• DES10654 •

Metal Industry Practice & Management 2015

Assignment 1

CAMERON MILLS

STUDENT ID: 22104340

TABLE OF CONTENTS

PREFACE

For many thousands of years the working of metals has defined so much of mankind's innovation, creativity and enterprise.

This workbook has been prepared to develop your procedural knowledge and understanding of how metal can be manipulated to achieve a desired outcome, with a focus on the joinery of metals in the school workshop.

The workbook is structured to align with the NSW Industrial Technology (Metal) Years 7-10 syllabus.

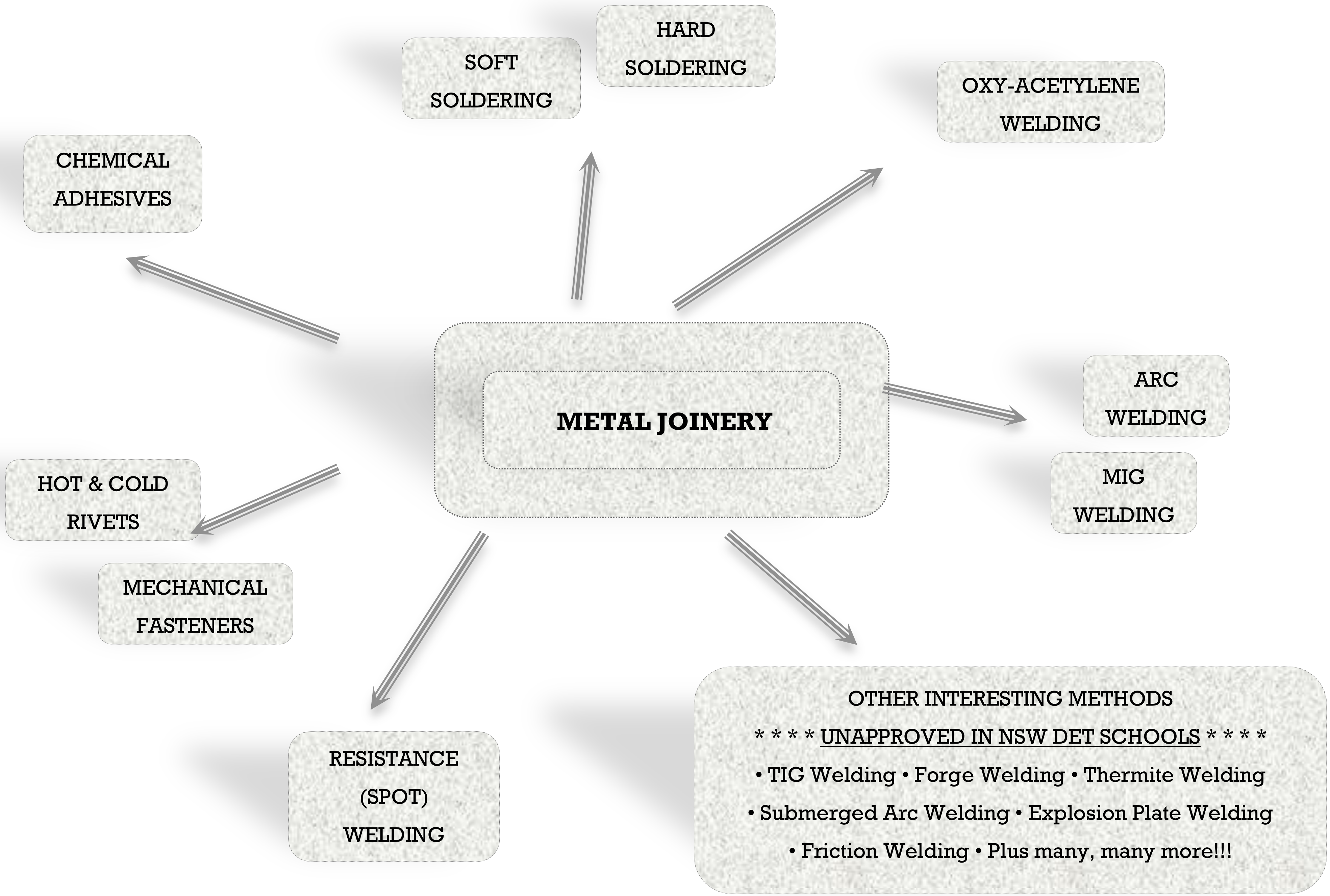
Students are encouraged to engage with the activities throughout the workbook so as to improve their knowledge and skills across the history, theory, application and practical aspects of metal joinery.

This workbook is by no means a thorough account of the various topics covered and should be considered as an introductory resource covering metal joinery.

I hope the information, presentation and activities in the following pages (and links) inspire students to appreciate the possibilities for working with metal as so many have before us.

Thanks to the many people and organisations for sharing their expertise so that others may also enjoy and learn valuable metal working skills. Thanks also to the Northern Beaches Secondary College, Manly Campus TAS department for allowing me access and use of their workshop in preparation of this workbook.

A listing of resources used to compile this workbook can be found in the references.


METAL JOINERY
CHEMICAL ADHESIVES
SOFT SOLDERING
HARD SOLDERING
OXY-ACETYLENE WELDING
ARC WELDING
MIG WELDING
HOT & COLD RIVETS
MECHANICAL FASTENERS
RESISTANCE (SPOT) WELDING
OTHER INTERESTING METHODS
* * * * UNAPPROVED IN NSW DET SCHOOLS * * * *
• TIG Welding • Forge Welding • Thermite Welding
• Submerged Arc Welding • Explosion Plate Welding
• Friction Welding • Plus many, many more!!!

SAFETY

Below is a summary of safety guidelines specific to the metal shop.

Always follow your General Safety Guidelines workshop notices, as well as the following specific safety advice.

The use of all equipment requires a teacher led induction and assessment process. This workbook is NOT an alternative to that process and no equipment may be used until teaching staff give permission to do so.

- *Whenever heating galvanised metals ensure adequate ventilation. Zinc oxide is produced when galvanising is oxidised. This is quite poisonous.*
- *Arc eye is the condition welders suffer when they expose the naked eye to intense ultra violet (uv) light. This can be very painful and cause long-term injury. Always wear suitable eye protection!*
- *Equipment safety in NSW schools prohibits the use of lead (symbol: Pb).*
- *Check your solders are lead free and do not work with lead sheet.*
- *Due to the extremely hazardous nature of molten metals no activities using volumes of molten metals can take place in schools. Forging, thermite & forge welding is off the curriculum!*
- *Remove all flammable liquids and materials from the work area.*
- *Synthetic clothing will melt to your skin, only wear appropriate safety clothing.*
- *Many of the operations within this workbook require application of extreme heat and burning is a real hazard. Ensure safe practices are in place to reduce risks to yourself and your classmates!*
- *Oxygen bottles contain highly pressurized liquid oxygen. The valve must be protected from damage or the bottle may become a missile. Always ensure the*

gas bottles are secured, fitted with a protective cover and only transported by qualified teaching staff.

- *All bottles, especially acetylene MUST be stored and used only in the upright/vertical position and regulators set below 15psi (100kpa) as acetylene is unstable over this pressure.*
- *Never lube or oil any oxyacetylene equipment.*
- *Flashback arrestors prevent flame travelling into hose lines on oxyacetylene equipment. Check your torch heads have these.*
- *When attaching the oxyacetylene nozzle only use firm finger/hand pressure, or light tool pressure. The over-torquing with tools may damage the fragile o-ring seals.*

ACTIVITY

I have read and understand the various issues surround safety and shall, at all times, abide by them.

Signed: ______________________________

Dated: ______________________________

SAFTEY LINKS:

http://www.curriculumsupport.education.nsw.gov.au/secondary/technology/safety/faqs/equip_materials.htm

http://www.curriculumsupport.education.nsw.gov.au/secondary/technology/safety/student_activities/index.htm

SAFETY – IN THE METALSHOP

The chart below offers a visual guide of the correct safety apparatus and PPE that must be available and used as required during various workshop tasks herein.

	Chemical Adhesives	Soft Soldering	Hard Soldering & Oxyacetylene Welding	ARC & MIG Welding	Spot Welding	Hot Riveting	Cold Riveting	Mechanical Fasteners & prep	Grinding Prep
Welding Screen				✔					
Welding Mask	✔			✔					
Flame Retardant Shirt			✔	✔					
Leather Apron				✔		✔			✔
Welding Gauntlets				✔		✔			
Work Gloves			✔		✔				✔
Disposable (nitrile) gloves	✔								
Hair Protection			✔	✔		✔			✔
Tinted Goggles (Shade 5)			✔						
Clear Goggles	✔	✔			✔	✔	✔	✔	✔
Covered Work Boots		✔	✔	✔		✔			✔
Hotwork Tongs		✔	✔	✔		✔			
Powered Ventilation		✔	✔	✔	✔	✔			
Fire control measures*	✔	✔	✔	✔	✔	✔	✔	✔	✔

Welding Screen

Welding workshops are often shared with other working areas. To reduce the hazards of harmful UV exposure and sparks heavy welding screens are installed to shield welding workplaces.

Welding Mask

The mask is critical safety equipment for all MIG and ARC welding processes. Modern masks use photo-electro LCD screens to shield the welders' eyes from harmful UV radiation. Changes to sensitivity, speed and shielding levels are user selectable.

Flame Retardant Overalls/Shirt

Welding, grinding and hot torches present a range of hazards to users, from splatter to accidental contact against hot surfaces or flames. The welding process also emits harmful UV light, which can cause significant burns (like an intense sunburn). Flame retardant shirts or overalls protect welders from these hazards.

Leather Apron

The leather apron is an effective first line of defense for a welder's body and actually prevents heat buildup and possible damage to overalls.

Welding Gauntlets

These heavy gloves run to forearm length and protect from burns cased by direct and radiated heat sources. They also protect welders from injury caused by contact with sharp surfaces, especially sheet metal and sharp ground edges.

Work Gloves

These gloves provide less protection from burn hazards however they are adequate for general workshop tasks where cutting or general heat hazards present. Workers should be VERY mindful of the potential for cutting injury from sharp metal edges, esp sheet metal.

Disposable (Nitrile) Gloves

These are a latex alternative suitable for general chemical & biological protection. They are also great at keeping hands clean from grease, oil & soot. They are NOT suitable for protection from cutting or burning hazards – ***do not use for hotwork!***

Hair Protection

Most welding processes present a serious hazard from burning hair ignited by hot sparks. Angle grinders are also a real risk for longer hair being caught in the wheel with devastating results. Welders wear caps, bandanas and beanies for this reason.

http://bit.ly/1CO81Nd

Tinted Goggles

These protect welders from the intense light emitted from brazing processes an also the red hot splatter that can occur. They are not suitable for ARC or MIG use.

Clear Goggles

Clear goggles and full-face shields allow workers full visibility and protect the eyes from injury when grinding, drilling AND chipping slag off. NEVER assume you do not need eye protection, sight is a precious gift, keep it that way.

Respirator

Welding, hot torches and grinding oxidizes chemical fluxes, metals, oils & other contaminants creating a toxic plume of harmful gases and dusts. Although most these hazards should be exhausted through powered ventilation the respirator is a necessary PPE addition.

http://bit.ly/1CO8zmh

Covered Work Boots

Molten lumps of metal will always find there way into light, casual footwear. Dropping sharp and/or heavy steel objects is also a significant hazard to each of your ten toes and the bigger parts they are connected to. Most industrial shops require steel cap boots.

Powered Ventilation

Welding fume is a potent, poisonous cocktail that must be managed. Paints, coatings, plating, alloy formulations and chemical residues release toxic gases when oxidized under the extreme heat and UV light of the welder's arc. These can include zinc oxide (from galvanized steel), Phosgene/hydrogen chloride (from oxidised degreaser) and manganese and cadmium fume which can have significant health effects (Jeffus, 2008, p. 29-30).

