*Literacy and Essential Skills in Industrial Arts*

# *WELDING COURSE*

ESSENTIAL SKILLS

# *Student Notes*

**A project of Literacy Ontario Central South**

Canada
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Literacy Ontario Central South

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# DISCLAIMER:

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This manual is intended to provide an opportunity for students to learn about the Essential Skills and Welding in both a real life situation and an LBS environment. This manual provides basic guidelines for safe practices inside a literacy setting. Do not assume, therefore, that all necessary warnings, precautionary measures, and legal standards are contained in this document and that other or additional measures may not be required.

The opinions and interpretations in this publication are those of the author and do not necessarily reflect those of the Government of Canada.

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# ORIENTATION

## WELCOME

**Document Use**

Welcome to introduction to welding art.

This course was designed with four primary goals.

1. To help you develop your Essential Skills; skills that will help you in your "work, learning and life"
2. To help you develop technical skills for a hobby as well as for work
3. To help you develop your artistic and creative abilities
4. To give you the opportunity to have fun, meet new people and expand your network of contacts

Call the instructor to let them know if you are unable to attend a class.

## COURSE FORMAT

**Reading Text, Document Use**

In addition to the information in these Student Notes, this course will be presented through a mix of group instruction, demonstration and discussion, followed by independent work.

There will be times when your instructor may ask you to stop what you are working on so that they can provide information to the entire class.

It will be important that you ask other students for help. Helping each other and sharing ideas and opinions is a great way to learn.

Before you are asked to complete any step in this welding course, your instructor will provide a demonstration.

Your instructor will:

- demonstrate the safe use of all the welding tools and equipment you will need in this course
- demonstrate all of the techniques you will be using to complete your project
    - This will include a group demonstration of welding and cutting techniques

You will then have the opportunity to try all of the tools, equipment and techniques while working independently on your project.

The instructor will be available to answer your questions and provide individual support and guidance as you work, so ask them questions anytime.

## *STUDENT NOTES*

**Reading Text**

Although this course will focus on oral instruction and hands-on work you will also have information and instructions to read.

In this package you will find all the Student Notes for this course. You will be asked to read a section of the notes during each class. If you prefer, you can read the material at home. You can also read ahead in the notes.

These Student Notes include information that will help you learn more about the topics presented and demonstrated in class. They can also be used as a reference and guide as you work on developing your welding skills.

There is a Table of Contents at the front of these Student Notes to help you find the information you need.

At the end of course you can take these notes home with you. They will be helpful as you work on future welding projects.

**Note**: You can record your own notes on the pages of these Student Notes.

In your Student Notes, you will find web links. If a recommended site is no longer available, please inform your instructor.

You will be working at your own pace therefore you may find that you are ahead or behind in the notes. Talk to your instructor if you have any concerns.

## *ICON LEGEND*

**Reading Text, Document Use**

Throughout this course you will see icons in the written material. These icons are designed to help you visually identify the content of the section you are reading.

Icons Include:

STUDENT NOTES – At the top of each page of Student Notes you will find this icon on the left side, followed by the name of the section on the top right side. This icon and the section titles will be helpful if you are looking for information listed in the Table of Contents.

ESSENTIAL SKILLS – Under each section heading you will notice this icon, bordered by two lines. The icon will be followed by a list of words. These words represent the Essential Skills you would use if you actually completed the steps outlined in the section. For example, if the text states that you need to "measure the electrode stickout" you would find Numeracy listed as an Essential Skill. This list will also identify the Essential Skills you are using as you read the information in the section. For example, Reading Text will be listed if you need to read more than two sentences in the section. Document Use will be listed if you need to read a bulleted list or complete a document.

TASK – If you see a “T” at the top of a page, you will find step-by-step directions for completing an Essential Skills task. These tasks are designed to help you develop your Essential Skills while at the same time providing information that will help you gain the skills you need in welding. In most cases the tasks will be handed out during class and you will be given time to complete them before the class ends. Some tasks are designed to be completed independently and others are designed to be done in large and small groups.

When you see this image in a box on the page there will be some additional information to consider.

## *ESSENTIAL SKILLS*

**Reading Text**

We consider the Essential Skills component of this course to be very important. These skills provide the foundation that makes it possible to learn all other skills. There are nine Essential Skills; Reading Text, Document Use, Numeracy, Writing, Oral Communication, Working with Others, Thinking Skills, Continuous Learning and Computer Use.

Essential Skills are used every day at work, at home and in a welding shop. While these skills are important in your personal life they are essential for success at work. Essential Skills will help you find and keep a job and manage change in the workplace.

Essential Skills are transferable. This means that the same skill can be used in different situations. For example, in this welding course you will have many opportunities to develop your problem solving skills. You may find that the next time you have a problem at home, at school or at work, your problem solving skills will be stronger.

## *THE NINE ESSENTIAL SKILLS*

**Document Use**

Experts have identified the nine Essential Skills required for success in the Canadian Workforce.

For more information visit:

www.hrsdc.gc.ca/eng/workplaceskills/essential_skills/general/home.shtml

Essential Skills Include:

**Reading Text**

Reading materials in the form of sentences or paragraphs

**Document Use**

Tasks that involve a variety of information displays in which words, numbers, symbols and other visual characteristics (e.g. lines, colours or shapes) are given meaning by their spatial arrangements

**Numeracy**

Using numbers and thinking in quantitative terms to complete tasks

**Writing**

Writing text and writing in documents, such as filling in forms, and non-paper-based writing such as typing on a computer

**Oral Communication**

Using speech to give and exchange thoughts and information

**Working with Others**

Employees working with others to carry out their tasks

**Thinking Skills**

The process of evaluating ideas or information to reach a rational decision. They include six specific skills:

**Problem Solving**

Addressing problems that require solutions

**Decision Making**

Deciding between options

**Critical Thinking**

Assessing, evaluating ideas or information to reach a rational judgment of value

**Job Task Planning and Organizing**

Planning and organizing tasks

**Significant Use of Memory**

Memorization of procedures, codes, numbers, remembering information, learning from an experience

**Finding Information**

Using text, people, databases or systems to find information

**Continuous Learning**

Workers participating in an ongoing process of acquiring skills and knowledge

**Computer Use**

Using different kinds of computer applications and other related technical tools

## *ESSENTIAL SKILLS CHECKLISTS*

**Reading Text**

As you work on your welding skills, read your Student Notes and complete the assigned tasks, you will be developing your Essential Skills.

There will be time at the end of each class to talk with the others in your group about the Essential Skills you used in the class.

There will also be time at the end of each class to complete your own individual Essential Skills checklist. As you complete the checklist you will have the chance to identify all of the Essential Skills you used in the class.

After you have read these introductory notes, you will be able to check off Reading Text on your Essential Skills checklist.

# *ESSENTIAL SKILLS IN WELDING*

**Reading Text, Document Use**

Welders need to draw on their Essential Skills in all nine areas; however welding demands that the welder have a higher skill level in some areas. For example, welders need to have strong numeracy skills.

Essential Skills Examples for Welders:

- Welders need a knowledge of applied mathematics (e.g., fractions, measuring) and geometry (Numeracy)
- They need to be able to spot problems and solve them as they work (Thinking Skills, Problem Solving)
- They need to communicate clearly with co-workers and clients (Communication)
- Welders must read blueprints and job specifications (Document Use)
- They may work independently and/or as a member of a team (Working with Others)
- Welders need the ability to plan projects and think in steps (Job Task Planning and Organizing)
- Welders must be committed to ongoing learning and skill development (Continuous Learning)

On the other hand, writing is not an Essential Skill that would be critical to the success of a welder, even though at times they may need to record information or write notes to customers.

## *TECHNICAL SKILLS*

**Document Use**

In addition to the Essential Skills you will develop in this class, you will also develop technical skills when you begin to weld.

The technical skills you may develop in this course include:

- setting up and using a Gas Metal Arc Welder and Gun
- welding stringer and weave beads
- using tools, e.g. a grinder
- measuring and calculating
- converting from Imperial to SI

You will also develop:

- form perception
- motor coordination
- manual dexterity

## *CAREER EXPLORATION*

**Reading Text, Document Use**

**Thinking Skills: Critical Thinking**

Although this welding course is not designed to prepare you for a specific job, you may discover that you have the skills and interests necessary for a career in welding. If you enjoy this course, you may want to research careers where welding skills are needed.

There are two groups of metal:

**Ferrous metals**: metals that contain iron.

**Non-ferrous metals**: all other metals and alloys that have no iron content.

The National Occupational Classification States:

- Welders operate welding equipment to weld ferrous and non-ferrous metals. This unit group also includes machine operators who operate previously set up production welding, brazing and soldering equipment. They are employed by companies that manufacture structural steel and platework, boilers, heavy machinery, aircraft and ships and other metal products, and by welding contractors and welding shops, or they may be self-employed.

http://www5.hrsdc.gc.ca/NOC/English/NOC/2006/ProfileAlphabetic.aspx?val=7&val1=7265&val10=W

Welders are often involved in the initial fabrication of machines and equipment. They may also complete maintenance and repair work. Welders are needed in the construction, auto, steel and aerospace industries.

Some people will work as full-time welders but many companies need people who can weld on occasion.

If you are thinking about a career in welding, consider the following lists.

For more information and an entire list of job titles visit:

http://www5.hrsdc.gc.ca/NOC/English/NOC/2006/QuickSearch.aspx?val65=7265

Welders Must:

- read and follow blueprints or welding process specifications
- set up, operate, adjust and shut down welding machines
- operate cutting torches
- apply a knowledge of ferrous and non-ferrous metals
- assess welds and make adjustments and corrections as they work
- troubleshoot problems with equipment
- complete measurements in both SI (Metric) and Imperial
- assess angles and complete calculations
- solve problems and make decisions
- understand and apply all safety procedures

Welders must be able to:

- focus and pay attention to detail
- observe (watching and listening)
- avoid distractions
- work in small spaces
- stay physically fit
- demonstrate excellent hand-eye coordination
- have good eyesight

## *SUMMARY*

**Reading Text**

In addition to developing the skills needed to weld, you will also develop Essential Skills and technical skills that will help you at work, school and at home.

As mentioned, there are many jobs that require skills similar to the ones you will be developing. As you work through this course, think about your interests, skills and career. At the end of each day, ask yourself, “What skills did I develop that I could add to my résumé?

# SAFETY

## INTRODUCTION

**Reading Text**

As you know this course is an introduction to Gas Metal Arc Welding (GMAW). GMAW is one of the many welding techniques that use an electric arc to melt metal.

This section of your Student Notes will focus on working safely in a welding shop and in this GMAW welding class. This includes your own safety as well as the safety of those around you. If you don't work safely you can be exposed to the risk of serious and life threatening injury.

Unsafe practices will expose you to the risk of burns from metal, flames, sparks and spatter, as well as exposure to fumes and gases. You could also be exposed to the risk of burns and eye damage from arc rays. You will use welders and other equipment powered by electricity, which exposes you to the risk of shock. You may need to chip or grind metal which can produce sparks and flying metal. Last, but not least, welders work with high pressure gases in cylinders that could explode if not handled properly.

