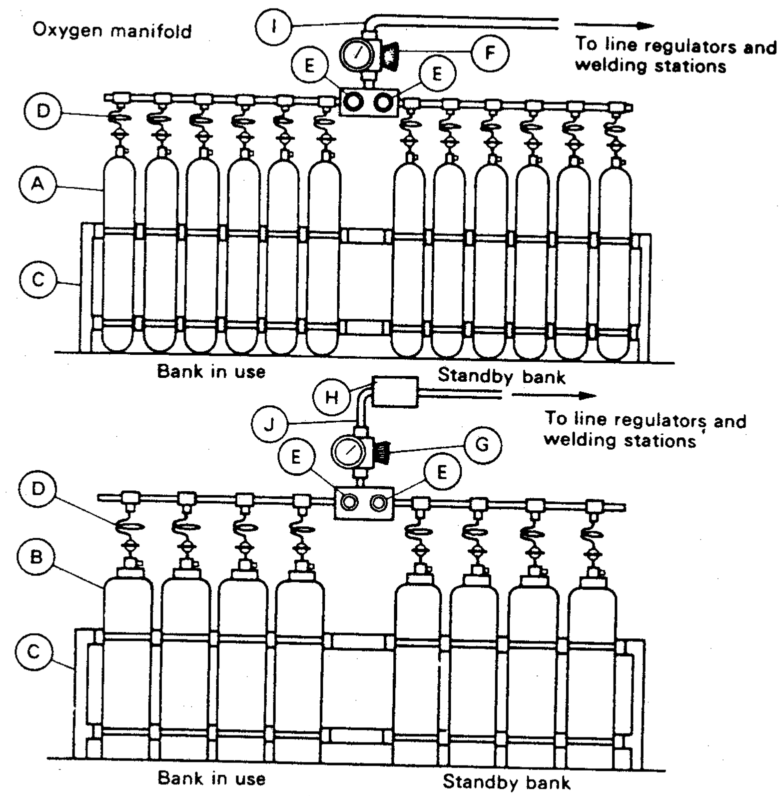
11.3 Discharge rate

Should OXYGEN be withdrawn from a cylinder at too great a rate of consumption, *a rapid drop in pressure will occur, with the result that the cylinder valve may freeze.* When flame cutting heavy cast-iron sections, which involves a high rate of gas consumption, it is advisable to couple together sufficient oxygen cylinders to complete the work — this also applies when repairing large castings which have to be preheated.

The rate of acetylene consumption also has to be kept below a certain limit. Acetylene cylinders should never be discharged at a rate which will empty them in less than 5 hours. This means that *the discharge rate must be limited to less than 20% of the total cylinder content per hour.* This is not because of freezing, as with oxygen, but because should this limit be exceeded acetone will be drawn off and mixed with the acetylene. Acetylene which contains small quantities of acetone vapour will lower the flame temperature. Unlike oxygen, the volume and pressure of acetylene are not in linear proportion which means that the gas consumption cannot be reliably found from the loss in pressure in the cylinder during a welding operation.

The sizes of acetylene cylinders in general use are 2·8 m^3 and 5·7 m^3.

In workshops, where welding gases are needed in several places, or at high rates of consumption, it is of considerable advantage to use a manifold system. Instead of having cylinders at each place of work, they are assembled in one centralised position in specially designed racks and connected by a manifold, as shown in Fig. 11.3. These gases are then distributed by means of a pipeline to the different work-places.



A Oxygen cylinders
B Acetylene cylinders
C Storage rack
D High-pressure coupling pipe ('pig-tail')
E Separate valve for each bank
F Oxygen output regulator and pressure gauge (Line pressure 4.15 bar)
G Acetylene output regulator and (Line pressure 620 millibar)
H Anti-Flashback device (acetylene)
I Oxygen supply line (copper pipe)
J Acetylene supply line (steel pipe)

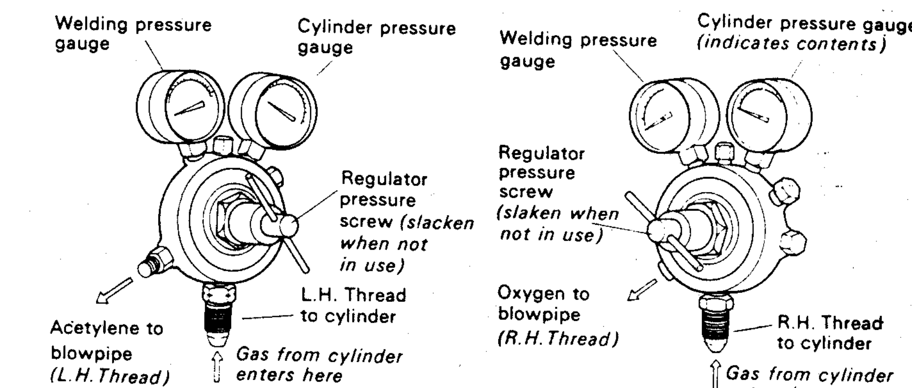
Fig.11.3 The manifold system for gas welding

ADVANTAGES OF MANIFOLDS:

More space available at work-place.
No replacement of cylinders inside the workshop.
Less transportation.
More effective use of the gas.
The cylinders are easily reached in case of fire.

11.4 Automatic pressure regulators

These are fitted to the oxygen and acetylene cylinders to reduce the pressure and control the flow of the welding gases. Examples are shown in Fig. 11.4. They are fitted with two pressure gauges. One indicating the gas pressure in the cylinder, and the other indicating the reduced outlet pressure. The operation of the pressure gauge is explained in Section 11.5.



(a) **Acetylene pressure regulator** *(b)* **Oxygen pressure regulator**

Fig.11.3 Pressure regulators

The four principal elements which constitute a pressure-reducing regulator are:

1. A *valve* consisting of a nozzle and a mating seat member.
2. An *adjustable screw* which controls the thrust of the cover spring.
3. A cover spring which transmits to a diaphragm the thrust created by the adjusting screw.
4. A diaphragm connected with the mating seat member.

Figure 11.5 illustrates two basic types of *'single-stage' regulator.*

In the 'needle type' regulator the inlet pressure tends to close the seat member against the nozzle. The outlet pressure on this type of regulator has a tendency to increase somewhat as the inlet pressure

decreases. *This increase is caused by a decrease of the force produced by the gas pressure against the seating area as the inlet pressure decreases.* This type of single-stage regulator is sometimes referred to as 'inverse' or 'negative' type.

In the *'nozzle type' regulator* the inlet pressure tends to move the seat member away from the nozzle, therefore the outlet pressure decreases somewhat as the inlet pressure decreases. *This is because the force tending to move the seat member away from the nozzle is reduced as the inlet pressure decreases.* This type of single-stage regulator is referred to as 'direct acting' or 'positive' type.

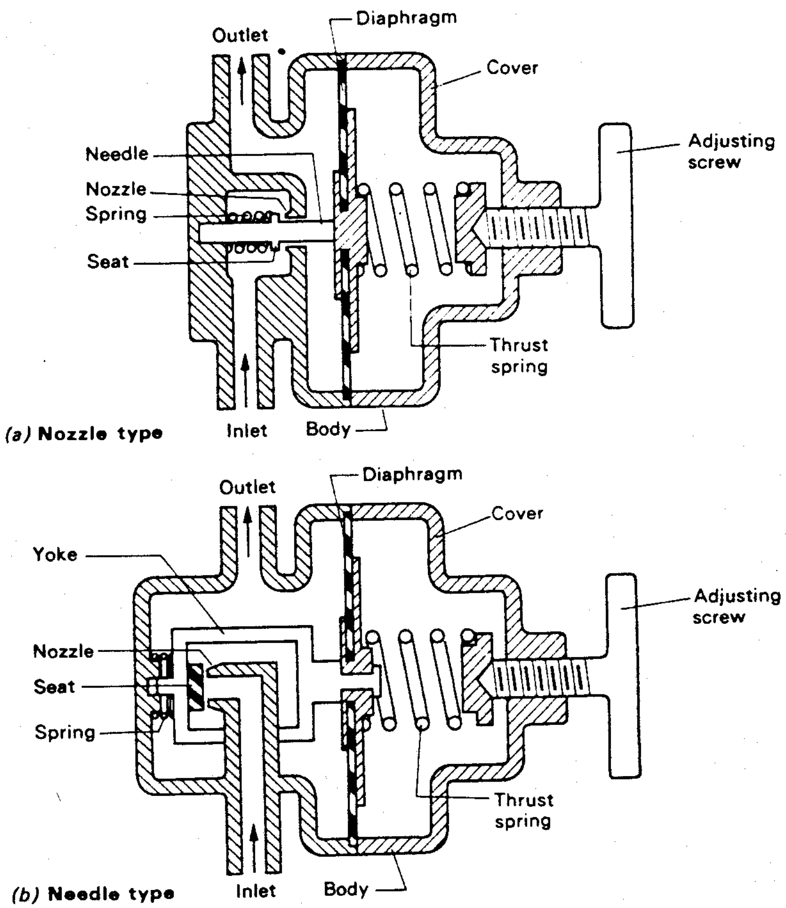


Fig. 11.5 Single-stage regulators

THE GAS OUTLET PRESSURE FOR ANY PARTICULAR SETTING OF THE ADJUSTING SCREW IS REGULATED BY A BALANCE OF FORCES.

This balance is between the cover spring thrust and the opposing forces created by a combination of the outlet pressure against the underside of the diaphragm and the inlet pressure against the seating area.

When the inlet pressure decreases, its force against the seat member decreases, allowing the cover spring force to move the seat member away from the nozzle. Thus more gas pressure is allowed to build up to re-establish the balanced condition.

A smaller outlet pressure on the underside of the diaphragm is all that is necessary to close the seat member against the nozzle. The opening between the seat members and the nozzle is reduced, which results in less gas flow.

11.5 The pressure gauge

Inside a pressure gauge there is a BOURDON TUBE. This is a copper-alloy tube of oval section. bent in a circular arc. One end of the tube is sealed shut and attached by light linkage to a mechanism which operates a pointer. The other end is fixed, and is open for the application of the pressure which is to be measured. The internal pressure tends to change the section of the tube from oval to circular and this causes it to straighten out slightly. The resultant movement of the tube causes the pointer to move over a suitably calibrated scale. An example of a bourdon tube pressure gauge is shown in Fig. 11.6.

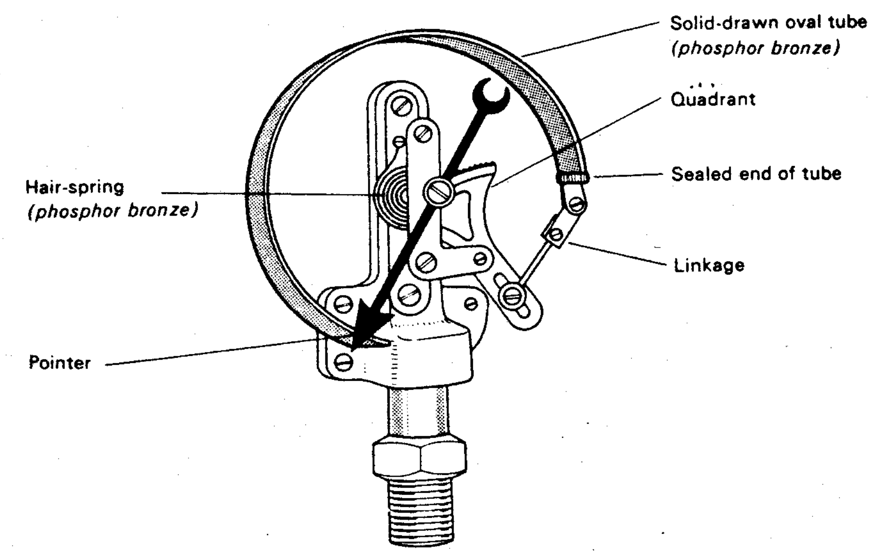


Fig. 11.4 Bourdon tube pressure gauge

Bronze (braze) welding

Bronze welding is a method of joining metal in which the filler rod melts at a lower temperature than the base material. It is not a fusion process. Bronze welding is often used to make a joint between dissimilar thicknesses of materials.

Safety

When bronze welding galvanized steel:
(a) check ventilation arrangements
(b) avoid overheating the joint.

Before commencing to bronze weld mild steel:

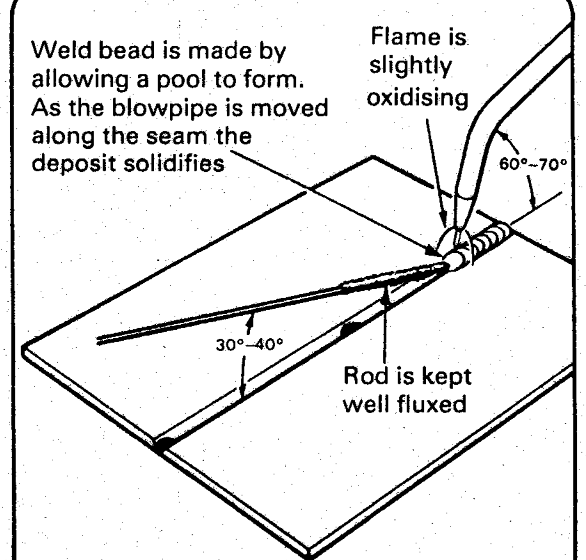
(i) Ensure that the filler rod is of suitable composition (BS 1453:C2).
(ii) Remove oil, grease and dirt, using solvent.
(iii) Free joint surfaces from surface oxides by grinding, filing or wire brushing.

Note: When preparing a joint for the bronze welding of galvanized steel care MUST be taken to preserve the zinc coating in the area to be joined. Before welding apply a protective coating of copper welding flux in paste form to all faces affected by the heat of welding.

(iv) Coat the filler rod with flux either by heating and dipping into powder or by applying in paste form. Pre-fluxed rods may be used.

Mild steel (untreated and galvanized)
Guideline conditions: butt joints
Flat and vertical positions

Thickness mm	Preparation	Gap mm	Nozzle size	Filler rod mm	Pitch of tacks mm
1	Square edge	0·8	1 (29 litres/hr)	2·4	25
1·5	Square edge	0·8	1 (29 litres/hr)	2·4	40
3	Square edge	0·8	3 (86 litres/hr)	3·2	75
6	60°–90° V	1·5	7 (200 litres/hr)	4·8	130



Bronze welding mild or galvanised steel sheet

Tackwelding procedure

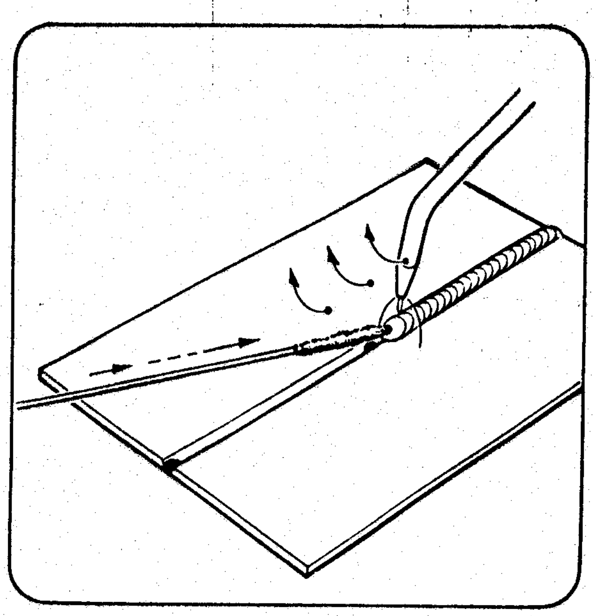
(a) Set the plate with a slight taper between the joint faces.

(b) Set a slightly oxidizing flame.

(c) Pre-heat the tackweld area.

(d) Keep the blowpipe at an angle of 60°–70° to the line of the weld, with the filler rod at an angle of 30°–40°.

(e) Direct the flame to the joint edges. Introduce the filler rod to deposit sufficient filler material to bridge the gap and prevent the tack area from overheating. When correct surface temperature is reached the bronze filler material will flow, thus creating the tackweld.



Welding procedure

(a) Commence welding at one end and continue until the joint is complete.

(b) Filler rod and blowpipe angles are as for tackwelding. To prevent oxidation or overheating of base material ensure that the flame impinges only on the melting filler rod or the weld deposit.