Ensure you always direct the powered ventilator close to the work piece and breathe easy!

Tongs

Tongs and pliers are a good alternative to fingers and hands for moving and securing heated objects.

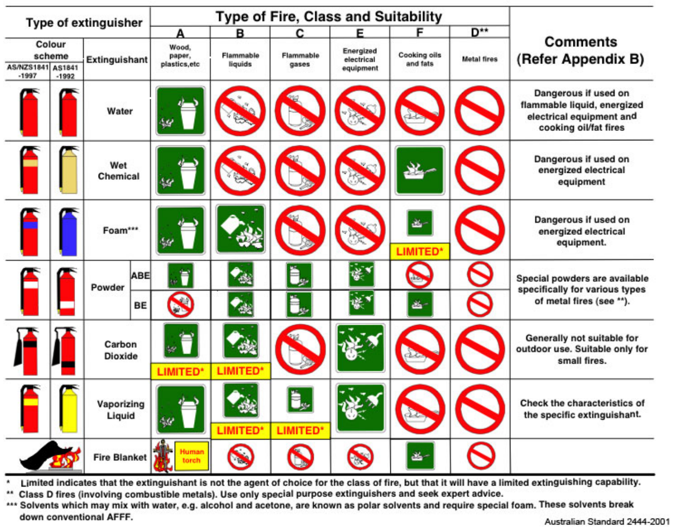
Fire Control

Fire Control Systems include fire extinguishers, fire blankets and sand buckets. A generally suitable extinguisher is the Australian Standard AB(E) type dry chemical (white band) extinguisher. These are suitable for carbonaceous solids, flammable and combustible liquids and fires of electrical origin. This covers a range of possible sources such as wood, paper, cloth, rubber, plastics, grass, coal, petrol, kerosene, oil, tar, paint and wax. NOTE AB(E) type may not be very effective for dangerous class C (flammable gases) such as LPG, PROPANE, MAPP GAS or Acetylene. In the event of fire a fire emergency call 000.

For more info refer to

http://www.hsc.csu.edu.au/metals_engineering/compulsory/13014A/4321/emergency_equip.htm

Type AB(E) Extinguisher
Retrieved from http://bit.ly/1FSLUWz



Extinguisher Type Chart
Retrieved from http://bit.ly/1FSMgw8

Metal Joining Processes

The following chart provides a general indication of the techniques that are typically used in joining of solid metals, sheet metals and metal pipe. Of course, in engineering there are always rules to be broken. techniques vary across industries, standards, cost, usage, need and technologies shift.

	Chemical Adhesives	Soft Soldering	Hard Soldering & Oxyacetylene Welding	ARC & MIG Welding	Spot Welding	Hot Riveting	Cold Riveting	Mechanical Fasteners & prep	Grinding Prep
SOLID METALS	✔	✔	✔	✔		✔		✔	✔
SHEET METAL	✔	✔	✔		✔		✔	✔	✔
METAL PIPE	✔	✔	✔	✔				✔	✔

ADHESIVE PROCESSES

Advances in chemical engineering have led to the improvement in adhesives that are now claimed by manufacturers to achieved tensile strengths of up to 5000psi (3m.com.au, n.d.). Used in jewellery, automotive, general industrial assembly and electronics these adhesives offer a viable alternative to some of the older technologies listed below. In fact manufacturers claim adhesives are "capable of reducing or replacing the need for threaded fasteners, welds or rivets, resulting in a higher quality assembly" (Henkel N.A, n.d.).

An added benefit of adhesives is they can be used to join metals to a variety of substrates including rubbers, timbers, other dissimilar metals including magnets, porous, acidic and polyolefin surfaces. Loctite 454 is a universal adhesive for such uses whilst Loctite 415 & 496 are marketed at different viscosities for specialized metal jointing.

It is important to be mindful of an adhesive's temperature performance. Although adhesives such as Loctite Epoxy Weld are promoted for use "as a convenient alternative to welding" it has a service temperature of less than 150°C (3M™ Scotch-Weld™ Metal Instant Adhesive MC 100 is only 80°C (Loctite Products, 2014) whereas the common 60/40 (Sn/Pb) Tin/Lead alloy soft soldered joints have a melting point at about 183°C. The melting point for hard solders is about 400°C.

SAFETY ISSUES

Metal adhesives are often cyanoacrylates, epoxy resin or polyurethane based. All require WHS risk management.

Cyanoacrylates (CA) are instant glues such as Superglue.

- They release strong fumes and should be used in a ventilated area.
- CA reacts with moisture and readily bonds skin and eyelids. Protective eyewear must always be worn when using CA and avoid chemical burns to the skin through contact.
- Separation of glued fingers is best achieved with a few minutes soaking in warm soapy water, gently prying apart. More serious cases, e.g., eyes glued requires immediate medical attention.
- WikiP says CA contact with leather, wool or cotton can produce an exothermic reaction causing burns or even fire. Do not use with these natural materials.

Steel water piping was commonly used with a threaded joint, more so before PVC piping became preferred. Sometimes this was braised with soft or hard soldering (including lead based solder!). Today's technology replaces the braising process with Teflon tapes and engineered joint compounds that act as adhesives to physically support the joint by locking the thread (e.g., in the case of vibration) and also create an effective pressure seal against liquids or gasses within the pipe. Such products include Hernon Dripstop 940 (Pipe sealant with Teflon).

FEATURES

- **Cyanoacrylate**
    - Short shelf life
    - Very fast set
    - Typically a 1 part adhesive, activators speed up cure time.
    - Cures in contact with atmospheric moisture
    - Joint tends to be somewhat brittle
    - Joint only suitable for close contact of substrates
    -

- **Epoxy**
    - Long shelf life (if unmixed!)
    - Typically 2 part adhesive
    - Performs well across larger gaps and can fill large voids
    - Formulations vary (ie. Working & cure times, strength, flexibility, colour, thermal & chemical resistance)
    - Joints generally have some flexibility
    - Often machineable and paintable and can be coloured and filled for effect or performance.

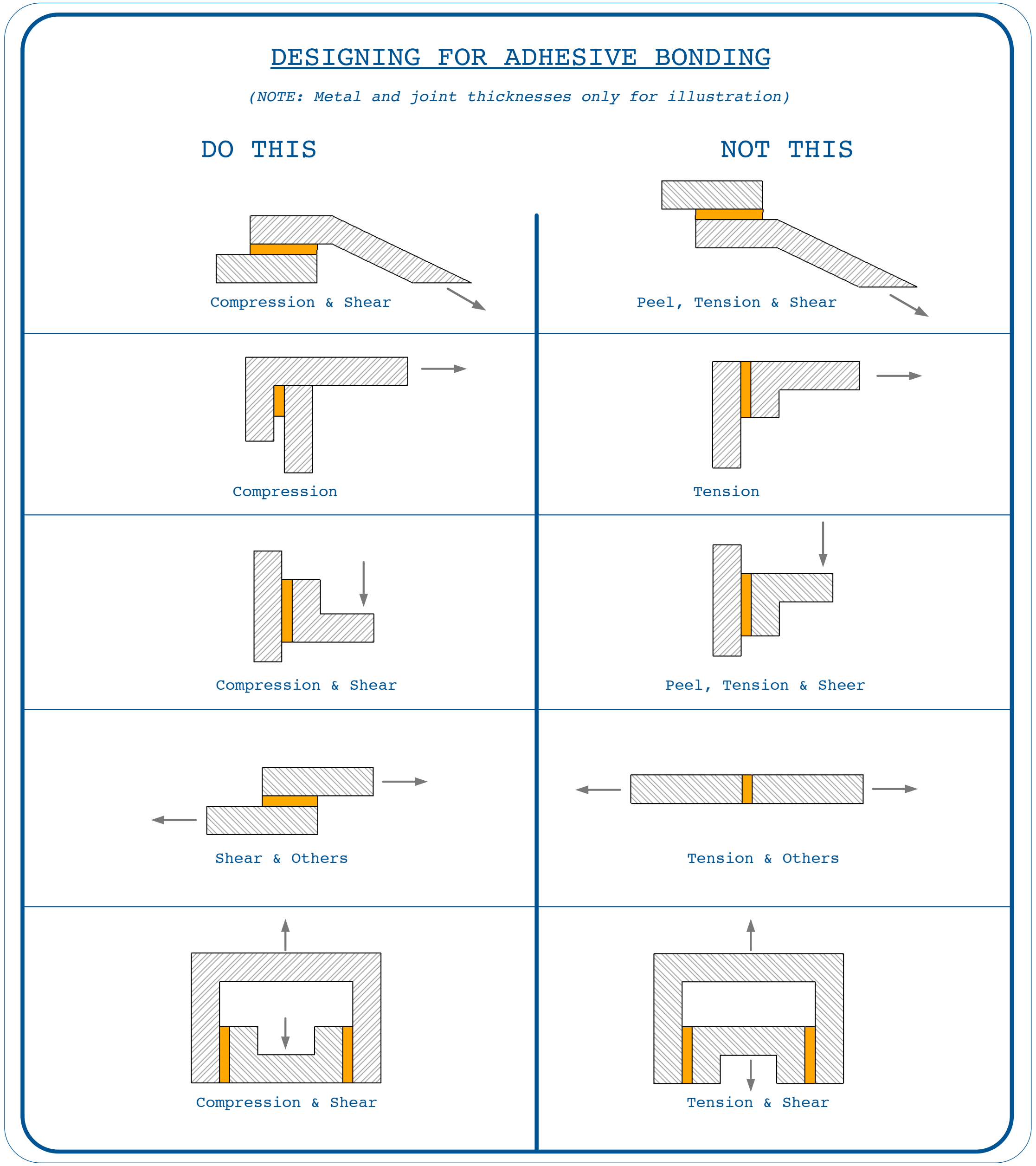
Adhesives can be ideal for thin metals and light work. The extreme heat of welding often causes thin metals to warp and dis-colour. Adhesives do not alter the metals properties and can actually reduce load stresses causes by welding. They do not damage destroy galvanized coatings, which can to corrosion, and provide sealing as well as bonding in the same process (thefabricator.com, 2013).

Adhesives can be an efficient alternative to rivets screws and welding. The opportunities for it use are vast although it is critical to ensure application follows manufacturers guides and particularly that suitable substrates are used, surfaces are properly prepared, usually meaning clean and contaminant free, and that joints are properly designed. Overleaf is a visual guide for adhesive bond design that covers many typical applications.

The use of adhesives in commercial bonding of metals is a somewhat new and specialised technique. The European Stainless Steel Development Association relate a range of applications from door handle assemblies to stainless steel building facades, Kosmač (2013) explains effective joint design transmits the applied loads through a relatively weaker adhesive (p. 4).

It is interesting to note he also claims "The actual mechanism of adhesive attachment is not yet fully understood. No single theory explains adhesion in general".

ACTIVITY *Consider the claimed 5000psi adhesive tensile strength mentioned earlier. Design a virtual experiment using a heavy sling, an average sized male hippopotamus, a few cows and a square inch of metal. What kind of adhesive would you use and how would you fasten the hook to the 1"x 1" plate?*



http://www.thefabricator.com/article/assembly/designing-for-adhesive-bonding

FASTENERS

Mechanical fasteners for metal are growing in popularity and have a lot going for them. The European Aluminium Association informs they are a repeatable, predictable fastening option for a wide variety of joint designs that don't require (the associated hazards of) heat to install and can be tested without costly or destructive methods (1994, p4-5).

A variety of metals and coatings are used in fastening technologies to meet engineered and environmental performance requirements. Metals commonly include mild and high tensile steels, brass, silicon bronze and stainless steels. Coatings include zinc, nickel, chrome and galvanized coatings as well as polyester and epoxy powder coatings.

This workbook can't cover every application of mechanical fasteners, it's a broad topic! Instead, a list of common definitions is provided as a reference to help you develop your knowledge of fastening techniques.

