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TECHNICIAN MANUFACTURING TECHNOLOGY II

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HODDER AND STOUGHTON

LONDON SYDNEY AUCKLAND TORONTO

Cover photograph reproduced by
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British Library Cataloguing in Publication Data

Pritchard, R.T.
Technician Manufacturing Technology II.
1. Production engineering
I. Title
670.42′02462 TS176

ISBN 0 340 22099 6

First published 1981

Photo Typeset by Macmillan India Ltd. Bangalore

Printed in Great Britain for
Hodder and Stoughton Educational,
a division of Hodder and Stoughton Ltd.,
Mill Road, Dunton Green, Sevenoaks, Kent,
by Richard Clay (The Chaucer Press) Ltd., Bungay, Suffolk

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Preface

Few people outside the engineering industry appreciate the importance of manufacturing technology in meeting the demands and needs of present day civilisation. It is skill in engineering manufacture that makes possible a standard of living beyond the wildest expectations of the previous generation, and it is the emergence of the machine tool within the last 150 years that has enabled the civilised world to provide the essentials of existence.

The need for efficient and well trained technician engineers is now greater than ever if we are to combat the steady and ever increasing flow of products from the emergent nations who are making the fullest use of modern techniques and processes.

This class book is written to assist those engaged on the second year of the technician's course, and is a continuation of the preceding volume, *Technician Workshop Processes and Materials*. Once again I have attempted to keep the text simple and direct, making the fullest use of line diagrams to illustrate the basic principles underlying the art of engineering manufacture.

I have also avoided the temptation to produce this volume as an 'exam passer'; it is an engineering text book, written in the hope and expectation that it will stimulate an interest in manufacturing technology, and help establish engineering manufacture as a vital and all important part of the education of young people.

R. T. Pritchard

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CHAPTER 1

Welding Processes

1.1 INTRODUCTION TO WELDING PROCESSES

Welding is a metal joining process. It may be defined as 'the art of joining two metal parts in such a way that the resultant joint is equivalent in composition and characteristics to the metals used.' This is shown in Fig. 1.1, where parts A and B are to be joined together. When properly welded, the bar C is equivalent to the solid bar D; in other words the welded bar has suffered no weakening effect due to the welding process. For example, the ultimate tensile strength (UTS) of the composite bar at C is equal to that of the solid bar shown at D. This is the purpose of all

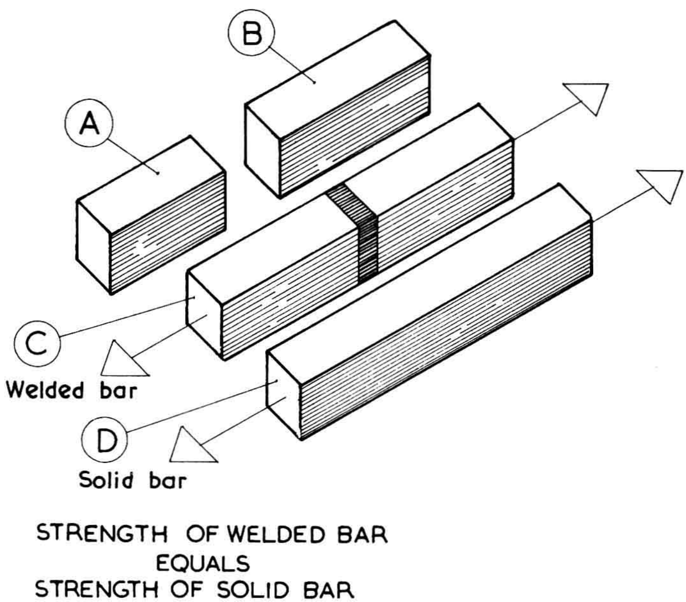

Fig. 1.1 Essentials of a welded joint

welding processes: the production of a homogeneous bond between two metal parts joined together.

