4
Preparation for welding

4.1 Introduction

The need for degreasing and oxide removal has been covered in Chapter 2. This chapter will review both the handling and storage of aluminium and the options available for cutting, machining and pickling and cleaning of the alloys prior to welding. There are a number of thermal processes available to the fabricator for either cutting or weld preparing, as discussed in this chapter. One process that is not available for the cutting of aluminium, however, is the oxy-gas process used so widely to cut the carbon and low-alloy steels. Instead, arc or power beam processes or machining must be used to provide the correct edge preparations for welding.

Correct and accurate edge preparations are essential for the production of sound, defect-free welds in aluminium. Edge preparations are required to achieve full penetration to the root of the joint, to enable the correct analysis of weld metal to be achieved, to assist the welder to produce defect-free joints and to do this at an acceptable cost. The design of edge preparations for specific welding processes will be dealt with in the chapters dealing with the individual processes.

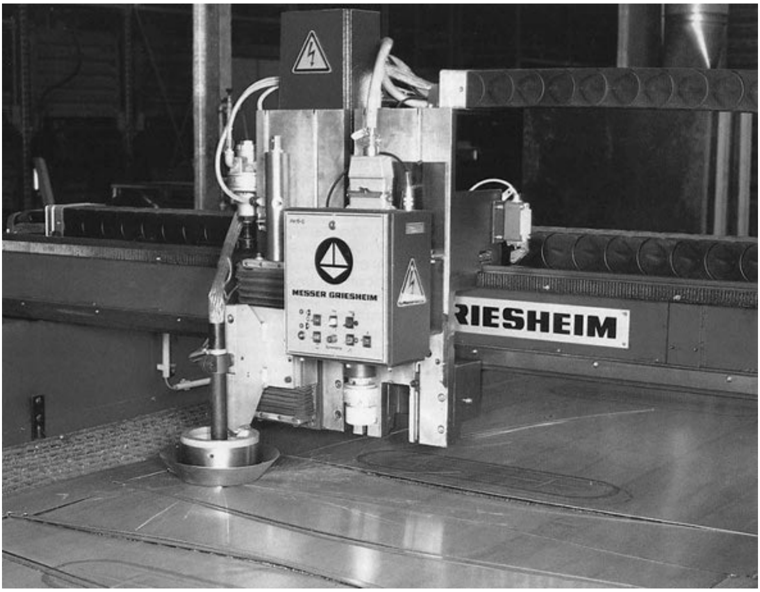
4.2 Storage and handling

Good handling practices are required if aluminium components are to be supplied to the customer in an unmarked condition. Aluminium is a relatively soft material and is easily scored or dented by clumsy handling or the use of inappropriate lifting equipment. Over-centre edge clamps, commonly used on steels, can score plate edges and steel chains can produce scratches and dents. A solution to marking by clamps is to face the jaws with a soft material – wood or polythene blocks are excellent as packing materials. Lifting should be carried out with nylon ropes or webbing straps. Remember that these softer materials are far more easily damaged than steel and more regular maintenance of any lifting equipment will be necessary. Hard particles can also become embedded in the packing or lifting strops, resulting in marking of the components.

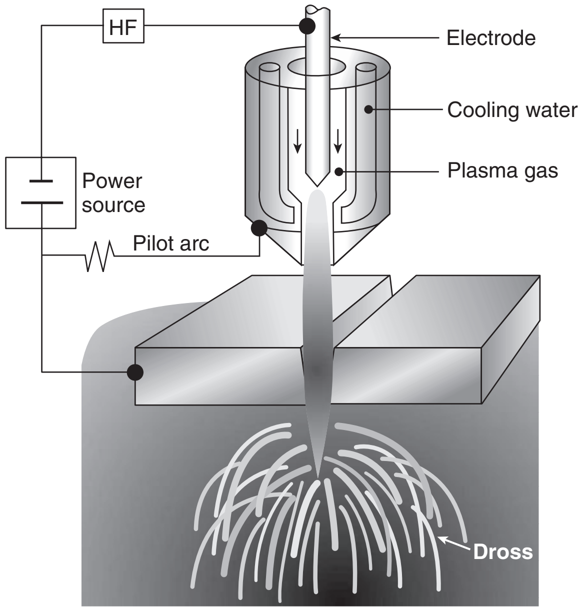
Storage is important if the surface condition of the aluminium is not to suffer. Ideally, items should be stored indoors in a dry, clean and well-ventilated storage area. Storing plates flat may give rise to water staining from condensation collecting on the surface. This can be particularly damaging if the plates are stacked directly one on top of another, when a thick layer of hydrated oxide can rapidly form at the interface. Plates should always be separated in storage and ideally stacked on edge to provide good air circulation. This reduces the risk of accumulating water and dirt on the flat surfaces and prevents other items being stored on top. It also assists in reducing the risk of scratches from dragging plates off the stack.