Definitions to know when fastening

BLIND HOLE A hole that does not pass through a component and has only one opening.

BOLT An externally threaded, cylindrical fastener with a head at one end and a threaded blunt end at the other. Bolts are designed to fit into non-threaded holes to join parts and are assembled with a nut.

BOLT HEAD The enlarged shape on one end of a bolt. The type of bolt head determines the type of tool used to tighten it.

CARRIAGE BOLT A type of bolt with a round head and a square neck underneath that prevents the bolt from turning while the nut is tightened.

CHAMFERED Angled or beveled along an edge.

CORROSION RESISTANCE The ability of a material to resist chemical destruction from an environment. Corrosion resistance is the most important physical property for fasteners.

COTTER PIN A pin with two ends originally positioned together that are fitted through a hole and then bent backwards to lock the pin and other components in place.

Dome Head Bolt A type of bolt with a rounded head above the head's flats that is made of wear-resistant material. Dome head bolts are used in industrial and farming equipment.

External Thread A thread that spirals around the exterior surface of a cylindical component.

Flat Washer A common type of round washer that is flat with a hole in the enter. Also called a plain washer.

Hex Bolt A bolt with a six-sided head.

hex key A small hexagonal-shaped wrench that is used to fasten socket head cap screws.

Internal Thread A thread that spirals around the interior surface of a hole.

Load The overall force that is applied to a material or structure. A fastener that supports the weight of an object is withstanding a load.

Locking Nut Any nut that is designed with features for providing extra security against unintended loosening of the nut and bolt.

Locking Washer Any type of washer designed with a feature that adds tension and helps prevent loosening of the joint.

Machine Screw A common type of screw with a blunt end that is assembled into a threaded hole.

Nut A small device with internal threads that is fitted onto a bolt to join parts. Most nuts are square or hexagonal.

Pin A thin, often straight, cylindrical non-threaded fastener used to secure the position of two or more machine parts.

Screw An externally threaded, cylindrical fastener with a head and a threaded flat or pointed end opposite the head. Screws are designed either to fit into a threaded hole or form threads into material.

Sealant A substance applied to a joint that dries and hardens to lock components in place.

Set Screw A type of screw with a rounded or cone-shaped end designed to fit into a matching recess. A set screw is typically used to lock a component onto a shaft.

Shank The cylindrical length of the bolt that extends from the underside of the head to the point or end.

Socket A device that covers a nut or bolt completely for tightening or loosening. Sockets attach to various devices that are used to tighten the bolt or nut.

Split-Ring Washer A type of locking washer with a split section that is intentionally bent out of shape. As a nut is tightened, the split-ring washer is forced back into a flat shape, which adds tension to the joint.

Strength-To-Weight Ratio The relationship between a material's strength and its weight. Materials that are light but also very strong have a high strength-to-weight ratio.

Structural Bolt A large, heavy-duty hex bolt used for structural applications in buildings and bridges.

Stud An externally threaded fastener that is threaded at both ends. Unlike bolts, studs do not have a head.

Tensile Strength The ability of a material to resist forces that attempt to pull apart or stretch it.

Tension A pulling force that is directed away from the object and attempts to stretch or elongate the object.

Thread A raised, helical rib or ridge around the interior or exterior of a cylindrically shaped object. Threads are found on screws, nuts, and bolts and are used to fit parts or provide motion.

Threaded Fastener A type of fastener that contains threads. Bolts, screws, and nuts are examples of threaded fasteners and are the most common type of fastener.

Tolerance The unwanted but acceptable deviation from a desired dimension. Increasingly accurate dimensions require tighter tolerances.

Torque The amount of force applied to tighten a bolt, screw, or nut.

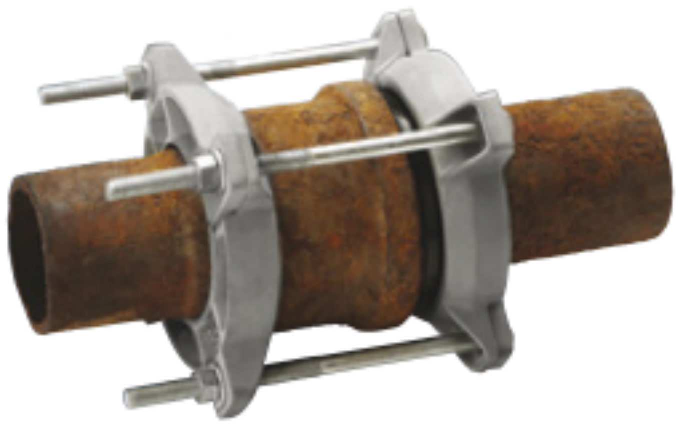
Washer Face The completely flat side of a nut that is intended to contact the surface of a washer.

Wrench A type of hand tool that tightens and turns bolts and nuts. Wrenches contain fixed or moving jaws or a round attachment that grips the nuts or bolts.

Source: *http://www.toolingu.com/class-700117-overview-of-threaded-fasteners-117.html*

Mechanical fasteners can join just about all types of sheet and solid plate steels. Whether they are the best fastener for the particular job is something you can decide once you have read through this workbook. They are also suitable in some applications for joining metal pipe but these are specialised applications. As mentioned in the adhesives section steel water pipe is secured with a range of threaded angle joints. With imagination these may have some place in the art metal or design workshop.

As quality fasteners are mass-produced to exacting material and dimensional tolerances engineers and fabricators can be assured of predictable and repeatable performance results. A possible variable occurs as the fastener is fitted. This can also be managed by using a torque wrench. These allow the installer to apply an accurate turning force, known as torque to the fastener ensuring it is neither too loose, or tight and will perform optimally.



Clamping pipe joints can stop leakage.

http://water.pentair.com/water/Images/WEBS-34.pdf

A range of torque wrenches

http://www.cditorque.com/images/CDI-HP-Collage.jpg

Most metal fasteners incorporate a helical thread design (think nuts, bolts and screws), beyond which are a range of adaptations and accessories that complement their use, or act in isolation, including pins, clips, and washers etc. There are also other fasteners types including rivets that have their own section within this workbook.

Considering the threaded fasteners, a range of types exist from industrial fasteners, structural bolts, self-drilling screws (generally for sheet and very light gauge metal use only), socket type screws and threaded rod studs.

Various chemical and mechanical technologies serve to retain the fastener in place, or connected to other fastener components. These include assorted split pins, lock nuts, star and spring washers as well as grouting, epoxy and thread locking adhesives.

Images http://www.fastenersaustralia.com.au/products.htm

ACTIVITY

1) Download the Thread guide from http://www.fastenersaustralia.com.au/threadguide.htm and convert the following common fractional inches to metric mm.

1/16" mm. 1/8" mm. ¼" mm.

½" mm. 1" mm.

2) You find a few 3/16" bolts and decide to fit new trucks to your skateboard. What size hole (using your dad's best metric drills) will you drill through the deck to suit the bolts?

3) Find 10 definitions (above) that are new to you and research what they are, how they perform, where they are used and if any realistic alternatives exist.

Construction workers tightening the bolts on the Sydney Harbour Bridge, ca. 1931

www. http://nla.gov.au/nla.pic-vn6247855

RIVETING

Rivets have a long history of joining metals in fabrication, perhaps more than any other method. A rivet simply holds two or more metal panel surfaces together by way of a metal pin or rod, which passes through the panels. The rivet is held in place by generally expanding both ends of the rivet so that it is mechanically locked thru the hole. The rivet design pulls the panel surfaces together applying compressive force and friction of the contacting surfaces.

Rivets are a reliable, versatile and effective method of joining metallic panels from thin aluminium aircraft skins to heavy industrial and structural construction. They are seldom used in metal pipe joinery although there are many specialty rivets, including tubular rivets. The riveting process employs two major types: 1) Blind (pop) riveting, where a tool actuates the rivet design to mechanically draw the rivet end open forcing the panels together in compression; 2) Hot riveting, where a very hot (light yellow) ductile rivet is placed into a hole between two panels and the ends are quickly rounded or countersunk to lock the rivet in place. Heavy pneumatic or mechanical hammers are usually used for this process. As the rivet cools it contracts and tightly compresses the sheets together.

Solid (Hot) Riveting

Solid riveting was the only reliable means of joining metal from "the dawn of the industrial revolution" and has been used in shipbuilding until the 1950's. Nearly every piece of structural steel on the Sydney Harbour Bridge is held in place with solid rivets. (johnoxley.org.au, n.d.).

Solid riveting as a mature technology is labour intensive and requires access to both sides of the joint. It is somewhat slow and dangerous. Advanced and automated welding technologies and other fastening systems are seeing a decline in the use of solid riveting (www.roymech.co.uk).

Solid rivets can be used in a lap or butt joints and are considered extremely strong, reliable and permanent.

ACTIVITY 1

Watch this fascinating video (https://youtu.be/JPQ7CzVHdMs) from 8:00 to 12:00 minutes, or more if you like! List the WHS issues you see and how we would better manage safety risks today.

ACTIVITY 2

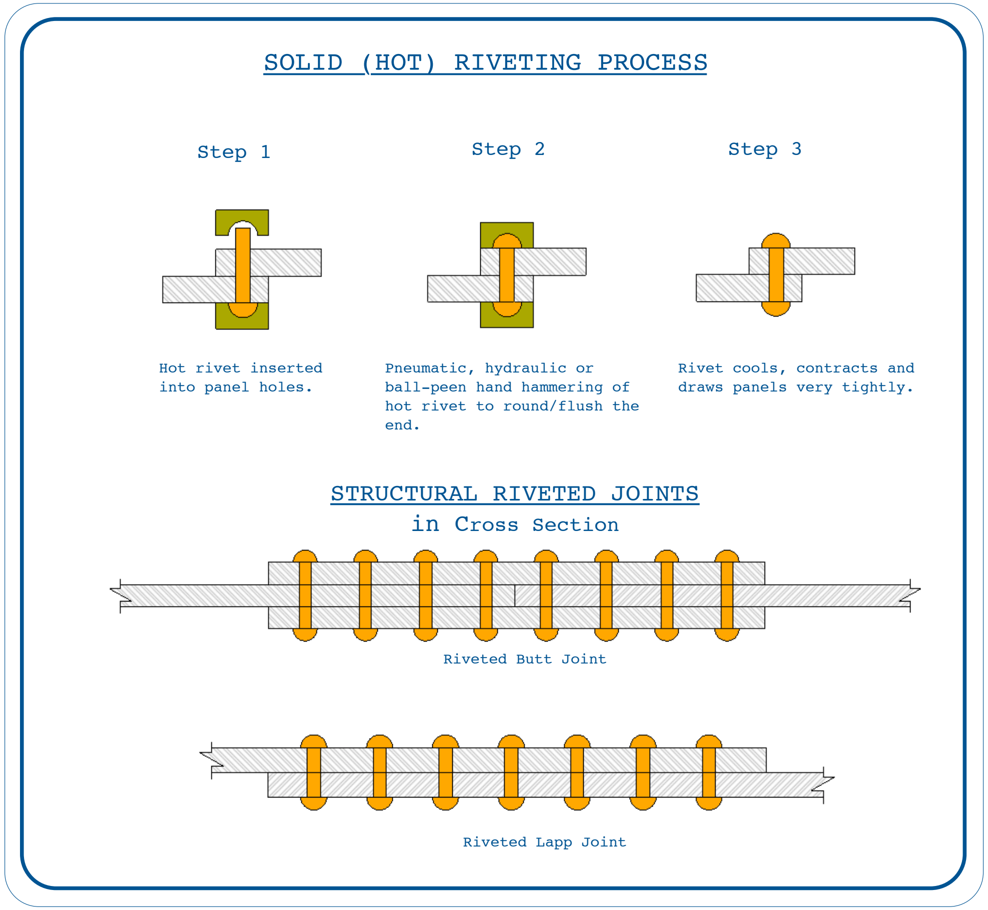
From info in the video estimate the total weight of rivets (in metric tons). Assuming each rivet took 1 minute to prepare & install calculate the total work days (8 hours) to install all rivets.