(c) When the pool is established (in the manner of tackwelding) withdraw the flame slightly to allow partial freezing of the deposit. Reintroduce the filler rod to melt further deposit, at the same time reintroducing the flame. Careful observation of the weld area is necessary to ensure that adequate bonding is achieved and uniformity of weld size.

(d) To avoid a terminal crater, filler rod is added and the flame is withdrawn.

(e) Remove the flux residue.

Visual examination

The weld profile should be of adequate proportion. The surface should be bright and free from porosity. The penetration bead should be uniform and overlapping the joint faces on the 'other side'.

T joints

Tackwelding and welding techniques are generally similar to those used for butt joints welded in the flat and vertical positions.

Mild steel (untreated and galvanized)
Guideline conditions: T joints
Flat and vertical positions

Thickness mm	Nozzle size	Pitch of tacks mm	Filler rod
1	1 (29 litres/hr)	25	2·4 mm
1·5	1 (29 litres/hr)	40	2·4 mm
3	3 (86 litres/hr)	75	3·2 mm
6	7 (200 litres/hr)	130	4·8 mm

Cast iron

Before commencing to bronzeweld cast iron ensure that:

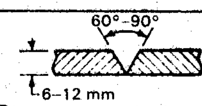
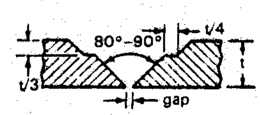
(a) the filler rod is of suitable composition (BS 1453:C4 or C2)

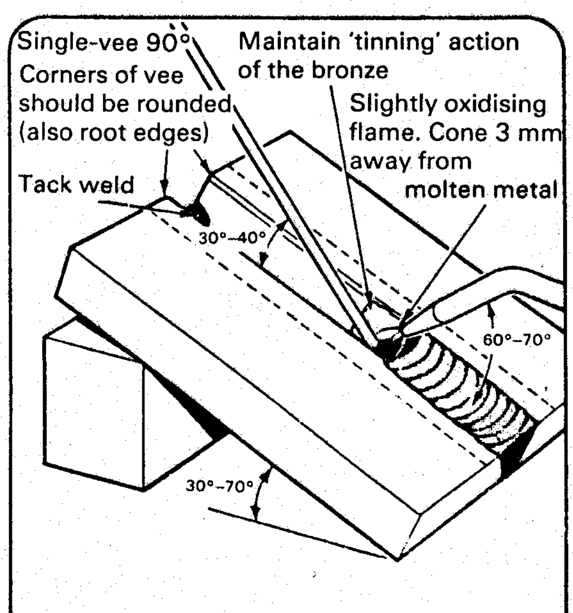
(b) all parts are free from oil, grease and dirt

(c) all joint surfaces are free from surface oxide. Edge of preparation must be free from sharp corners

(d) the filler rod is coated with flux by heating and dipping into powder. Pre-fluxed rods may be used.

Guideline conditions: butt joints
Flat and vertical positions

Thickness mm	Nozzle size	Gap	Filler rod	Preparation
6	3 (80 litres/hr)	0·8–1·5 mm	4·8 mm	
12	5 (140 litres/hr)	0·8–1·5 mm	4·8 mm	Gap up to 1·5 mm max. desirable
25	10 (280 litres/hr)	0·8–1·5 mm	6·4 mm	



Bronze welding cast iron

Butt joints (flat position)

Tackwelding procedure

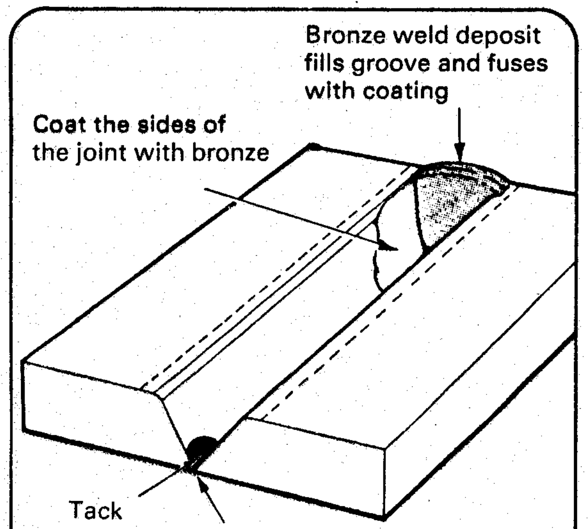
(a) Set the plates with correct gap, correctly aligned and adequately supported and secured. Where possible set the joints at an incline to aid control of the molten metal.

(b) Set a slightly oxidizing flame.

(c) Pre-heat the tackweld area until the surface is blue.

(d) Keep the blowpipe 60°–70° to the line of the weld and the filler rod at an angle of 30°–40°.

(e) Direct the flame to the joint edges. Introduce the filler rod to deposit sufficient filler material to bridge the gap and prevent the tackwelded area from overheating. When correct surface temperature is reached bronze filler material will flow, thus creating the tackweld.



Bronze welding cast iron.
Making the coating and deposit

Welding procedure

(a) Commence at one end and continue until the weld is completed.

(b) The filler rod and blowpipe angles are as for tackwelding.

(c) (i) First coat the surfaces of the joint with a layer of filler metal for a distance of approximately 20 mm along the joint, ensuring that it is correctly bonded.

(ii) Return to the starting point and commence to add sufficient material to produce a satisfactory weld. This method is repeated continuously until the weld has been completed. Ensure fusion between consecutive deposits.

(d) Conclude the weld by adding sufficient filler rod to obtain a good reinforcement and bonding and compensating for any shrinkage.

(e) Remove flux residue by scraping or wire brushing whilst the flux is molten.

Visual examination

The weld profile should be of adequate proportion. Surface should be bright and fee from porosity. Penetration bead must be uniform.

Butt joints (vertical position)

In the vertical position it is necessary to vary the technique generally as follows:

(a) The initial tackweld at the base of the weld run is increased in size so that it forms a platform on which to build the remainder of the weld, ie. the tack weld literally becomes a short, full-section segment of the weld.

(b) Intermittent tackwelds (where required) will be made as in the flat position.

(c) When commencing the weid (or restarting) sufficient pre-heating of the existing deposit is necessary to ensure fusion with subsequent deposition. The weld is carried out by depositing a single layer ensuring bonding.

(d) The movement of the filler rod and blowpipe will follow the contour of the weld in a circular motion to ensure uniformity of the weld size.

(e) Ensure that the filler rod is interposed between the flame and the joint faces to avoid overheating of the faces.

Copper sheet (including copper and copper alloys)
Thickness range covered 0·5 mm to 1·6 mm.

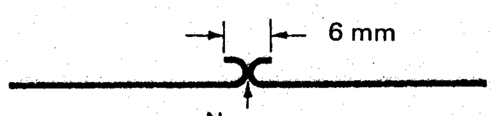
Butt, T and lap joints
Before commencing to bronze weld copper sheet ensure that:

(a) the filler rod is of suitable composition: BS 1453:C2

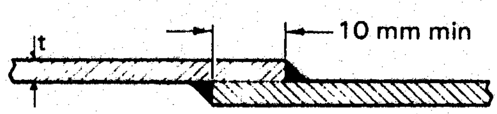
(b) all parts are free from oil, grease and dirt

(c) all joint surfaces are free from surface oxides. Use wire wool

(d) the filler rod is coated with flux by heating and dipping into powder. Pre-fluxed rods may be used.



No gap
Joint preparation recommended for 0·5 mm to 0·9 mm thick sheet
Upset butt



Preparation recommended for 1·2 mm and thicker
Lap joint

Copper sheet: Butt, T and lap joint welding conditions
Flat and vertical positions

Thick-ness mm	Nozzle size	Filler rod mm	Pitch of tacks mm	Gap
1	3 (80 litres/hr)	2·4	25	Butt only $\frac{t}{2}$
1·2	5 (140 litres/hr)	3·2	40	
1·6	7 (200 litres/hr)	3·2	40	

Notes:
(a) Nozzle sizes are based on sheets of approximate size 150 × 100 mm.

(b) For greater areas, also when making T joints, it may be necessary to increase the nozzle sizes quoted.

Tackwelding procedure
(a) Set the plates with correct gap—slightly tapered space.

(b) Set a slightly oxidising flame.

(c) Pre-heat the plates until the surface oxides just begin to form.

(d) Hold the blowpipe over the tackweld area at an angle of 60°–70° and the filler rod at 30°–40°, then deposit the tackweld.

(e) Repeat tackwelds at recommended pitch until completed.

Welding procedure
(a) Hold the blowpipe and filler rod at the angles given for tackwelding.

(b) Commence at one end and continue with a slight weaving motion, adding the filler rod at regular intervals until the seam is completed.

(c) Terminate the weld, keeping the reinforcement up to full section.

(d) Remove the flux residue.

Visual examination
The deposit should be of uniform size, bright in appearance and free from porosity. Ensure adequate penetration, where appropriate.

Mild steel tubes
(Range covered 12 to 27 mm diameter.)

Guideline conditions—butt and branch joints

Diameter mm	Wall thickness	Nozzle size	Filler rod	Gap	Preparation
12	1·2 mm	1 (29 litres/hr)	2·4 mm	Pipe wall thickness	60° vee preparation
19	1·6 mm	1 (29 litres/hr)	2·4 mm	$\frac{t}{2}$	
27	3·2 mm	2 (57 litres/hr)	3·2 mm	$< \frac{t}{4}$	

Butt joints
Clean and prepare the joint surfaces as for mild steel plate.

Tackwelding procedure
(a) The procedure is as for mild steel plate. Ensure the tubes have been accurately aligned.

(b) Make three tackwelds at 120° spacing around the tube, avoiding the point at which welding will commence.

Welding procedure
(Pipe or tube fixed with its axis horizontal.)
(a) Commence welding at the 6 o'clock position (overhead welding) and stop at the 12 o'clock position.

(b) Repeat the procedure for the other half of the joint.

(c) Ensure adequate fusion at the weld junctions.

(d) Remove flux residue by carefully chipping, scraping and/or wire brushing while the flux is still hot.

Visual examination
The weld profile should be of adequate proportion. The surface should be bright and free from porosity.

The penetration bead should be uniform.

Mild steel tubes
Branch joints: set-on 90°, of equal diameters (with or without hole in the main tube)
Welding conditions

Nozzle size and filler rod sizes are as shown in the table for mild steel tube butt welding conditions (page 68). Filler rod and blowpipe angles are the same as in mild steel bronze welding.

Note: When welding main tubes without a hole it may be necessary to use a larger nozzle to offset the effects of the change in section and related heat distribution.

Welding procedure

(a) Mark out and prepare the branch tube saddle; file and fit to the main tube. In the case of a main tube requiring a hole, the prepared branch may be used as a pattern to mark out the hole. Alternatively, templates may be used.

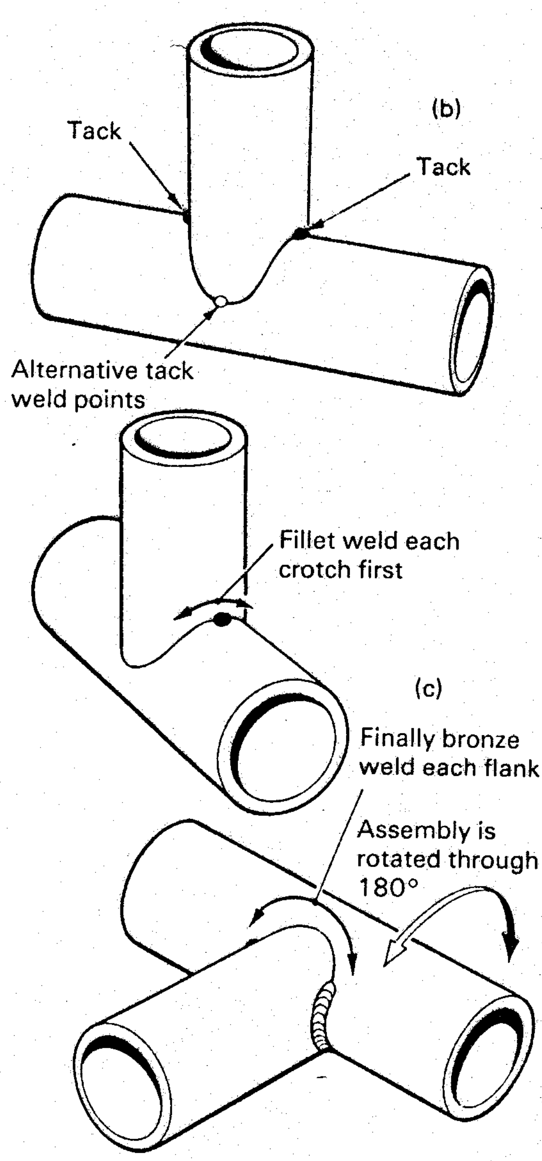
(b) Set and locate the branch on to the main tube and tackweld at both crotches or both flanks.

(c) Proceed to complete the weld as shown in the illustration. Note that the crotch welds are made in the horizontal-vertical position and the flank welds in the flat position. This is following rotation of the assembly through 90° and 180° respectively.

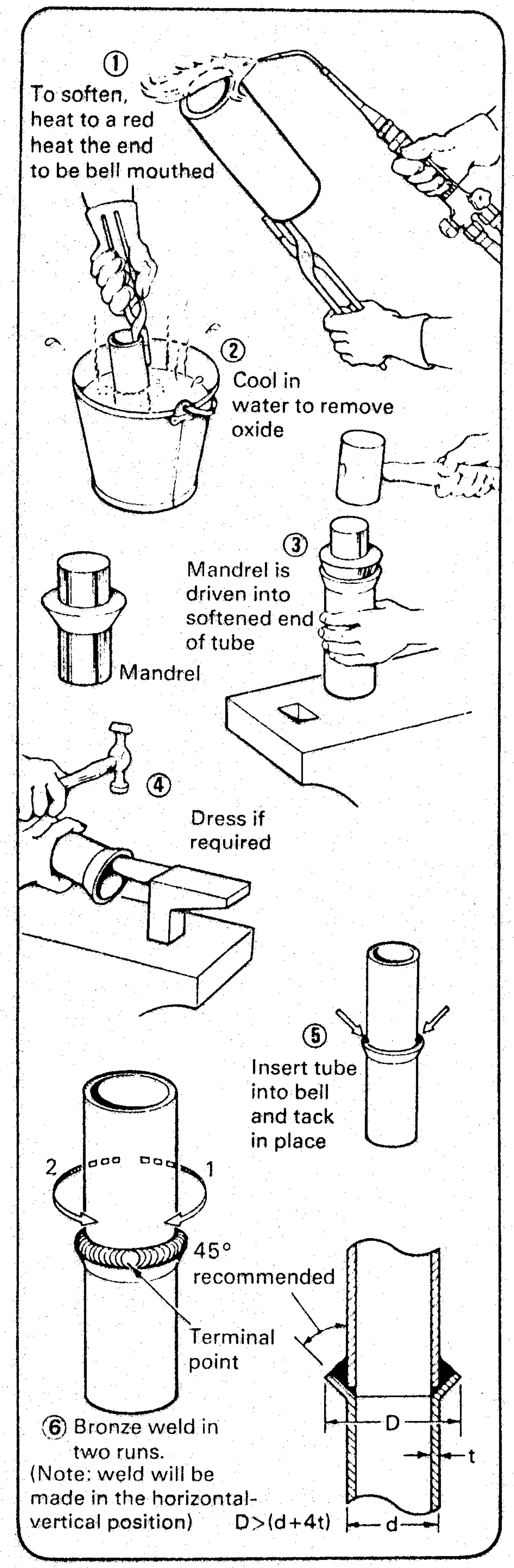
(d) Remove the flux residue by carefully chipping, scraping and/or wire brushing, while the flux is still hot.

Visual examination

Ensure uniform weld profile, bright appearance of deposit and freedom from porosity.



Method of tacking and bronze welding pipes in mild steel
Diameter range from 12 to 30 mm
Wall thickness from 1 to 3 mm



Copper (or copper alloy) tubes
(Range covered: 12 to 27 mm diameter.)

Guideline conditions—bell butt joint

It is recommended that, when copper tube is to be welded, a 'bell' butt joint formation is used. (See illustration.)