4.3 Plasma-arc cutting

Plasma-arc may be used for either cutting or welding and is the most widely used thermal process for cutting of aluminium alloys in manual, mechanised or fully automated modes (Fig. 4.1). In the latter case cuts of excellent quality can be achieved in material of up to 250 mm thickness at high cutting speeds.



4.1 Fully programmable CNC plasma-jet cutting system. Courtesy of Messer Griesheim.



4.2 Schematic illustrating the principles of plasma-jet cutting. Courtesy of TWI Ltd.

Plasma-arc utilises a specially designed torch in which a tungsten electrode is recessed inside a water-cooled copper annulus, through which is passed the plasma gas. An arc is struck between the electrode and the workpiece, *transferred arc plasma-arc*, or between the electrode and the annulus, *non-transferred arc plasma-arc*. Transferred arc plasma-arc is used for cutting purposes (Fig. 4.2). The plasma gas is heated by the arc to an extremely high temperature within the annulus and is ionised – it becomes a *plasma*. At the same time it expands in volume due to the high temperature and, being forced through the constriction of the nozzle, reaches very high velocity. The heat for welding and cutting is therefore provided by a 'flame' or plasma jet of high-velocity gas at temperatures of up to 15 000 °C, which has the characteristics of being highly concentrated, virtually insensitive to stand-off distance and extremely stiff. This makes it an ideal candidate for cutting purposes.

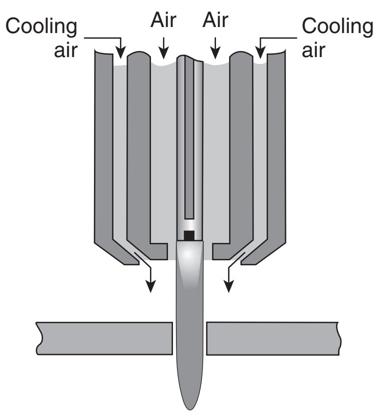
The cut is made by the plasma jet piercing the component to be cut to form a *keyhole*, a hole that penetrates completely through the item. This is filled with the gas and is surrounded by molten metal. The force of the plasma jet alone may be sufficient to remove this molten metal but with thicker material a secondary cutting gas may be required to assist in metal removal. This secondary gas is supplied via a series of holes around the plasma nozzle designed to blow away the molten metal to give a clean, high-quality and narrow cut. Plasma gases include air, argon, argon–hydrogen, nitrogen and carbon dioxide. Cutting can be performed manually or mechanised with higher cutting speeds being achievable with mechanised and automated systems.

A plasma cut edge is generally not completely square. The top edge of the cut may be rounded by some 1 or 2 mm, particularly if the cutting energy is high for the thickness of plate being cut or when high-speed cutting of thin material is being carried out. The plasma jet also tends to remove more metal from the upper part of the component than the lower part, resulting in a cut wider at the top than the bottom with non-parallel sides. This 'bevel' angle may be between 3° and 6°. The cut surface may also be rough. The quality of the cut is affected by gas type, gas flow rate, cutting speed and operating voltage. High gas flow rates and high voltages will improve the squareness of the cut and mechanised cutting will give an improved appearance.

Arc cutting produces a HAZ and may cause melting at the grain boundaries. This results in micro-cracking, primarily of the heat-treatable alloys – the 7000 series being particularly sensitive. As the thickness increases, the likelihood of such cracking also increases. For this reason it is advisable to machine back the plasma cut edges by about 3 mm, particularly if the component is to be used in a dynamic loading environment.

The composition of the gas for plasma cutting depends on the required quality of the cut, the thickness of the metal to be cut and the cost of the gas. Air is the cheapest option and single gas systems utilising air and a hafnium electrode have been developed for the cutting of materials up to approximately 6 mm in thickness (Fig. 4.3).

Above this thickness nitrogen, carbon dioxide, argon–hydrogen or mixtures of these gases may be used. For the thicker materials over, say,



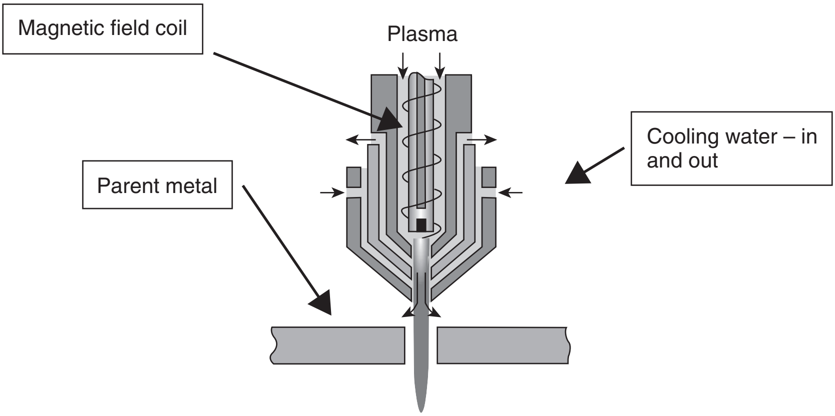
4.3 Air plasma cutting. Courtesy of TWI Ltd.