All of these risks can be greatly reduced or eliminated by following proper safety procedures. Additionally, there have been advances in the welding tools, equipment and safety clothing you will be using. There should be no reason why you can't work safely, free from the dangers that have been associated with the welding trade.

**Note**: This section is only an introduction. Your welding instructor will provide you with a detailed safety lesson before you begin welding.

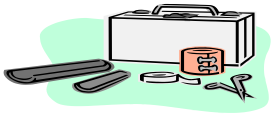
As mentioned, you are responsible for your own safety and the safety of those around you, so please follow the instructions provided by your instructor, read this section of your Student Notes and apply all of the recommended safety tips whenever you are watching demonstrations or working on your own project.

## *ACCIDENT REPORTING*

**Reading Text, Oral Communication**

Minor injuries can be treated with items found in a First Aid Kit; however, we ask that you inform your instructor if you have an injury, even if your injury seems like a minor one.

We also ask that you immediately report any spills, accidents, and/or damage to any tools. An instructor will be able to assist you with clean up and repairs.



## *BURN SUMMARY CHART*

**Reading Text, Document Use**

Serious accidents are rare, but it is important that you work with caution. You may be working with an acetylene torch which can produce a flame up to 3,482° Celsius (6,300° Fahrenheit), hot enough to preheat metal to 871° Celsius (1,600° Fahrenheit). To put that into perspective, water boils at about 100° Celsius (212° Fahrenheit).

| Degree | Skin Identification | Healing | Treatment |
|---|---|---|---|
| First Degree | Red and painful | Healed in 3-6 days | Soak area in cool water, apply antibiotic ointment and cover with gauze |
| Second Degree | Red or splotchy, painful, swollen with blisters | Healed in 2 to 3 weeks | Soak in cool water, see your doctor, apply an antibiotic cream, leave blisters, cover with new dressing daily, check your tetanus record, watch for infection, protect it from sunlight and do not scratch |
| Third Degree | White and charred, may not be painful because of nerve damage | Long healing process | **Seek Immediate Emergency Medical Attention** |

- Never put anything oily on a burn, it will make it worse
- When in doubt seek medical attention

## *SAFETY TIPS*

**Reading Text, Document Use, Oral Communication**

**Thinking Skills: Critical Thinking, Decision Making**

The safety tips in this section will focus on welding, although many of these tips are transferable to other situations. The tips in this section should be applied whether you are working on your project or watching a demonstration.

Be Alert:

- Work only when you are well rested
- Do not work with tools, equipment or chemicals if you have been drinking alcohol or using drugs
- Focus on the job at hand
- Inspect each tool before you begin
- Be aware of the movement of others
- Know where the fire extinguisher and First Aid Kit are located
- Never smoke or allow anyone else to smoke in your work area

Follow the Rules:

- Read manuals and follow all safety procedures
- Wear the appropriate clothing and protective gear for the job you are doing
- Listen carefully to your instructors and follow their direction
- Follow all written instructions
- Read labels and Material Safety Data Sheets (MSDS) for all products
- Be able to recognize symbols, for example:

**Workplace Hazardous Materials Information System (WHMIS) symbol for:**


Compressed Gas


Flammable and Combustible Material

**Restricted Product Labels for:**


Explosive


Flammable

**Note**: WHMIS training is not part of this course. You can sign up for a WHMIS course or wait until you have the opportunity to complete the course as part of your on-the-job training.

<u>Organize Your Work Area:</u>

- Return everything to its proper place
- Remove any hazards from your work area
    - Anything flammable, volatile or explosive
- Store gas cylinders in a separate, protected area
- Have a place for your tools and always return them
- Clean your work area and pick up anything on the floor
- Design your work area to be safe and efficient
- Ensure you set up your work area where you have good ventilation

Handle Tools and Equipment Safely:

- Talk to your instructor before using any tools or equipment
- Read manuals and safety guidelines before using power tools
- Follow all manufacturers' safety guidelines
- Wear all the recommended safety equipment
- Inspect all tools and equipment before you begin
- Check power cords for damage or wear
    - Never leave cords lying across the floor or near heat
    - Never twist or tangle power cords
- Unplug tools before working on them, adjusting them or setting them up
- Ensure that your work area is tidy before you begin
- Safely store or hang up tools when you are finished

Hammer injuries are listed as one of the top five metal worker injuries. This includes eye injuries from metal shards flying off hammers.

**RPM**: refers to the number of times something rotates in a minute - Revolutions Per Minute.

**Note**: Never touch a spinning grinder. The grinder spins a disk at speeds of up to 10,000 RPM's and it can cut to the bone in an instant.

Plan Ahead:

- Think through all of your steps before you begin
- Have a plan for your finished work
    - Know where you will set hot metal to cool
    - Know where you will set your torch

## *WELDING GEAR*

**Reading Text, Document Use**

**Thinking Skills: Decision Making**

This section lists the gear you will need for GMAW welding; however some of the items can be used for other types of welding. Welding gear should be worn when you are welding and when you are watching a welding demonstration.

Clothing:

- Select heat and fire resistant clothing that will protect you from high temperatures, sparks and flames
  - Choose heavy clothing made of tightly woven natural fibers
  - Leather, cotton or wool are good choices because natural fibers are flame resistant - synthetic fabric such as nylon can melt to your skin
- Wear long sleeved, non-flammable welding jackets/shop coats/coveralls
- Wear long pants that cover the tops of your shoes or boots
  - This prevents hot metal from falling inside your shoes
- Wear long sleeved shirts and tuck your shirt into your pants
- Wear light weight, high top, leather, steel toed shoes or boots with rubber soles (synthetic shoe scan melt)

- Wear a cap, that will fit under your helmet
  - Make sure your hair is tied back
- Remove anything flammable from your clothing
  - Check your pockets
  - Remove things such as lighters and matches
  - Check that your clothes are oil free

- Avoid wearing anything that could trap hot metal or sparks
    - For example, avoid cuffs, open neck shirts and baggy pockets
- Wear old clothes in case your clothes are damaged
    - However, don't wear anything baggy or frayed
    - Save money by shopping at second hand clothing stores
- Remove rings or jewellery before you begin

**Decibel**: The loudness of a sound is measured in decibels (dB). The sound of a hammer hitting metal can be above 85 dB, a powersaw 110 dB.

For more information visit: http://www.gcaudio.com/resources/howtos/loudness.html

Safety Equipment:

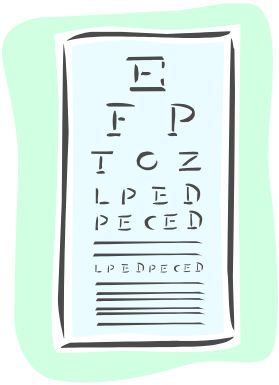
- Wear approved safety glasses (clear lenses, not tinted or reflective) with side shields to protect your eyes from sparks and flying metal
    - Wear safety glasses when you are chipping, grinding, filing or using a wire brush
    - You can buy CSA approved prescription safety glasses
- Wear leather work gloves designed for GMAW welding
    - Select gloves with gauntlets (the wide cuff that extends past your wrist)
    - Select light, unlined gloves
    - Check your gloves for damage before using
- Wear ear protection
    - Noise can cause you to feel tired, which can increase the chance of accidents
    - Your hearing can be damaged if you are exposed to sounds over 90 decibels for extended periods of time

Welding Helmet and Shield:

- Wear an approved welding helmet
  - Match the helmet to the type of welding you are doing
  - Welding helmets have darkened shields/visors designed to protect your eyes and face
  - Wear a helmet and shield whenever you are welding or watching someone else weld
- Select shields/visors appropriate for the type of welding you are doing
- The shade of visor you need is based on the amperage you will be using
- For GMAW, choose a visor with a #10 filter
- Remember, before you pull the trigger/strike an arc, lower your shield
- Lower your shield if you are near other welders or are watching a demonstration
- Wear safety glasses under your welding helmet

**Note**: A visor/shield will protect your eyes from exposure to arc rays. Brief exposure to electric arc rays can inflame your cornea, burn your retinas or any exposed skin. In the short term, exposure can cause discomfort, swelling, and in some cases temporary blindness. Long term exposure can result in permanent damage and cataracts. It is essential that welders protect their eyes.

Before you begin welding, arrange to have your eyesight tested. You must be able to clearly see the electrode wire, your weld pool and your weld. Wear prescription glasses if necessary. Good eyesight will mean that you can see your work without having your face near the arc. This will allow you to work safely in a more comfortable position.



## *WELDING SAFETY*

**Reading Text, Document Use, Oral Communication**

**Thinking Skills: Critical Thinking, Decision Making**

The following section will introduce safety tips specific to welding. Topics will include ergonomics, protecting others, the safe use of a welder, the safe use of compressed gas, avoiding fumes, the safe use of electrical equipment, arc safety and chemical safety.

## *ERGONOMICS*

Welders need to be aware of the physical challenges of the job. Welding is demanding work so it is important to be physically fit if you plan on making welding your career.

Welders complete detailed work that requires them to stay in one position for long periods of time and/or work in awkward positions. Welders also use physical force and repetitive motions (gripping, twisting, reaching and bending) which can cause injuries over time.

If you are a hobbyist working on small projects, you will likely have more control over your work environment; however, it is still important to be aware of the physical demands of being a welder.

**Note**: Physical work can cause fatigue, which can lead to mistakes and injuries.

**Ergonomics**: the study of how workspaces and equipment can be designed to be efficient, safe and productive. This includes adjusting the positions of the worker, the tools and the equipment.

The following list applies to welders on the job and in a home workshop.

<u>Protect Your Muscles and Joints</u>

- Adjust the position of your work table so it's comfortable for you
- Have things positioned so you don't need to reach for them

- Stretch before you begin working
- Find the most comfortable position
    - Sit on a stool whenever possible
    - Your body should be well supported
- Find a stable, comfortable position if you must stand
    - If possible, lift one foot onto a stand, keep your back straight, keep your feet apart, with one foot in front of the other
- Keep your elbows close to your body and support your arms
- Place items you are working on at waist or elbow level
    - Just below elbow level if you are sitting
- Select tools that are the right weight for you
- Hold tools properly
- Take breaks and stretch
- Follow these safe lifting guidelines:
    - Ask for help
        - If someone is helping you lift, communicate clearly
        - Use any available lifting aid e.g. a dolly
    - Move to the object rather than reaching for it
    - Bend your knees - don't stoop
    - Bring your chin in to force your back to stay straight
    - Tighten your stomach muscles
    - Lift with your leg muscles
        - Leg muscles are stronger than back muscles

http://healthandfitness101.com/wp-content/uploads/2008/05/lifting-pic.jpg

## *PROTECTING OTHERS*

When you are working near other people, let them know when you are about to start welding.

Anyone in your work area must wear eye protection. Arc rays can reflect off other surfaces, so damage can occur even if the person is not looking directly at the arc. In addition to wearing eye protection people in your work area should also wear safety gear.

**Note**: If you are welding at home, you may consider a rule that states: "No one is allowed in your work area when you are welding". This rule should also include pets. That being said, it is often recommended that welders avoid working alone. If you are welding alone, ensure that others are aware of your activities. Keep a telephone handy in your workshop.