ACTIVITY 3

Assume the cross sectional butt joint (to right) has a diamond shaped array of rivets with one at each end and a total of 20 in all. Draw a plan view of joint, including rivet holes and indicate hidden joints with dotted lines. The material width is your decision, each rivet shank is 5mm & head OD is 15mm.

Activity 4

If the rivets are ductile mild steel and heated to a light yellow, roughly what temperature (°C) are they out of the furnace?



Adapted from http://www.roymech.co.uk/Useful_Tables/Rivets.html

Blind (Pop) Riveting

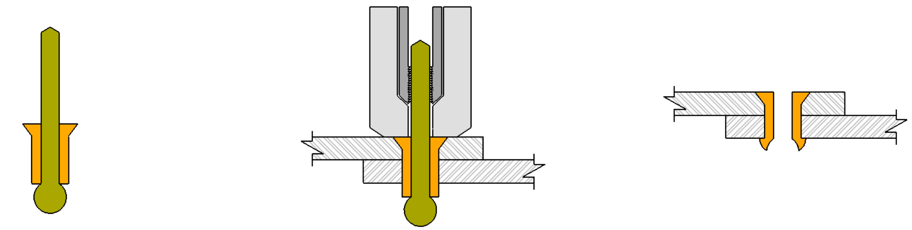
Pop rivets got their name from the company that first developed them and blind riveting describes the benefit of being installed without access to both sides of the material, unlike solid rivets. They were designed to be simple and efficient to fit and come in a range of materials including steel, aluminium, copper, nylon and stainless steel.

Roymech (n.d.) explains blind rivets are used across a range of non-structural applications where the joint thickness does not normally exceed 25mm and the rivet is generally limited to 6-8mm. Rivet types include;

- Standard for general rivet applications

BLIND (POP) RIVET PROCESS

Step 1 | Step 2 | Step 3



A suitable rivet is selected. This is an aluminium countersunk rivet.

The rivet gun pulls the mandrel away from the rivet whilst keep the rivet in place in to hole.

The mandrel expands the rivet head and then breaks away leaving the rivet secure in place.

Adapted from http://www.roymech.co.uk/Useful_Tables/Rivets.html

Rivet images: http://www.rivetsonline.com/rivets-en.html

- Sealed to achieve fluid pressure tightness
- Peel to distribute a larger mushroom shaped crown to spread force across softer materials
- Grooved to improve grip within a variety of materials.

Generally the blind rivet is used for lighter applications with thinner plate than that used in solid rivets therefore they are not as strong. The correct selection of a rivet type and its sizing to meet the hole depth and diameter are vital considerations to ensure intended performance.

Remember there is wide a range of rivets to suit a variety of applications. In most cases a handheld rivet gun can be used for smaller riveting. Larger rivet guns provide more force to fasten heavier rivets and can also be automated.

Common rivet guns

http://www.rivetsonline.com

Activity

Describe blind rivet specifications (material, length and type) for the following uses. Note where riveting would not be appropriate:

- *Joining hull section to ribs of aluminium dingy*
- *Fastening a compliance tag to a trailer*
- *Fastening a metal bracket to a masonry wall*
- *Assembly of a sheet metal tool box*
- *Joining the drawbars to the chassis of a heavy trailer*
- *Fastening an aircraft's skin to it structural framework*
- *Joining two pieces of polycarbonate sheet*

SOFT SOLDERING

Soldering and brazing are one of the oldest methods of joining metals and historical evidence dates back thousands of years.

ACTIVITY

Find three methods of soft soldering that was used anytime before the industrial revolution. Explain how and why this method was used.

The word solder has a Latin origin *solidare* meaning "fasten together" (Oxford English Dictionary) and is the process of process of permanently bonding metals through the use of alloys which have a lower melting point than the parent material (Cain, 1985, p.9). It is important to differentiate soldering from welding, where welding involves the coalescence of welding rod and/or parent material into one joint, soft soldering and brazing does not truly melt the parent material.

In the 21st century soldering is widely associated with the joining of wires and other components to electronic circuit boards. This is a form of soft soldering that typically uses flux resin core soldering wire and electronic heating irons.

This workbook covers the other application of soft soldering, where a filler material known as solder bonds metal pieces, referred to here as the parent material. Cain (p. 7) explains soft & hard soldering is best explained as a function of the amount of heat required to liquefy the filler alloy, where soft soldering occurs below about 400°C and hard soldering generally above.

As an ancient art soldering (and brazing) was once the domain of skilled armorers, tinsmiths, silversmiths and jewelers. Still with some basic knowledge, training & practice students can easily achieve quality & dependable joins soft soldered joins. Let's begin with the following materials, tools and techniques.

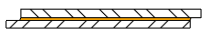
Effective joint design increases the contact area of solder to parent. A butt joint is improved with angled grinding (creating a V shape) and the lap joint allows significant surface area contact for bonding. Advanced joint designs such as the

ACTIVITY

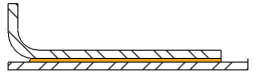
Is the Sketchup drawing (to right) of soldering iron a soft soldering or brazing activity?

Cleanliness of the parent material is important to achieve good solder bonding. A light sand with clean wet & dry paper is acceptable although take care to remove any abrasive contaminants, and oils from contact with dirty rags & fingers etc.

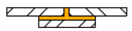
SOFT SOLDERED AND BRAZED JOINTS



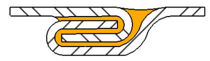
Soldered lap joint. A cranked lap offers a more flush surface.



Peeling can occur due to limited filleting at left of image as fold rises.



Butt joints are strengthened with an additional layer of metal below.

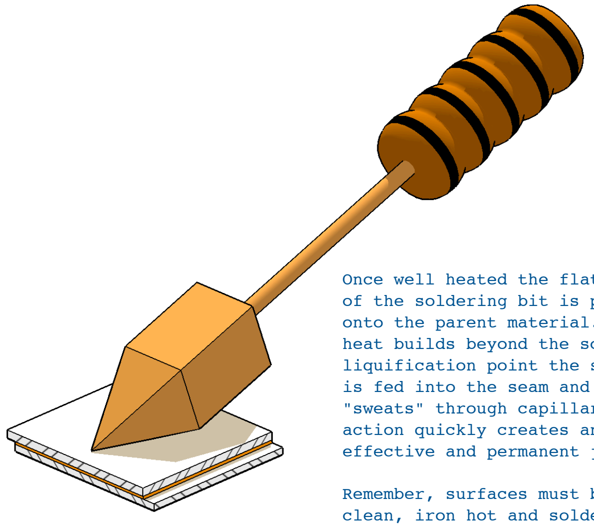


The very reliable lock-joint is used on tin cans and pressure vessels.

Solder and braze travels by capillary action into the narrow cavity between parent materials. Seen here in orange the gaps are exaggerated to indicate the filler alloys. Other speciality joints such as L joints, cranked lap and scarf joints are also employed in soldering & brazing.

Various brazing rods. Notice the flux covering the rod on right side.

Heavy soldering iron, possibly hand made including copper forging of bit in the earlier days of the industrial arts workshop.



Once well heated the flat edge of the soldering bit is pressed onto the parent material. As heat builds beyond the solder's liquification point the solder is fed into the seam and "sweats" through capillary action quickly creates an effective and permanent joint.

Remember, surfaces must be clean, iron hot and soldered surfaces fluxed.

Flux acts to prevent the parent surface from oxidizing. Surface oxidisation occurs when metal is heated and this prevents the filer material (solder) from bonding to the parent material. To apply flux, lightly coat the parent material using a brush. Dipping the hot soldering bit into a flush/water mix also aids in soldering joints.

Heat is applied to the bit using a small gas furnace, or directly with a blowtorch. Yellow MAPP gas and propane torches are suitable for thinner material, as they do not generate significant hot spots. When using a soldering iron care should be taken not to overheat the bit, yet it must be hot enough to retain enough temperature to liquefy the solder.

Solder is available in stick and rolled wire forms. A variety of grades are available to suit various applications from fine copper work to heavier automotive and other engineering applications. The ratios of tin, lead and other metals including cadmium, silver, bismuth, antimony, and zinc determine the final alloy and its working properties (Cain, p. 24-17).

The use of soldering has significantly declined into the 21st century. Still, it is a worthwhile skill and is a valid technique for joining many metals, especially lighter gauges, copper & steel plumbing pipe and sheet metals. Joints are easily undone for re-work and repairs, due to the low heat thermal distortion of the parent material is minimal and it requires low cost tools and materials (p. 15).

Activity

Solder can be a hazardous alloy in both liquid and solid states. What precautions can be taken to minimise risks to the user?

HARD SOLDERING (BRAZING)

Hard soldering, known as brazing is a similar process to soft soldering. Brazing is useful in the joining of light pipework, sheet and thinner plate sections. Ableson & Pateman (1988) explain "Hard soldering is often called brazing and is similar to silver soldering. It is the process of joining steel by using a non-ferrous filler rod. The parent metal is not molten during the process and the join is similar to a soft soldered join but far stronger" (p. 111). Cain (p. 7) explains hard soldering uses filler (brazing rods) that melts above 400°C. Cain warns us NEVER allow soft solder to contaminate a brazed joint, and never braze a soft soldered joint, it will fail (p. 84). Brazing is an ideal process for joining cast iron and dissimilar metals (Youtube, ChuckE2009).

Brazing rods: Brass rod was the go-to alloy for historical brazing work, comprising of copper & zinc it is still suitable for steel and copper jointing although requires significant heat into the parent materials to become liquefied. Silver-brazing alloys are generally favoured due to lower heating requirements and equivalent joint strength (Cain, p.31). A bewildering range of specialised brazing rods and foils are available. They include combinations of silver, copper, tin, zinc, (toxic) cadmium, manganese, palladium and Nickel. Cain advises AG14 is an ideal cadmium free all rounder for brazing (p. 40).

Flux is a specialised component of brazing and soft soldering. Flux removes oxides and other impurities from heated metals. Fluxes are designed to melt near (but below) the temperatures of the brazing rod to be used. Because silver brazing alloys liquefy well before the brasses it is important to use the correct flux compound as advised by the manufacturer. Many brazing rods are coated with flux and this ensures the correct flux will be used. Fluxes rods have a tendency to absorb the moisture in humid air and this can reduce their effectiveness (p. 50).

Heating work pieces in preparation for brazing depends somewhat on the type of brazing rod. Very high heat brass rods will need oxyacetylene or a brazing hearth. For lower temp silver brazes specialised OXYMAPP and OxyPropane gases are more suitable for brazing as they heat the work area more uniformly than Oxyacetylene which easily causes hot spots (Jeffus, p. 806 and Cain, p.92) (Don't confuse with yellow MAPP gas which is mostly only practical for soft soldering and light silver brazing). It is advisable to use care when brazing with oxyacetylene, do not overheat and melt the work piece, or boil the braze which can produce highly toxic fumes.

The method of brazing is, like soft soldering, quite simple. CAIN summarises many pages of detailed knowledge to say "Brazing is no more than cleaning the pieces, applying the flux, assembling the parts so that they cannot move, applying the heat and bringing the joint up to the right temperature at the right place, applying the alloy, and removing the flux after cooling. It IS as simple as that and provided that the joint is properly designed, as easy as, if not easier, than making a good joint with soft solder." It's also important to note Cain's earlier technical advice explained that the heating should really occur at the work-piece joint and the brazing rod melts into the joint. Do not overheat the rod, only heat the work-piece.

Brazing joints are shown in the diagrams on page 26 XXX to be suitable for a variety of sheet metal applications. Because of the coverage, joint strength and heat tolerance it is also suitable as an adjunct to riveting where sealed boilers etc are constructed. Brazing is commonly used today by plumbers to braze copper water pipe. The pipe is flared at one end, fluxed, mated and brazed to create a very strong, durable and sealed joint. Of course in this application is critical avoid what the Romans did in using lead in their brazing processes.