Table 4.1 Suggested parameters for plasma-jet cutting

Metal thickness	Plasma gas	Gas flow (l/min)	Shield gas	Gas flow (l/min)	Current (amps)	Voltage (volts)	Cutting speed (mm/min)	Method
1.0	Air	98					4800	Manual
1.5	Air	98					6300	Manual
3	Air	98					3000	Manual
6.5	Air	98					1000	Manual
6.5	N_2	34	CO_2	100			1800	Manual
6.5	Ar + H_2	25			200	50	1500	Manual
10	N_2	35	CO_2	100	200		1250	Manual
12.5	Ar + H_2	28			280	55	1000	Manual
25	Ar + H_2	33			330	70	500	Manual
50	Ar + H_2	45			400	85	500	Manual
6	Ar + H_2	55			300	140	7500	Mechanise
6	N_2	32	CO_2	100	115		1800	Mechanise
10	N_2	32	CO_2	100	120		900	Mechanise
12.5	N_2	32	CO_2	100	120		480	Mechanise
12.5	N_2	32	CO_2	100	300		3200	Mechanise
12.5	Ar + H_2	60			300	140	5000	Mechanise
25	N_2	70	CO_2	100	400		1800	Mechanise
25	Ar + H_2	60			375	160	2300	Mechanise
50	N_2	32	CO_2	100	400		800	Mechanise
50	Ar + H_2	60			375	165	500	Mechanise
75	Ar + H_2	95			420	170	380	Mechanise
75	Ar + H_2	45	N_2	100	400		500	Mechanise
75	Ar + H_2	45	N_2	100	700		650	Mechanise
100	Ar + H_2	95			450	180	750	Mechanise
125	Ar + H_2	95			475	200	250	Mechanise

12.5 mm, argon–hydrogen is regarded as the best choice for the plasma gas, this gas mixture giving the best quality cut, irrespective of thickness. The secondary cutting gas may be carbon dioxide or nitrogen. Table 4.1 lists the recommended cutting/shielding gases and typical parameters for plasma cutting the aluminium alloys. Water injection into the nozzle can be used in addition to the orifice gas. This restricts the plasma jet further and produces a better quality, more square, cut, although above 50 mm thickness these advantages are reduced.

A development of the process known as high-tolerance plasma-arc cutting (HT-PAC), also known as plasma-constricted arc, fine plasma or high-definition plasma, has been developed and is being used as a cheaper alternative to laser cutting of material less than 12 mm in thickness. This variation to the plasma-arc process achieves a better quality cut with more perpendicular faces, a narrower kerf and a less rough finish than the



4.4 HT-PAC torch. Courtesy of TWI Ltd.

Table 4.2 Suggested parameters for HT-PAC

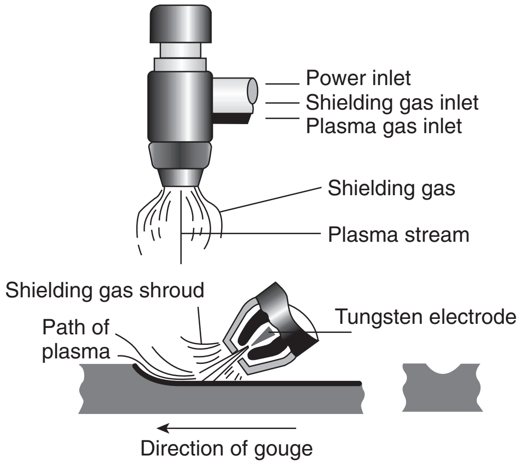
Metal thickness (mm)	Plasma gas	Shield gas	Current (A)	Stand off (mm)	Cutting speed (mm/min)
1.2	Air	Air	70	2	3800
2	Air	Air	70	2.5	2540
4	Air	Air	70	2	1800

plasma-arc cut by a combination of a redesigned nozzle and a constricting magnetic field (Fig. 4.4). Typical cutting parameters are given in Table 4.2.

A variation to the conventional plasma cutting process is the plasma gouging technique. This utilises a plasma-jet torch which, as shown in Fig. 4.5, is presented to the surface at a glancing angle. In doing so the surface is blown away and a groove is formed. The technique may be used to remove excess metal, to excavate for defect removal, to back-gouge the reverse side of welds and to establish a weld preparation. Needless to say it requires a skilled operator to achieve an acceptable surface and should not be entrusted to unskilled personnel since it is capable of removing large amounts of metal very rapidly.