Things to Consider:

- Sparks and molten metal can travel up to 10.7 metres (35 feet) from your weld
- Grinders and other tools will produce sparks
- Keep things off the floor, including cords, so others don't trip
- Let people know when metal and tools are hot
- Never walk away, leaving hot metal on a welding table
    - Someone may try to move it
- Clean up whenever you have finished working

Ideally, you will want to have a protective barrier between your work and other people in your work area. If you can, buy a heat resistant screen and spatter shields or build your own barrier.

## *THE SAFE USE OF WELDING EQUIPMENT*

Before You Begin:

- Check with your instructor before you begin
- Read the manual that comes with the welder or any other tool you are using
- Ensure that your work area is safe and clear of anything flammable
- Check that your welding equipment is in good repair and properly installed
    - Spend 5-10 minutes assessing your equipment before turning on the welder
        - Similar to a circle check done by truck drivers before each trip
    - Ensure that there are no frayed, cracked or bare spots on any cable or cord
    - Check that all connections are tight
- Confirm that the gas cylinder is connected properly (further details can be found further on in this section)
- Ensure that there will be space between your work and any compressed gas cylinders
    - No equipment should ever touch the cylinders, most importantly an electrode
- Double check that your work area is well ventilated
- Read the job/project requirements
- Check that the equipment and settings are right for the job
- Ensure that the equipment and the metal you are welding has been grounded
- Check that you are wearing all necessary safety equipment before you begin
- Use a vise to hold metal securely

Shut Down:

- Hang up the GMAW Gun
- Bleed the gas from the welding machine
- Turn off power and unplug any equipment you are not using

## *THE SAFE USE OF COMPRESSED GAS*

Depending on the methods you are using, you may use a variety of high pressure gases in cylinders for welding, cutting and shielding your work. It is critical that you learn how to use these gases safely. Improper use can result in asphyxiation, fire, explosions and poisoning.

Welders use pressurized oxygen and fuel gasses such as acetylene, natural gas, hydrogen, propane and butane. GMAW uses electricity for heat but requires the use of shielding gases including argon, helium and/or carbon dioxide.

Even though shielding gases are not flammable the cylinders are still dangerous because the contents are pressurized. The pressure in the tanks could be more than 2000 psig, which is enough pressure to cause a very large explosion. There are many stories of damaged cylinder valves causing explosions that send tanks through concrete walls.

The following lists outline some of the steps you can take to stay safe. However, the manufacturers' instructions, labels and directions from your instructor must always take priority.

Some terms you may hear:

**psi**: pound per square inch or pound-force per square inch. The Imperial unit of pressure (one pound of force) on an area of one square inch.

**kPa**: pascal is the SI (metric) unit of pressure.

1 psi = 6.9 kPa

**psig**: pound-force per square inch gauge. A unit of pressure relative to the surrounding atmosphere at sea level.

The earths atmosphere exerts a pressure of 14.7 psi at sea level.

**psia**: pounds per square inch absolute. If you have 20 psi you need to add 14.7 to get the absolutte psi.

psi + 14.7 psi = 34.696 psia

**Note**: In this course you won't need to handle pressurized cylinders. Your instructor will demonstrate and set up anything you need for your practice welds.

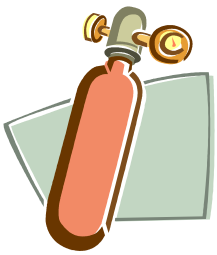
**Note**: The tips in this section are not designed to be followed step-by-step. They may not be in the order that your instructor or the manufacturer recommends. Please ask your instructor if you have any questions.

General Safe Handling Guidelines – Pressurized Cylinders:

- Check that the gas, cylinder and attachments are right for the job
    - Check that everything is in good working order, including the pressure regulator, flow meter, hoses and fittings
- Check that hoses are clear and tangle free - no kinks
- Protect the cylinder from extreme temperatures and harsh weather conditions
- Protect the cylinder from contact with oil and grease
- Mark empty tanks

Moving Cylinders:

- Ask for help moving a cylinder
    - Never drag a cylinder or lay it on its side to roll it
    - Protect cylinders from sudden movements or impacts
- Attach the cylinder to a hand cart
    - If necessary you can tip the cylinder and roll it
        - Keeping the cylinder upright, place one hand on the cylinder cap and one on the shoulder of the cylinder
        - Never lift with the valve



Using Cylinders for Welding:

- Follow all guidelines
    - In this class, your instructor will set up the tanks for you
- Check that you have enough gas in the cylinder to finish the job
    - You don't want to run out part way through a weld
- Attach the cylinder to something stationary such as a wall or support post, away from high traffic areas
    - Chain or strap the cylinder so it won't fall over or tip
    - Never bump or drop a cylinder
- Protect cylinders while you weld
    - Keep the electrode, arc and spark away from the cylinder
    - Never attach anything to or hang anything over the cylinder
- Crack the valve open briefly before installing a regulator
    - This will remove any dirt
- Stand off to the side when opening the valve
- Open the valve slowly until the pressure registers on the regulator, then move it to the correct operating position
- Adjust the flow meter to the correct rate
- Shut off tanks and cover the valve with a cap when you remove the regulator

Plasma, Acetylene and Oxygen:

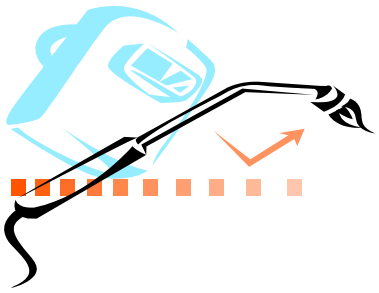
It is possible that you will be exposed to plasma, for plasma cutting and acetylene and oxygen for oxyacetylene cutting. These gases are all stored in pressurized cylinders so follow all safety guidelines and work with your instructor.

Acetylene is a highly flammable hydrocarbon gas. It is mixed with oxygen to produce a high temperature flame. It can burn at temperatures as high as 3,087º Celsius (5,589º Fahrenheit).

Acetylene is lighter than air and is colourless. It needs to be handled with extreme caution.

Plasma is a hot ionized gas made up of ions and electrons. Plasma is a good conductor of electricity and reacts to a magnetic field, but otherwise it has properties similar to those of a gas.

Oxygen is a colorless odorless gas that is necessary for combustion to take place.



Torch and Cutting Tips:

- Your instructor will demonstrate and/or make cuts for you
- Follow all manufacturers' guidelines
- Ensure that there are no flammables in the work area
- Wear proper safety gear
- Stand to the side when you open a tank valve
- Light the flame using an approved striker
    - Do not use a match
- Always point the tip away from your body
- Never direct the flame toward anything other than the metal you are working on

- Never walk around with the torch
- Never leave a torch unattended until it has been turned off, the flame is out and it has cooled
- Hang up the torch when you are finished
- Neatly coil the cables
- Clean your work area

**Flashback**: burning of gases inside the torch body or hoses. You will hear a loud hiss or squeal. Shut off immediately; find the cause and fix it before you continue working.

**Backfire**: a loud pop caused by flames backing up into the tip of a torch. It's caused by overheating the tip (working too close to metal with low gas pressure). Shut off immediately; find the cause and fix it before you contiue working.

**Note**: Never weld or cut any container that has ever held flammable material (gas), even if it is empty. **The container will explode.**

<u>Additional Tips for Using Acetylene:</u>

- Follow the manufacturers' recommendations for the correct pressure and tip size
- Open the valve on the acetylene cylinder no more than ¾-1 ½ turns so it can be closed quickly in case of emergency
    - Open the valve on the oxygen tank fully
    - Remember to stand to the side when you open any tank valve
- Leave the valve wrench in position on the acetylene cylinder as you work
- Check your pressure gauge before you begin
    - Never use acetylene at a pressure over 103 kPa (15 psig) because high pressure can lead to explosions
- Adjust the regulators to the correct pressure for the job

- Check that the reverse flow-check valves and flash arrestors are installed on the oxygen and acetylene lines
- Light acetylene first, the oxygen second
  - **"A" before "O" or up you go!**
- Follow proper shut down procedures
  - Shut off the oxygen first, then the acetylene
  - Close cylinder valves
  - Relieve any pressure from hoses
- Remove regulators and replace protective caps before moving cylinders
- Store oxygen cylinders away from acetylene cylinders

**Fumes**: smoke, vapor or gas.

At a miniumum, exposure to fumes can cause burning eyes and skin, dizziness, nausea and/or fever. In the extreme they can cause long term illnesses or death. For example, carbon monoxide can be fatal.

<u>Tips for Using a Plasma Cutting Torch:</u>

- Wear a respirator
- Ensure that compressed air pressure is 80 PSI
- Inspect the ground cable, torch cable and clamp for damage such as burns or cuts
- Clamp the ground cable to the base metal (the piece you are working on) or the workbench, as close as possible to where the base metal is placed
- Turn the machine on and adjust the cutting amperage dial
- Press the set button to purge the torch for about 5 seconds
- Place the torch tip 1/8 inch away from the metal you want to cut
- Squeeze the trigger

## *AVOIDING FUMES*

The process of welding can create fumes and smoke that will rise up from the weld area. Some fumes will be more harmful than others.

Fumes contain very tiny particles suspended in the gas. These particles come from heating the wire electrode and the base metal and from coatings on the metal. The gases often include ozone, nitrogen dioxide, carbon monoxide, carbon dioxide, hydrogen chloride and phosgene. You can't see or smell these particles so it is easy to forget about them.

<u>Precautions:</u>

- Read and follow the Material Safety Data Sheets (MSDS), labels and the manufacturers' instructions for any products you use
- Don't breath the fumes
    - Keep your face out of the welding zone
    - Wear a respirator if necessary
- Only work in a well ventilated area
    - Use an indoor ventilation system or a ventilation system directed at the arc
    - Keep the windows open
    - Use a portable fan to keep the air moving
        - **Note**: You will need to protect your work from drafts
- Remove any chemicals from the work area
- Remove any dirt, coatings, paints or oils from the metal
- Know the metal you are welding
    - Avoid welding any metal that has a shiny finish e.g. chrome plating
    - Never weld coated metals such as galvanized, lead, or cadmium plated steel

- Know the gas and wire electrode you are using
- Don't weld alone and keep others informed of your activities

Illness from Fumes:

- Never heat metal that contains cadmium. It can cause Cadmium Pneumonitis which is fatal. It is found in metal plating, nickel-cadmium batteries, pigments, plastics, synthetics, coatings and paint
- Metal Fume Fever is an illness caused by breathing metal fumes such as zinc oxide, (galvanized sheet metal) magnesium oxide or chromium
- Copper alloys may contain beryllium which is highly toxic
- Paint may contain lead, chromium and zinc

## *SAFE USE OF ELECTRICAL EQUIPMENT*

Whenever you are using electrical equipment it is important to follow safety procedures. Arc welding uses electricity to generate heat. This makes electric shock a potential risk for welders. For example, if a welder touches any part of the electrical circuit while they are touching the base metal, they could experience a shock up to 80 volts.

The human body ranges from 55-78% water and water is a good conductor of electricity. If your body is exposed to electricity the current will flow through you to the ground. This can result in a mild shock, serious burns, paralysis or death.

There are many factors that will affect the seriousness of an electric shock; including the surface area of the contact, where the current flows in your body and the environment (e.g. humidity). The key is to do whatever you can to avoid any type of shock.