The rapid and efficient joining of metal parts is a vital requirement of modern engineering manufacture and, to meet the demands of mass and flow production of engineering assemblies, enormous strides have been taken in the development of welding techniques within the last 50 years. No other engineering or manufacturing process makes greater use of scientific principles than the welding process.

Because fusion of the metal is an essential requirement of welding, it is convenient to indicate the principal welding processes according to the heat source. Fig. 1.2 shows three heat sources are employed:

(i) chemical,
(ii) electrical,
(iii) frictional.

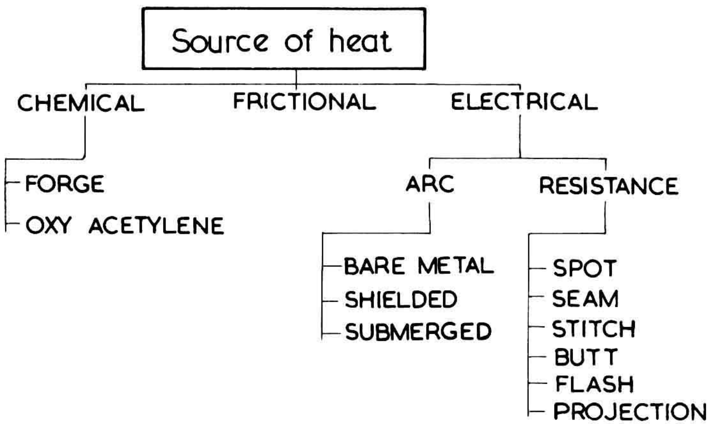

Fig. 1.2 Line diagram of welding processes

Much greater scope is offered by electrical sources of heat due to the fact that electricity is readily controlled and easily applied. Electrical methods of heat source are much in demand for the mass production of engineering assemblies due to the limitations of welding processes employing chemical methods of heat source.

1.1.1 Oxy-acetylene welding

The invention, in 1895, of the oxygen-acetylene blowpipe is credited to the French thermodynamicist Le Chatelier. All modern oxy-acetylene welding techniques owe their existence to this important development. Primitive engineers were able to forge precious metals into decorative ornaments, the technique adopted being the same as that used in forge welding at the present time, by inserting the metal into a suitable forge or fire. Forge welding was therefore a static process; the metal had to be taken to the source of heat. The introduction of Le Chatelier's blowpipe made possible a great surge forward in welding technology as the heat could now be taken to the parts to be joined.

The blowpipe represents a portable and compact chemical source of heat. The chemical combustion of oxygen and acetylene produces a high-temperature flame capable of melting all known metals. The control over the type and size of flame is a matter of skill and experience. Oxygen and acetylene are stored under pressure in separate containers, more commonly known as bottles. These bottles are extremely strong solid-drawn steel chambers capable of withstanding very high internal pressures. Each bottle is equipped with a *head* which carries a pressure regulator and two pressure gauges (Fig. 1.3A). The high-reading gauge indicates the pressure within the bottle; the second gauge shows the pressure of gas fed to the blowpipe, this pressure is adjusted using the pressure regulator.

Rigid safety precautions must be observed with regard to the storage and handling of the oxygen and acetylene bottles. All oxygen bottles are