4.3.1 Health and safety

The plasma-arc process uses higher open circuit and arc voltages than does the TIG process, with operating voltages as high as 400 volts in some applications. These voltages present a serious risk of electric shock and suitable



4.5 Plasma-arc gouging principles. Courtesy of TWI Ltd.

precautions must therefore be taken to ensure that cutting operations are carried out in a safe manner. Only fully trained operators should be permitted to operate the cutting equipment. All frames, casings, etc., should be connected to a good electrical earth and all electrical connections and terminals must be adequately protected. Any equipment maintenance or modification must be carried out by suitably trained and qualified staff and connections, insulation, etc. inspected at regular intervals for soundness and deterioration.

The plasma-arc produces large amounts of infra-red and ultra-violet radiation. All personnel in the vicinity of plasma-arc cutting operations therefore need to be provided with protective clothing, goggles and helmets to protect both eyes and skin. The operator must use the correct filter lenses for electric arc welding, with shade numbers ranging from 9 to 14, depending upon the current.

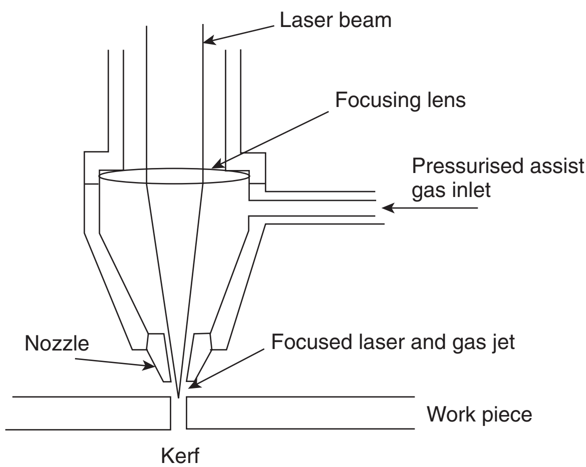
As with any thermal cutting process copious amounts of fume are produced. The fume will contain not only aluminium oxide but the oxides of the other elements present in the alloy, ozone, oxides of nitrogen, any surface plating or coating, any contamination and the cutting gases. These present a health hazard that is best dealt with at source by local fume extraction. Fume extraction, either local or general, will almost certainly be mandatory if the fume and gas limits set by the Control of Substances Hazardous to Health (COSHH) Regulations are to be complied with. Cutting in confined spaces presents a particular problem. Fume extraction and ventilation must be provided in these circumstances. It should be remembered that many of the cutting gases, although not toxic, are asphyxiant, are heavier than air and can accumulate in low-lying areas such as pits and wells. Forced ventilation should be considered in such circumstances.

When plasma-arc cutting is carried out under water the dross that is produced may build up on the tank bottom. Over a period of time this dross reacts with the water, producing hydrogen which may accumulate under the item being cut, leading to a risk of explosion. This is best avoided by cleaning the tank of the dross at regular intervals or using a forced circulation water supply to carry away any gas as it is formed.

Plasma-arc cutting is a very noisy process, the noise level increasing as the cutting current is increased. Ear protection is required for the operator and personnel working in the vicinity to avoid discomfort or ear damage.

4.4 Laser beam cutting

A laser (light amplification by the stimulated emission of radiation) generates a coherent beam of light at an essentially constant wavelength. When this beam is focused on a surface there is sufficient energy concentrated in this focused spot that the material may be melted or vaporised (Fig. 4.6). This enables the laser to be used for either welding or cutting. The laser light is produced by exciting a lasing medium, this being either a suitable gas or solid. The excitation is provided by the passage of an electric current or by means of high-intensity light. There are two commonly used lasers to be found in industrial applications: the gas CO_2 laser and the solid state crystal laser, the neodymium-doped yttrium–aluminium–garnet (Nd-YAG) laser. Of the two, the CO_2 laser is the most powerful with average power outputs of up to 50 kilowatts. Both types of laser can be designed to provide



4.6 Laser cutting principles. Courtesy of TWI Ltd.

a steady output, continuous wave (CW) laser light or in a pulsed output mode. In this latter case the power output on the peak pulse may be as much as 20 times the average power.