If you are with someone who experiences an electric shock:

- Turn off power at the fuse box or circuit breaker
- Call 911
- Turn off and unplug the equipment
- Administer First Aid and CPR only when the victim is away from the live electrical source

<u>General Electrical Safety:</u>

- Read manuals and follow the manufacturers' instructions
- Service and repair equipment according to the manual
- Turn the power off before making any repairs or adjustments
- Never operate any equipment when the protective covers are removed
- Check equipment and insulation regularly
- Check all connections before you begin
    - Are they tight, in good repair (free from burns or cracks)

- Repair or replace damaged parts immediately
    - Never operate equipment with a wire exposed
- Keep all cables on the same side of your body
- Never drape a cable over your body (e.g. across your arm or shoulder)
- Don't work next to the power source
- Never touch any live parts
- Check that your gloves and clothing are appropriate for the job and ensure that they are in good condition (no holes)
- Avoid water when working with any electrical equipment
    - Don't stand in or near water
    - Keep your hands and gloves dry
    - Change your clothes if you are sweating
- Stand on a dry floor
    - Cement is ideal or wood or rubber surfaces
    - Never stand on metal
- Turn off any piece of equipment you are not using
- Never work alone

Electricity will always travel along the path that provides the least amount of resistance. Work carefully so you do not become the path of least resistance.

Welding machines may interfere with some pacemakers. Please consult your physician before welding.

<u>Additional Electrical Safety for Welders</u>

- Have an electrician set up and service your welding system
- The welding machine must be grounded at the power source

- You will need to connect a ground wire to the base metal you are welding
    - You can also clamp the ground to a metal table where the base metal is resting
    - Connect the ground as close to the welding area as possible
- Never touch the ground or the wire electrode when the power is on
- Don't rest any bare part of your body on the metal you are welding
- Check that all cables are the right size for the current you are using
- Never hold the torch under your arm
- Always assume that the wire electrode is hot (electricity is flowing)

**Note**: There can be voltage in the machine even after you turn the power off.

## *ARC SAFETY*

An electric arc is the heat source for all types of arc welding. It is possible that a welding arc can reach temperatures of 1,635º Celsius (3,000º Fahrenheit). As a result, arc welding can cause burns and fires and even explosions if it is not used properly.

Also, rays from a welding arc produce the type of radiation that can cause burns to your eyes and skin. A burn from an electric arc can feel like a bad sunburn.

If you have skin or eye damage from an arc, used a clean damp dressing to cool the area and seek medical attention.

Arc Safety Steps:

- Only strike an arc when your helmet shield is down
- Wear all recommended safety clothing and make sure you don't have any exposed skin
- Remove all flammable and combustible material from your work area
    - For example, gas cylinders, rags, wood, dust, paper, cloth, chemicals, cleaners, liquids and lighters
    - If possible, work in an area surrounded by concrete – it is best not to weld over wood floors or on a wooden workbench
- Check your work area when you have finished welding to ensure there are no sparks smoldering anywhere
- Assume all metal is hot
    - Wear gloves or use pliers when picking up or moving metal
    - Remember, metal conducts heat
- Never touch the end of the welding torch until the power is off and it has cooled
- Never oil welding equipment, the residue can ignite

- If your clothing catches on fire
    - Stop, drop and roll – Never Run
    - Roll back and forth until the flames are smothered

## *WORKING WITH CHEMICALS*

**Reading Text, Document Use**

**Thinking Skills: Critical Thinking, Decision Making**

Read labels and the Material Safety Data Sheets (MSDS) for any chemical you use in class, at work or in your home. You will find MSDS sheets in all workplaces that use chemicals.

Whenever you are using chemicals remember that they can be absorbed through your skin, eyes and mouth. It is important that you wear gloves, wash your hands regularly, keep your hands away from your face, and try not to rub your eyes or mouth.

It is important that you avoid eating and smoking while you are working with chemicals.

***Material Safety Data Sheets*** – MSDS are documents written for people who use hazardous materials. They contain information about the physical or chemical hazards associated with using the material. They outline the safe handling, storage and disposal as well as steps for dealing with emergencies, fires, spills and overexposure.

Any material covered by the Workplace Hazardous Materials Information System (WHMIS) must have an MSDS. This means that if you are working with a hazardous substance, you must have access to MSDS in your workplace and you should be trained to work with the material safely. http://www.meridianeng.com/msds.html

## *CLEAN UP*

**Reading Text, Document Use**

You will be responsible for cleaning up your work area as you go. You will also be responsible for cleaning your work area at the end of each class.

- Keep your work area clean
- Put tools and equipment away properly when you are finished with them
- Store scrap metal in designated areas
- Use the garbage and recycle bins for the appropriate items
- Store chemicals safely when you are finished with them
- Wipe up any chemical spills

## *THE ENVIRONMENT*

**Document Use**

- Plan before you start to work; this will help eliminate waste
- Save leftover pieces of metal so that others may use them on their projects
- Use small pieces of metal that others were not able to use
- Use newspaper or a cloth for clean up rather than paper towel
- Recycle cans and glass bottles

# WELDING

## INTRODUCTION

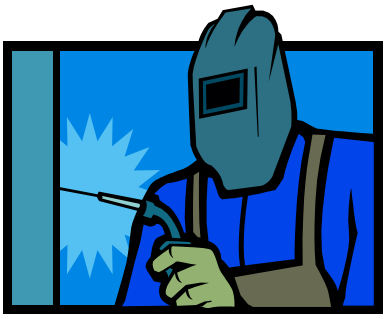
**Reading Text, Document Use**

This course will provide you with an introduction to Gas Metal Arc Welding. You will receive information about welding, in addition to gaining in-class hands-on experience.

In addition to safety, this course will cover the following:

- Welding tools and machines
  - E.g. GMAW welders and grinders
- Introduction to plasma cutters and oxyacetylene cutters
- Shielding gases
- Laying beads in flat and horizontal positions

Most people learn basic welding skills quickly; however, welding is a skilled trade. To become an expert you need to be willing to commit to many hours of practice.



If you decide that you enjoy welding enough to pursue it as a hobby or as a career, you can take what you have learned in this course and apply it towards another training program for welders.

**Note**: Please ask your instructor for information about the options available to you if you want to continue your training.

This course introduces Gas Metal Arc Welding (GMAW). GMAW is also known as Metal Inert Gas (MIG).

## *DEFINITION AND PROCESS DESCRIPTION*

**Reading Text, Document Use**

Welding involves using heat, filler material and/or pressure to permanently join two or more pieces of metal. This includes both the repair and fabrication of metal structures and sculptures.

The metals being welded are placed side-by-side, exactly where you want them to be joined. This creates a seam.

**Note**: These notes will only refer to the process of welding two pieces of metal, although it is possible to weld more than two.

To create a weld, the metal must get hot enough to melt. Welding temperatures will range from approximately 800º to 1,635º Celsius (1,500º to 3,000º Fahrenheit) depending on the process and the type of metal you are welding. In this course the heat source you will be using will be an electric arc.

For a weld to be successful, you need to apply a small, focused, intense concentration of heat along the seam. When heat is applied to the seam between the two metals they will both melt. The liquid metal from each piece combines in what is called a weld puddle.

It is important to melt the metal a bit at a time, rather than creating one large puddle of metal. This means you need to apply the heat source to a small localized area. Once the metal melts, you can then move the heat source along the seam, melting the metal as you go.

In most cases you will want to add a filler material to the weld puddle. This is done by melting metal from another source (a wire or rod) into the weld puddle. This filler material mixes with the liquid from the two base metals.

As the weld puddle cools, it solidifies; this is often referred to as freezing. The final result is a weld that is a mixture of the two base metals plus the filler material. The welded metal is now technically one solid continuous piece of metal that will be as strong as, or stronger than, the original base metals.

**Note**: Metals melt at different temperatures and have different characteristics. As you develop your skills as a welder you will learn more about the different metals and how they respond to heat.

In most cases, the two metals you are joining will need to be the same type of metal. However, it is possible to weld different metals together, such as carbon steel and stainless steel.

**Coalesce**: to merge two things into one. This term is used to describe the process of welding where metals mix and become one solid piece.

**Fusion**: to merge or blend two or more things. Welding fuses the metal together.

For more information about the metling point of various metals visit the following site: http://www.muggyweld.com/melting.html

## *SOLDERING AND BRAZING*

Soldering and brazing are techniques that also use heat to join metal. However, these processes use a filler material with a lower melting point than the base metals. This means that the filler melts but the base metals remain solid.

As the filler material melts it runs across the seam and down between the two metals. As the filler material cools, it hardens joining the metals together. Although the join will not be as strong as a welded joint, soldering and brazing can be used to join two different metals. For example you can solder brass and copper together.

**Note**: Soldering and brazing use the same process, however soldering uses a filler with a melting point below 427° Celsius (800° Fahrenheit) and brazing uses a filler that melts at temperatures above 427° Celsius (800° Fahrenheit).

## *THE WELDING PROCESS – SUMMARY*

1. High heat is applied to a small area along a seam where two base metals meet
2. Heat is applied long enough to melt the base metals
3. The two metals melt and form a liquid pool of molten metal called a weld puddle
4. The two base metals combine in the weld puddle
5. A filler material is melted into the weld puddle
6. The liquid filler mixes with the liquid base metals
7. The weld puddle cools and solidifies (freezes)
8. The end result = one solid piece of metal

## *THE WELDER*

**Reading Text**

A welder is a person who uses equipment to join metal together permanently. They build new metal structures and fix broken ones.

Welders work in a variety of situations with a variety of metals. The tools, techniques and processes used by welders are also diverse; therefore many welders decide to specialize in one specific area. Some even specialize in plastic welding.

In the past few years automated welding machines have made their way into production settings; however, welding is one trade that has been difficult to fully automate. Welders are still in demand. They are considered to be highly skilled trades' people.

Welding is called a craft because welders are required to work with their hands. It is also called a craft because welders need skills, training, experience and specialized knowledge.

Although welders use tools and equipment, their success is based on their hands-on work. They need excellent hand-eye coordination and the ability to identify and solve problems as they work. The quality of the weld depends on the skill of the individual welder not the quality of the equipment they are using.

As mentioned, welding can be learned quickly but it can take years to become a highly skilled welder. This means that to become a skilled welder you need patience, dedication, perseverance and the ability to learn from your mistakes.

Skilled welders are also known for their commitment to continuous learning. They are always improving their existing skills and learning new skills.

# *WELDING ART*

**Reading Text**

This course will introduce you to welding. If you are interested in developing your welding skills further, you may want to consider welding as a hobby or career. There are endless job possibilities for welders however you can also develop your welding skills for personal use. You may even decide to develop your welding skills so you can build decorative and artistic pieces.

**Sculpture**: a piece of art that is three dimensional. It is a representation of another thing.

For more information about art and welding, you may want to search the internet. Try searching "weldng art", "welding projects", welding sculptures".

Although welders usually work in manufacturing, there are a growing number of welders who use their craft as a way of expressing themselves creatively. Many artists are also learning to weld so they have another medium for their work.

Artistic welders may build smaller functional pieces such as railings, tables, coat racks, magazine racks and furniture. They may also produce decorative pieces including candleholders, wall hangings, plant hangers and floor lamps. The possibilities are endless.