Spot Welding

Spot welding takes advantage of the properties of electrical resistance in different metals. The electrode tips on a spot welder are usually made from copper, which is an excellent electrical conductor. Electrical current flows through the electrode tips where it meets more resistance in the steel work piece. This creates a type of friction where the metals join and a molten blob forms. As the electrode tips are under slight pressure they ensure the weld is well formed inside the joint as the weld cools. (Youtube, Resistance Spot Welding).

Spot welding is a simple skill although there are a few issues to consider and it is not suitable for all metal joining applications.

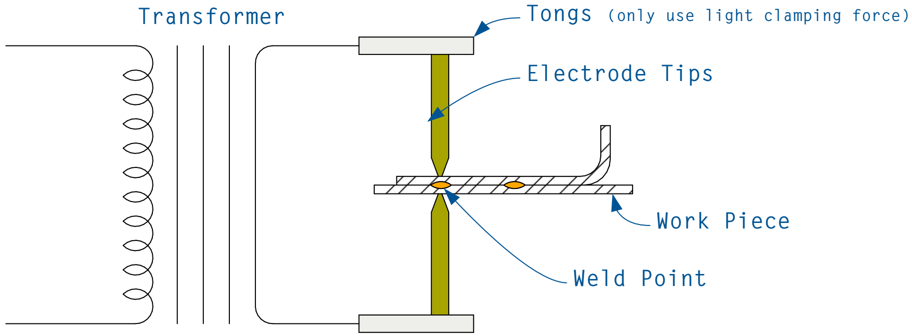
Solid metals will generally be too thick for entry level spot welding units and metal pipe often makes it impossible to allow both electrodes access to complete the weld. Spot welding is, however, ideal for thinner sheet metal. Properly setup a spot welder quickly creates a reliable weld.

Several factors influence reliable spot welding:

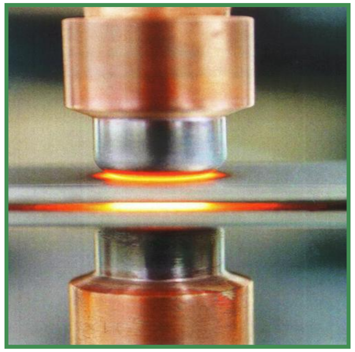
- **Material thickness.** Check the sum of your metals thickness (all pieces) does not exceed the machines capability! It is likely to be in the area of only 3mm.
- **Joint preparation.** Joints should be securing clamped with suitable clamps, vice grips etc. The electrodes should not be very tight and are not designed as clamps.
- **Metal preparation.** Often zinc & galvanized sheet is jointed with spot welding. Molten zinc releases zinc oxide, a highly toxic fume and also reduces the weld strength. Best practice would be to grind the zinc surfaces before welding as the weld will destroy the anti-corrosive benefits of the coating anyway (Millerwelds.com. p. 3.5)

- **Weld (heat) time.** This can be measured in cycles, 50 to a second and is normally set to be very brief (20 to 80 cycles). Complicated formulas can be used to determine accurate weld times although a good rule of thumb is to ensure the metal melts but does not get so hot as to boil which is hazardous and will weaken the joint. Weld time is a function of the current at the electrodes and as most spot welders do not adjust current, so weld time is the main user variable.

SPOT (RESISTANCE)WELDING

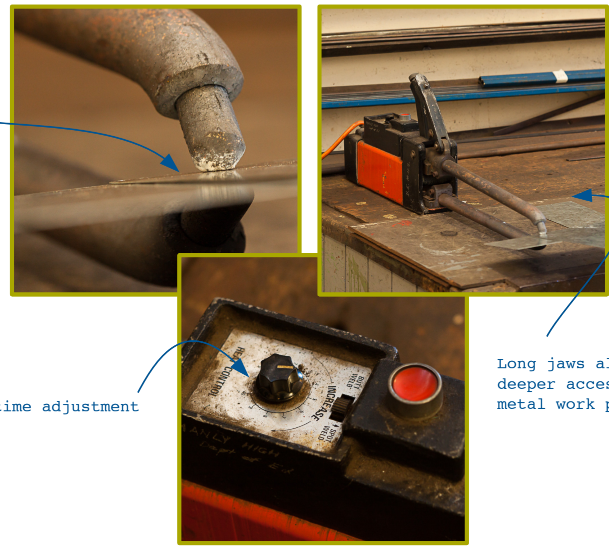


The basics of a resistance spot welder



Spot welding at work
(http://bit.ly/19WeGK8)

Notice the oxide build up on electrode tips. Clean up with light file.



Weld time adjustment

Long jaws allow deeper access to metal work pieces.

- **Hold time** allows the weld to cool once the current stops flowing. It is only momentary but necessary to ensure the weld is hardened, wait a moment before releasing clamps and/or electrode tongs.
- **Electrode tip condition** is a big issue in the workshop. Over time they flare out and also collect oxides and chemical compounds that reduce efficient current flow into the weld area. Have your teacher breathe new life into them with a quick dressing using a #0 metal file, restoring the flat tipped conical shape.
-

"The ideal time and current density condition is somewhere just below the level of causing metal to be expelled" (Millerwelds.com, p. 3.6).

ACTIVITY

1) *Describe 3 benefits of spot welding.*
2) *Research the dangers of zinc oxide fumes and steps to take to minimise occurrence and inhalation.*
3) *Make a good spot weld and carefully cut it in half (in section view per drawings on page xxx) to examine the weld quality. List your observations.*

OxyAcetylene Welding

Being the first section in the manual welding family it is important to read this whole section before attempting manual welding of any kind. Information in this section will develop knowledge, skills & techniques in other welding methods, such as stick (arc), MIG & even TIG for your later welding pleasure.

Certified welder ChuckE2009 says oxyacetylene welding "is the easiest to learn" with a relatively cool molten weld puddle, stating "nothing gives you control over the puddle like oxyacetylene welding, none of the other processes do" *(*Youtube, Plasma VS Oxy-Fuel Cutting*,* n.d.). The problem with oxyacetylene is that its "time consuming and outmoded but was first type of welding in common use, and is considered a WWI technology" .

The veteran welder Steve Bleile (who informs much of this section) says "By definition oxyacetylene welding is a process of fusion". Similar base metals are heated until they melt and the molten puddles are intermixed. When they cool the pieces are fused together. In most situations a filler rod of the same materials is used to add metal to the molten puddle and build up a weld bead. "The working pressure for oxyacetylene welding will only be around 3-5psi (20-35kPa) (*Oxyacetylene welding,* Youtube)

.

Jeffus warns the oxyacetylene torch creates hot spots at the inner flame tip and is relatively cool away from this tip. The correct tip and technique is recommended (p.806).

Perfect puddle, flame tip distance and filler rod dip location.

https://youtu.be/pVv8a_FVIOU

OXYACETYLENE WELDING

A slow and simple welding process that requires the right setup for great results

OXYACETYLENE Cheat Sheet

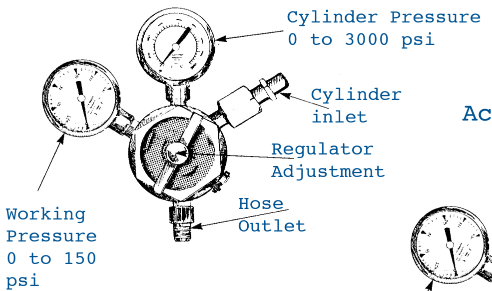
Cold Rolled Sheet & Mild Steel Plate

Tip Size	Metal (mm) Thickness	Working Pressure (psi) OXY	ACET
000	.8	3-5	3-5
00	.8-1.2	3-5	3-5
0	.8-2.0	3-5	3-5
1	1.6-2.5	3-5	3-5
2	1.6-3.0	3-5	3-5
3	3.0-5.0	3-6	4-7
4	4.8-6.0	4-7	5-10

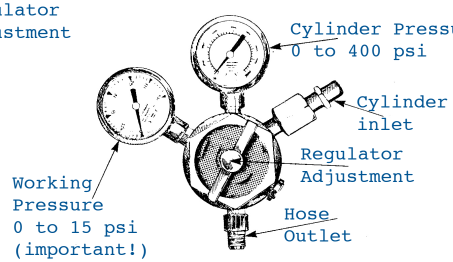
Balance oxygen/acetylene mix to reach a neutral flame with a tight bright conical inner.

www.youtube.com/watch?v=pVv8a_FVIOU

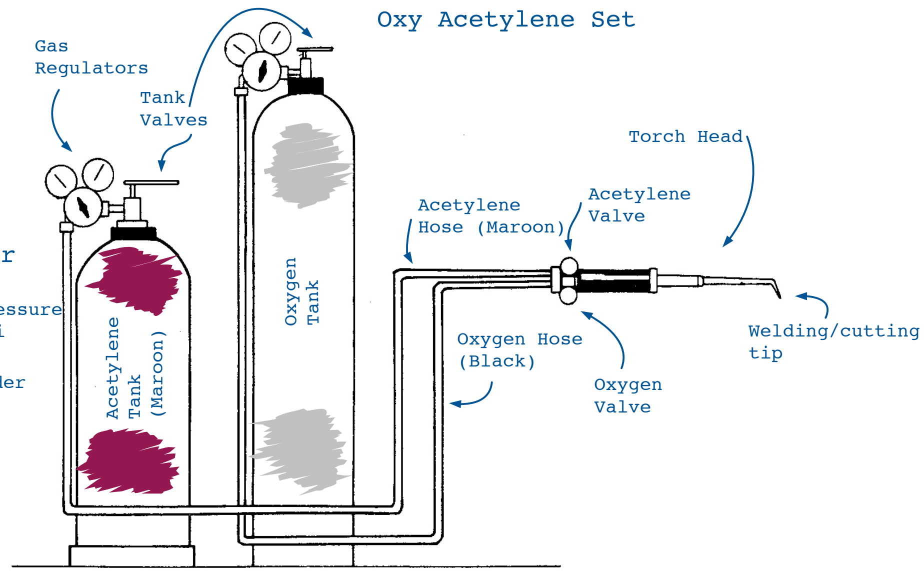
Oxygen Regulator



Acetylene Regulator



Oxy Acetylene Set



Equipment images adapted from http:// .agedweb.org/agmech/TOC.htm Chart & flames from https://youtu.be/pVv8a_FVIOU

Material Preparation

Aside from the poisonous fumes created when super-heating oils, degreasers, paints, fillers, galvanised and other coatings trying to weld without first cleaning them off will just incorporate impurities into the weld making a difficult, weak, and amateur looking weld. It's quite normal to take more time preparing the joint than the actually welding!

Gas Preparation Procedure

• See Oxyacetylene cheat sheet following for correct working pressures •

(adapted from https://youtu.be/pVv8a_FVIOU)

1) Open Oxygen bottle valve fully. (Begin slowly and do not stand in front of regulator)
2) Open Acetylene bottle ½ to 3/4 turn ONLY.
3) To adjust regulators you need torch head valves open. With regulators BOTH SHUT, slightly open the torch head acetylene valve and then open acetylene regulator until working pressure valve rises to required pressure, then close the Acetylene valve on the torch. Acetylene is now set for use.
4) Slightly open the torch head oxygen valve and then open oxygen regulator until the working pressure valve rises to required working pressure, then close the oxygen valve on the torch. Oxygen is now set for use.

Line leaks are uncommon but dangerous. Regular checks are simple and worth the effort. A handy way to find hose/line leaks is:

1) Complete gas prep procedure but run working pressure up to max safe setting (15psi acetylene).
2) Close regulator valves. Lines are now under pressure with no feed from bottles.

This photo was setup and hopefully the only time we ever see OA gear in this state.