The wavelength of light from the CO_2 laser is 10.6 microns (micrometres) and at this wavelength is easily absorbed by most solids, enabling the CO_2 laser to be used on a wide variety of materials. This long wavelength has a disadvantage, however, in that it cannot be transmitted by glass or fibre optics but requires reflecting metal mirrors for manipulating the beam and materials such as zinc selenide or gallium arsenide for focusing lenses. The Nd-YAG laser light is an order of magnitude less at 1.06 microns, allowing the use of glass lenses for focusing and fibre optic cable for beam transmission. This offers a clear advantage over the CO_2 laser, since it permits the marriage of commercially available manipulating equipment such as NC (numerically controlled) gantries and robots with the laser. The power output of currently available Nd-YAG lasers is limited to around 6 kilowatts, however, restricting the thickness of materials that can be cut.

The laser cutting process consists of focusing the beam through a cutting nozzle onto the surface to be cut, the concentration of energy being sufficient to vaporise the material, creating a ‘keyhole’. With continuous wave lasers there is generally more melting than vaporisation and an assist gas is used to blow away the vapour and any molten metal, creating a narrow clean cut as the beam is traversed along the item. The pulsed lasers generally provide enough energy that the laser beam imparts sufficient force to the vapour that the vapour itself removes any molten metal. The assist gas, introduced either through the cutting nozzle or co-axially with it, is used not only to blow away any molten metal but also to protect the lens from spatter or debris ejected from the cut.

The assist gas for cutting aluminium may be oxygen, nitrogen or air. Oxygen is a reactive gas with aluminium and will give higher cutting speeds than nitrogen. Nitrogen, however, will give a better quality cut in terms of squareness and roughness than will oxygen. Air is a compromise but is the cheapest of the gases. Gas pressure is an important variable that needs to be controlled to give the best quality of cut – high gas pressures give the most effective metal removal but too high a pressure may damage the focusing lens, since this forms part of the pressure system. As the assist gas pressure is increased the lens also needs to be thickened in order to carry the increased pressure. The pressure of gas in the cut is also influenced by the distance between the nozzle and the workpiece. For example, high-pressure cutting may require a stand-off distance of only some 2.5 mm. The relationship between stand-off and pressure in the kerf is not simple, however, as most laser cutting is done with supersonic gas velocities. It is essential that the nozzle stand-off distance and nozzle condition are closely controlled to provide consistent and high-quality cuts. Typical laser cutting parameters are given in Table 4.3.

A number of advantages accrue from using a laser for the cutting of weld preparations:

- Low heat input, resulting in minimal distortion and narrow heat affected zones.
- Edges that are smooth and perpendicular to the surface and often require no further cleaning before welding.
- Narrow kerfs and heat affected zones, meaning that more efficient nesting can be achieved, resulting in material savings.
- Very thin materials can be cut without distortion.
- Very accurate cuts can be made, resulting in more easy assembling for welding, this giving reduced fit-up time, more accurate fit-up and fewer weld defects.
- The process is easily automated and can be readily interfaced with other NC equipment (Fig. 4.7).

The main drawbacks to the use of lasers for the cutting of aluminium are as follows:

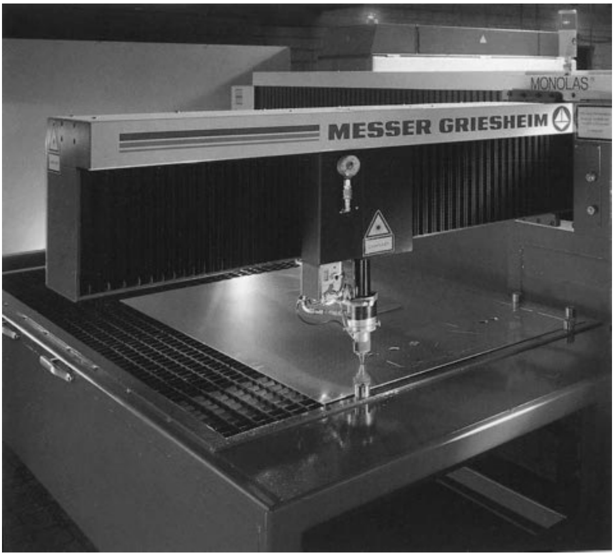
- The capital cost of equipment, which may be in the order of several hundreds of thousands of pounds for a laser interfaced with suitable manipulating equipment. A 1.5 kW CW Nd-YAG laser interfaced with a robotic system, together with its appropriate safety equipment will cost in the region of £250k to £300k at today's (2002) prices.
- The coupling of the beam with the work surface is not very good since aluminium can be highly reflective. This means that higher power is needed to cut an aluminium component than a similar item in steel. Aluminium may also reflect the beam back into the lens, resulting in damage, although this problem has lessened with the development of more accurate lenses and focusing systems.
- Laser cut aluminium may have a heavy dross on the underside of the cut. Removal of this can make the process non-competitive with other processes. Higher gas pressures will assist in reducing or eliminating the problem.
- The cut edges of the age-hardening alloys may contain microfissures that will need to be removed.