Diameter mm	Wall thickness mm	Nozzle size	Filler rod mm	Pitch of tacks
12 to 19	1·2	2 (57 litres/hr)	2·4	180°
	1·6	3 (80 litres/hr)	2·4	spacing
	2·5	3 (80 litres/hr)	2·4	
25 to 27	1·2	3 (80 litres/hr)	2·4	120°
	1·6	3 (80 litres/hr)	2·4	spacing
	2·5	5 (140 litres/hr)	2·4	

Tackwelding

(a) Prepare the bell joint (and inserted tube) with wire wool to remove surface oxides.

(b) Tack weld at 120°; 180° for small-diameter tubes.

Welding procedure

(a) Heat the tube until the surface changes colour.

(b) Point the cone at the place where the weld is to commence.

(c) Melt a little bronze filler rod into the lip formed by the mandrel on the lower tube.

(d) Commence the weld at the 6 o'clock position progressing vertically upwards to 12 o'clock. Repeat for the opposite side.

Note: In this position a variation in technique is required to maintain control:

(i) The requisite amount of filler rod is deposited at the leading edge of the previously completed deposit.

(ii) The filler rod is withdrawn and the flame is manipulated to draw or merge the new deposit with the previous one.

(e) Ensure that the weld deposit is of correct profile such that it completely covers and bonds (without over-spilling) the outer edge of the bell contour.

(f) Terminate the weld, keeping the reinforcement up to full section and ensuring fusion at recommencement and completion points.

(g) Remove the flux residue.

Visual examination

The deposit should be of uniform size and free from porosity. There should be freedom from penetration.

Branch joints: set-on 90°, of equal diameters
(*With* hole in the main tube)

(a) The manner of preparing and tackwelding, also welding of the joint, is similar to that used for mild steel branch joints. (See page 69.)

(b) The guideline conditions for welding branch joints are similar to those stated for bell butt joints.

(c) Ensure the complete removal of flux after welding.

Note: In the majority of circumstances copper pipe or tube assemblies will have a branch hole in the main tube. Where there is no hole in the main tube it may be necessary to use a larger size of nozzle than that stated in the relevant table.

Repair of steel and iron castings
Malleable iron castings must be bronze welded. Details relating to their preparation and welding conditions are referred to on page 65.

As bronze welding is carried out at a lower temperature than fusion welding, it may be necessary to preheat the casting to 450°C maximum according to the complexity of the casting.

Parts to be repaired must be accurately aligned and tackwelded or clamped in position.

Welding procedure

(a) Keep the rod well fluxed.

(b) Keep the flame condition slightly oxidizing.

(c) Plan the welding sequence to minimize stresses working towards an open edge.

(d) Bronze weld deposits on thick sections may be more readily controlled if carried out in the vertical position.

(e) Avoid overheating which is indicated by:
(i) poor bonding
(ii) fuming through loss of zinc.

(f) Shield the work piece from draughts.

(g) When the weld is finished always allow the casting to cool slowly.

(h) Never immerse the hot casting in water.

(i) Remove all flux residue.

Copper sheet (including copper and copper alloys)
Thickness range covered 0·5 mm to 1·6 mm.

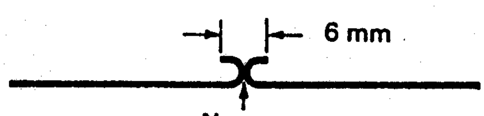
Butt, T and lap joints
Before commencing to bronze weld copper sheet ensure that:

(a) the filler rod is of suitable composition: BS 1453:C2

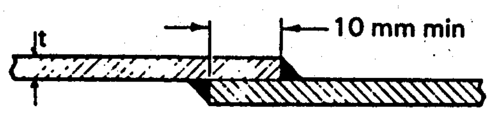
(b) all parts are free from oil, grease and dirt

(c) all joint surfaces are free from surface oxides. Use wire wool

(d) the filler rod is coated with flux by heating and dipping into powder. Pre-fluxed rods may be used.



Joint preparation recommended for 0·5 mm to 0·9 mm thick sheet
Upset butt



Preparation recommended for 1·2 mm and thicker
Lap joint

Copper sheet: Butt, T and lap joint welding conditions
Flat and vertical positions

Thickness mm	Nozzle size	Filler rod mm	Pitch of tacks mm	Gap
1	3 (80 litres/hr)	2·4	25	Butt only $\frac{t}{2}$
1·2	5 (140 litres/hr)	3·2	40	
1·6	7 (200 litres/hr)	3·2	40	

Notes:
(a) Nozzle sizes are based on sheets of approximate size 150 x 100 mm.
(b) For greater areas, also when making T joints, it may be necessary to increase the nozzle sizes quoted.

Tackwelding procedure
(a) Set the plates with correct gap—slightly tapered space.

(b) Set a slightly oxidising flame.

(c) Pre-heat the plates until the surface oxides just begin to form.

(d) Hold the blowpipe over the tackweld area at an angle of 60°–70° and the filler rod at 30°–40°, then deposit the tackweld.

(e) Repeat tackwelds at recommended pitch until completed.

Welding procedure
(a) Hold the blowpipe and filler rod at the angles given for tackwelding.

(b) Commence at one end and continue with a slight weaving motion, adding the filler rod at regular intervals until the seam is completed.

(c) Terminate the weld, keeping the reinforcement up to full section.

(d) Remove the flux residue.

Visual examination
The deposit should be of uniform size, bright in appearance and free from porosity. Ensure adequate penetration, where appropriate.

Mild steel tubes
(Range covered 12 to 27 mm diameter.)

Guideline conditions—butt and branch joints

Diameter mm	Wall thickness	Nozzle size	Filler rod	Gap	Preparation
12	1·2 mm	1 (29 litres/hr)	2·4 mm	Pipe wall thickness	60° vee preparation
19	1·6 mm	1 (29 litres/hr)	2·4 mm	$\frac{t}{2}$	
27	3·2 mm	2 (57 litres/hr)	3·2 mm	$< \frac{t}{4}$	

Butt joints
Clean and prepare the joint surfaces as for mild steel plate.

Tackwelding procedure
(a) The procedure is as for mild steel plate. Ensure the tubes have been accurately aligned.

(b) Make three tackwelds at 120° spacing around the tube, avoiding the point at which welding will commence.

Welding procedure
(Pipe or tube fixed with its axis horizontal.)
(a) Commence welding at the 6 o'clock position (overhead welding) and stop at the 12 o'clock position.

(b) Repeat the procedure for the other half of the joint.

(c) Ensure adequate fusion at the weld junctions.

(d) Remove flux residue by carefully chipping, scraping and/or wire brushing while the flux is still hot.

Visual examination
The weld profile should be of adequate proportion. The surface should be bright and free from porosity.

The penetration bead should be uniform.

Aluminium and its alloys

If the equipment is available, tungsten-arc gas shielded (TAGS) or metal-arc gas shielded (MAGS) processes are preferred for the welding of aluminium and its alloys.

Before commencing to weld aluminium:

(a) ensure that the filler rod is of suitable composition

(b) remove oil, grease and dirt, using a solvent, and thoroughly dry the plate

(c) prepare a narrow band, approximately 12 mm wide along the plate edge using wire wool

(d) coat approximately 125 mm of the rod by melting flux down its length. No other flux is required.

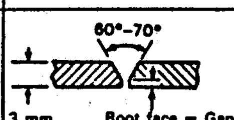
T and lap joint welding of aluminium is not recommended. Flux will be trapped at the abutting faces of the joint, thus making removal of the residue very difficult. Trapped flux usually causes severe corrosion problems. Flux residues must be thoroughly removed from the work.

> Safety
> The flux may be poisonous or corrosive. Follow the manufacturer's instructions carefully.

Aluminium

Guideline welding conditions—butt and corner joints

These conditions apply to flat, horizontal-vertical and vertical positions.

Thickness mm	Preparation	Assembly	Pitch of tacks mm	Nozzle size	Filler rod
1	As for stainless steel	No gap	25	1 (29 litres/hr)	2·4 mm
1·2		No gap	40	2 (57 litres/hr)	2·4 mm
1·5		No gap	40	2 (57 litres/hr)	2·4 mm
3		1·5–3 mm gap	75	5 (140 litres/hr)	3·2 mm

Note: A filler rod having a diameter 50 per cent greater than normal may assist for initial training purposes.

Butt joints

Tackwelding procedure

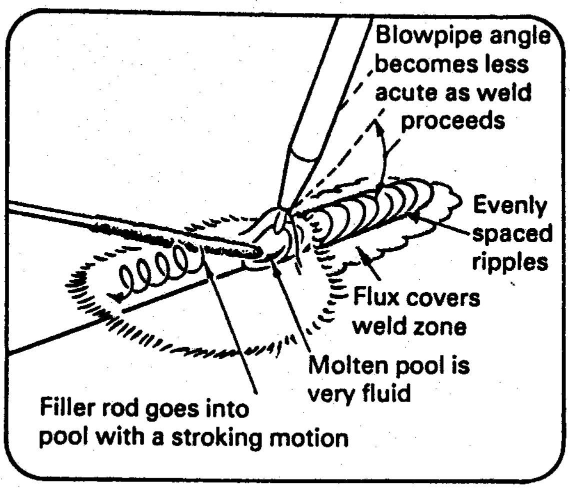
(a) Set the corners of the plates touching for the first tackweld. Taper space the plates about 1 mm per 100 mm run of joint when butt welding.

(b) Set a neutral flame.

(c) Pre-heat the plate prior to tackwelding.

(d) Keep the blowpipe at 30°–40° to the line of the weld and the filler rod at 30°–40°.

(e) Point the cone at the seam with the tip almost touching the plates and melt the aluminium. The metal will appear to shrink under a 'sac' of oxide. Break the skin of the 'sac' with the filler rod already fluxed. The flux will cause the oxide to dissolve, allowing the pool to unite both plate edges. Make neat, well-fused tacks at the recommended pitch.



Welding procedure

(a) Commence at a point one-fifth to one-third of its length or 50 mm maximum, along the seam and weld towards the furthest edge. Rotate the plate 180° and complete the weld.

(b) Maintain blowpipe and filler rod angles as for tackwelding.

(c) Keep the rod in the flame envelope as the blowpipe melts the seam, but use a slight stroking action along the seam to deposit the rod into the molten pool.

(d) Increase the rate of travel as the plate temperature rises.

(e) Prevent the formation of holes:

(i) decrease the blowpipe angle

(ii) deposit filler rod more quickly.
The rod can serve as a useful shield from the heat of the flame.

(f) Add filler rod more frequently and increase rate of travel as welding approaches the end of the seam. Reduce blowpipe angle or withdraw entirely to reduce heat input.

(g) Immediately after welding, wash off the flux in hot water and rinse thoroughly.

Visual examination
In a satisfactory weld there will be complete fusion of the root edges, adequate reinforcement, absence of craters and longitudinal cracks. The penetration bead should be smooth.

Aluminium pipe—butt joint
Welding position: Horizontal-vertical
pipe fixed with its axis: Vertical
Technique: leftward
Example procedure EP/OA/40

Material	Two pieces of pure aluminium pipe 50 mm diameter 1·5 mm wall thickness
Preparation	Square end
Assembly	Close butt—four tacks
Nozzle size	2 (57 litres/hour)
Regulators	Each 0·14 bar
Filler rod	2·4 mm

Weld in one run.

Copper

Before commencing to weld copper, check ventilation requirements and:

(a) ensure that the filler rod is of suitable composition

(b) remove oil, grease and dirt, using solvent. Clean the joint area with a wire brush or wire wool. The band of cleaned metal at the junction should be approximately 10 mm wide on the top and underside of the plate

(c) brush the flux paste on both sides of the joint. Fluxing of the welding rod is not normal practice. Use flux sparingly for economy and ease of post-weld removal.

Guideline welding conditions—butt joints

Welding is only recommended in the flat position.

Thickness mm	Preparation	Assembly	Nozzle size	Filler rod
1	Square edge	Taper gap 1 mm per 30 mm gap	3 (86 litres/hr)	2·4 mm
1·5	Square edge		5 (140 litres/hr)	3·2 mm
3	Square edge		10 (200 litres/hr)	4·0 mm

Note: Tackwelding is not applicable to copper.

Welding procedure

(a) Set the plates with a taper gap of about 1 mm per 30 mm run. Weld the plates on asbestos sheets. A groove in the asbestos sheet parallel to the line of the weld will assist penetration.

(b) Set the flame neutral or slightly carbonizing. Too much acetylene causes porosity. Pre-heat the plates prior to welding until a brightly coloured oxide film appears.

(c) Commence at a point one-fifth of its length or 50 mm maximum along the seam and weld towards the furthest edge. Rotate the plate 180° and complete the weld. Maintain blowpipe angle at 60°–80° and the filler rod at 25°–30° to the line of weld.

(d) Do no allow the cone to touch the molten pool or filler rod. Maintain a distance of 6 to 10 mm from the cone to the pool.

(e) When the pool is established:

(i) keep the rod in the flame envelope
(ii) keep the rod in the molten pool
(iii) do not agitate the molten pool
(iv) use a slightly sideways motion with the blowpipe
(v) as the rod fuses into the pool progress along the seam.

(f) To avoid a crater at the end of the weld, or when ceasing to weld for any reason, remove the blowpipe slowly and add filler rod to give sound terminal reinforcement.

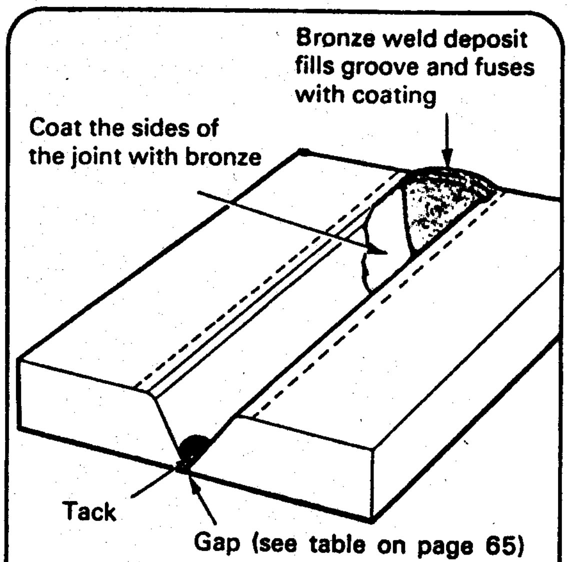
(g) After welding:

(i) remove flux residue
(ii) lightly peen. This will consolidate and strengthen the weld.

Visual examination

Ensure fusion of the root edges, adequate reinforcement, freedom from porosity, absence of craters and longitudinal cracks. Penetration bead should be smooth.

Copper may also be joined by braze welding which is particularly applicable to pipe joints (see section commencing on page 63).



Bronze welding cast iron.
Making the coating and deposit

Welding procedure

(a) Commence at one end and continue until the weld is completed.

(b) The filler rod and blowpipe angles are as for tackwelding.

(c) (i) First coat the surfaces of the joint with a layer of filler metal for a distance of approximately 20 mm along the joint, ensuring that it is correctly bonded.

(ii) Return to the starting point and commence to add sufficient material to produce a satisfactory weld. This method is repeated continuously until the weld has been completed. Ensure fusion between consecutive deposits.

(d) Conclude the weld by adding sufficient filler rod to obtain a good reinforcement and bonding and compensating for any shrinkage.

(e) Remove flux residue by scraping or wire brushing whilst the flux is molten.

Visual examination

The weld profile should be of adequate proportion. Surface should be bright and fee from porosity. Penetration bead must be uniform.

Butt joints (vertical position)

In the vertical position it is necessary to vary the technique generally as follows:

(a) The initial tackweld at the base of the weld run is increased in size so that it forms a platform on which to build the remainder of the weld, ie. the tack weld literally becomes a short, full-section segment of the weld.

(b) Intermittent tackwelds (where required) will be made as in the flat position.

(c) When commencing the weld (or restarting) sufficient pre-heating of the existing deposit is necessary to ensure fusion with subsequent deposition. The weld is carried out by depositing a single layer ensuring bonding.

(d) The movement of the filler rod and blowpipe will follow the contour of the weld in a circular motion to ensure uniformity of the weld size.

(e) Ensure that the filler rod is interposed between the flame and the joint faces to avoid overheating of the faces.

11.2 Oxygen and acetylene cylinders

The differences between an oxygen cylinder and an acetylene cylinder are clearly illustrated in Fig. 11.2.