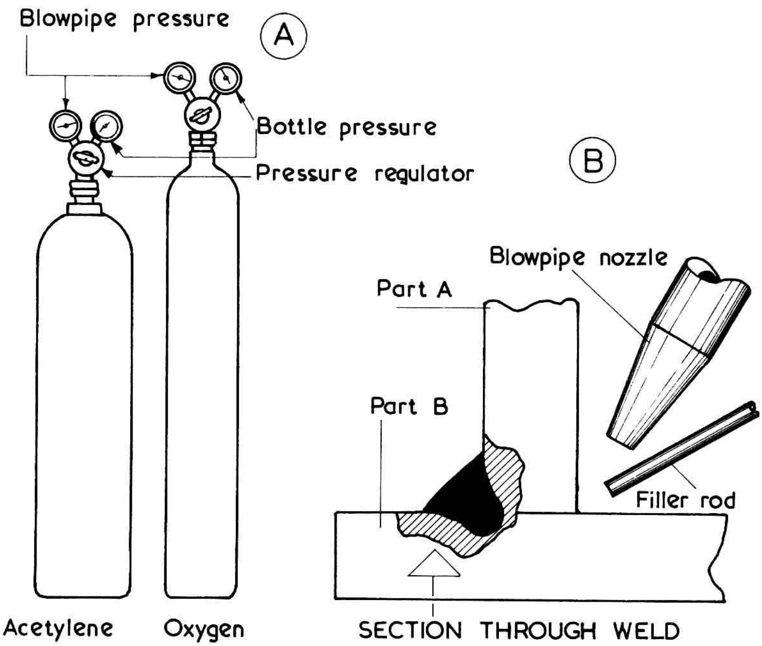

Fig. 1.3 Principle of oxy-acetylene welding

painted black with right-hand threads for the outlet connections. Acetylene bottles are painted a maroon colour, and all outlet connections have left-hand threads. It is important that oxygen and acetylene bottles are not subjected to shocks or exposed to heat or flames. Fig. 1.3B shows the basic technique underlying oxy-acetylene welding, the example shown is known as a *vertical fillet weld.* The blowpipe heats the parts until a pool or puddle of liquid metal appears; note the use of filler or welding rod to augment and reinforce the welded joint. A section of the finished weld is shown on the left-hand side of the diagram. The solidification of the liquid pool of metal, together with the additional metal supplied by the filler rod, results in a homogeneous joint between the welded parts A and B. Skill and experience are required to ensure that the weld is neat, uniform and free from porosity or blowholes.

1.1.2 Oxy-acetylene cutting

The oxy-acetylene flame can, with suitable modifications, be used as a cutting tool on steel plates and bars. Intricate profiles may therefore be cut from steel stock, using manual movement of the cutting torch. Profiles may also be cut using special-purpose flame cutting machines.

Principle of flame cutting

Fig. 1.4A shows a section through the cutting head of an oxy-acetylene blowpipe or cutting torch. The diagram shows that the cutting head has two outlets: the outer orifice supplies a mixture of oxygen and acetylene, the inner orifice a jet of pure oxygen. As shown in Fig. 1.4B the purpose of the oxy-acetylene flame, emerging from the outer orifice, is to preheat the steel to a temperature of about 900°C; at which point the operator depresses a small trigger on the cutting torch. This releases a jet of pure oxygen, through the centre orifice, which brings about violent oxidisation of the preheated steel. The pressure of the oxygen jet is such that the iron oxide and molten metal particles are carried away at high speed and a neat, clean cutting face results.

The cutting action is illustrated in Fig. 1.4C, the rate of movement of the cutting torch determines the cutting speed; for example, when cutting a profile from mild steel plate of 50 mm thickness, a suitable cutting speed is about three millimetres per second (3 mm/s). This means that a circular plate of one metre diameter can be flamecut from a 50 mm thick steel sheet in about 18 minutes. A relatively clean cut is possible when cutting mild steel, and this is due to the fact that the melting point of the iron oxide (Fe_3O_4) is well below that of the iron or ferrite present in the steel. This allows the molten iron oxide to be blown away leaving a smooth clean edge. Non ferrous metals and stainless steels do not leave a clean face because their oxides do not possess a lower melting point than the parent metals, and a certain amount of edge-melting is inevitable.