4.4.1 Health and safety

The laser cutting process is a thermal process and therefore metal fume mixed with the assist gas will be generated. This fume will need to be removed, preferably by local fume extraction at source. As laser cutting is

Table 4.3 Parameters for laser cutting

Process	Thickness (mm)	Average power (kW)	Pulse frequency (Hz)	Pulse width (ms)	Assist gas	Gas pressure	Cutting speed (mm/min)
Pulsed Nd-YAG							
	1.2	0.174	120	1	oxygen	4	6000
	2	0.414	100	0.5	oxygen	6	540
	4	0.224	31	1.5	oxygen	7	60
CW Nd-YAG							
	2	2	na	na	oxygen		4500
	2	2	na	na	nitrogen		300
CW CO_2							
	1.2	1.41	na	na	oxygen		3800
	2	1.2	na	na	oxygen		3000
	4	1.5	na	na	oxygen		1200

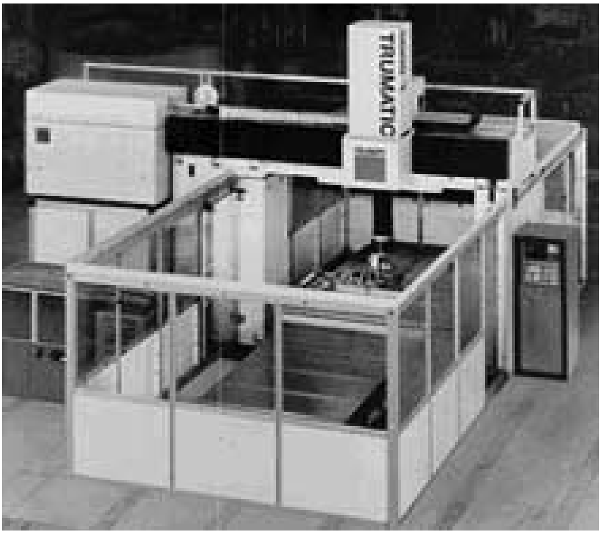


4.7 CNC CO_2 laser cutting machine. Courtesy of Messer Griesheim.

performed with mechanised or automated systems using remote control there is only a limited risk of fume exposure for the operator. However, a laser cutting system generally has a very high usage and fume extraction will be required to control the general fume level within the shop.

The voltages used in laser equipment are sufficiently high to present a serious risk of electric shock. Access panels should be secured and suitably marked to highlight the risks. Only authorised and trained personnel should be permitted access to the equipment for repair and maintenance purposes. A typical laser work cell is illustrated in Fig. 4.8.

There are two hazards associated with laser radiation which, depending upon the wavelength, can damage either the eye or the skin. The radiation can damage the retina and/or the cornea, particularly the shorter wavelength radiation which can be focused by the lens of the eye on to the retina. Exposure of the skin can result in burns. With high-power lasers these burns may be deep and can cause permanent damage. To prevent such damage it is generally necessary to position the laser inside a suitable enclosure with interlocks to prevent access when the laser is operating. Screening of the CO_2 laser beam can be provided by clear glass or acrylic screens. Tinted welding screens are required for the solid state lasers since the radiation is closer to the wavelength of visible light than that of the gas laser. Personal eye protection for the operator is also recommended, selected to filter out the appropriate wavelength of laser light.



4.8 Laser welding and cutting work cell. Courtesy of TWI Ltd.

Visible radiation is also emitted during laser cutting, this light being similar to that produced from a welding arc containing both ultra-violet and infra-red light. To filter this out requires tinted filter glasses, the density of the shade being sufficient that no discomfort is felt when viewing the bright plume associated with the beam. This radiation may also cause skin reddening. It goes without saying that all personnel involved in laser processing operations should be fully trained in the use of eye and skin protection equipment.

4.5 Water jet cutting

Water jet cutting uses an abrasive powder introduced into a very high-pressure and velocity water jet and is capable of cutting both metallic and non-metallic materials essentially by a process of erosion. Water velocity is in the region of 2500 km/h (1600 mph) and water pressure between 2000 bar (30 000 psi) and 4000 bar (60 000 psi). One of the most important uses of water jet cutting is the roughing out of parts prior to finish machining. The great advantage that water jet cutting has over the laser or plasma-arc is that no heat is used in the process. There are therefore no heat affected zones and no thermal distortion. Parts can be cut very accurately and closely nested, resulting in material savings. Cut part tolerances are very small, simplifying the task of fitting up for welding.

Although aluminium up to 450 mm in thickness can be cut using the process, the limitations with water jet cutting are the cutting speed, which may be only a quarter the speed of a laser cut component, particularly in thin sections. The other limitation is the bevel or taper of the cut face which may be twice that of laser cutting, some 25% of the nozzle diameter or around 0.2 mm at the optimum cutting speed. The bevel can be reduced by slowing the cutting speed with the penalty of an increased cost.