Oxygen

This is supplied to the welding torch from a solid drawn steel cylinder where it is contained in compressed form. Oxygen cylinders are usually supplied in capacities of 3·4 m^3, 5 m^3, and 6·8 m^3. Mild steel cylinders are charged to a pressure of 13 660 kN/m^2 (136·6 bar) and alloy steel cylinders to 17 240 kN/m^2 (172 bar).

The oxygen volume in a cylinder is directly proportional to its pressure, and the consumption for a welding job can, therefore, be found by noting the pressure drop during the welding operation. For example, if it were noted that the original pressure of a full oxygen cylinder had dropped 5% during a welding operation, then 1/20 of the cylinder contents would have been consumed.

THE VALVE OUTLET ON AN OXYGEN CYLINDER HAS A RIGHT-HAND SCREW THREAD.

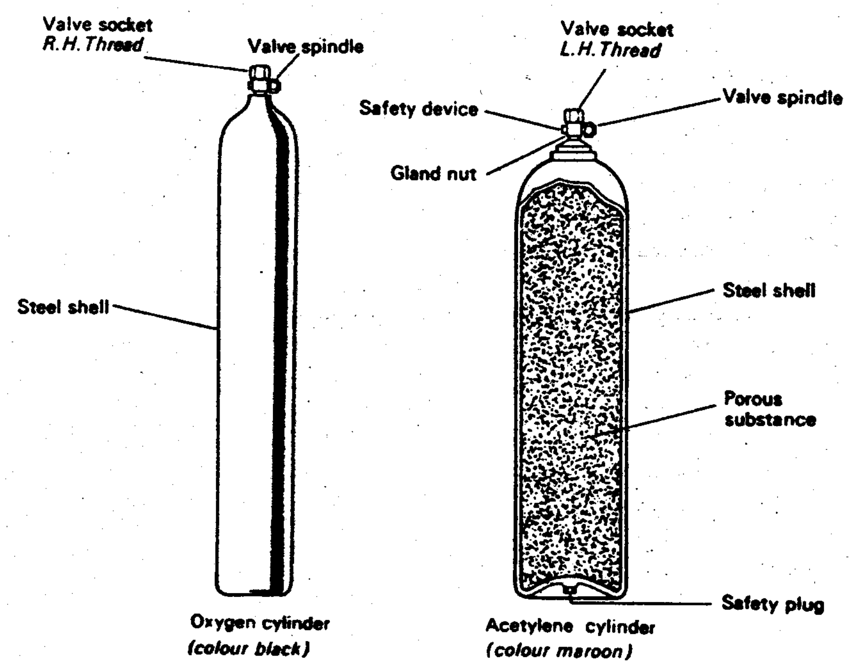


Fig.11.2 **Acetylene and oxygen cylinders**

Acetylene

For high pressure welding is supplied in a solid drawn steel cylinders as shown in Fig. 11.2. *High pressure acetylene is not stable and for this reason it is dissolved in* acetone, *which has the ability to absorb a large volume of the gas and release it as the pressure falls.* One volume of acetone at atmospheric pressure and at a temperature of 15°C is capable of dissolving about 25 volumes of acetylene. *This dissolving capacity can be increased in proportion to the pressure.* Acetylene cylinders are charged to a pressure of 1 552 kN/m^2 (15·5 bar), and as one atmosphere is equivalent to one bar it follows that, at the same temperature, one volume of acetone absorbs approximately $25 \times 15 = 375$ times its own volume of acetylene at a pressure of 15 bar.

Because of the danger of explosions to which compressed acetylene is susceptible, the steel cylinder is filled with a porous substance, and the construction of the cylinder, its filling and testing, are all strictly controlled by the manufacturers in the interests of safety. The pores in the filling material divide the space into a large number of very small compartments which are completely filled with 'dissolved acetylene'. *These small compartments prevent the sudden decomposition of the acetylene throughout the mass, should it be started by local heating or other causes.*

THE VALVE OUTLET ON ACETYLENE CYLINDERS IS FITTED WITH A LEFT-HAND SCREW THREAD.

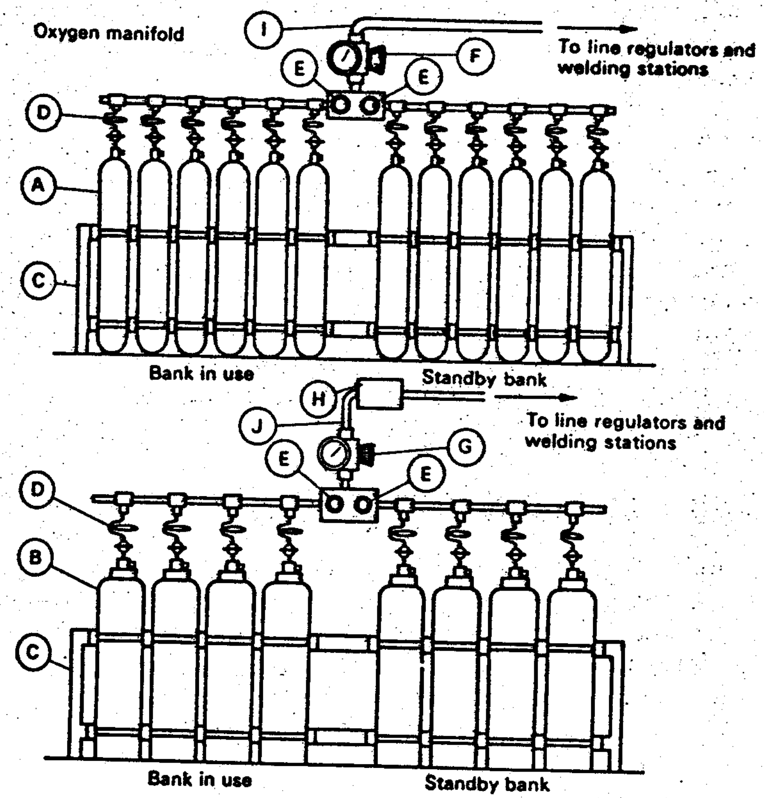
11.3 Discharge rate

Should OXYGEN be withdrawn from a cylinder at too great a rate of consumption, *a rapid drop in pressure will occur, with the result that the cylinder valve may freeze.* When flame cutting heavy cast-iron sections, which involves a high rate of gas consumption, it is advisable to couple together sufficient oxygen cylinders to complete the work — this also applies when repairing large castings which have to be preheated.

The rate of acetylene consumption also has to be kept below a certain limit. Acetylene cylinders should never be discharged at a rate which will empty them in less than 5 hours. This means that *the discharge rate must be limited to less than 20% of the total cylinder content per hour.* This is not because of freezing, as with oxygen, but because should this limit be exceeded acetone will be drawn off and mixed with the acetylene. Acetylene which contains small quantities of acetone vapour will lower the flame temperature. Unlike oxygen, the volume and pressure of acetylene are not in reliably found from the loss in pressure in the cylinder during a welding operation.

The sizes of acetylene cylinders in general use are 2·8 m³ and 5·7 m³.

In workshops, where welding gases are needed in several places, or at high rates of consumption, it is of considerable advantage to use a manifold system. Instead of having cylinders at each place of work, they are assembled in one centralised position in specially designed racks and connected by a manifold, as shown in Fig. 11.3. These gases are then distributed by means of a pipeline to the different work-places.



A Oxygen cylinders
B Acetylene cylinders
C Storage rack
D High-pressure coupling pipe ('pig-tail')
E Separate valve for each bank
F Oxygen output regulator and pressure gauge (Line pressure 4.15 bar)
G Acetylene output regulator and (Line pressure 620 millibar)
H Anti-Flashback device (acetylene)
I Oxygen supply line (copper pipe)
J Acetylene supply line (steel pipe)

Fig. 11.3 The manifold system for gas welding

More space available at work-place.
No replacement of cylinders inside the workshop.
Less transportation.
More effective use of the gas.
The cylinders are easily reached in case of fire.

11.4 Automatic pressure regulators

These are fitted to the oxygen and acetylene cylinders to reduce the pressure and control the flow of the welding gases. Examples are shown in Fig. 11.4. They are fitted with two pressure gauges. One indicating the gas pressure in the cylinder, and the other indicating the reduced outlet pressure. The operation of the pressure gauge is explained in Section 11.5.

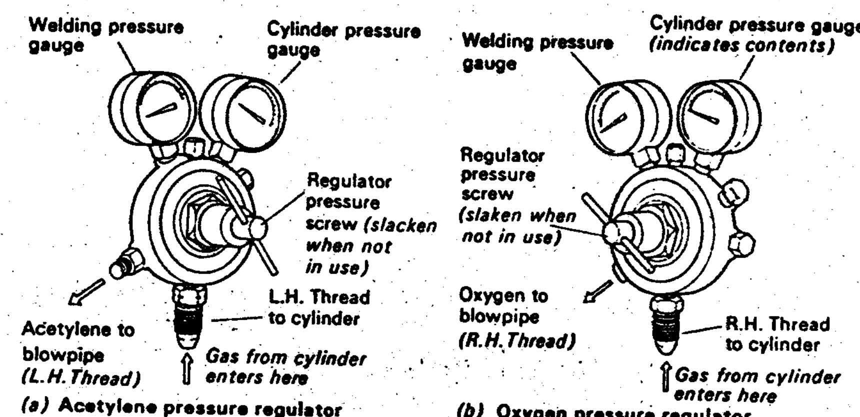


Fig. 11.3 Pressure regulators

The four principal elements which constitute a pressure-reducing regulator are:

1. A *valve* consisting of a nozzle and a mating seat member.
2. An *adjustable screw* which controls the thrust of the cover spring.
3. A cover spring which transmits to a diaphragm the thrust created by the adjusting screw.
4. A diaphragm connected with the mating seat member.

Figure 11.5 illustrates two basic types of *'single-stage' regulator.*

In the 'needle type' regulator the inlet pressure tends to close the seat member against the nozzle. The outlet pressure on this type of regulator has a tendency to increase somewhat as the inlet pressure

reliably found from the loss in pressure in the cylinder during a welding operation.

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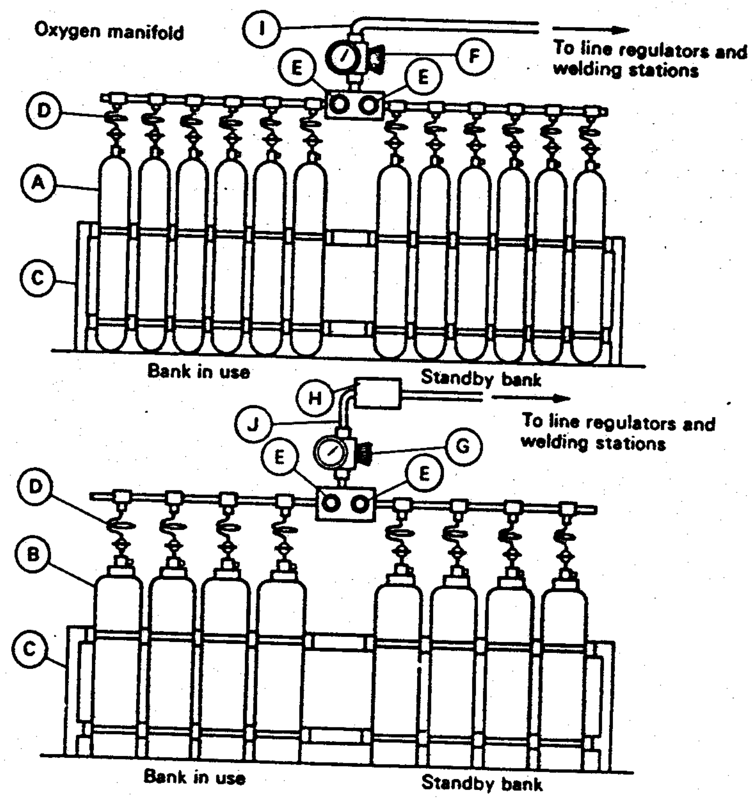

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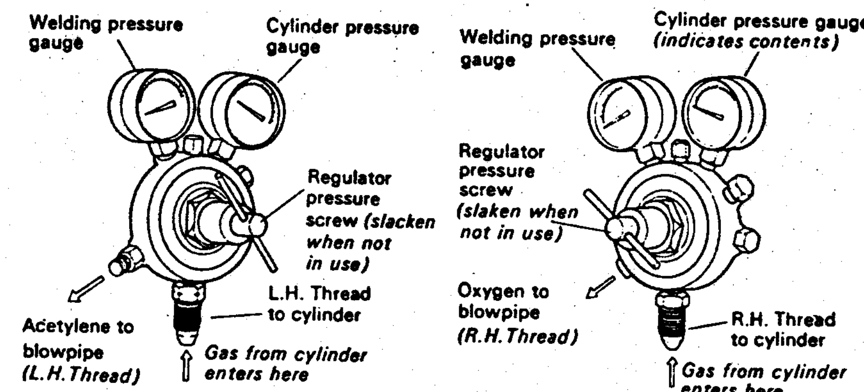

(a) **Acetylene pressure regulator** *(b)* **Oxygen pressure regulator**

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to as 'inverse' or 'negative' type.

In the '*nozzle type' regulator* the inlet pressure tends to move the seat member away from the nozzle, therefore the outlet pressure decreases somewhat as the inlet pressure decreases. *This is because the force tending to move the seat member away from the nozzle is reduced as the inlet pressure decreases.* This type of single-stage regulator is referred to as 'direct acting' or 'positive' type.

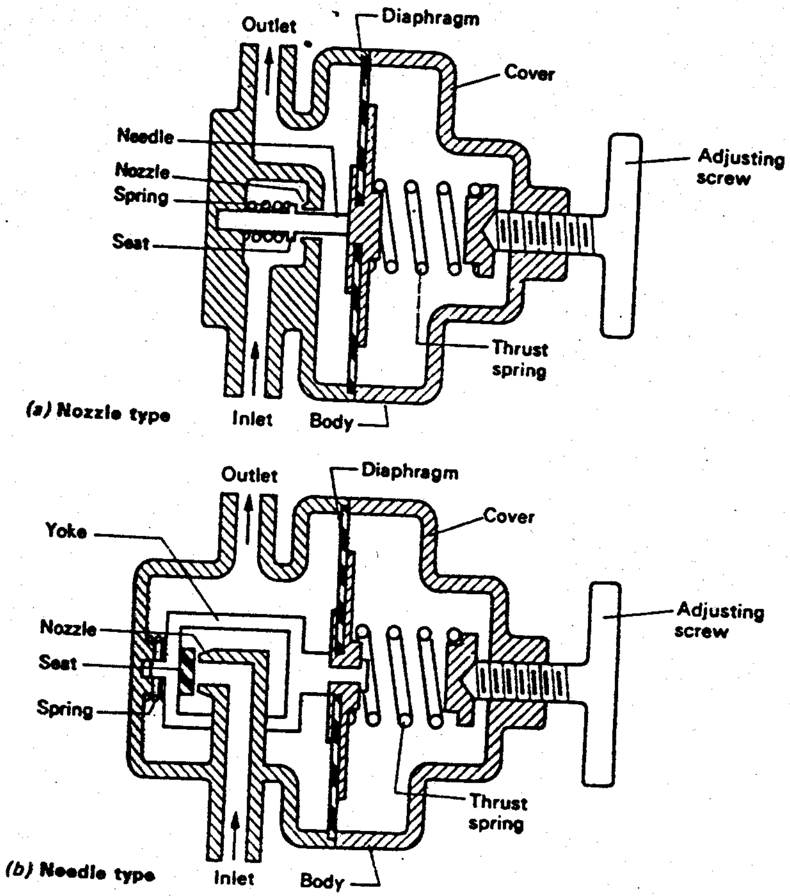

Fig. 11.5 Single-stage regulators

THE GAS OUTLET PRESSURE FOR ANY PARTICULAR SETTING OF THE ADJUSTING SCREW IS REGULATED BY A BALANCE OF FORCES.

... of the diaphragm and the inlet pressure against the seating area.

When the inlet pressure decreases, its force against the seat member decreases, allowing the cover spring force to move the seat member away from the nozzle. Thus more gas pressure is allowed to build up to re-establish the balanced condition.

A smaller outlet pressure on the underside of the diaphragm is all that is necessary to close the seat member against the nozzle. The opening between the seat members and the nozzle is reduced, which results in less gas flow.