Welders also use welding techniques along with their creativity to produce larger works including gazebos, arbours and gates.

Increasingly welders are creating sculptures like the one in the image below.

http://www.curbly.com/DIY-Maven/posts/2115-the-art-of-welding

# *INTRODUCTION TO METAL*

**Reading Text, Document Use**

Metal is a class of chemical element. As a general rule, metal:

- can be described as having ductility – (this means it can be hammered into thin sheets or drawn into wire)
- can be described as having malleability – (this means it can be shaped or bent without breaking or cracking)
- is solid at room temperature (except mercury)
- can be melted or fused
- is opaque (light can't go through it)
- can reflect light when polished
- conducts electricity and heat
- can be combined with other metals to create an alloy

An alloy is produced by mixing metals or by mixing metals and non-metallic substances.

When carbon is added to iron the result is steel, also known as carbon steel. Therefore steel is an alloy, (a mix of iron + carbon).

There are two types of metals, ferrous and non-ferrous metals. Ferrous metals contain iron. Steel contains iron therefore it is a ferrous metal.

Although most metals can be welded, steel is one of the easier metals to weld. It is also strong and affordable. Carbon steel can have a mild, medium and high carbon content. Most people learning to weld will use mild carbon steel because the low carbon content makes it easier than high carbon steel to work with. In class you will use mild carbon steel.

## *WELDING TERMS AND DEFINITIONS*

**Reading Text, Document Use, Oral Communication**

The following definitions include some of the words you may hear in this course. You don't need to memorize all of the words in this chart; however it is likely that many of them will become familiar to you as you work through this course.

This list does not cover all the terms you may come across. Ask your instructor if you have any questions or hear a word you don't know.

You may also find it helpful to return to this list after reading through these Student Notes and completing your first hands-on welding class.

| Terms | Definition |
|---|---|
| **AC** | Alternating current is the current that comes into your home. It's called alternating because the direction (flow) of electrons changes back and forth between positive and negative polarity throughout each cycle. It is important to know that an alternating current does not work well with GMAW welding. |
| **Acetylene** | This is a colourless gaseous flammable hydrocarbon fuel (carbon and hydrogen). Acetylene is well known for being highly combustible. It can produce an intense heat. |
| **Alloy** | An alloy is a mixture of metals or metals and non-metallic substances. For example, bronze is an alloy because it is a mixture of copper and tin. Carbon steel is an alloy because it is a combination of iron and carbon. |
| **Ampere** | Ampere is used to measure the amount of electricity that flows past a point in a conductor every second (the current). In arc welding, the temperature of the arc is controlled by the amperage/current. In GMAW amperage is controlled by the wire feed speed, which in turn controls the amperage. |

| | |
|---|---|
| **Arc** | An arc is created when an electric current flows across the gap between two electrodes. In welding this is the gap between the electrode and the base metal. |
| **Arc Welding** | Arc welding is any welding process that uses an electric arc to produce heat hot enough to melt metal. There are many different arc welding processes. |
| **Base Metal** | The metal (or alloy) that is being welded or cut. Also called the work piece. |
| **Conductor** | Any material that allows electricity to flow through easily. Most metals are good conductors. Copper is the best conductor which is why it is used in electrical wire.<br><br>Water is also a good conductor. This is important to know because humans are 55-78% water. This means electricity can travel through the body easily causing a shock that can end in death. You have no time to get out of the way because electricity travels at the speed of light, (299,337 kilometres per second or 186,000 miles per second). |
| **Consumable** | This is a term used to describe a product that is only used once. For example, in cooking, flour is a consumable; the spoon used for stirring is not. In welding the filler material is the consumable; the welding gun is not. |
| **Current** | Current is another name for amperage. It is the measure of the electricity that flows past a single point in a conductor every second. |
| **Deposition Rate** | The speed in which the filler is added to the weld puddle is measured in "weight of metal deposited in a unit of time" called the deposition rate. |
| **DC** | Direct current describes a current that only flows in one direction. |
| **Dross** | This is the scum that forms on molten metal, usually caused by oxidation. |
| **Electrodes** | Electrodes are the conductors of electricity. Electricity enters and leaves electrodes. |
| **Fabrication** | Making/creating something new. In industry it refers to using raw materials to build machines, structures or equipment. |
| **Ferrous Metal** | Metal that contains iron. |
| **Filler Metal** | The filler metal is the metal that is added to the weld puddle. It mixes with the base metals to create the weld. In GMAW the electrode is also the filler material. |
| **Flux** | Flux is a chemical used for cleaning and removing any contaminants from the metals before they are welded. |
| **Fusion Zone** | This is the area between the base metals where you direct the heat. It is where the weld puddle forms and the filler material is deposited. |

| | |
|---|---|
| **Ground** | In electricity, an electrical current needs to follow a path back to the source. A ground provides this return path. It ensures that the circuit is complete. The ground also protects the welder from electrical shock. |
| **Heat Affected Zone** | This is the area of the base metal that has been affected by the welding heat but not melted. It is outside the actual weld. The metal in this area is often discolored. It is important to know that the heat may weaken the metal in this area; therefore you want to keep this zone small. |
| **Inert Gas** | An inert gas is a gas that will not undergo a chemical reaction with other elements. Welders use argon and helium. |
| **Joint** | The place where two or more metal pieces are joined by a weld. |
| **Kerf** | When metal is cut using oxyacetylene or plasma cutting, Kerf refers to the width of the cut. |
| **Melting Point** | The temperature at which a metal melts and becomes liquid. The melting point will depend on the metal you are using. |
| **MIG Gun or GMAW Gun** | This is the piece of equipment that the welder holds as they weld. It has a trigger that allows the welder to stop and start the arc, the electrode flow and the shielding gas. It also allows the welder to position the electrode, the shielding gas and the arc. A MIG gun may also be called a torch. |
| **Non-ferrous metals** | Metals that do not contain iron, including aluminum, brass, bronze, copper, lead and nickel. |
| **Polarity** | Polarity refers to the direction of the flow of electrons in the welding circuit. |
| **Plasma** | Plasma is a partially iodized gas. Plasma is a good conductor of electricity. |
| **Resistance (electricity)** | Resistance is the opposition something provides to the flow of an electrical current. If something is a conductor it offers low resistance. When an electrical current meets resistance, heat is produced. The more resistance, the more heat. |
| **Root of the Weld** | This is the part of the weld that is the farthest from the heat source. It is the bottom of the weld, where the weld meets the base metal. |
| **Tack Weld** | A small temporary weld used to hold the pieces together so they don't move when they are being permanently welded. |
| **Shielding Gas** | This is the gas used to displace the oxygen from around the weld puddle, protecting it from contamination. Welders use inert gas and/or carbon dioxide. |
| **Slag** | When metal is heated impurities come to the surface and stick to the metal. This is |

| | |
|---|---|
| | called slag. When the weld is finished, welders need to chip and scrap off the slag. |
| **Spatter** | This describes the small drops of liquid metal that are thrown away from the welding arc. When they cool they form solid bits of metal near the weld. Spatter needs to be chipped and scraped off. |
| **Voltage** | Voltage is the pressure that moves electrons through a circuit, travelling through the conductor. It is the force that makes amperage/current flow. It measures electric potential. |
| **Weld Penetration** | Heat will penetrate the base metal. A welder needs to achieve the right amount of weld penetration; too far and you will burn through the metal; not far enough and the weld will be weak. **Note**: It is important that the welder carefully controls the heat source. |
| **Weld Puddle** | The melted metal, including the two base metals and the filler metal, form a puddle of liquid. It is essential that a welder learns to read and control the weld puddle. |

# *HISTORY OF WELDING*

**Reading Text, Document Use**

Society moves through stages as it develops. Archeologists studying prehistoric European and Mediterranean societies divided these stages into three separate time periods called ages. These ages were named after the materials humans were using to create the tools and weapons of the day. The names of these three stages are; Stone Age, Bronze Age and Iron Age.

## Stone Age

The term Stone Age refers to a prehistoric time starting 2.5 million years ago when humans used stone for making tools and weapons. A stone was shaped by chipping it with another harder stone until it was the right shape.

## Bronze Age

The Bronze Age, from 3,300 to 1,200 BC, followed the Stone Age. It was a time period when humans learned to melt and combine copper and tin to produce bronze (an alloy). Bronze does not rust, therefore many objects from this time period can be found in museums.

## The Iron Age

The Iron Age dates from 1,200 to 550 BC. Iron is a very hard substance when it's cool; however, it can be softened and shaped with heat. Iron changed the way weapons and tools were made. During this time period the role of the village blacksmith grew in importance.

## The Blacksmith

Blacksmiths were the primary metal workers from the Bronze Age to the 1800's. They were the first to use a welding technique called forge welding. They used this technique to attach two pieces of metal permanently. The blacksmith would heat the two pieces of metal in a forge, until they were white hot; at this temperature the metal would be soft but not liquid. They would place these two hot pieces of metal on an anvil, overlapping them slightly. They would then hammer the two pieces together forcing the molecules of each piece to align. The end result would be one solid, very strong piece of metal with no joints or seams.

## Recent History

Blacksmiths used forge welding for thousands of years. The techniques did not change much in all that time.

In the mid 1800's welding began to emerge as a separate field of metal work. The field developed quickly. Considering the field of welding is relatively new, the pace of change has been significant.

**Forge**: a furnace used to heat metal to a very high temperature.

The following list summarizes the developments since the early 1800's.

### Late 1800's

- Other heat sources were discovered offering an alternative to using a forge
  - Acetylene lead the way for gas welding and cutting
  - Developments in electricity made arc welding and resistance welding possible
- As manufacturing grew, welding become increasingly important

**Note**: Oxidation was a significant problem for early welders. It made the welds brittle and porous causing the welds to fail.

1900-1930

- Coated metal electrodes were developed to protect the weld from oxidation
- Gas welding and cutting processes were developed further
- Pressurized gases were produced
- The blow torch was developed
- Welding machines were developed

1930-1970

- Semi-automatic welding was developed
- Gas Tungsten Arc Welding (GTAW) was perfected (WW II, 1940's)
- Gas shielding techniques were developed to protect the metal from oxygen contamination
- Shielded Metal Arc Welding was developed for welding non-ferrous metals (late 1940's)
- Flux coated consumable electrodes became the most popular metal arc welding process
- Gas Metal Arc Welding was developed for aluminum and other non-ferrous metals
    - Later it was used for steel
    - Now it's used for welding carbon steel, stainless steel, aluminum and copper
- Self-shielded wire electrodes were used with automatic equipment
- Electroslag Welding and Submerged Arc Welding were developed

For more information youi can use the internet to search "History of Welding".