4.6 Mechanical cutting

Although the methods mentioned above can be applied to many fabricating activities, mechanical cutting techniques are used by most welding workshops as being the most cost-effective and versatile method. Cutting and machining equipment is freely available in most fabrication shops and is frequently less capital intensive than the sophisticated laser or plasma cutting systems discussed above. Furthermore, the systems described in Sections 4.2, 4.3 and 4.4 are capable of straight or simple bevel cuts only – if double bevel preparations are required then two or more cuts are necessary and J-preparations are not feasible. Edge preparations can be produced in a number of ways such as high-speed milling machines, edge planers, routers and various types of saws. Where air-powered equipment is used care needs to be taken to ensure that the air supply is clean, dry and oil-free to prevent contamination of the surfaces, which would give rise to porosity during welding.

Routers, planers and edge millers are capable of producing J- and U-preparations when fitted with the correct shape of tools. The equipment for these tasks can be hand-held and similar to that used for wood working, the only requirement being the need for slightly greater power or floor mounts for greater capacity. High cutting speeds can be used without the need for lubricants or coolants, although this does not remove the need for thorough cleaning. Hand-held rotary cutting machines are ideally suited to back-gouging and for removing excess weld metal. The depth of cut can be adjusted and various cutter forms are available, including V-blades for bevelling and flat blades for weld cap removal.

The guillotine can be used to shear sheets of up to 6 mm thickness without the need for further preparation work. Over this thickness some dressing of the sheared edges is necessary if the best weld quality is to be achieved. Shearing of the edges of alloys containing more than 3.5% Mg is not recommended if the edges are to enter service ‘as sheared’ because of the risk of the work-hardened edges suffering from stress corrosion cracking. Edges that are welded after shearing do not suffer from this problem.

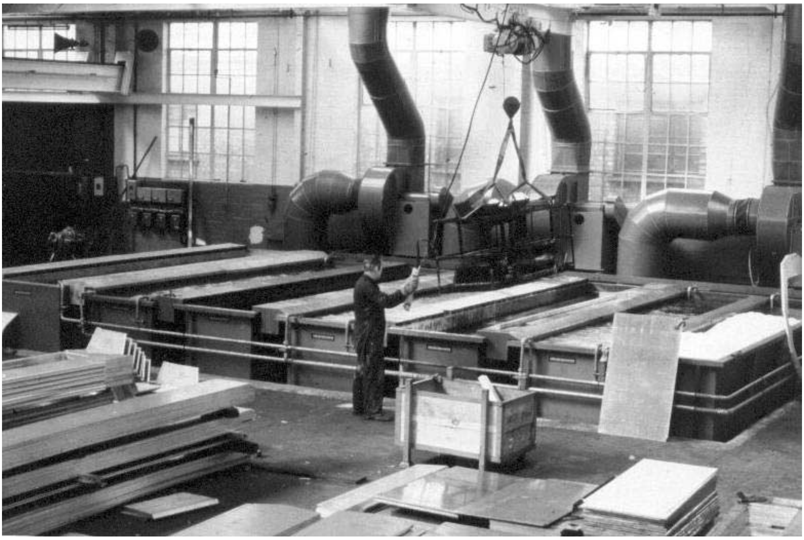
Sawing is a very effective method of cutting and bevelling aluminium using either portable or floor-mounted equipment. To achieve a good quality cut high cutting speeds are necessary, around 2500 metres per minute (mpm) peripheral surface speed for high-speed steel circular saw blades, 3500 mpm for tungsten-tipped blades and 1800 mpm for band saw blades. It is usual for band saw blades to have wider spacing on the teeth than for steel to prevent snagging, 8 to 16 teeth per centimetre being recommended. Band and circular saws can produce straight cuts and, when equipped with a tilting table, bevelled cuts. The saw cut surface tends to be rough and readily traps grease and dirt, making cleaning and degreasing difficult. It is recommended that the sawn faces are milled or filed to produce a smooth surface when the best quality of weld is required.

Grinding is best performed with high-speed, semi-flexible aluminium oxide grinding discs. Care needs to be taken to ensure that the grinding is controlled and is not heavy handed. Over-enthusiastic grinding can give a torn and rough surface which will be difficult to clean. Material may also be smeared over the surface, physically trapping dirt and grease and giving rise to porosity on welding. Rotational speed of the discs needs to be in the region of 8500 rpm. Care should be taken that the grinding machines are capable of maintaining these speeds when under load – some machines are incapable of attaining or maintaining these speeds in operation. Grit sizes range from 24 to 120 and the discs selected should be of the non-loading type. Under these conditions the discs should not become clogged and the speed of metal removal should not be affected. Grinding can be used to clean the weld preparation prior to welding, to blend the weld into the parent metal, to remove excess weld metal and to back-grind a partially penetrated weld to sound metal. To achieve the best results this requires suitable and well-maintained equipment operated by trained personnel.