3) Note working pressures, allow a few minutes, then check again if oxygen OR acetylene pressure has fallen.
4) If pressure falls check for connections tightness. Test again and if fails assume hose leakage and report equipment as requiring service and prohibit further use until repairs complete.

Lighting the Torch

1) Open torch acetylene valve 1/8" turn, ensure torch pointed safely and use sparker to ignite. Further open acetylene valve until soot almost ceases and/or the orange flame is feathering at the end.
2) Slowly open oxygen and a long flame develops. Continue turning oxygen until the bright blue inner cone forms a tight tip at the torch nozzle. This tip is called a neutral flame. If too much oxygen is present the tip thins out, becomes more transparent and a distinct sound of rushing gas can be heard, that is when an oxidizing flame develops. Adjust for a neutral flame.

The flame heat under this setup should be ideal for most oxyacetylene welding jobs (although maybe too intense for the brazing work covered in that section).

Extinguishing the Torch

1) Close the acetylene valve at the torch head.
2) Close the oxygen valve at the torch head

Shutting the System Down

1) Closes valves on both bottles
2) Open acetylene valve on torch
3) When acetylene high pressure and working pressure gauges read zero close the acetylene regulator.
4) Close the acetylene torch vale.
5) Repeat steps 2-5 for oxygen.

If the tip doesn't make a neat neutral flame it may be dirty. See your teacher for assistance to clean it.

ACTIVITY *Remember this…*

Turn acetylene ON FIRST & OFF FIRST.

Using a 0, or 00 torch tip, angle the torch about 45° in the direction your will weld along the seam. This is called fore-hand technique. Bring the torch onto the work so that the blue cone is about 3mm off work piece. Using a small circular (or zigzag) motion heat an area about 3-5mm with tip heat until a molten puddle occurs. The bright cone contains unoxidised acetylene that will add impurities to the weld, keep the cone out of the puddle.

If using a filler rod keep the rod in front of the flame just above the forward edge of the puddle, but not in the flame. This pre-heats metal ready for melting as you rhythmically dip the filler rod into the center of the puddle. Move the tip forward along the weld seam, relax and keep breathing, maintaining the rhythm as you add filler to the moving puddle. To avoid a creating a crater dip the rod a few more times as you finish. You're now welding with gas!

ACTIVITY: *Research backhand technique and explain the difference and effect it has on the welding bead.*

When selecting the right filler rod size consider that every time the filler rod is dipped in the puddle, the puddle will cool a little. Maintaining the puddle heat and balancing the rod thickness is key.

When butt welding thin sheet bring them firmly together and weld without filler. You may tack the ends (and along the run) first. When butt welding 3mm sheet and beyond leave a very small gap and use filled rod. Pipe can be done in the same way although it is far more prudent to use a flared end and fillet weld technique to the lapped joint instead. A trick to welding pipe as welding is to rotate the pipe if possible.

If you find the flame pops during welding it maybe going out (and sometime re-lighting) because of excess heat or proximity to the weld. Ease the heat off or back off a little.

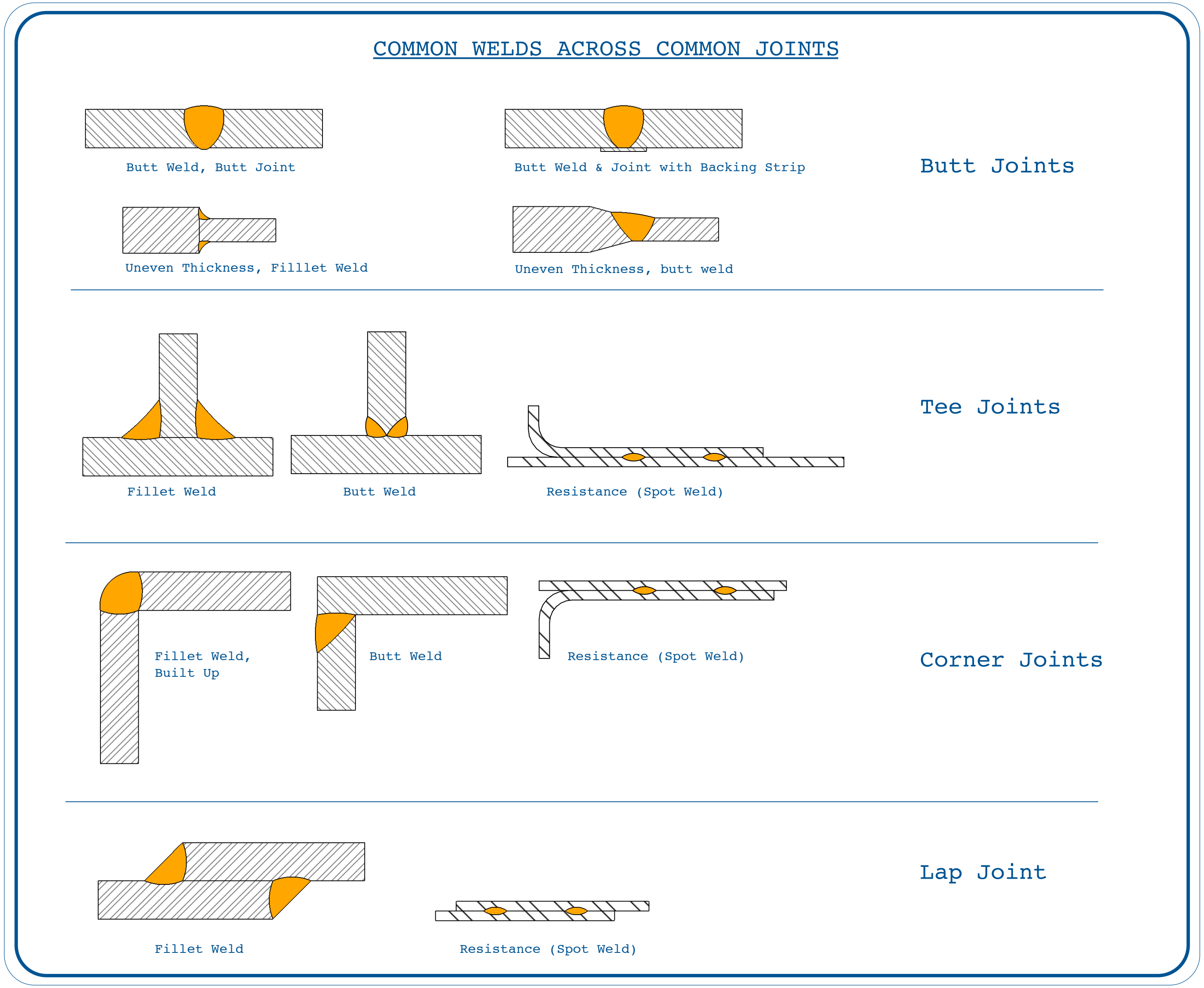
When solid materials approach 4.5mm it is more difficult to achieve good penetration with the puddle. From this thickness upward grind a 45° chamfer to each end and butt them together creating a V that the filler rod fills when welding. This might take more than one pass and needs cleaning between passes.

Joining metals, whether soldering, brazing or welding requires appropriate joint design and a method to hold materials in place during welding.

A variety of magnetic and mechanical clamps are available to hold work pieces in place. Be mindful not to burn them, or weld them to the work as you go along. Also remember they may heat with welding nearby, wear gloves and be careful. The final advice is not to use magnet clamps as shown below left. Can you see why not?

The common fillet, butt and resistance welds indicated in orange are typical of techniques used in various joint types across many welding technologies including brazing, stick, arc, MIG & TIG (and spot as listed).

Notice (esp' in the fillet lap joint) welds stay local to the welding area and do not sweat into the joints like soft soldering or brazing. Also notice how the welds have rounded sections where they contact metals indicating how the weld coalesces (melts) into the parent material.



Adapted from Vause, 2002, p53.

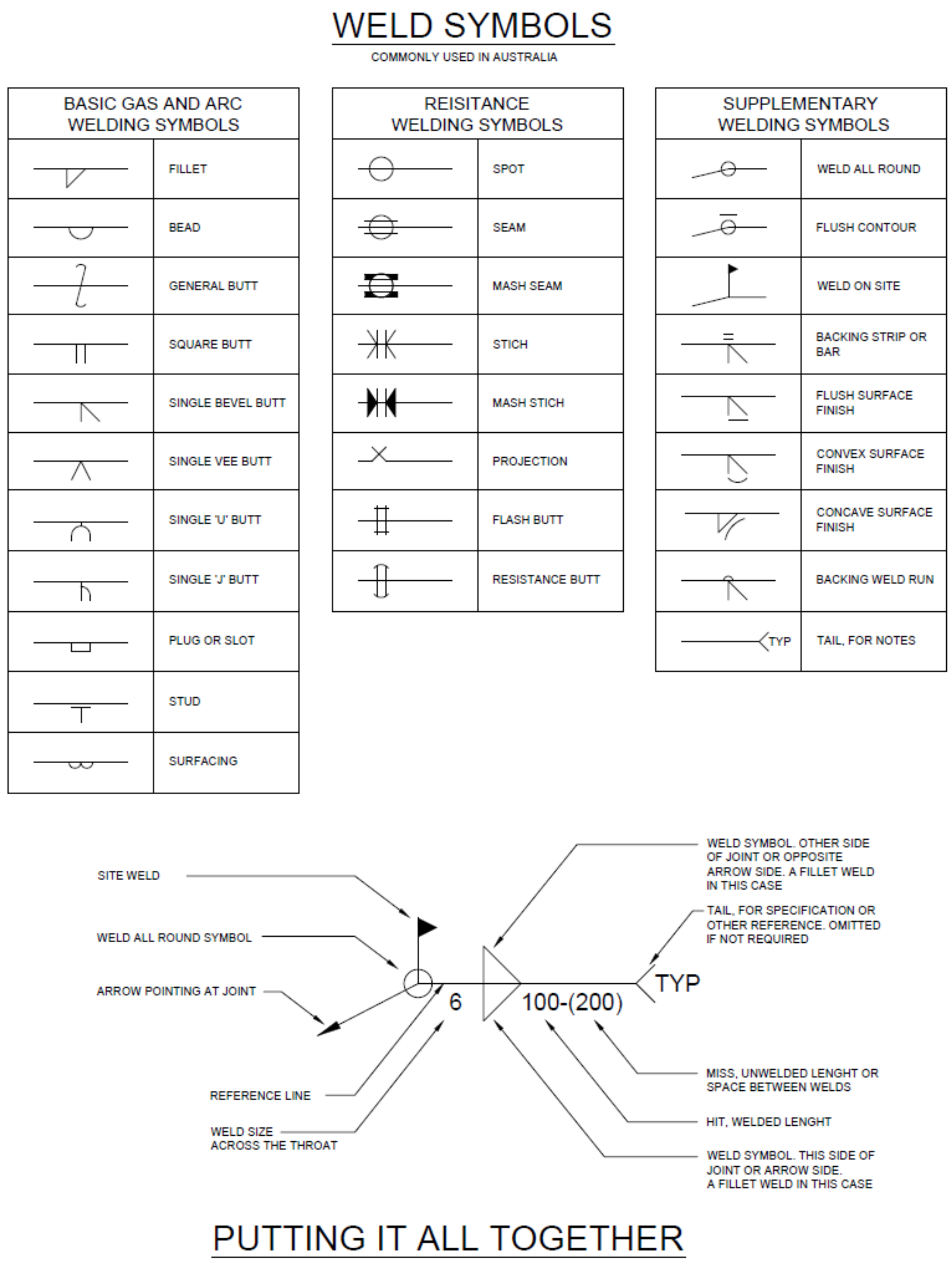
Welders have their own codes to standardise work specifications and job requirements. To the right is a summary of weld symbols commonly used in Australia.

ACTIVITY

Can the butt and fillet welds shown above be achieved with ARC, MIG and OXYACETYLENE gas welding? What other technology is required to achieve all welds shown?