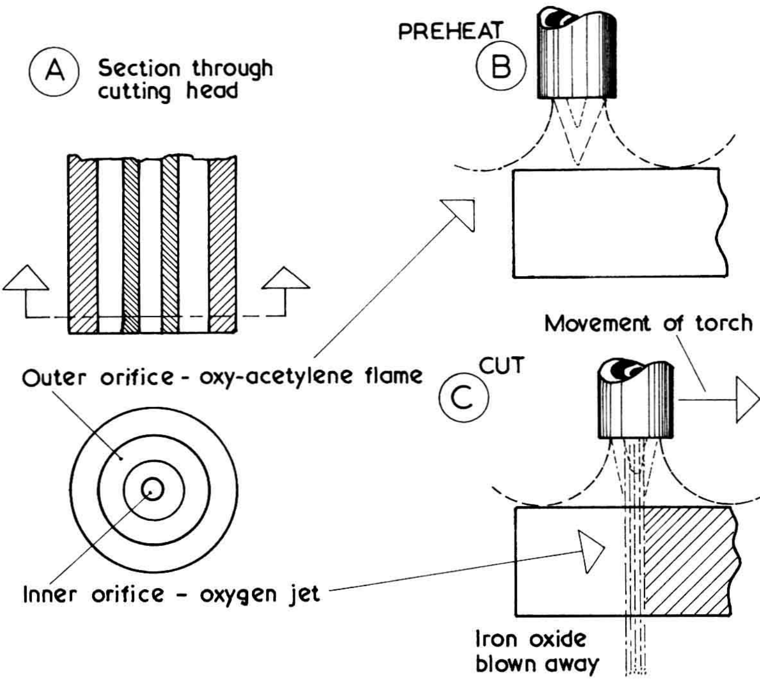

Fig. 1.4 Principle of flame cutting

Profile cutting machines

For simple one-off jobs, for example flame cutting a circular disc, a radius bar may be used. The principle is identical to that of using a pair of dividers to scribe a circle on a steel plate. If large numbers of circular components requiring flame cutting, a suitable profile cutting machine will be used. All profile cutting machines are essentially copying devices; it is necessary to make a template or drawing of the required profile. Many ingenious devices are used to transfer the outline of the profile into movement of the cutting flame.

Modern profile cutting machines are capable of cutting accurate profiles from 150 mm thick mild steel plate by the electronic scanning of an inked drawing. Accuracies in the region of ±0.1 mm are claimed for straight lines and gentle curves; with the deviation of the electronic scanning head, which guides or controls the path taken by the cutting flame, less than 0.075 mm from the inked line. Profile cutting machines with multi-cutting heads are also available, allowing the production of several components of complicated profile at each setting of the profile cutting machine. Fig. 1.5 illustrates the principle involved.

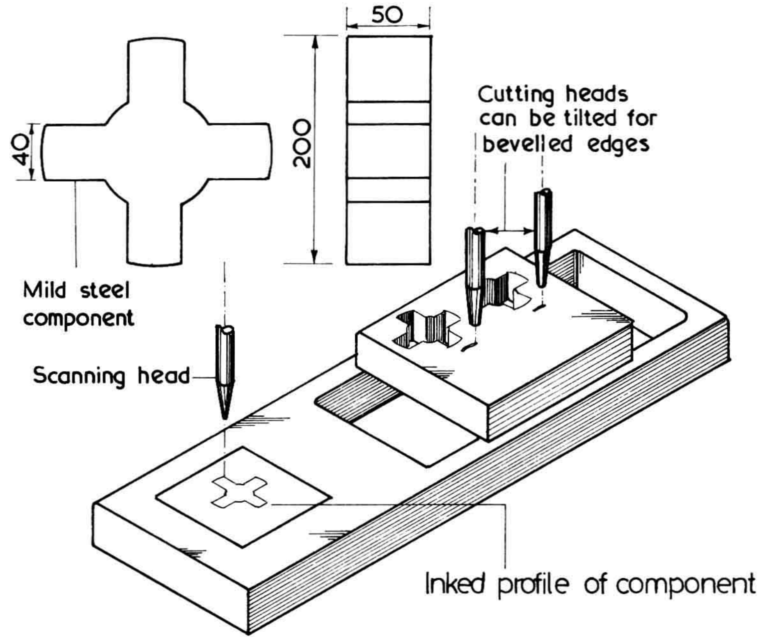

Fig. 1.5 Principle of profile cutting machine

1.1.3 Principle of alternating current arc welding

When oxy-acetylene welding it is necessary to add additional metal to the weld using a filler rod. Both filler rod and blowpipe need to be manipulated with great care during the welding process so a high degree of manual skill or dexterity is essential for the production of high quality welds. At the same time, thick metal sections require deep penetration using large nozzles producing large flames, with grave risk of turbulance, blow holes and scale, reducing the efficiency of the weld.