Hand-held abrasive belt sanders are readily available and enable finishing operations to be carried out without too great a risk of damage owing to incorrect manipulation of the sander. Belt widths of 3–100 mm can be purchased; the narrow belts in conjunction with sander arms of up to 500 mm in length enable dressing operations to be carried out when access is very restricted.

Most machining and grinding operations can be carried out without lubrication. Dust may therefore be a problem and operators may need to be equipped with dust masks or respirators and the equipment with dust collectors. Noise can also be a problem and ear defenders will be needed for some of the machining and grinding tasks.

One last but very important point to be made before ending this section on the cutting and machining of weld preparations is that the equipment must not be used on aluminium if it has been used on other metals. Cross-contamination of aluminium with copper, iron, etc., may result in welding or service problems. Wire brushes, grinding discs, cutters and milling heads must only be used on aluminium and should be identified as such if there is any possibility of cross-contamination. Machining equipment should be



4.9 Typical pickling shop. Courtesy of R. Andrews.

thoroughly cleaned of any foreign metals before being used on aluminium alloys.

4.7 Cleaning and degreasing

Components for welding may be flat, preformed, sheared, sawn or milled to give the desired shape or to provide the weld preparation. Lubricants used during these processes *must* be removed if weld quality is to be maintained. Degreasing may be accomplished by wiping, brushing, spraying or vapour degreasing with commercially available solvents. This is best done before any mechanical cleaning takes place. Mechanically cut edges may carry burrs along the cut edge that will trap dirt and grease. These burrs should therefore be removed from weld preparations by scraping with a draw tool – do not wire brush only as this may fail to remove them completely. Scraping is also an excellent method for removing the oxide film. Stainless steel wire brushes, stainless steel wire wool or files may also be used to remove the oxide. As mentioned above in Section 4.6, under no circumstances should carbon steel, brass or copper brushes be used. Make sure that any cleaning tools are segregated and are used only on aluminium, otherwise cross-contamination can occur.

In certain cases, particularly when striving to achieve freedom from porosity, chemical cleaning or pickling may be required. A pickling shop is illustrated in Fig. 4.9 and a schedule of chemical cleaning treatments is given in Table 4.4.

Table 4.4 Chemical treatments for cleaning and oxide removal

Solution	Concentration	Temp (°C)	Procedure	Container material	Purpose
Nitric acid	50% water 50% HNO_3 (technical grade)	18–24	Immerse 15 min Rinse in cold water Rinse in hot water Dry	Stainless steel	Removal of thin oxide film for fusion welding
Sodium hydroxide followed by nitric acid	5% NaOH in water	70	Immerse 10 to 60 s Rinse in cold water	Mild steel Stainless steel	Removal of thick oxide film for all welding and brazing operations
	Concentrated HNO_3	18–24	Immerse 30 s Rinse in cold water Rinse in hot water Dry		
Sulphuric – chromic acid	5 litres H_2SO_4 1.4 kg CrO_3 40 litres water	70–80	Dip for 2 to 3 min Rinse in cold water Rinse in hot water Dry	Antimonial lead lined steel tank	Removal of films and stains from heat treating and oxide coatings
Phosphoric – chromic acid	1.98 litres of 75% H_3PO_3 0.65 kg of CrO_3 45 litres of water	95	Dip for 5–10 min Rinse in cold water Rinse in hot water Dry	Stainless steel	Removal of anodic coatings

Once degreased and cleaned the parent material should be welded within a short period of time; typically four hours would be regarded as reasonable. The component must be maintained in a clean condition during this time and this may require the item to be covered with polythene sheets or brown paper. If the item is left standing overnight the joints may require an additional cleaning operation so it is advisable to clean only those parts that can be welded within a four or five hour production period.

There are a couple of points concerning cleanliness that are worth mentioning. If the chemical cleaning has been extremely good then it is possible to leave the components for a longer period of time, perhaps overnight if the storage conditions are clean and dry. It has also been noticed that when the items are 'super clean' the TIG or MIG welder can experience arc starting and stability problems. The reason for this is not clear but is probably associated with the complete absence of any oxide. It is thought that a small amount of oxide assists in the formation of an active anode spot, resulting in a more stable arc.

The aluminium fabrication area ideally should be separated physically from other fabrication areas. For example, dust from activities such as grinding, settling on the surface will cause problems, particularly if this is from the grinding of steel items in adjacent bays. Aluminium and steel should never be welded in the same welding booth. It cannot be emphasised too strongly how important attention to cleanliness is if sound, defect-free welds are to be made consistently.