11.5 The pressure gauge

Inside a pressure gauge there is a BOURDON TUBE. This is a copper-alloy tube of oval section. bent in a circular arc. One end of the tube is sealed shut and attached by light linkage to a mechanism which operates a pointer. The other end is fixed, and is open for the application of the pressure which is to be measured. The internal pressure tends to change the section of the tube from oval to circular and this causes it to straighten out slightly. The resultant movement of the tube causes the pointer to move over a suitably calibrated scale. An example of a bourdon tube pressure gauge is shown in Fig. 11.6.

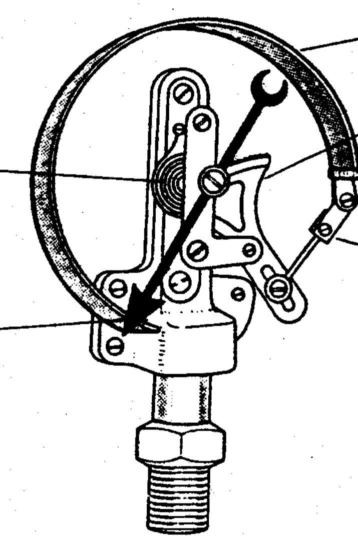

Fig. 11.4 Bourdon tube pressure gauge

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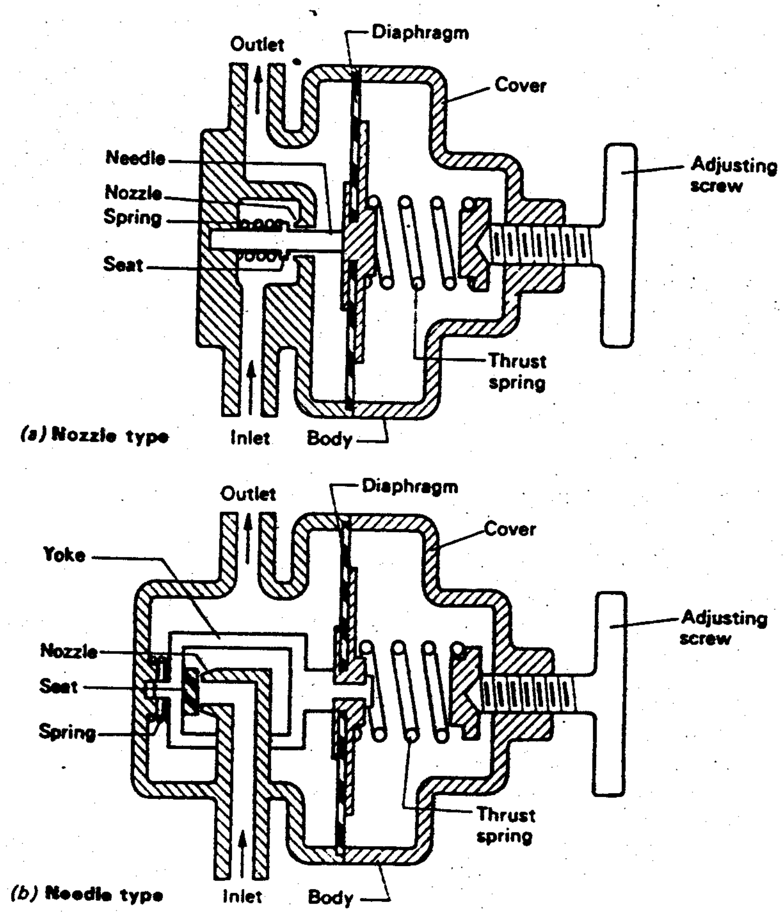

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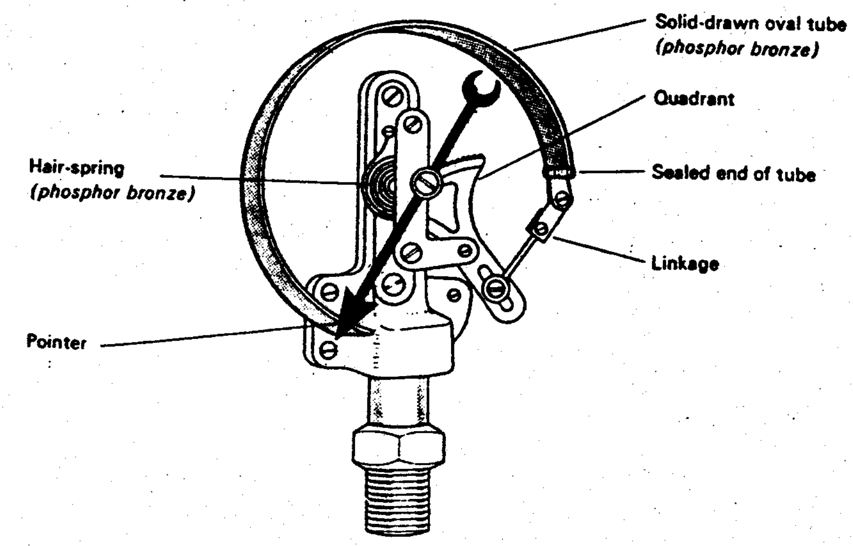


Fig.11.4 Bourdon tube pressure gauge

The gases having been reduced in pressure by the gas regulators are fed through suitable hoses to a welding torch.

The WELDING TORCH *is a specially designed piece of equipment used for mixing and controlling the flow of gases to the* WELDING NOZZLE *or* TIP. The torch provides a means of holding and directing the welding nozzle.

The basic elements of a high-pressure welding torch are shown in the simplified drawing, Fig. 11.7.

The fuel gas hose fitting on all welding torches has a left-hand thread, making it possible only to screw on the left-hand grooved nuts used on fuel gas hose. The other fitting, used for oxygen, has a right-hand thread.

There are two CONTROL VALVES usually positioned at the rear end of the torch.

After passing the valves, the gases flow through metal tubes inside the handle and are brought together by the GAS MIXER at the front end.

The NOZZLE is shown as a simple tube tapered down at the outlet end to produce a suitable welding cone.

This type of torch is provided with sealing rings in the torch head, or in the mixer seats to facilitate a hand-tight assembly. These rings are normally made of natural rubber or synthetic materials.

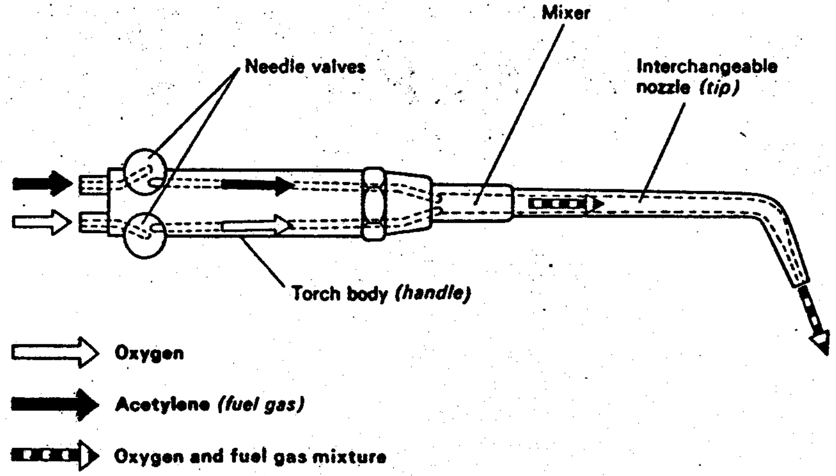


Fig.11.5 High-pressure welding torch

acetylene are thoroughly mixed before they enter the nozzle. Figure 11.8 shows a typical gas mixing chamber.

The two gases, controlled with respect to volumetric rate by needle valves are fed in at points marked A (FUEL GAS) and B (OXYGEN).

The mixing of the gases commences at point C, and continues throughout the chamber (as indicated by the small arrows) and forward to the welding nozzle where it is ignited.

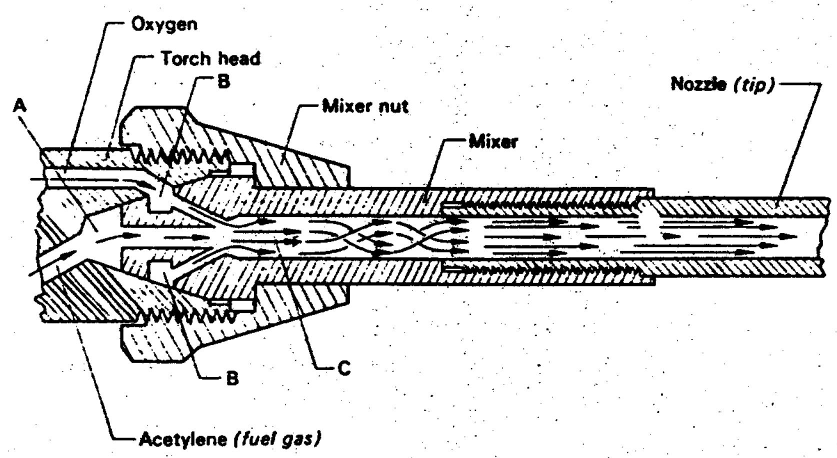


Fig.11.6 Mixing chamber for a welding torch

A well designed gas mixer will perform the following essential functions:

1. Mix gases thoroughly for proper combustion.
2. Arrest 'flashbacks' which may occur as a result of improper operation or welding procedure.
3. Stop any flame from travelling back farther than the mixer.
4. Permit a wide range of nozzle sizes to be used with one particular size of mixer.

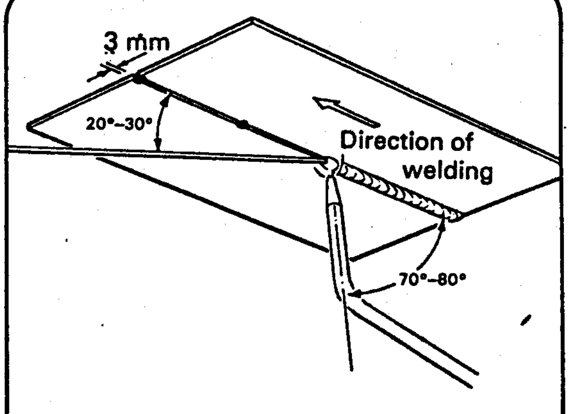
11.7 Welding nozzles

The welding nozzle or tip is that portion of the torch through which the gases pass prior to their ignition and combustion. A welding nozzle enables the operator to guide the flame and direct it with the maximum ease and efficiency.

Nozzles are made from a NON-FERROUS metal such as COPPER or a COPPER ALLOY. *These materials possess a* HIGH THERMAL

Welding in the overhead position
Single-V butt joint—single run
Leftward welding
Example procedure EP/OA/27

Material	Two pieces of mild steel 5 mm thick. Min size 200 mm x 150 mm
Preparation	80° inclusive angle
Assembly	Tackweld each end of the joint. Normal pitch of tacks 75 mm. Final gap 3 mm. Secure the assembly at a convenient working height with the seam facing downwards
Nozzle size	13 (370 litres/hour)
Regulators	Each 0·28 bar
Filler rod	3·2 mm BS 1453: A1



Overhead butt weld — 5 mm plate

1. At the right-hand end of the joint, fuse the tackweld and parent metal to form the weld pool.

2. When the molten pool is established, commence the weld by using a suitable blow-pipe and filler rod movement.

3. The flame is travelled in a leftward direction, in a circular looping movement, to maintain control of the molten metal.

4. Add the filler rod by piston movement as the blowpipe is returned to its starting point.

5. Hold the blowpipe nozzle at an angle of 70°–80° and the filler rod at an angle of 20°–30° from the horizontal as shown in the illustration.

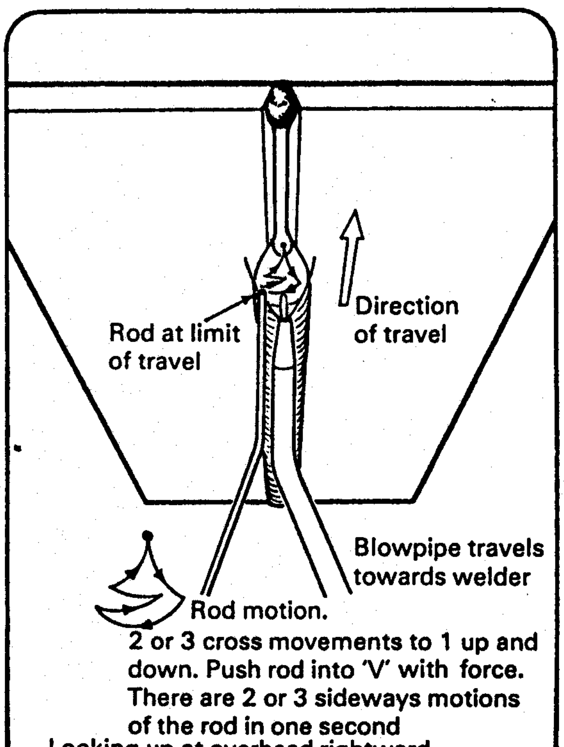
6. At the end of the seam the weld is terminated by adding sufficient filler rod to obtain adequate build-up at the end of the joint. Speed of deposition must be increased and the angle of the blowpipe changed as metal is quickly added to complete the joint.

Visual examination
The reinforcement is likely to be more pronounced than a joint made in the flat position. Although this is acceptable, it should be uniform and not excessive. The penetration must be sufficient to have fused the plate edges uniformly through the joint.

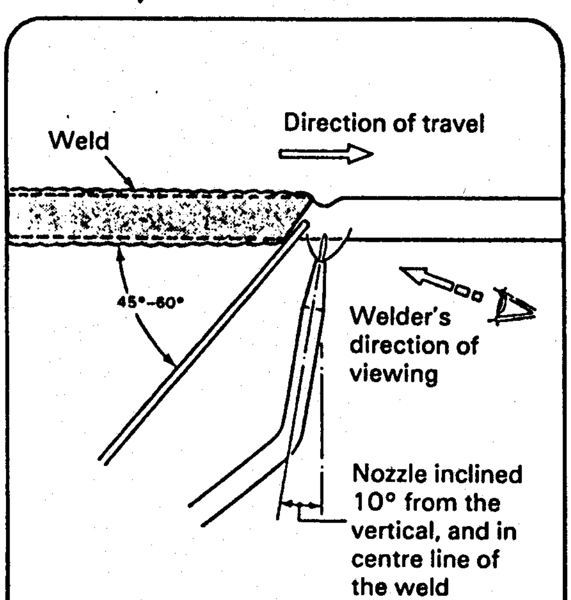
Single V-butt joint—multi-run
All-position rightward
Example procedure EP/OA/28

Material	Two pieces of mild steel 10 mm thick. Min size 250 mm × 150 mm
Preparation	70° inclusive angle
Assembly	Assemble by tackwelds at each end of the seam. Normal pitch of tacks 125 mm along the seams. Final gap 3 mm. Secure the assembly at a convenient working height with the joint in the overhead position.
Nozzle size	35 (1000 litres/hr)
Regulators	Each 0·62 bar
Filler rod	(For both runs) 3·2 mm BS 1453: A1

1. At the left-hand end of the joint fuse the tack-weld and the parent metal to form the weld pool.
2. When the molten pool is established, commence the weld by suitable blowpipe and filler rod movement in a rightward direction.
3. The flame is travelled in a slightly circular movement to ensure fusion, and control of the molten pool.
4. The filler rod is added by side-to-side motion of about 2 or 3 movements per second. Penetration is ensured by one up-and-down movement through the root after 2 or 3 sideways movements.
5. Hold the blowpipe nozzle at an angle of 80° and the filler rod at an angle of 45°–60° from the line of the weld as shown in the illustration.
6. Continue for 50 mm to complete the first run, moving the filler rod and flame simultaneously but with the blowpipe travelling to the left as the filler rod travels to the right (or vice versa).



Looking up at overhead rightward weld (all-position rightward)



Section along joint, showing rod and blowpipe angles from the side

7. The second run is superimposed on the first, using the same technique for a distance of 40 mm. The rod and blowpipe are moved as before, oscillating alternately, along the seam. The fusion must be complete and the weld face reinforcement slightly convex.

8. The third weld is a continuation of the penetration bead. It is commenced by remelting the weld about 12 mm back. The technique is a continued application of the all-position right-ward method.