A great advantage of arc welding process is that the electrode used to strike the arc acts as a filler rod, this allows the arc welding process to be readily automated with less reliance on human skill.

Fig. 1.6 shows the basic principle of alternating current (AC) arc welding with the mains supply taken to a transformer. Note that the input to this transformer is of high voltage and low amperage, whilst the output is low voltage and high amperage. The output from the transformer is about 80 to 100 volts, hence there is little risk of electrical shock to the operator. The voltage required to strike the arc exceeds the voltage needed to maintain it, an average striking voltage of 80 volts would result in a working voltage of 30 to 40 volts.

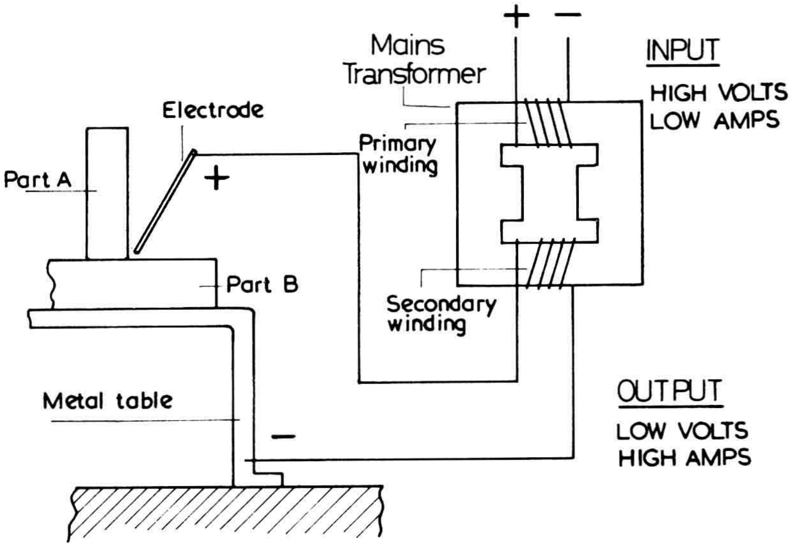

Fig. 1.6 Principle of AC arc welding

The arc

Fig. 1.7 shows a close-up view of the arc produced between the electrode tip and the metal to be welded. Possessing a temperature around 3000° C, a pool of liquid metal quickly forms with droplets from the arc