1970-Present

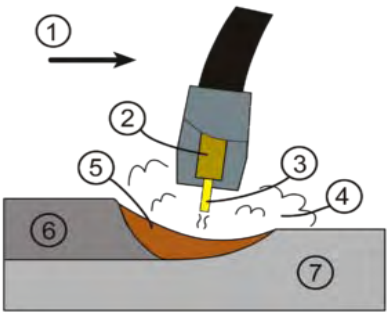
- Friction Welding, Laser Beam Welding, Electron Beam Welding and Robotic Welding were developed

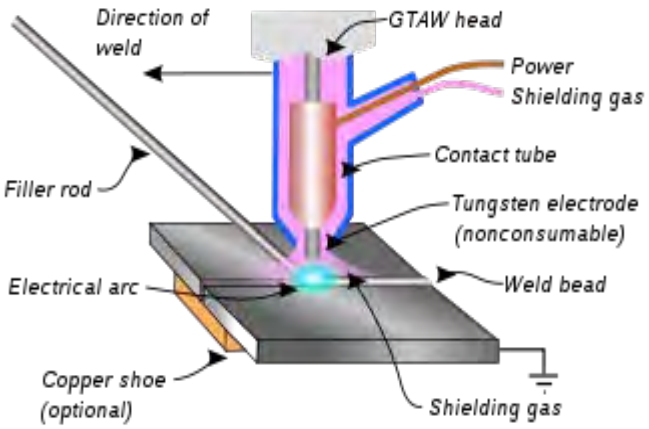
## *TYPES OF WELDING*

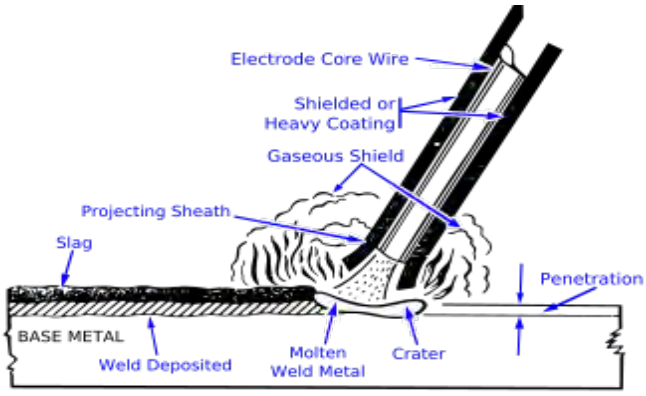
**Reading Text, Document Use**

There are many different welding techniques. The following chart summarizes the three most common types of arc welding options, including GMAW, which this course will cover in detail.

All of these arc welding processes use an electric arc as their heat source. They also all need filler material. Finally they all need some way of shielding the weld puddle from contaminants.

| Type of Welding | Description |
|---|---|
| **Gas Metal Arc Welding (GMAW)**<br><br>Also known as:<br>MIG welding | With this process, a wire electrode is used. The wire has two functions; it helps to create the arc that produces the heat and, as it melts, it becomes the filler material. The electrode is a bare wire that comes out of the gun when the trigger is squeezed. It comes out automatically in a continuous motion. The welder must direct the electrode to the weld area. An arc is created between the wire electrode and the base metal, producing the heat. As the heat melts the electrode it is fed into the weld puddle where it becomes the filler.<br><br>To protect the weld puddle from oxygen, which causes contamination, a continuous flow of carbon dioxide or an inert gas such as argon or helium is directed toward the weld puddle. The gas displaces the oxygen creating a protective shield. The trigger controls the flow of shielding gas.<br><br>GMAW Weld Area Image.<br>**(1)** Direction of travel<br>**(2)** Contact tube<br>**(3)** Electrode<br>**(4)** Shielding gas<br>**(5)** Molten weld metal<br>**(6)** Solidified weld metal<br>**(7)** Workpiece<br>  |

| | |
|---|---|
| **Gas Tungsten Arc Welding (GTAW)**<br><br>Also known as TIG and Tungsten Arc welding. | GTAW welding also has a wire electrode that is involved in creating the arc; however in this case the electrode does not become the filler material.<br><br>The electrode wire is made of tungsten which does not melt at welding temperatures.<br><br>If a filler material is needed, the welder holds the gun in one hand and a filler rod in the other hand. They then direct the filler rod toward the weld puddle where it will melt.<br><br>As with GMAW, a shielding gas is used to provide a shield for both the tungsten electrode and the weld puddle.<br><br>A high degree of skill is needed for this type of welding.<br><br>  <br> |

| | |
|---|---|
| **Shielded Metal Arc Welding (SMAW)**<br><br>Also known as stick welding. | Like GMAW, SMAW uses an electrode wire that has a dual purpose; it is needed to create the arc and it also becomes the filler material when it melts.<br><br>In SMAW the electrode has a third role. It provides the shielding gas that protects the weld puddle. The electrode wire is coated in flux that produces an inert gas when it burns. The gas provides the shield for the weld puddle by displacing the oxygen. Unlike GMAW and GTAW, no separate shielding gas source is needed.<br><br>  |

Images:

http://en.wikipedia.org/wiki/Gas_metal_arc_welding

http://en.wikipedia.org/wiki/Gas_tungsten_arc_welding

http://en.wikipedia.org/wiki/Shielded_metal_arc_welding

## *TYPES OF CUTTING*

**Reading Text, Document Use**

In addition to learning about GMAW, this course will also introduce you to metal cutting techniques. Both plasma cutting and oxyacetylene cutting will be demonstrated. The following chart summarizes two cutting options.

| | |
|---|---|
| **Plasma Cutting** | Plasma cutting is used to cut both ferrous and non-ferrous metals. It works with any metal that will conduct electricity including aluminum, brass, cast iron, copper, steel, stainless steel and titanium. It is a method that will make clean cuts in metal up to 15.24 centimetres (6 inches) thick.<br>Plasma cutting uses a small constricted arc that melts the metal. Compressed air or inert shielding gas is used to blow the molten metal out of the kerf (cut).<br>Plasma cuts faster than oxyacetylene.<br>You will need a power source, supply cable, gun, inert gas, or compressed air, work cable and clamp.<br>**Note**: Plasma is a gas that can conduct electricity. It can reach temperatures of up to 27,760° Celsius (50,000° Fahrenheit).<br><br>Follow all safety precautions. As mentioned, you must never cut containers, tanks or cylinders that may have held flammable materials. |
| **Oxyacetylene Cutting**<br><br>Also known as Oxy-Fuel cutting. | Oxyacetylene cutting uses the combustion (igniting) of acetylene and oxygen to produce a flame that can reach up to 3,482° Celsius (6,300° Fahrenheit), hot enough to heat metal to 871° Celsius (1,600° Fahrenheit). It then uses pure oxygen to burn away the hot metal.<br>It only works with steel because steel will oxidize at these temperatures. You can use this method to cut steel up to 31 centimetres (12 inches) thick.<br>**Note**: Follow all safety precautions. This method produces molten slag that can cause burns and fires.<br><br>**Note**: This is a more difficult technique to master than plasma cutting. |

# GAS METAL ARC WELDING (GMAW)

## INTRODUCTION

**Reading Text, Document Use**

As mentioned, Gas Metal Arc Welding is also known as Metal Inert Gas (MIG) welding.

GMAW is one of the easiest welding processes to learn. You should have the basic skills developed by the end of this course. Once you have the basics, it's just a matter of investing the time to practice your technique so that you improve the quality of your welds.

GMAW is one of the most common types of arc welding because it is a quick and adaptable process. It can be used on ferrous (with iron) and non-ferrous metals ranging in size from very thin to extremely thick. It is used in factories, art studios and home workshops, making it one of the best welding methods to learn. It is also popular because it is easy to automate which is why you will find GMAW in industry, particularly the auto industry and other production settings.

In this class you will learn about "semi-automatic GMAW" also known as "manual GMAW". The term manual is used because the gun is hand held and moved along the seam by the welder. However, it is more accurately called semi-automatic GMAW because the flow of the electrode wire and shielding gas is automatic.

It has been said that it is possible to learn the basic GMAW skills quickly but it takes years to master.

There are many variables to consider including type of:

- metal
- joint
- shielding gas
- electrode

As well as:

- volts
- current
- wire feed speed
- electrode diameter
- stick out
- travel speed
- environmental conditions
- weld joint position

In production settings you may come across mechanical and automated GMAW. In mechanical GMAW, the machine does the welding but there must be an operator watching the process and adjusting the settings. With automated GMAW, machines or robots control the settings and they do the actual welding.

**Note**: When GMAW is compared to other types of welding it is said to be the safest method; however serious injuries are still a real possibility. Please follow all safety procedures outlined in these Student Notes and presented by your welding instructor.

## *GMAW EQUIPMENT AND CONSUMABLES*

**Reading Text, Document Use**

As you gain practical experience in this course you will learn about the different pieces of equipment needed for GMAW welding. This section of your notes will provide you with a brief introduction.

Semi-Automatic (Manual) GMAW Equipment:

- A welding machine
  - Provides the power and houses the controls
- Electrode wire feed unit
  - Houses a coil of electrode wire
  - Powers the rollers that move the electrode from the machine to the gun and out through the gun nozzle

**Note**: The power supply and electrode wire may both be contained in the same unit or they may be in separate units.

- A welding gun
  - This is the part you hold in your hand
  - It has a trigger that turns the power on and off
  - The electrode wire and shielding gas come out of the gun nozzle
  - The welder uses the gun to direct the electrode wire and shielding gas to the area they want to weld
- Ground clamp
  - The ground clamp attaches to the metal you are working on. Its role is to complete the electrical circuit so that the arc is maintained. It will also protect you from receiving an electrical shock
  - The clamp can also be attached to a metal workbench that the base metal is attached to

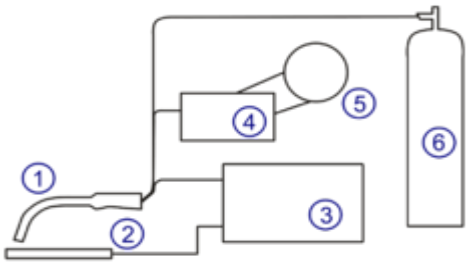
GMAW Consumables:

- Shielding gas
  - Stored in a pressurized cylinder
- Electrode wire supply
  - A spool of coiled electrode wire


Welding Machine (Wikipedia)

**Welding Equipment Diagram:**

**(1)** Welding torch/gun
**(2)** Base metal grounded to the power source
**(3)** Power source
**(4)** Wire feed unit
**(5)** Electrode source
**(6)** Shielding gas supply




GMAW Circuit Diagram (Wikipedia)

GMAW Welding Gun

The hand held welding gun is a similar shape to a pistol, which is why it is called a gun. Most guns have a goose neck; however, you can buy guns with straight or flexible necks.

***Conduit***: The gun is attached to the welding machine and the gas cylinder through a supply cable (conduit). This conduit provides a channel for the power cable, control cable, electrode wire liner and electrode and the shielding gas line. This supply cable runs from the machine to the gun, then through the gun. Some gun models also have an internal water cooling system; others rely on the shielding gas to provide the cooling.

***Contact Tip***: If you look at the end of the nozzle you will see a copper contact. This tip is connected to the welding power source through the power cable. The tip has a hole in the centre. The hole must be just large enough for the wire electrode to pass through. This is the place where the electrical current transfers from the power supply cable, to the contact tip and then to the electrode.