9. The fourth weld is a continuation of the second and follows the same technique.

10. Each weld run is terminated by adding sufficient filler rod to obtain an adequate build-up at the end of the run. The speed of deposition must be increased and the angle of the blowpipe changed as metal is quickly added to complete the run.

Visual examination
The weld reinforcement profile should be uniform along the length of the joint. The root penetration must be sufficient to have fused the plate edges uniformly through the joint.

Gases

Gases used may be argon, helium or hydrogen or mixtures of these. Different gases may be used for the orifice and the shielding nozzle. Equipment often includes flowmeters and valves to supply the required mixture. (Unlike manual metal-arc welding, the presence of hydrogen does not normally cause difficulties when welding steel).

Ensure that the gas mixture recommended by the equipment manufacturer is used. Ensure that the flowmeter used is correctly calibrated for the gas flowing through it.

Arc striking

The arc cannot be struck directly between the tungsten electrode and the work. Instead, a pilot arc is started between the electrode and the orifice, either by a high frequency supply or by depressing the electrode to touch the orifice entrance.

Touch striking

In some applications of the plasma process this pilot arc can be increased in power sufficiently to enable a weld to be made, in which case it is called a non-transferred arc, and no welding return connection to the work is required. In most cases the arc is transferred to the work. This happens when the contractor carrying the main welding current is switched in-circuit, usually by means of a foot-switch or torch-switch. The welding current is then transferred from the tungsten electrode to the workpiece through the copper orifice (or anode). The electrode, orifice and shielding gas nozzle are all mounted in a torch similar to a conventional Tungsten-arc gas shielded torch.

Equipments vary considerably in torch construction and operational procedures. The examples chosen illustrate the principles. Always read the manufacturer's instruction book.

Safety

Hydrogen

Hydrogen cylinders are colour-coded red and have left hand threads on the connectors. (See Module F10 Instruction Manual).

Ensure that only hydrogen regulators are used on hydrogen cylinders. The cylinders are filled to a pressure of 175 bars and the regulators must be suitable for use at this pressure.

ACETYLENE and PROPANE regulators are made for lower cylinder pressures and MUST NOT be used for hydrogen cylinders.

Ensure that the system is free from leaks. Hydrogen leaks easily and is flammable and explosive. When burning, the flame is almost invisible. Hydrogen is lighter than air and when released, will rise to form an explosive mixture in the ceiling of an enclosed space.

Ensure that the inert gas (argon or helium) used to form a mixture with hydrogen is connected, and that the supply does not fail.

Mixtures in normal use are safe, but if the inert gas supply fails the torch will be fed with pure hydrogen.

The use of a mixture ready-made by the cylinder supplier eliminates most of these hazards, and for this reason it is preferred.

Safety

Electrical
When used for cutting, plasma equipment works at a higher voltage than other arc-welding equipment (open circuit voltages of 120V or more are common).

Check the torch and cable carefully before switching on; do not use them if any insulation is damaged.

Switch equipment off before dismantling torch for adjustment or maintenance.

Connect the welding return lead to the work.

Earth the work in the usual manner.

Do not attempt to clean the torch by inserting a wire in the orifice; switch off and dismantle.

Pilot arc
The pilot arc is inside the torch; it is not as bright as the usual high current welding arcs and is visible only if viewed along the axis of the orifice. The hot gas jet, which is usually visible, emanating from the orifice can set fire to flammable materials such as clothing, or cause burns, even with the low power of the pilot arc.

Make sure that if the pilot arc is left running the torch is parked in a safe place where it will not cause fires or burns. Switch off the pilot arc during work breaks, or if no safe place is available.

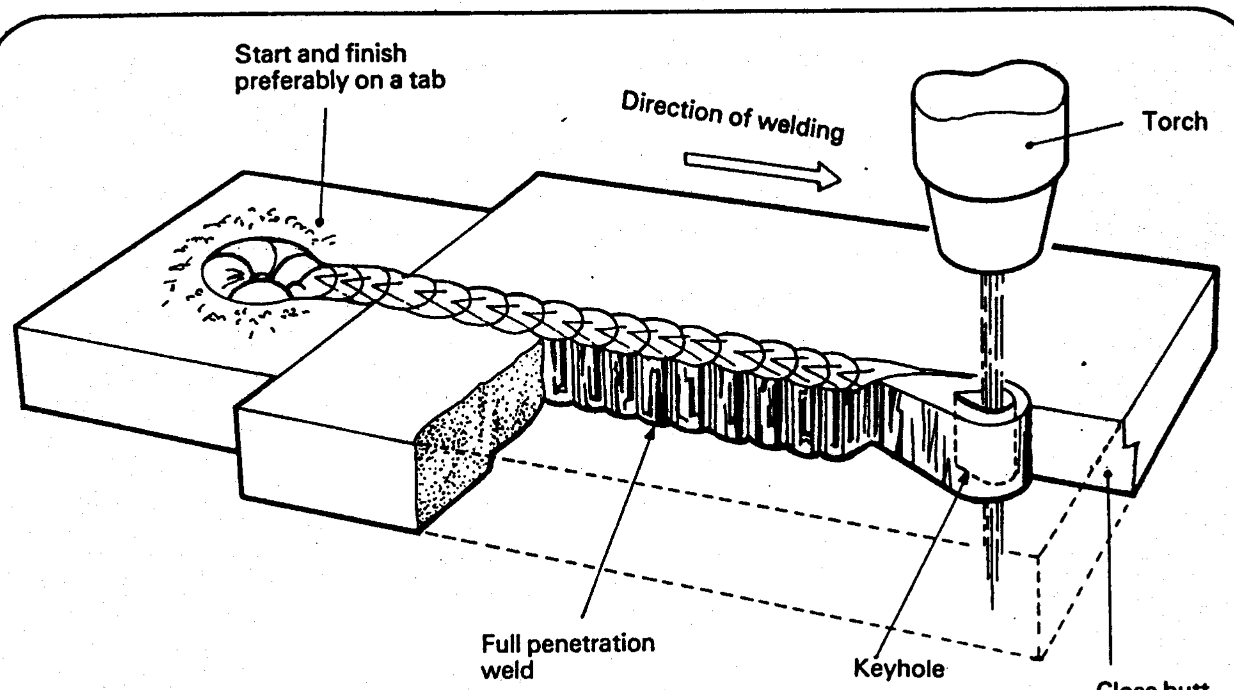
Other applications
As well as plasma arc and micro-plasma welding, there are two other applications of the constricted arc principle: plasma surfacing and plasma cutting. These are not within the scope of this manual.

Plasma arc welding

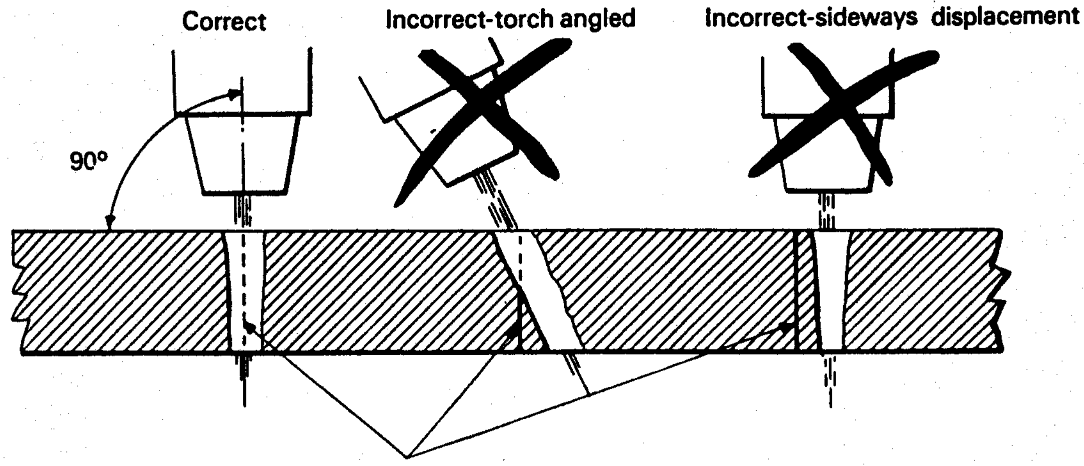
Keyholing

A common application of plasma arc welding is to produce full penetration butt welds from a close butted square edge preparation by the keyhole technique, in which the gas jet from the orifice blows a hole through the weld pool on the joint line, giving a deep narrow weld which minimises distortion. The flat position must be used.

The start and finish of the weld bead may be irregular, so they should preferably be on tabs which can be discarded after welding. Alternatively current may be slowly reduced to provide the usual crater-filling action; it is normally unnecessary to use filler.



Keyholing



Because of the shape of the weld pool, correct torch alignment is essential.

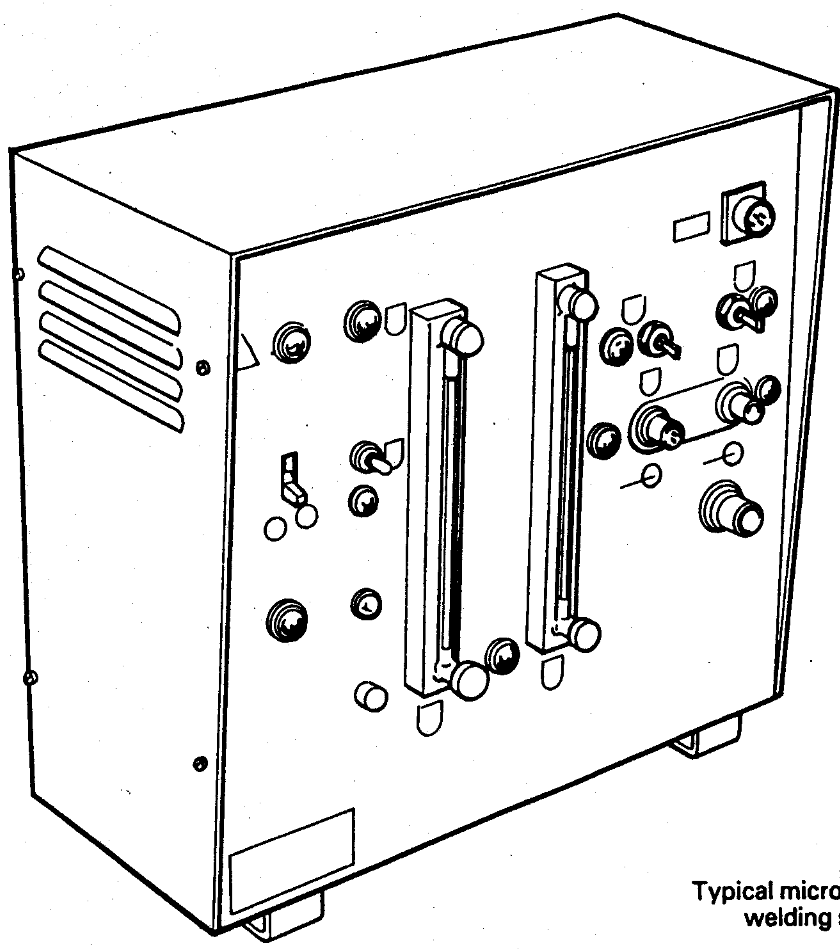
Plasma arc welding
Guideline conditions
Welding in the flat position — Butt joints
Preparation: square edge
Assembly: close joint

Joint type	Material		Current A	Orifice size	Plasma gas: Argon	Shield gas: 95% Argon 5% Hydrogen	Backup gas: Argon
	Type	Thickness mm		mm	l/min.	l/min.	l/min.
Key-hole	Mild steel	1.5	40–50	1.6	1.5–2.0	7.5	Not required
	Stainless	1.5	25	0.8	0.5	7.5	0.14–0.28
	Mild steel	2.4	60–70	1.6	1.5	7.5	Not required
	Stainless	2.4	50	1.2	0.75	7.5	0.14–0.28
	Mild steel	3	70–80	2.1	1.5	7.5	Not required
	Stainless	3	75	2.1	1.5	7.5	0.14–0.28
	Nickel alloy	3	160	3.2	0.5	7.5	0.14–0.28
	Stainless	5	100	2.1	1.125	7.5	0.14–0.28
Fusion	Mild steel	1.5	40–50	1.6	1.5–2.0	7.5	Not required

Note: The above data is for guidance only.
Conditions will vary for different applications and other materials. Always refer to the equipment manufacturer's recommendations for these and other materials.

Micro-plasma welding

The constricted arc used in micro-plasma welding runs at a current in the range 0.1 to 16A and can be used to weld materials of thicknesses from 1.6 mm down to 0.02 mm or less (with conventional tungsten-arc gas shielded welding, as the current is reduced, the arc becomes increasingly unstable – it no longer takes the shortest path from the end of the electrode to the work, it tends to go out, and it is difficult to strike and maintain).



Typical microplasma welding set

As the process is used to work on thin materials, joints must fit well and will often be difficult to see. If the welder's eyesight is less than perfect, he may experience difficulty in guiding the torch and/or he may suffer eyestrain. In this case an optician should be consulted to see if suitable spectacles can help. As a further aid, magnifying lenses which fit into the normal filter goggles can be obtained.

Safety

Providing that correct eye protection is used there is no risk of eye injury. (Because of the low arc current in micro-plasma welding, goggles with a shade number 4 to 7 filter are usually adequate but full face protection is recommended).

Welding in the flat position — Butt joints
Preparation: square edge
Assembly: close joint
Guideline conditions — Stainless steel

Thickness mm	Preparation or backing bar Fig. no.	Welding conditions		
		Current amps	Plasma gas: Argon litres/min.	Shielding gas: 98% Argon 2% Hydrogen litres/min.
0.05	1 & 2	0.7	0.24	7
0.10	1 & 2	1.7	0.24	7
0.13	2	2	0.24	7
0.20	2	3	0.24	7
0.30	3	4	0.24	7
0.46	3	9	0.28	7
0.71	3	10	0.33	7
1.2	3	13	0.42	7

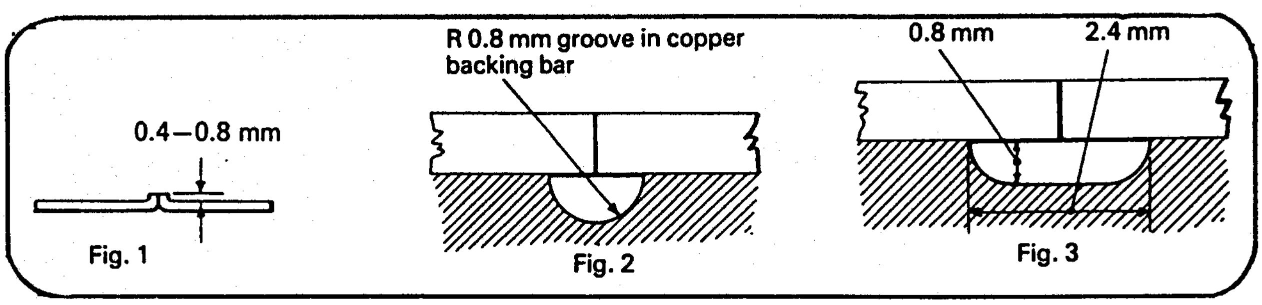
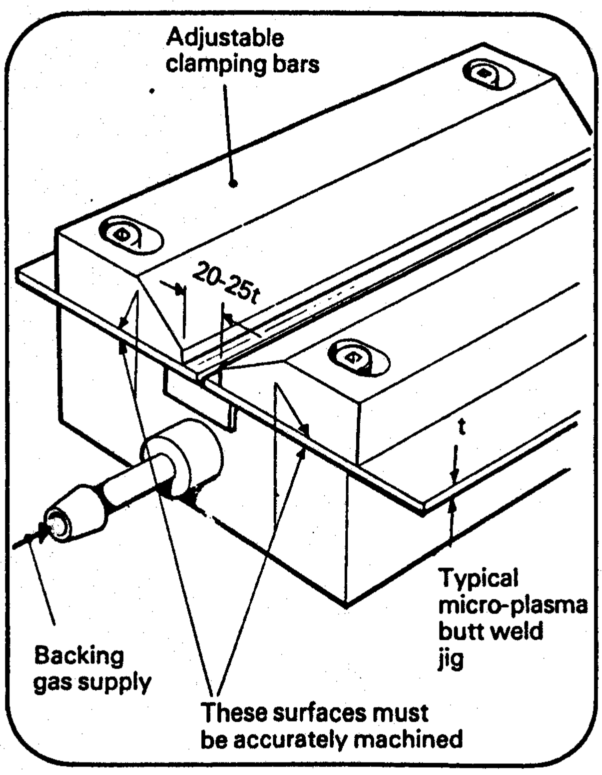