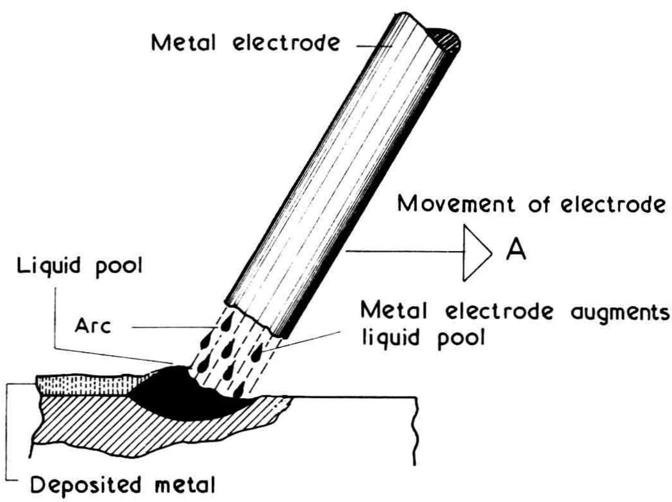

Fig. 1.7 Bare metal electrode

tip augmenting or adding to this molten pool. Movement of the electrode in the direction of arrow A results in the deposition of metal along the path of the electrode; in this way, a *fusion weld* is produced. A constant gap needs to be maintained between the tip of the electrode and the surface of the molten pool, a distance about equal to the diameter of the electrode is found to be satisfactory. Note that at Fig. 1.7, a bare metal electrode is shown. Such an electrode is seldom used when AC arc welding due to the fact that oxygen and nitrogen tend to be absorbed from the atmosphere thus weakening welded joint. This undesirable state of affairs is further aggravated by the fairly rapid cooling of the deposited metal, with the result that covered or coated electrodes are always used in association with AC arc welding.

1.1.4 Shielded-arc welding

The use of coated electrodes is more commonly referred to as *shielded-arc welding*. The basic principle of this technique is illustrated in Fig. 1.8. The electrode is covered with a shield or coating of a hardened flux, extruded under high pressure on the outside surface of the electrode. This flux has a higher melting point than the metal electrode; and coating extends beyond the electrode tip during the welding operation. This extension, together with the gaseous shield resulting from the melting flux, shields or protects the molten pool and the molten globules drawn from the electrode tip. This prevents contamination of the weld

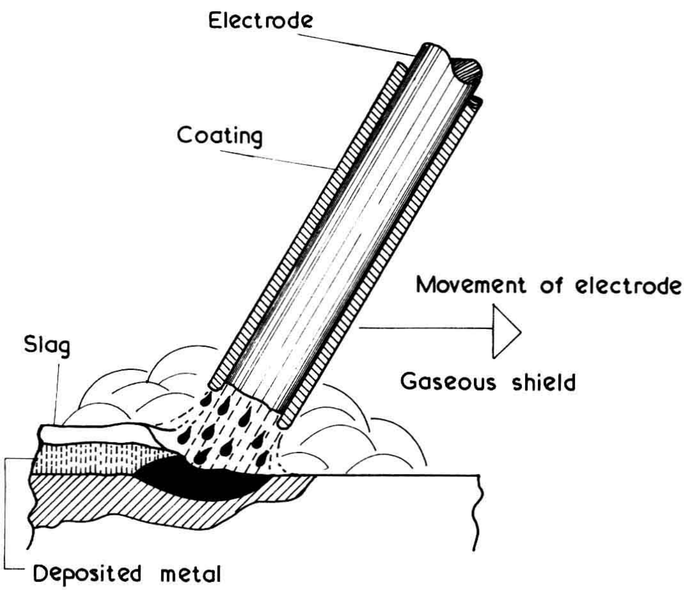

Fig. 1.8 Coated electrode

by the oxygen and nitrogen present in the atmosphere. A further advantage is afforded by the layer of sodified flux, more commonly known as slag, which provides an insulating layer on the surface of the weld. This not only protects the weld from the atmosphere, but also promotes slow cooling and hence a more reliable joint.

Extensive use is now made of shielded arc AC welding in modern welding practice, with automatic welding of steel components a common place event. The advent of the shielded arc represents one of the greatest advances in welding technique. Transformers are cheap and reliable, requiring the minimum of maintenance; armoured conducting cables allow a high degree of mobility, with a good degree of operator safety ensured because of the low voltages required. Perhaps the main disadvantage is the relatively short length of the electrodes used; average lengths varying between 200 and 450 mm.

Long welding runs necessitate constant electrode changing, with the possibility of faults at the changing points, and much loss of welding time as the electrodes are changed and the arc re-struck.