ACTIVITY

Using the chart to right record the standardised weld symbols on each of the examples on the above page.



http://www.draftsperson.net/images/6/63/Weld_Symbols.png

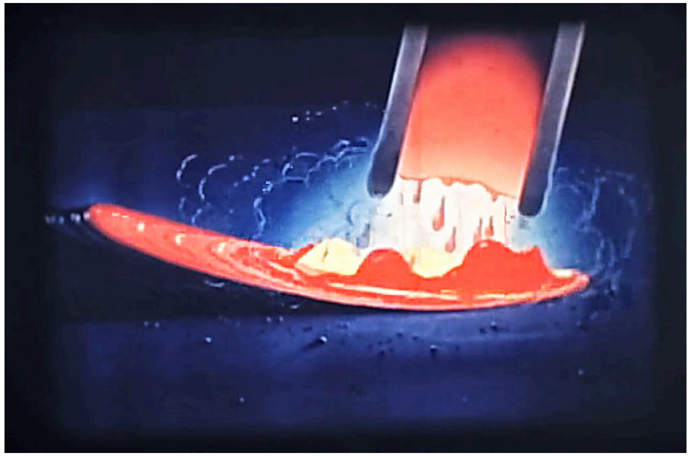
ARC WELDING (STICK • SMAW • MMAW)

Shielded Metal Arc Welding, Manual Metal Arc Welding, Arc or just Stick welding is all the same process, it's many names suggest how widely used it is around the world. For simplicity, lets stick to stick welding.

Stick welding is a portable and versatile process that does not require significant investment in equipment, in fact being portable and not subject to wind it is ideal for outdoors use and often the choice for farm, maintenance and general repair work yet still has a place in workshop production too.

Stick welding "uses a coated metal electrode to provide an electrode, filler material and shielding gas" (tokentools.com.au, n.d.). The electrode is held in the stick holder and connected to the power source.

The work clamp carries an opposing polarity from the power source to the work piece or welding bench. When the electrode is 'struck' against the work piece an electrical arc ignites at very high temperature to liquefy the electrode and gasify its coating.



How Arc Welding Works

https://www.youtube.com/watch?v=TeBX6cKKHWY

The image above shows a hot electrode depositing droplets of molten filler into the weld pool. The arc is surrounded by the gases from vaporizing flux.

ACTIVITY*: Watch the video linked below the image.*

Power supplies can be either AC (alternating current) or DC (direct current) and this can significantly influence welding results. The AC arc travels both way 120 times per second and creates more spatter, less penetration and more arc outages than a DC arc. DC supplies are preferred in stick welding as the current flows in only one direction, using less current, easier arc strike and smaller electrodes. THey can usually be user configured to be DCEP (Electrode Positive) or DCEN (Electrode Negative).

In DCEP (reverse polarity) electrons travel from the work piece into the electrode and this creates deeper weld penetration and "the best welding arc characteristics".
In DCEN (straight polarity) current flows toward the work piece from the electrode which provides shallower weld penetration with high electrode melting rates. (Miller iOS app & Jeffus, p.54) Understanding power supplies is important as electrodes are discerning sticks and need to be properly matched for effective welds.

All stick electrodes are coated in flux. Miller iOS app explains its four purposes:

- To shield the weld from atmospheric contaminants
- Stabilise and guide the arc
- Support slag generation, deoxidisers and scavengers
- Add elements to weld chemistry.

Here some slag is chipped away to reveal a (dubious) weld. Also notice the spatter created by a combination of poor technique and an AC power source.

Stick electrodes are classified to the AWS system where a code system indicates their critical properties and helps welders select the right type.

As an example in this code **E7018-X**

E Indicates that this is an electrode

70 Indicates how strong this electrode is when welded. (Measured in thousands of pounds per square inch.)

1 Indicates in what welding positions it can be used.

8 Indicates the coating, penetration, and current type used. (See Classification Table below)

X Indicates that there are more requirements. (See Additional Requirements below)

WELDING POSITIONS

1 Flat, Horizontal, Vertical (up), Overhead

2 Flat, Horizontal

4 Flat, Horizontal, Overhead, Vertical (down)

Flat Position	Usually groove welds, fillet welds only if welded like a "V"
Horizontal	Fillet welds, welds on walls (travel is from side to side).
Vertical	Welds on walls (travel is either up or down).
Overhead	Weld that needs to be done upside down.

Take note of current types below as this is important setup information

CLASSIFICATION TABLE

Class	Electrode Coating	Penetration	Current Type
Exxx0	Cellulose, Sodium	Deep	DCEP
Exxx1	Cellulose, Potassium	Deep	AC, DCEP
Exxx2	Rutile, Sodium	Medium	AC, DCEN
Exxx3	Rutile, Potassium	Light	AC, DCEP, DCEN
Exxx4	Rutile, Iron Powder	Medium	AC, DCEP, DCEN
Exxx5	Low Hydrogen, Sodium	Medium	DCEP
Exxx6	Low Hydrogen, Potassium	Medium	AC, DCEP
Exxx7	Iron Powder, Iron Oxide	Medium	AC, DCEN
Exxx8	Low Hydrogen, Iron Powder	Medium	AC, DCEP
Exxx9	Iron Oxide, Rutile, Potassium	Medium	AC, DCEP, DCEN

(Adapted from www.red-d-arc.com, n.d.)

The Miller iOS app (2015) lists the techniques required lay down better stick welds.

- The stick electrode must be compatible with the material to be welded, and the technique being used otherwise the weld will probably be lower quality.

- Stick welding requires flux to be evenly deposited around the arc, therefore a position where the stick rises vertically from the weld joint, or leaning out to no more than 20° off is ideal.
- The electrode tip should be kept off the weld surface by about the same thickness as the electrode itself (excluding flux). This gives an ideal rule of thumb arc length.
- Arc travel speed is a matter of experience. A fast "stringer bead" will be about the length of the electrode whilst a weaving action will use more electrode in a shorter distance. With experience welders can determine the optimal bead thickness and height.
- Amperage must be adjusted to the electrode size and to ensure complete melting of both the electrode and its flux based coating.

Before welding Abelson & Pateman suggest, now that you have prepared the joint, selected a suitable electrode and set the amperage, to get comfortable and rehearse the movement of your hand through the welding zone. (p. 122-123).

Starting a weld can be challenging for students although it is a simple, repeatable technique not too dissimilar from striking a match (Vasue, p.48). Ensuring your mask is on (assuming it is an auto mask), hold the electrode about 5cm from a piece of scrap metal. Bring the electrode down sharply onto the scrap and drag 5cm and lift. This should remove any flux from the end of the rod and hopefully generate sparks as the electrode is dragged along. Bring it up and repeat a little more slowly, this is putting heat into the electrode and establishing some hand eye coordination for the welding novice. Following the third strike keep the electrode to within a few mm of the scrap metal and work on keeping the arc energized whilst slowly drawing the stick towards you. If you stick the electrode to the metal a 'dead short' occurs. **DO NOT PANIC** and throw the scrap metal/work piece around! Just quickly release the electrode from the stick holder and then safely cut it off and start again (Vause, p. 48).

An excellent instructional for striking an arc is on Chuck's YouTube channel https://youtu.be/SzDuQpHId10

With practice and further instruction you will gain confidence and understanding of stick welding techniques.

ACTIVITY: *Download this detailed stick welder's user guide and refer to it before, and as you improve your knowledge and technique in stick welding. http://www.millerwelds.com/pdf/guidelines_smaw.pdf*

This guide has an electrode and amperage guide which is very important for welders to use.

ACTIVITY*:*

1) Name an electrodes with these characteristics

   a. smooth easy fast with low penetration
   b. Suitable for very low amperage
   c. Suitable for cast iron
   d. Suitable for stainless steel

Electrode manipulation is technique of moving the electrode tip about the metal seam as it is arcing. This creates different welding beads as indicated by Miller (2013, p. 10):

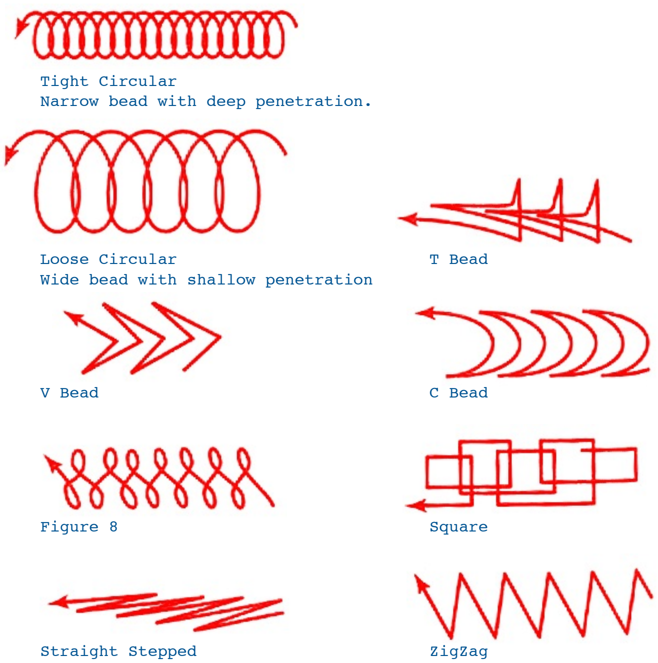
- A stringer bead is a straight weld with no manipulation
- A weave bead uses side to side almost zigzig manipulation
- Advanced weave patterns can cover wide areas in one pass but should not be more than 2 ½ times the electrode thickness.

Activity

The direction and angle of the electrode along the weld seam has an effect on the weld's depth & width. Research this and sketch 4 different techniques and weld cross sections for angled-pushed, vertical-pushed, angled-pulled, vertical-pulled. Is the angled-pushed shallow and wide, and is the angled-pulled deep and narrow?

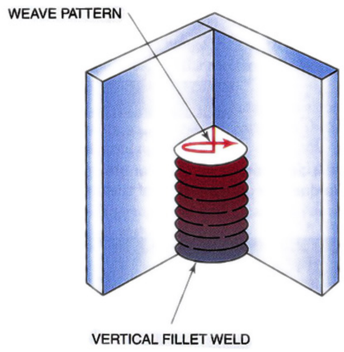
Electrode Manipulation & Welding Weave Patterns

Often welders have their favoured weave patterns yet each can be well suited to certain joint types and welding conditions. This is a summary of some weave patterns.



Magic Weaving Pipe Weld

http://bit.ly/1EeyBAF



Adapted from Jeffers, 2008, p. 77-78.

Slag is a by-product of the welding process and must not mix into the weld, instead it should rise to the surface and harden. A short arc with continuous even electrode melt assists this to occur. Always allow slag time to cool before chipping and always remove slag before laying further welds. Slag inclusion is a significant fail in welding as it reduces the weld strength. Slag also allows the weld to cool slowly which promotes ductility. Welders know where their slag is as is a much brighter yellow than pure molten metal (Vause, p. 20).

MIG Welding (GMAW)

MIG (Metal Inert Gas) Welding is known in some parts of the world as Gas Metal Arc Welding (GMAW).

MIG Welding, like oxyacetylene and stick welding employs extremely high temperatures (up to 6000°C) to create a fusion of the parent metal and the filler electrode. The metals coalesce and quickly cool into a weld. MIG welding differs from oxy-acetylene welding in that it uses an electrical arc to generate welding temperatures and shields the weld from oxidisation through delivery of an inert gas over the weld site (Vause, 2002, p. 81). Stick welding also utilises an electric arc but instead uses super heated flux from the welding rod's coating, rather than MIGs blanket-like gas delivery to shield the weld. MIG welding also uses a long form wire roll of filler metal to act as the electrode being continuously fed into the arcing weld.

MIG equipment includes:

- Compressed gas cylinder/s contain blends of shielding gas that isolate the weld from atmospheric contamination. A range of blends including argon, carbon dioxide, helium and oxygen are used, depending on variables such as the material being welded and the technique employed.