Fig. 1 Fig. 2 Fig. 3



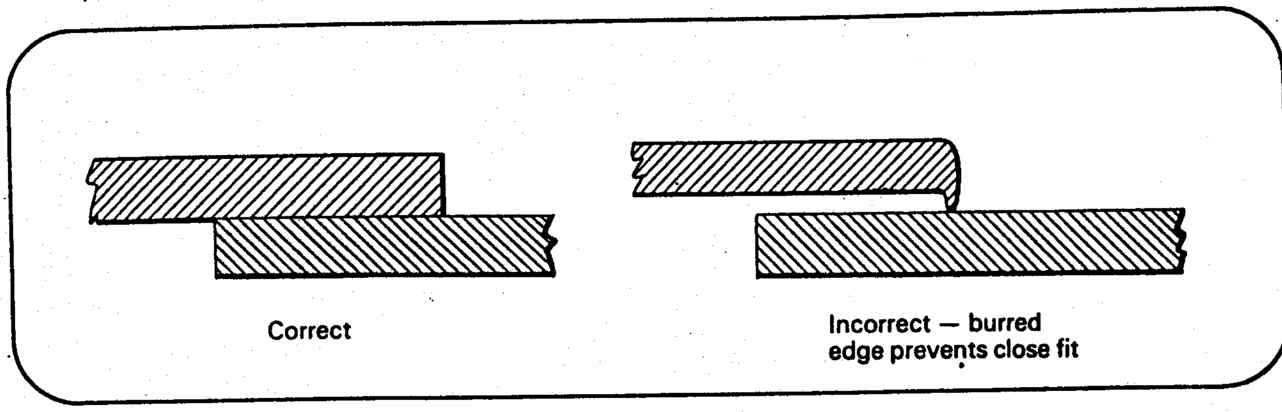
Notes:

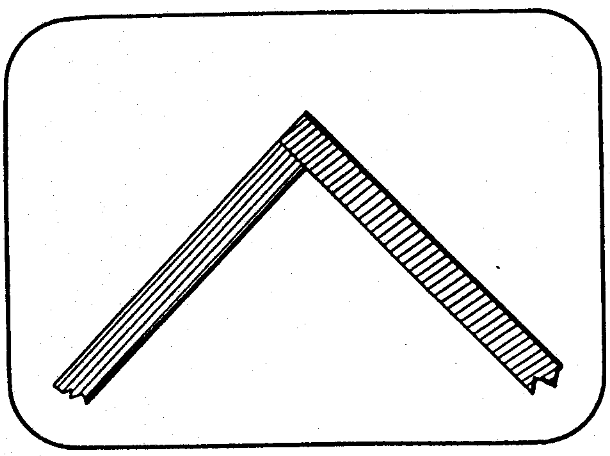
(a) As the material thickness reduces, the tolerances on assembly must be reduced accordingly. The best results are obtained by using a jig (illustrated on the left) in conjunction with backing bars as shown in Figs. 2 and 3.

(b) The data applies to joints made in 18/8 stainless steels using a butt welding jig.

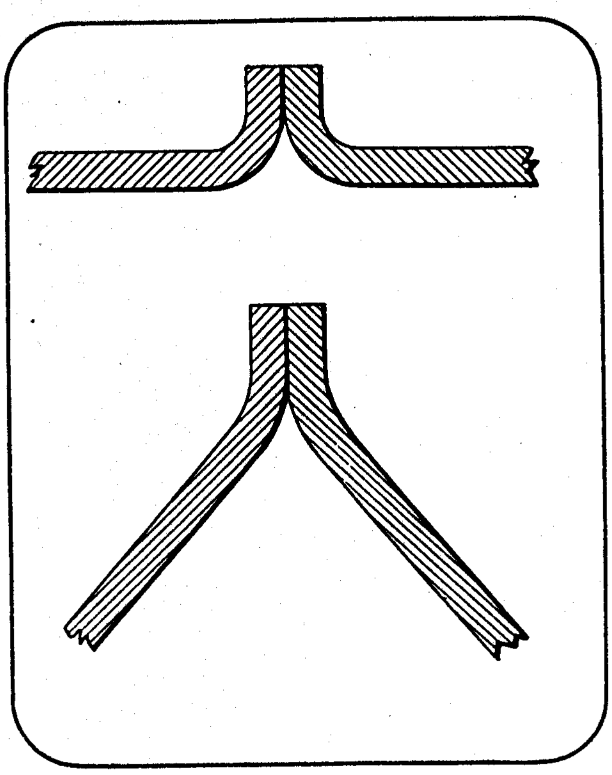
(c) Similar settings are applicable to edge, corner and fillet welds.

Lap joints
The edges of a butt joint have to be cut accurately to fit closely without gaps: a lap joint eases this requirement, but the edge to be welded must still be cut without burrs, and fit close to the other piece.





Corner joints
Accurate preparation and assembly is essential.



Edge welds
These can be used in some butt and corner joints, and when prepared and assembled so that the edges spring together can accommodate errors which would be unacceptable in normal butt and corner joints.

Module phases tests

1. General

The phase tests presented in this series have been devised to measure the progress of trainees who are taking tungsten-arc gas shielded welding module F22.

It is emphasised that these tests are merely examples and that alternative tests of items of production with similar skill demands can be used.

The tests have, in the main, been arranged in an order based on the skill elements given in the Training Specification, but this order can be varied to suit local conditions or individual trainees.

Trainees should reach a satisfactory performance in any test, or parts of a test, before being allowed to undertake training in the next skill element.

All phase tests must be satisfactorily completed before the trainee can be awarded the Board's Certificate of Engineering Craftsmanship.

2. Assessment

Each phase test shows an engineering production item (or refers to a specific welding technique) and a time is to be given for its completion in a specific material, or materials, using the appropriate preparation, assembly and welding techniques and procedures.

The items to be assessed are indicated in the panel headed ASSESSMENT.

Where an alternative phase test is selected it must include a similar number and type of skill elements.

Before commencing each test, the trainee should be given time to study the drawing and the sequence of operations required to produce the workpiece.

On completion of test, it should be examined by the trainee's supervisor, or other competent person, who will determine whether it is satisfactory in ALL of the following elements:

(a) *Dimensional accuracy*

All dimensions must be within the given range. The use of correct methods of edge and gap preparation and component parts assembly should be considered and account should be taken of the degree and nature of any distortion which occurs.

(b) *Quality*

This assessment appertains to weld appearance; absence of gaps; undercutting and surface defects. Where visual or macro-examination of the weld is called for, the assessment should include quality of weld metal; root penetration; absence of inclusions; degree of fusion; freedom from cavities and other defects.

Note: In order to make a satisfactory assessment, it will be necessary to check that the trainee selected and used the appropriate electrode, filler rod, and welding conditions, and followed the correct weld procedure and techniques.

(c) *Time*

A time is to be set (usually by the supervisor) for the satisfactory completion of the job. Towards the end of the training period, this should approximate to the time in which a skilled craftsman would normally complete this particular task.

The details and results of the phase tests must be entered in the trainee's log book and signed by his supervisor.

BAB. III

BAHAN-BAHAN YANG DIPAKAI DALAM LAS LISTRIK

Dalam melakukan kegiatan praktek las listrik, harus ada bahan-bahan yang dipergunakan atau dipakai.
Bahan yang dipergunakan harus diketahui jenisnya terle - bih dahulu, dengan diketahuinya bahan yang akan di las, maka akan dapat pula ditentukan elektroda yang akan dipa kai dalam pengelasan tersebut, serta mesin las jenis apa yang akan dipergunakan supaya pengelasan tersebut dapat berhasil dengan baik dan menurut semesternya.

A. Bahan Uatama.

Bahan utama yang dimaksudkan disini adalah bahan benda kerja yang akan di las, dalam hal ini adalah lo gam.
Disini penulis tidak akan menyinggung proses pembuat- an logam tersebut. Tetapi penulis akan menitik berat- kan kepada faktor-faktor yang berhubungan dengan pema kaian bahan dalam kerja las secara umum, untuk itu be rikut ini di uraikan hal-hal yang berhubungan dengan faktor-faktor tersebut antara lain mengenai :

1. Jenis Bahan.
   Jenis bahan benda kerja yang digunakan dalam me - ngelas harus diketahui oleh siswa, sehingga penge- tahuan dibidang ini dapat membantu siswa dalam me- nentukan jenis elektroda yang harus dipakai untuk mengelas bahan tersebut.
   Menurut garis besarnya bahan dan logam dapat dibe- dakan atas dua golongan antara lain :

   a. Logam Ferro
      Logam ferro ini dapat dibedakan menurut jenis -

nya atas :

1). Baja kerbon rendah (besi)
2). Baja karbon sedang
3). Baja karbon tinggi
4). Baja campuran
5). Baja tuang.

b. Logam non Ferro.
Yang termasuk logam-logam non ferro ini antara lain adalah :

1). Kuningan
2). Tembaga
3). Aluminium
4). Perunggu
5). Dan lain-lain

Pada umumnya logam-logam ferro dan non ferro tersebut sering dijumpai dalam perdagangan dan konstruksinya berbentuk :

1. Profil-profil (I. T. U. L).
2. Batang dengan berbagai bentuk penampang seperti bulat (∅), segi empat (◻) dan sebagainya.
3. Pipa dalam berbagai penampang seperti, bulat (∅) segi empat (◻) dan sebagainya.
4. Plat-plat.
5. Dan sebainya.

Jadi dapat disimpulkan bahwa jenis-jenis bahan harus diketahui terlebih dahulu sebelum melakukan pengelasan agar dapat memilih elektroda yang tepat untuk mengelas bahan tersebut.
Disamping itu agar siswa mengetahui bahwa bahan-bahan tersebut akan sering dijumpai dalam konstruksi konstruksi sebagai jenis dan bentuk.

2. Komposisi Kimia dari Bahan.

Komposisi kimia dari bahan juga harus diperhatikan, sebab logam-logam ferro dan non ferro kwalitasnya ditentukan oleh komposisi kimianya.

Demikian juga komposisi kimia dari bahan perlu diperhatikan mengingat terjadinya reaksi-reaksi yang tidak diinginkan akibat dipanaskan oleh busur nyala dalam mengelas.

Reaksi-reaksi yang tidak diinginkan ini bisa berbentuk gas-gas beracun, korosiperobahan sifat fhisik dari bahan yang dilas.

3. Tidak Cair dari Bahan.

Tidak cair menunjukan suatu suhu, dimana pada suhu tersebut bahan mulai mencair. Ini perlu diketahui untuk pengaturan besar ampere yang digunakan untuk mengelas bahan tersebut. Sehingga pengelasan tersebut dapat dilakukan dengan baik dan sempurna.

4. Berat Jenis Bahan.

Berat jenis bahan ini berguna untuk perhitungan berat dari suatu benda kerja ataupun konstruksi yang dibuat. Berat jenis ini banyak hubungannya dengan tujuan pemakaian bahan serta perhitungan pemakaian bahan.

5. Kekuatan Tarik dan Modulus Kenyal.

Benda-benda yang akan dilas nantinya akan dipergunakan pada bebagai konstruksi, tentu saja dalam pemakaian akan mengalami beban atau gaya tertentu. Oleh sebab itu perlu diketahui terlebih dahulu kekuatan tariknya. Dengan diketahui angka atau besarnya kekuatan tarik dari bahan tersebut, maka dapat ditentukan serta elastisitet yang terjadi.

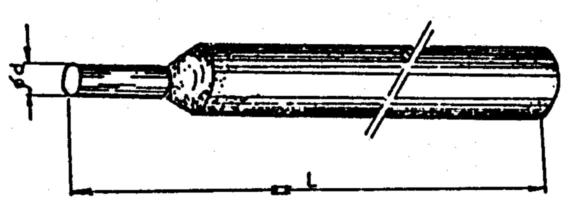
B. Elektroda Las (Bahan Tambah)

Dalam mengelas, elektroda ini mempunyai peranan terpenting dimana elektroda ini berfungsi : sebagai pembuat busur nyala, melalui ujung elektroda tersebut dan sebagai bahan tambahan dalam pengisian sambungan las.

Proses pengelasan ini terjadi pencairan bersama atau serentak antara elektroda dan benda kerja yang di las.

Elektroda ini terbuat dari bermacam jenis logam (logam ferro dan non ferro) seperti : baja,baja tuang, tembaga, perunggu, allumanium dan lain-lain sebagainya, atau tergamtung pada komposisi kimia dari pada bahan (logam) yang akan di las.

Elektroda yang akan dipergunakan untuk mengelas baja carbon terbuat dari baja carbon dengan prosentase 0,1 - 0,18 % C (carbon) dan 0,25 - 0,4 % P & S (phospor dan Sulfur), sedangkan untuk mengelas baja campuran dipergunakan elektroda yang dipakai dalam mengelas listrik busur nyala, biasanya dalam bentuk batangan kawat (kawat las) dengan ukuran diameter dan panjang tertentu seperti dapat dilihat pada gambar.21.



Gambar.21

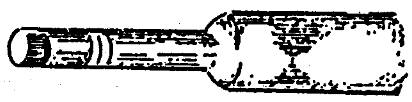
ELEKTRODA LAS

1. Jenis-jenis Elektroda.

Berdasarkan balutannya elektroda las dapat dibedakan atas beberapa jenis antara lain :

a. Elektroda Berbalut.
Elektroda las ini terdiri dari kawat inti dan dibalut dengan lapisan yang terbuat dari campuran bahan-bahan seperti : Soda silikat, Alumi - nium silikat, besi mangan, Titan dioksida, kalsium karbonat dan sebagainya.
Elektroda yang dipergunakan untuk mengelas dibuat dalam bentuk batangan dengan diameter ka - wat ini di atas 1,2 mm dengan ukuran panjang 450 mm. Elektroda berbalut ini terdiri dari ujung (pemegang) elektroda yang mempunyai jarak dengan pembalut sekitar ± 3 cm, kawat inti dan ujung penyalaan pada elektroda ini berfungsi untuk menjaga hubungan listrik sewaktu terjadi busur nyala dalam proses pengelasan, dimana balutan elektroda berfungsi untuk mempermudah pemeliharaan busur nyala, juga untuk mengikat kotoran kotoran dan melindungi cairan las dari pengaruh oksidasi dan netrogen, serta menyempurnakan komposisi cairan las. Untuk lebih jelasnya menge - nai elektroda berbalut ini dapat dilihat pada gambar 22.

elektroda bersalut tipis



elektroda bersalut tebal

Gambar. 22

ELEKTRODA BERBALUT

Pada umumnya elektroda berbalut ini dapat pula dibedakan atas dua jenis yakni :

1) Elektroda berbalut tipis

Elektroda berbalut tipis mempunyai tebal balutan 0,1 mm dan berat lapisan atau balutan sekitar (1-5%) dari berat elektroda. Elektroda yang berbalut tipis ini dapat mempertinggi kestabilan busur nyala, tetapi hasil pengelasan mempunyai sifat-sifat mekanik yang kurang (tidak baik), karena kurangnya pemeliharaan dari cairan logam sewaktu pengelasan berlangsung.

2) Elektroda berbalut tebal

Elektroda berbalut tebal ini mempunyai tebal balutan sekitar 1 - 3 mm, dan berat balutan 15 - 30 % dari berat elektroda seluruhnya.

Sebagai keuntungan dari elektroda berbalut tebal ini antara lain : Dapat mempertinggi kestabilan busur nyala, dan melindungi lapisan logam cair yang dilakukan gas-gas pelindung dan busur nyala di sekeliling terak. Disamping itu dapat mencegah terjadinya -

pencemaran (kontaminasi) dari oksidasi dan nitrogen pada logam cair dan perlambatan terjadinya pendinginan pada tempat-tempat pengelasan.