1.1.5 Direct current arc welding

The principle of direct current arc welding is illustrated in Fig. 1.9. It differs from AC arc welding in the manner of obtaining the current necessary to strike the arc. A DC generator is used, which itself may be driven by an electric motor or a diesel installation. DC arc welding is much used for welding non-ferrous metals and cast iron; with bare metal electrodes preferred. Unlike AC arc welding the polarity of the electrode when DC welding is of considerable importance; much higher temperatures are attained when the electrode is given negative polarity. On the

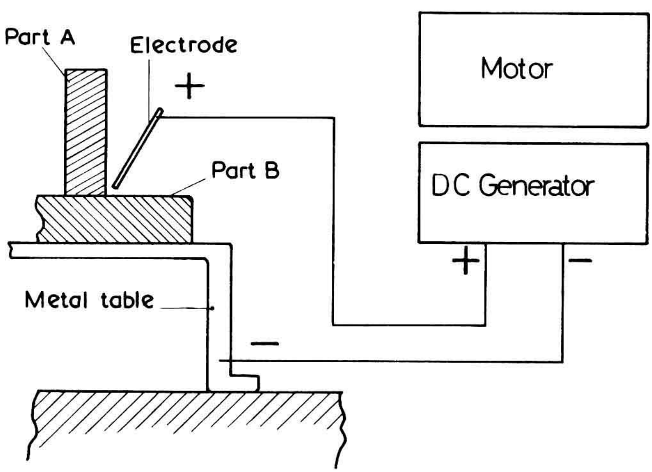

Fig. 1.9 Principle of DC arc welding

other hand the heat input is reduced if the electrode is given positive polarity. Thin-sectioned joints would be best welded with a positive electrode.

When bare metal electrodes are used it is essential that the atmosphere be prevented from coming into contact with the liquid pool of metal comprising the weld area, this is achieved by enveloping the weld with an inert gas or covering the weld area with a powdered flux.

1.2 JOINT IDENTIFICATION AND PREPARATION

The wide and varied application of welding processes in all kinds of engineering manufacture makes it vitally necessary that a rigid code of welding procedure be maintained at all times. This means that all welded joints be clearly indicated on working drawings with no possibility of the wrong type of joint produced. It needs to be appreciated that steel structures such as ships, bridges, oil rigs and pipe lines are essentially welded fabrications, and the failure of a welded joint can lead to the most grave and serious consequences. Fig. 1.10 shows the basic principles involved when indicating a welded joint. At A we see the terms

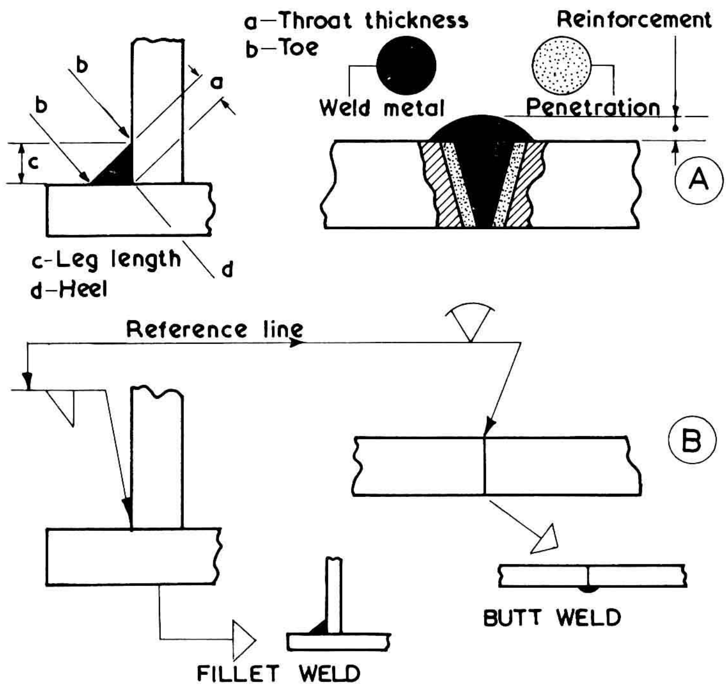

Fig. 1.10 Weld identification