***Trigger***: The trigger turns the power on and off. When you pull the trigger:

- the current flows to the gun then to the contact tip
    - From the contact tip, it transfers to the electrode – energizing the electrode

**Conduit**: a pipe or tube that covers and protects electrical cables.

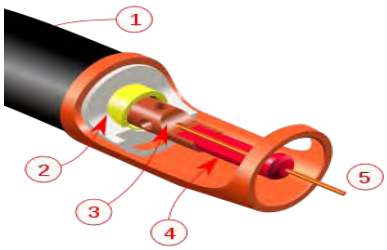
The conduit that connects the welding machine to the torch will be about 3.7 metres (12 feet) long.

As you work check that this cable is free of any sharp bends.

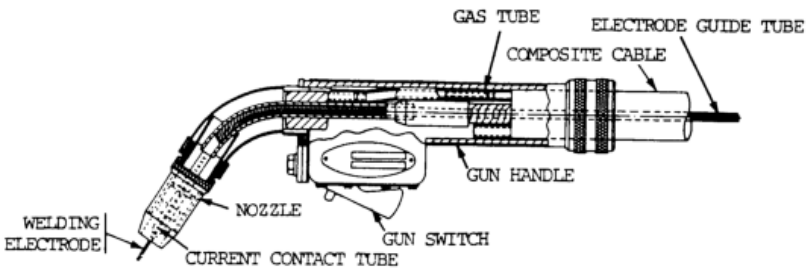
**Note**: It is important that you read the manual that comes with the gun you are using.

**Safety**: Check the components of your gun before you begin welding. Make sure it is clean and in good repair.

- a valve opens, starting the flow of shielding gas
    - From the cylinder, it travels through the gas line, and out the nozzle of the gun
- the electrode wire comes from the spool
    - It moves from the coil in the machine, through the electrode liner in the conduit, and out of the end of the gun in a continuous flow




***GMAW Torch Tip Cutaway Image***:
**(1)** Torch handle,
**(2)** Casing
**(3)** Shielding gas diffuser
**(4)** Contact tip
**(5)** Nozzle output face
(Wikipedia)



## Shielding Gas

As mentioned, if oxygen and other gases in the atmosphere come into contact with your weld puddle, the weld will be contaminated, making it porous, brittle and weak. To protect the weld a shielding gas is directed at the weld area in order to displace the oxygen.

Shielding gas is stored in a pressurized cylinder. The flow of the gas is controlled by a regulator. When the trigger is pulled, a valve opens in the machine allowing the gas to flow from the cylinder through a gas hose connected to the gun. It travels through the gun and out the nozzle.

The nozzle of the gun is aimed at the weld puddle. When the shielding gas reaches the weld zone it displaces the oxygen, protecting the weld.

Carbon dioxide works well and is less expensive than inert gases. However, when carbon dioxide is used there will be more splatter and less penetration.

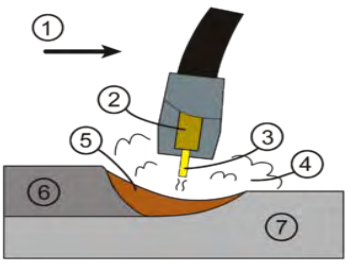
A combinaton of carbon dioxide and another inert gas are also used.

Shielding gas affects the arc, the size and shape of the bead and the quality of the weld.

The sheilding gas you will use will depend on the job requirements.

**GMAW Weld Area Image**

**(1)** Direction of travel
**(2)** Contact tube
**(3)** Electrode
**(4)** Shielding gas
**(5)** Molten weld metal
**(6)** Solidified weld metal
**(7)** Base metal
(Wikipedia)




**Note**: As mentioned earlier, Gas Tungsten Arc Welding (also known as GTAW or TIG welding) uses the same method for shielding the weld puddle. However, other welding processes such as SMAW use an electrode that has a flux coating. As the flux burns, it produces an inert gas which displaces the oxygen, shielding the weld.

## *ELECTRICITY*

**Reading Text, Document Use, Oral Communication**

Knowledge of electricity is not necessary for success in this course; however a basic understanding will be helpful. If you are interested in pursuing a career in welding or if you decide to set up your own shop at home you will want to learn more about electricity. Understanding electricity will help you set up and operate a welding machine.

**Note**: If you decide to set up your own workshop, it is best to work with an electrician.

If you are interested in learning more about the role of electricity in welding you can visit the following site: http://www.millerwelds.com/resources/basicelec/

**Remember**: Electricity will always travel along the path that provides the least amount of resistance. Work carefully so you do not become the path of least resistance.

Understanding Electricity

Electricity is the flow of electrical power in a circuit, from a source, through a conductor and back to the source.

The term current (amperes) describes the flow or amount of electrons through a conductor. A conductor is anything that allows electrons to flow. Metal is considered a good conductor.

Electrical power travels in a closed (continuous) loop or circuit. If the circuit is open (a break in the continuous loop) the electrons cannot complete the circuit so the power will not flow. If the circuit is closed, there is no break in the loop, which means the electrons can complete the circuit and the power will flow.

When you pull the trigger on the gun, you are closing the circuit which will allow the power to flow. When you release the trigger you are opening the circuit so that the electrons cannot complete their circuit and the power stops.

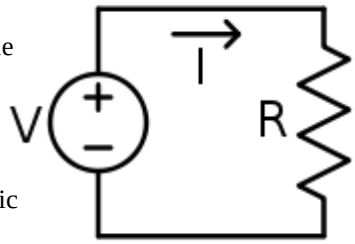
Electrical energy is either direct current (DC) or alternating current (AC). The standard household electrical current is an alternating current (AC). It's called an alternating current because the electron flow changes direction continuously (back and forth from positive to negative **and** negative to positive) throughout the cycle. With a direct current, the electrons flow in one direction only, (positive to negative **or** negative to positive).

**Basic Electric Circuit Diagram**

**(1)** The voltage source V on the left drives a current "I" around the circuit, moving the electrical energy into the resistor "R"

**(2)** The current continues on from the resistor, back to the source, completing the circuit

a. A resistor is a component of an electrical circuit that has resistance and is used to control the flow of electric current




(Wikipedia)

## Welding Machine

Electrical arc welding uses electricity to supply the power for all the functions of the machine including creating the electric arc. The electricity can come from a line current or a generator.

The electricity entering the welder will provide anywhere from 110 to 575volts. However, welding machines need a much lower voltage. Therefore the machine needs a transformer to reduce the voltage so it's the right level for welding.

**Voltage**: contols the arc length. GMAW machines will provide the constant voltage necessary for maintaining a consistant arc.

GMAW machines are Constant Voltage (CV) machines.

The electricity entering the welding machine will be an alternating current (AC). However, if AC is used to weld, the quality of the welding arc (the heat source) will be negatively affected by the electrons continually changing direction. Therefore, direct current (DC) is preferred for arc welding. The welding machine will have a rectifier to convert AC to DC. DC current will allow for a continuous arc and temperatures hot enough to melt the base metal and the filler material.

To control the intensity of the arc you will need to adjust the amperage. You may not find a specific amperage control on the welding machine because the wire feed speed controls the amperage. Therefore, you will need to adjust the wire feed speed if you need to adjust the amperage.

Set the amperage (wire feed speed) and voltage to the settings recommended by the manufacturer for the electrode you are using or follow the recommendations outlined in the job specifications. After you make a test weld you may need to adjust these settings. Continue adjusting until you find the right balance.

## Positive and Negative Charge

There are two kinds of electrical charges, positive and negative. You will want your machine set up so that the electrode wire is positive and the base metal is negative. This is called DC reverse polarity. You will need to ask your instructor for assistance.

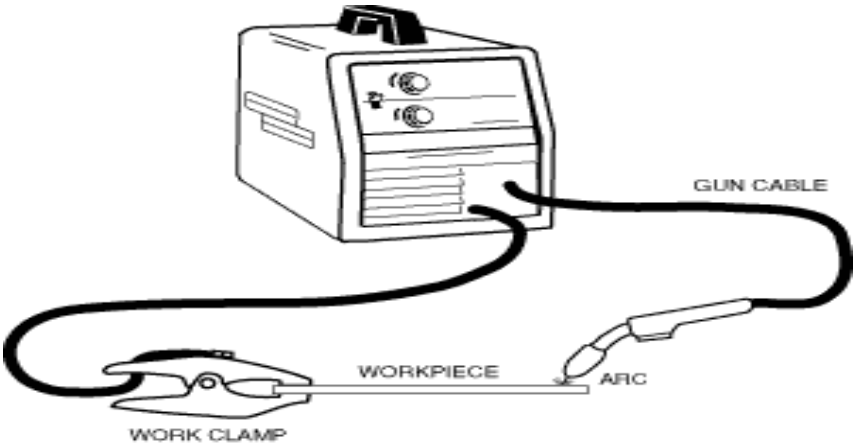
## Grounding Your Work

As mentioned, a circuit is completed only when the electrons flow in a continuous loop. Once the current has travelled to the base metal it needs a path back to the welding machine to complete the loop. This means you must ensure that the base metal is grounded before you try to weld.

**Note**: If a ground is not attached you won't be able to create an arc.

The ground wire is attached to the welding machine. Grounding your work involves clamping the other end of this ground wire to the base metal. The ground wire provides the current with a path back to the power source.

As an alternative you can attach the base metal to a metal workbench and then attach the ground to the workbench.




Power Summary

- The welding machine converts incoming AC current to DC
- The voltage travels through the gun to the copper tip at the end of the gun
- From the copper tip, it transfers to the electrode (the wire)
- It travels across the gap between the electrode and the base metal, creating an arc
- From the base metal the current follows a ground which is attached by clamps the to the base metal (or a metal workbench)
- The current then travels back to the power source completing the circuit

## *THE ARC*

**Reading Text, Numeracy, Oral Communication**

The electrical arc creates the bright light people often think of when they think about a welder at work. The arc is created when an electric current flows across a gap between the electrode wire and base metal. As the current travels across the gap it is heated to an extreme temperature.

If the wire electrode and the base metal touch, the current is transferred from one to the other without having to cross the gap. If this happens, an arc is not produced, which means there is no heat generated. On the other hand, if the electrode and the base metal are too far apart, the current will not be able to cross the gap. Therefore it is important that you establish the right distance between the electrode and the base metal.

An arc in GMAW can reach temperatures between 6,000°-8,000° Celsius (10,832° and 14,432° Fahrenheit). but much of this heat dissipates.

## *MAINTAINING THE ARC*

To get a good consistent weld, you need to control the “nozzle to work distance”. Therefore once the arc is established welders need to be able to keep the size of the gap between the wire and base metal consistent.

Welders need to have good eyesight, a steady hand, and be keen observers. This attention to detail allows them to make small adjustments in the “nozzle to work distance” while they are welding.

## *THE ELECTRODE*

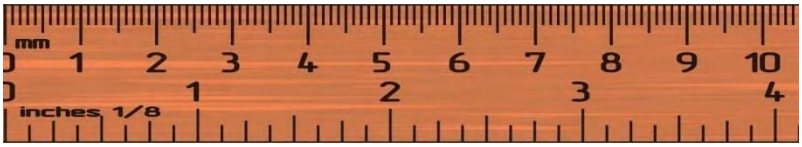
As mentioned, the electrode wire comes in a coil that must be installed in the welding machine or wire feed case. In GMAW, the wire is automatically fed through rollers in the machine, through the liner in the conduit and out through the contact tip at the end of the gun.