Pada umumnya tujuan atau maksud dari pada pembalutan kawat inti dari elektroda ini adalah :

a. Membuat busur nyala jadi stabil
b. Menjaga busur nyala tetap baik selama pengelasan.
c. Pengontrol reaksi yang terjadi selama pengelasan.
d. Melindungi cairan logam selama pengelasan berlangsung.
e. Menjaga karakteristik pengelasan dengan baik.
f. Memelihara proses pembuatan terak sewaktu pendinginan benda kerja yang dilas.
g. Menjamin lapisan (endapan) logam mempunyai susunan kimia, fisik dan sifat mekanik yang baik.

Untuk menjaga elektroda jangan menjadi lembab yang dapat membuat busur nyala jadi tidak stabil (baik), maka elektroda berbalut ini sebaiknya harus disimpan di dalam lemari pemanas yang mempunyai temperatur sekitar 100^{o}C

Pemanasan elektroda ini didalam tempat penyimpanan dapat dilakukan dengan pemanasan listrik atau dengan bahan kimia pemanas.

3). Elektroda Polos (tidak berbalut).

Pada dewasa ini elektroda yang tidak berbalut ini sangat jarang sekali dipergunakan dalam proses pengelasan, disebabkan sangat sukar untuk memelihara kestabilan busur nyalanya bila dibandingkan dengan elektroda berbalut. Pada umumnya elektroda tidak berbalut ini banyak digunakan dalam mengelas otomatis, dan mengelas tangan apabila mempergunakan untuk mengelas benda yang tidak begitu penting atau berkwalitas rendah seperti untuk mengelas : pagar-pagar, terali jendela rumah dan sebagainya.

2. Ukuran-ukuran elektroda.

Faktor yang terpenting untuk mendapatkan ha - sil pengelasan yang berkwalitas tinggi, adalah pe- milihan yang tepat dari pada elektroda, besar arus yang dipergunakan, serta teknik pengelasan. Besar arus yang dipergunakan dalam pengelasan tergantung dari pada diameter elektroda, tebal bahan benda kerja yang akan di las, jenis atau bentuk sambung- an las, kecepatan mengelas posisi pengelasan, te- bal dan tipisnya balutan elektroda, serta panjang benda kerja yang akan di las.
Tetapi dalam pelaksanaannya (praktek) hanya dengan pemilihan dari pada diameter elektroda yang akan digunakan, dan besar arus untuk mengelas sehubung- an dengan tebal dan tipisnya bahan benda kerja yang akan di las.

Pada umumnya elektroda las ini mempunyai ukur an-ukuran tertentu, untuk menyatakan diameter dari elektroda ini biasanya disingkat dengan (D) maupun panjangnya (L). Baik ukuran diameternya (D) maupun ukuran panjangnya dinyatakan dalam matrik (mm). Inchi dan beritis (SWH).

Ukuran-ukuran diameter elektroda yang banyak terdapat dalam perdagangan dan telah dinormalisasi kan dapat dilihat pada tabel I

Demikian juga untuk ukuran panjang elektroda las yang sering dijumpai dalam perdagangan dan di- normalisasikan, biasanya ukuran panjangnya 250 mm, 350 mm dan 450 mm.

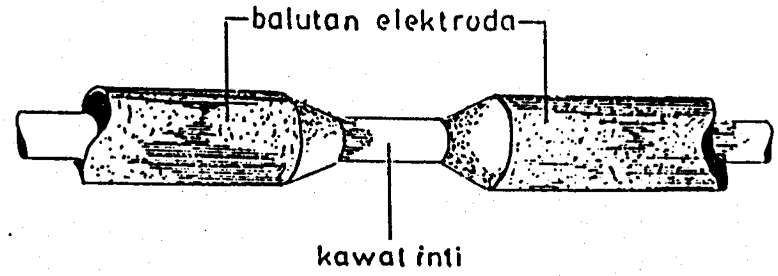
TABEL. I

UKURAN DIAMETER KAWAT INTI ELEKTRODA

No.	Metrik (Internasional)	Inchi (Amerika)	S W G (British)
1.	1,5 mm	1/16"	16 SWG
2.	2,0 mm	3/32"	14 SWG
3.	2,6 mm	1/18"	12 SWG
4.	3,25 mm	5/32"	10 SWG
5.	4,0 mm	3/16"	8 SWG
6.	5,0 mm	3/16"	6 SWG
7.	6,0 mm	-	4 SWG
8.	-	¼"	
9.	8,0 mm	5/16"	
10.	10,0 mm	3/8"	

Elektroda las ini biasanya dalam perdagangan dibungkus dalam kotak karton (dus) dengan ukuran berat tertentu seperti : 5 kg, 20 kg, 25 kg dan sebagainya.
Dalam dus tersebut berisikan elektroda yang sejenis dengan ukuran diameter dan panjang yang sama, sebagaimana yang dapat dilihat pada etiket tertentu pada kotak elektroda tersebut.

Untuk mengelas kampuh-kampuh yang panjang dapat digunakan elektroda las ganda (berbalut ganda), dimana keuntungan dalam mempergunakan elektroda ganda ini adalah mempercepat sambungan rigi-rigi las dan mempersingkat waktu. Untuk menjepit elektroda las (mengurangi waktu penjepitan elektroda), elektroda ganda ini banyak juga dijumpai dalam perdagangan. Elektroda ini dapat dilihat pada gambar 23.



Gambar. 23

ELEKTRODA GANDA

3. Simbol-simbol Elektroda

Pada negara yang memproduksi elektroda las terdapat simbol-simbol tertentu pada elektroda tersebut yang mempunyai arti tertentu, sebagai contoh dapat diambil elektroda yang dinormali - sasi berdasarkan American Welding Society (AWS) dan American for Testing Matrials (ASTM) yang menggunakan simbol (E) untuk elektroda las busur nyala dan simbol (R) untuk elektroda las Otogen (las karbit) yang diikuti dengan empat atau lima angka dibelakangnya. Untuk lebih jelasnya dapat dilihat contoh dibawah ini.

Contoh simbol dan artinya, sebagaimana ada terdapat pada elektroda E - 6010 dapat diartikan sebagai berikut :

E. = Elektroda untuk las listrik

60 = Besarnya tegangan tarik elektroda las

1 = Posisi pengelasan yang harus dilakukan jika menggunakan elektroda ini (posisi mengelas)

0 = Karakteristik pabrik

(1) Contoh simbol yang terdapat pada elektroda las berdasarkan normalisasi menurut AWS anta-

ra lain sebagai berikut :

- EXXXX = Elektroda untuk las listrik.
- E60XX = Elektroda las listrik mempu- nyai tegangan tarik dari hasil pengelasan 60 x 1000 psi = 60.000 psi.
- EXXIX = Elektroda listrik, dimana angka I menunjukan bahwa elektroda tersebut dapat dipakai untuk segala posisi pengelasan.
- EXX2X = Elektroda untuk las listrik dimana angka 2 menunjukan bahwa elektroda tersebut dapat dipakai untuk mengelas pada posisi horizontal.
- EXX3X = Elektroda untuk las listrik dimana angka 3 menunjukan bahwa elektroda tersebut hanya dapat dipakai untuk posisi dibawah tangan.
- EXXXI = Elektroda untuk las listrik dimana angka I pada deretan belakang sekali menunjukan bahwa elektroda tersebut dapat dipakai untuk mesin las AC atau mesin las AC dengan polaritas DCRP.
- EXXX2 = Elektroda untuk las listrik dimana angka 2 pada deretan belakang sekali menunjukan bahwa elektroda tersebut dapat dipakai untuk mesin las AC atau me

sin las AC dengan polaritas DCRP.

- EXXX3 = Elektroda untuk las listrik di mana angka 3 pada deretan bela kang sekali menunjukan bahwa elektroda tersebut dapat dipakai untuk mesin las AC dan DC.

- EXXX4 = Elektroda untuk las listrik di mana angka 4 pada deretan bela kang sekali menunjukkan bahwa elektroda tersebut dapat dipakai untuk mesin las AC dengan polaritis DCRP dengan jenis ba lutan elektroda yang berlainan dengan simbol EXXXI.

- EXXX5 = Elektroda untuk las listrik di mana angka 5 pada deretan bela kang sekali menunjukan bahwa elektroda tersebut dapat dipakai untuk mesin las dengan polaritis DCRP.

- EXXX6 = Elektroda untuk las listrik di mana angka 6 dibelakang sekali menunjukan bahwa elektroda ter sebut dapat dipakai untuk mesin las listrik AC atau mesin las AC dengan polaritas DCRP.

- EXXX7 EXXX8 = Elektroda untuk las listrik di mana angka 4,7 dan 8 pada eret an belakang menunjukan bahwa elektroda tersebut berbalut -

serbut besi dan hanya dapat di pakai untuk mesin las AC dan DC,

- E70XXX	=	Elektroda untuk las listrik di
- E80XXX	=	mana angka 70, 80, 90, 100 pa-
- E90XXX	=	da deretan atau dibelakang hu-
- E100XXX	=	ruf E menunjukan bahwa elektro da tersebut dari paduan atau campuran lagom (logam campuran)

4. Kode-kode warna elektroda.

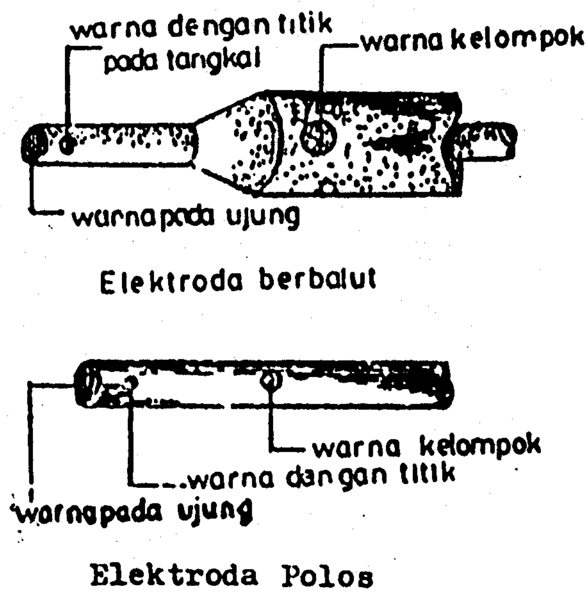
Untuk memudahkan mengenal elektroda sesuai manurut klasifikasinya masing-masing, maka AWS juga memberikan kode-kode dengan warna-warna t. tertentu untuk setiap jenis elektroda las, biasanya kode-kode inidiberikan pada tiga tempat antara lain :

- Pada ujung balutan elektroda.
- Pada tangkai elektroda.
- Pada ujung elektroda.

Warna-pada ujung balutan menunjukan warna kelompok atau jenis elektroda tersebut : umpamanya elektroda E7016, dengan warna hitam.
Pada tangkai elektroda juga diberi warna hitam berupa titik, demikian juga pada ujung elektroda tersebut diberi warna hitam.

Jadi dapat disimpulkan kode-kode warna pada elektroda-elektroda tersebut adalah bertujuan untuk dapat dengan mudah membedakan jenis atau kelompok dari masing-masing elektroda las tersebut.

Untuk lebih jelasnya mengenai kode-kode warna dari elektroda las ini dapat dilihat pada gambar.24 .



Gambar.24

KODE-KODE WARNA ELEKTRODA UNTUK ELEKTRODA BERBALUT DAN ELEKTRODA TAK BERBALUT (POLOS)

BAB III
PROSEDUR PENGELASAN

A. Pendahuluan.

Dalam melakukan kegiatan pengelasan untuk memperoleh keterampilan dibidang praktek las listrik harus mengikuti prosedur-prosedur kerja tertentu, yang harus di lakukan secara berurutan. Suatu pekerjaan tidak akan bisa dilakukan atau dilaksanakan dengan baik jika prose - dur pengerjaannya tidak dilakukan secara berurutan. Dengan kata lain agar pekerjaan dapat berjalan lancar dan berhasil dengan baik, maka pelaksanaannya harus ber dasarkan atau menurut prosedur-prosedur kerja tertentu yang telah ditetapkan.

B. Prosedur=Prosedur Pengelasan.

Prosedur-prosedur kerja yang dimaksudkan dan yang akan diuraikan adalah prosedur-prosedur kerja yang bersifat umum, dengan arti kata hampir seluruh pekerjaan las listrik mengikuti prosedur kerja tersebut.
Prosedur kerja yang dimaksudkan tersebut akan diuraikan sebagai berikut :

1. Tahap perencanaan.
   Dalam tahap perencanaan ini tercakup beberapa hal an tara lain :
   a. Pemilihan bahan
      Bahan yang dipakai didasarkan pada kegunaan benda kerja tersebut meliputi ; tempat pemakaian, ke - kuatan bahan, serta bentuk kampuh dan jenis elektroda yang akan dipergunakan.
   b. Perhitungan pemakaian bahan
      Perhitungan pemakaian bahan perlu direncanakan un-

tuk dapat menghitung banyaknya bahan benda kerja yang diperlukan dan banyaknya elektroda yang akan di gunakan.

c. Penyediaan alat.
Alat-alat yang disediakan di dasarkan kepada konstruksi yang akan dibuat bentuk kampuh las, dan penghalusannya kelak.

d. Pembuatan gambar kerja.
Gambar kerja merupakan kesimpulan dari perencanaan, dari gambar kerja dapat dipedomani mengenai ; jenis bahan, banyak pemakaian bahan, bentuk kampuh las yang akan dipergunakan.

2. Tahap Pelaksanaan.
Setelah tahap perencanaan selesai, tahap berikutnya adalah tahap pelaksanaan, dalam tahap pelaksanaan ini tercakup di dalamnya antara lain :

a. Tahap persiapan.
Dalam tahap persiapan ini adalah mempersiapkan hal-hal yang berhubungan dengan keselamatan kerja (pakaian las, dan perlengkapan lainnya), penyediaan alat-alat perkakas, dan yang paling penting sekali adalah hal-hal yang berhubungan dengan pesawat las antara lain ; menentukan besarnya arus listrik (ampere) dan tegangan yang akan dipergunakan dalam pengelasan.
Arus listrik yang dipergunakan dalam pengelasan di tentukan oleh diameter elektroda yang dipergunakan, tebal bahan serta jenis elektroda yang dipakai dan posisi pengelasan.
Perkiraan arus listrik yang akan dipergunakan dalam mengelas dapat dilihat pada tabel yang tertera pada setiap bungkus elektroda, sebagai

contoh dapat dilihat pada tabel dibawah ini :

TABEL II

PERKIRAAN ARUS LISTRIK YANG DIGUNAKAN

DIAMETER X PANJANG ELEKTRODA (mm)	DAERAH ARUS (AMPERE)	POLARITAS ELEKTRODA
2,6 X 350	45 - 95	AC atau DC

Demikian juga halnya dalam tahap persiapan ini, pengaturan tegangan (voltage) harus disesuaikan dengan kebutuhan dalam pengelasan, sebagaimana dapat dilihat pada contoh pengaturan voltage untuk mengelas sesuai dengan diameter elektroda yang di pergunakan.

TABEL III

PENGATURAN VOLTAGE BERDASARKAN DIAMETER ELEKTRODA

DIAMETER ELEKTRODA DALAM (mm)	TEGANGAN KERJA DALAM (Volt)
1,5 - 4,0	20 - 30
4,5 - 6,5	30 - 45

b. Tahap penyeletelan benda kerja.

Terutama untuk benda kerja yang besar diperlukan perangkaian yang baik untuk mempermudah penyetelan kampuh las.

Selaia itu penyetelan ini juga bertujuan untuk mengatasi atau menghindari perubahan bentuk yang terjadi akibat penas selama pengelasan b berlansung.

Dalam hal ini duperlukan alat penyetelan seper ti :

- Klem C
- Pasak
- Baut
- Rantai
- Dan sebagainya.

c. Tahap pengelasan.

Setelah dilakukan tahap-tahap tersebut diatas (a dan b), pada tahap pengelasan ini dilakukan pengelasan terhadap benda kerja sesuai dengan bentuk, kwalitas, serta kekuatan sambungan las yang diinginkan dalam pengelasan benda kerja tersebut.

d. Tahap finishing

Tahap finishing, maksudnya adalah tahap mengha luskan hasil-hasil pengelasan yang kurang baik serta menghaluskan hasil pengelasan dengan ja- lan menggerinda, mengikir, mengamplas dan se - bagainya. Selanjutnya hasil pengelasan terse - but di cat (jika perlu). Jadi tujuan finishing ini adalah untuk benda kerja tersebut jadi ra- pi dan halus.