- Gas is transferred from the cylinder to the MIG gun inside a hollow work cable. As gas leaves the cylinder its pressure and flow are regulated by a gas regulator/flow meter.

- The same work cable also feeds electrode wire from the wire feeder to the mig gun tip.
- The power source converts 240AC mains power to a constant source of regulated DC power that can be controlled by the user. Wire feed speeds directly alter the amperage whilst voltage is user selected by the user.

- The MIG gun allows the welder to deliver the shielding gas, electrode filler wire and electrical current to the weld. They have a trigger to begin wire feed and gas flow, a nozzle to direct gas flow and a tip from where the electrode exits.
- Negative (Earth) clamp to work Piece
- Wire feed unit which delivers the spooled electrode wire into the work cable. Sometimes these are housed inside the power supply chasis and sometimes as a separate unit.

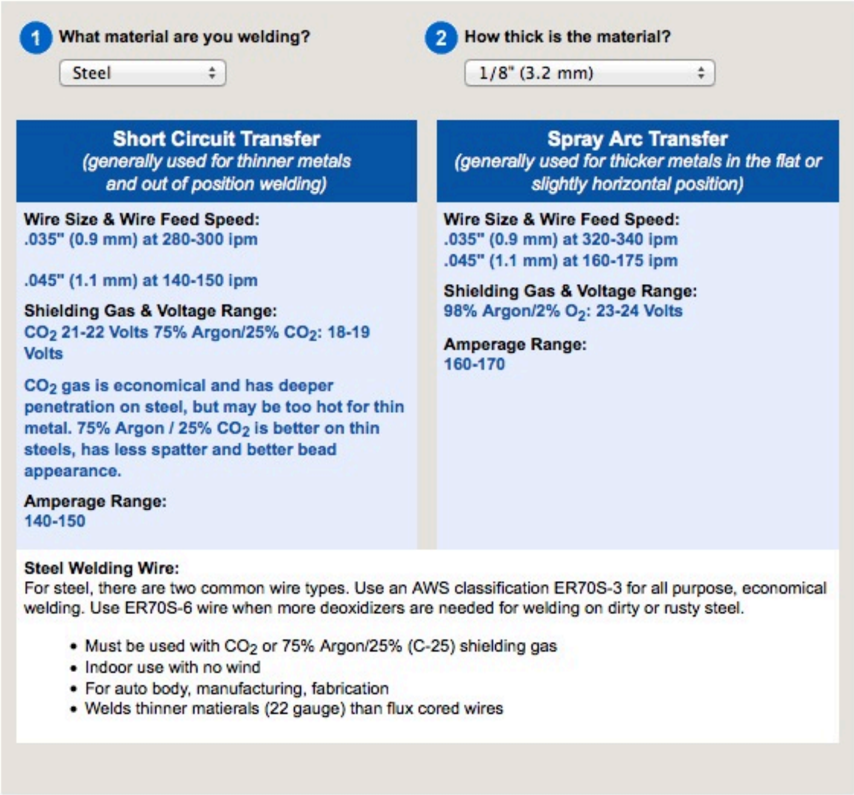
Ableson & Pateman (1988) advise MIG welding is particularly suitable for welding thin metals such as car bodies and sheet metal" (p. 128). However MIG is also entirely capable of welding thick sections of solid plate with the right power, consumables, settings and technique. A suitable setup technique for thin metals is known as short circuit transfer, whilst thicker metals are welded with spray arc transfer (also known as axial spray metal trf).

There are several other metal transfer types including globular and pulsed-arc but these are probably not relevant at this level.

Short circuit transfer uses lower wire feed sped/low current and Jeffus explains it is the most common MIG method used. The electrode wire is allowed to enter the weld pool creating short circuit. It is a somewhat forgiving process tolerating a range of electrode diameters and shielding gas blends. Conversely spray arc metal transfer is MIG on steroids with a high current arc creating hundreds of tiny molten drops and leaving the work area almost spatter free.

Understanding the complexity of accurate setup for any given weld is a trade skill and not something within the narrow scope of this workbook. Millerweld.com (MIG app) explains MIG is a versatile process capable of welding "most metals and alloys" because "the electrode wire and shielding gas can be matched to the weld material.

21st century learners can now quickly harness the power of various apps available over the web and for smartphones that do all the heavy lifting to inform welders of their ideal MIG setups.



http://www.millerwelds.com/resources/calculators/mig_solid_amperage_calculator.php

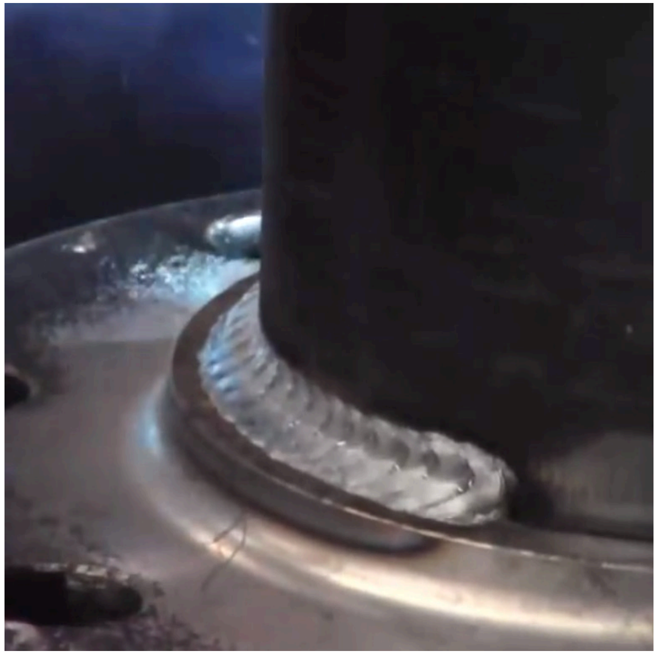
Activity

Find and install (sorry Android users) the iOS app "Miller weld setting calculator". Androiders, seek out the browser based calculator on millerwleds.com. Make a list of your shielding gas, electrode thickness, offcut metal types/thicknesses and power supply range. Establish some settings using short circuit and spray arc transfer and record them in your portfolio.

Activity 2

Using the recommended settings perform some practice welds, photograph them and also add to your portfolio.

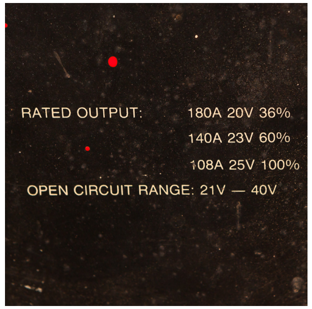
Great example of handheld single pass MIG weld on heavy pipe using a rotary work bench.



https://youtu.be/GPx7dyBazjk

Refer the diagram "common welds across common joints" to appreciate the possibilities when MIG welding. MIG welding offers several benefits in that it welds most common metals and is relatively simple to perform, properly setup it has a high deposition rate and because it uses wire rolls can run very long welds without stopping. It doesn't create slag and can be performed in various standard and difficult positions. Wind or strong ventilation must be managed or the shielding gas can be prematurely blown away (Miller iOS app). Other MIG issues are that is can laydown good looking welds that actually have low strength through lack of penetration, small bottles of shielding gas is relatively expensive and large cylinder rental is also costly (Lofting, 2013, p. 85).

The power supply's duty cycle should be considered as the benefit of potentially long runs might be unachievable because the power supply can only run part time at high amperages. This image shows a duty cycle for a MIG welder.



Once your equipment, settings, safety and work piece (and clamping) are in place practice a weld. Jeffus explains "the most common problem with gas metal arc [MIG] welding is caused by uniformed welders". Therefore the best welding technique advice this inexperienced author offers is for the visual learners to hit Youtube. Several excellent channels include Miller Welders, ChuckE2009, weldingtipsandtricks and WeldFever.

ACTIVITY

Research the two general methods for torch position (keyword hint "MIG", "pull" & "push" and direction of travel and note and the different weld characteristics, and their benefits, in your own portfolio.

FINAL ACTIVITY

In your travels be observant of all the metal joinery described in this workbook. Machinery, transport, construction, production and art, it's all around us. Has the information in the workbook helped you to appreciate human kind's ingenuity and engineered problem solving and solutions?

I hope it has better equipped you to tackle your next project in safely, reliably, efficiently and skillfully joining metals together!

Cameron Mills, 2015.

Adapted from http://www.browndogwelding.com/custompricing/

References

3m.com.au. (n.d.). *3M Scotch-Weld Instant Adhesives*. Retrieved from http://bit.ly/1IjwGt8

American Welding Society. (2005). *Safety in welding, cutting and allied processes*. Retrieved from http://www.aws.org/technical/facts/Z49.1-2005-all.pdf

European Aluminium Association. (1994). *Definition and classification of mechanical fastening methods*. Retrieved from http://www.alueurope.eu/talat/lectures/4101.pdf

Henkel N.A. (n.d.). Metal Bonding|Metal Adhesives - Henkel North America. Retrieved from http://www.henkelna.com/industrial/metal-bonding-structural-adhesive-13573.htm

How arc welding works [Animated image, Youtube]. (n.d.). Retrieved from http://www.youtube.com/watch?v=TeBX6cKKHWY

Jeffus, L. F. (2004). *Welding: Principles and applications*. Clifton Park, NY: Thomson/Delmar Learning.

Kosmač, A. (2013). *Adhesive bonding of stainless steels*. Retrieved from Euro Inox website: http://www.euro-inox.org/pdf/map/Adhesive_bonding_EN.pdf

Loctite Products. (2014). *Technical data sheet - Epoxy Weld Bonding Compound*. Retrieved from http://www.loctiteproducts.com/tds/EPXY_WELD_T_tds.pdf

Lofting, R. (2013). *Welding*. Wiltshire: The Crowood Press.

Millerwelds.com. (2012). *Handbook for resistance spot welding*. Retrieved from https://www.millerwelds.com/pdf/Resistance.pdf

Millerwelds.com. (n.d.). *Guidelines for shielded metal arc welding (SMAW)*. Retrieved from http://www.millerwelds.com/pdf/guidelines_smaw.pdf

Millerwelds.com. (n.d.). Miller iOS application. Retrieved from https://itunes.apple.com/au/app/miller-weld-setting-calculator/id452837820?mt=8

Red-D-Arc Welderentials. (n.d.). *Welding electrode clasifications*. Retrieved from http://www.red-d-arc.com/pdf/Welding Electrode Classifications.pdf

Riveting - SHF - John Oxley. (n.d.). Retrieved from http://johnoxley.org.au/explore-the-fleet/john-oxley-1927-steam-ship/restoration/how-is-it-done/riveting

Rivets. (n.d.). Retrieved from http://www.roymech.co.uk/Useful_Tables/Rivets.html

thefabricator.com | Designing for adhesive bonding. (2013). Retrieved from http://www.thefabricator.com/article/assembly/designing-for-adhesive-bonding

TokenTools. (n.d.). Arc Welders Under 150Amps. Retrieved from https://weldingstore.tokentools.com.au/arc-welding-equipment/arc-welding-machines/inverter-arc-welders-less-than-150-amps.html

Tooling U-SME. (n.d.). *Threaded Fasteners Training Overview | Tooling U*. Retrieved from http://www.toolingu.com/class-700117-overview-of-threaded-fasteners-117.html

Vause, W. A. (2002). *The art of welding*. Dorset: Special Interest Model Books.

Youtube: OxyAcetylene welding [Video file]. (n.d.). Retrieved from https://youtu.be/l6HVJHsOGa0

Youtube: Oxyacetylene welding [Video file]. (n.d.). Retrieved from https://youtu.be/pVv8a_FVIOU

Youtube: Plasma vs oxy-fuel cutting [Video file]. (n.d.). Retrieved from https://youtu.be/DWiZSK7vBxY

Youtube: Resistance spot welding [Video file]. (n.d.). Retrieved from https://youtu.be/AwL1CAg43PU