Most jobs will specify the type and size of electrode wire you need.

### Stickout

Stickout is the term used to describe how far the electrode sticks out beyond the contact tip at the end of the gun nozzle. It is the distance measured from the contact tip to the tip of the electrode. Stickout affects amperage so it is important to have the stickout right for the job. The stickout distance depends on the type of welding you are doing.

In this course you will likely need a stickout of about 12.7 millimetres (1/2 inch). However, the length of the stickout will depend on your specific project. Ask your instructor to recommend a stickout length for your project.



# *METAL TRANSFER*

**Reading Text, Document Use**

As you know in Gas Metal Arc Welding you will be using an electrode that has a dual role; it helps to create the arc and it melts into the weld puddle becoming the filler material.

As the electrode melts, it needs to get from the tip of the wire electrode into the weld puddle. There are three methods used for transferring the filler material to the weld puddle. They include: Short Circuit, Globular and Spray.

## Short Circuit Transfer

With this method, the tip of the wire enters the weld puddle. When the electrode reaches the weld puddle, it closes the gap between the electrode wire and the base metal. This interrupts the arc, causing a short circuit. The short circuit causes the current in the wire to increase, until the material drops off into the weld puddle. Once it breaks off, the arc is reestablished. This process repeats about 200 times per second. In short circuit transfer, the metal transfers when the electrode actually makes contact with the weld puddle.

## Globular Transfer

With this method, large molten droplets, called globules, form at the tip of the wire electrode as it melts. These globules can grow to twice the size of the diameter of the wire. The droplets of filler metal let go because of the force of gravity. The arc is never interrupted so the filler transfers across the arc as it enters the weld puddle.

Spray Transfer (axial spray transfer)

The spray transfer method is similar to the globular transfer, only the droplets are smaller and the process happens much quicker. An electromagnetic force forms around the electrode which actually causes a pinching of the electrode between the contact tube and the tip of the wire. The small droplets of molten filler metal that have formed at the tip of the electrode are pinched off several hundred times per second, creating a spray of small drops. The arc is never interrupted so the tiny drops cross the arc in a stream. The drops are smaller in diameter than the wire electrode.

## *METAL TRANSFER METHOD – SUMMARY CHART*

| | Short Circuit | Globular | Spray |
|---|---|---|---|
| **Conditions** | • Low current/amperage and voltage levels<br>• Smaller diameter electrodes (.035 to .045 inch)<br>• Shielding gas usually 100% carbon dioxide **or** 75% argon and 25% carbon dioxide<br>• Low heat | • Higher current/ amperage and voltage levels than short circuit<br>• Electrodes with diameter .045 to .16 inch in diameter<br>• Longer stickout and longer arc length<br>• Shielding gas usually 100% carbon dioxide or 75% argon and 25% carbon dioxide | • Highest current/ amperage voltage levels<br>• Larger electrodes than globular<br>• Shielding gas usually argon rich |
| | | | |
| **Characteristics** | • Arc stops and starts<br>• Low heat<br>• Low deposition rates<br>• Small, fast freezing weld puddles | • Higher heat than short circuit<br>• Higher disposition rates | • Arc is stable<br>• High heat<br>• High deposition rates<br>• Large weld puddle |
| | | | |
| **Applications** | • Thinner metals<br>• Best with low and medium carbon steel<br>• Any weld position | • Thicker metals<br>• Ferrous metals e.g. low and medium carbon steel<br>• Best on flat and horizontal positions | • Thicker metals<br>• Stainless steel and aluminum<br>• Flat and horizontal positions |
| | | | |
| **Advantages** | • Works in any position and all joint types<br>• Smaller weld zone, therefore less of the base metal is affected | This method is seldom used today | • Little spatter<br>• Excellent penetration<br>• Stable and efficient<br>• Produces a high quality weld |
| | | | |
| **Disadvantages** | • Spatter is produced | • Least preferred method<br>• Poor penetration<br>• Lumpy weld bead appearance<br>• A lot of spatter<br>• Not ideal for thin metals because of the high heat | • Not ideal for thinner metals because of the high heat<br>• Weld puddle very fluid |

## *WELDING BEADS*

**Reading Text**

The weld you create by depositing filler material in a single pass is called a bead. A weld bead may be a straight, thin line of filler along a seam (a stringer bead) or a wide bead made by moving the electrode side-to-side along the seam (weave bead).

You will learn to run a bead fairly quickly; however it takes time to develop the ability to identify whether it is a good weld or a bad weld. With practice you will be able to identify problems and causes and know what corrections you need to make.

An experienced welder can do all of this while they are welding. They see problems developing, assess it quickly and take action to correct it before they finish the weld.

## *WORK AND TRAVEL ANGLES*

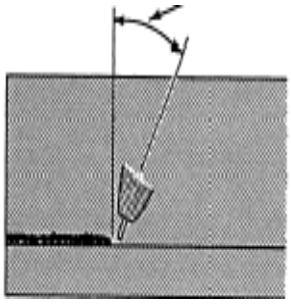
**Reading Text, Document Use, Numeracy, Oral Communication**

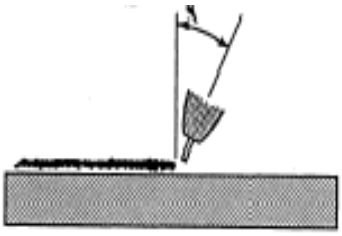
There are two angles to consider, travel angle and work angle. This describes the angle of the electrode.

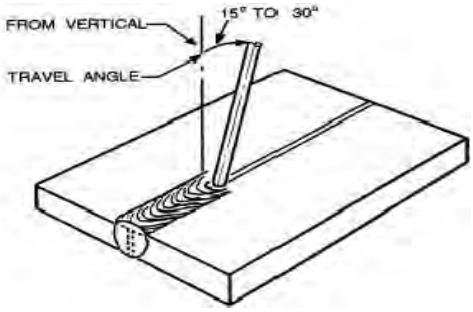
The angles you use will depend on the joint you are welding. Angles will also affect the bead shape.

This will become increasingly clear as you practice your beads. Ask your instructor to help you find just the right work and travel angle.

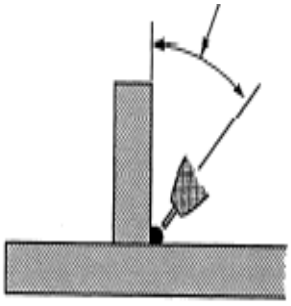
Travel Angle

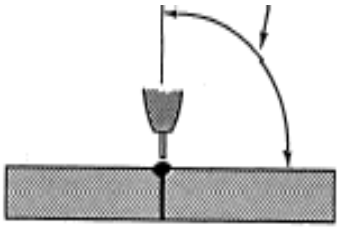


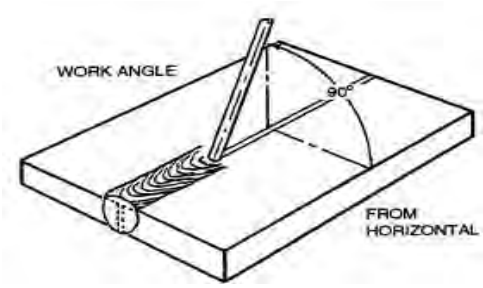




Work Angle







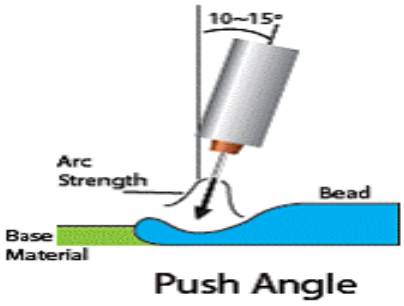
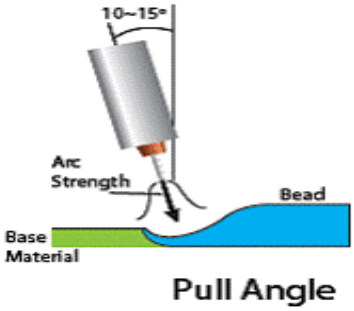

http://www.tpub.com/content/construction/14250/css/14250_144.htm

## *TRAVEL SPEED AND TRAVEL DIRECTION*

The travel speed is the rate at which you move the electrode/arc along the seam.

Travel direction is determined by whether you decide to use a push or pull technique.

## *TRAVEL DIRECTION – SUMMARY CHART*

| | Push | Pull |
|---|---|---|
| Also known as: | • Forehand weld technique<br>• Lead angle | • Backhand weld technique<br>• Lag angle<br>• Drag angle |
| Position |  <br>• Working forward<br>• The arc, shielding gas and weld puddle are ahead of the weld<br>• The electrode points at the part of the seam that has not yet been welded<br>• The electrode points in the direction it is travelling<br>• The gun tips back, behind the weld<br>• Needs an angle of 15 to 30 degrees |  <br>• Working backward<br>• The arc, shielding gas and weld puddle are behind the weld<br>• The electrode points at the part of the seam that has just been welded<br>• The electrode points away from the direction it is travelling<br>• The gun tips forward in the direction of the weld – ahead of the weld<br>• Needs an angle of 15 to 30 degree |
| Results | • Usually less penetration<br>• Wider beads | • Usually greater penetration<br>• High, narrow beads |
| Advantages | • Preheats the metal<br>• Easier to see the weld puddle and arc<br>• Faster welding speeds<br>• Better gas shielding<br>• Best for thin metals | • Increased penetration<br>• Best with thick metal<br>• Best for flat and horizontal positions |
| Disadvantages | • More spatter<br>• More chance of undercut<br>• Puddle slow to cool | • Harder to see the weld puddle and arc<br>• May cause overlap |

**Images:** [http://www.daihen-usa.com/techtips/torchangles.html](http://www.daihen-usa.com/techtips/torchangles.html)

## *VARIABLES – Bead and Penetration*

**Document Use**

As you will have gathered, there are many things that will affect the weld bead and the penetration.

## *SUMMARY CHART*

| Factors | Penetration Increased | Penetration Decreased | | Deposit Rate Increase | Deposit Rate Decrease | | Bead Size Increase | Bead Size Decrease | | Bead Width Increase | Bead Width Decrease |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Amperage/ Wire Feed Speed | *up* | *down* | | *up* | *down* | | *up* | *down* | | | |
| Voltage | *up* | *down* | | | | | | | | *up* | *down* |
| Travel Speed | *down* | *up* | | *down* | *up* | | *down* | *up* | | *down* | *up* |
| Stickout | *down* | *up* | | *up* | *down* | | *up* | *down* | | *down* | *up* |
| Gun Angle | *backhand* | *forehand* | | | | | | | | *forehand* | *backhand* |

## *WELD TYPES*

**Reading Text, Document Use, Numeracy**

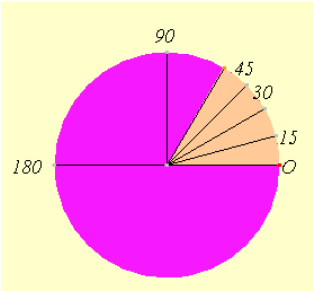
There are two common types of welds; the fillet weld and the groove weld.

**Note**: There are many variations of these two welds and there are many other types of welds; however, these are the two basic weld types you will learn as a beginner.

### Fillet Weld

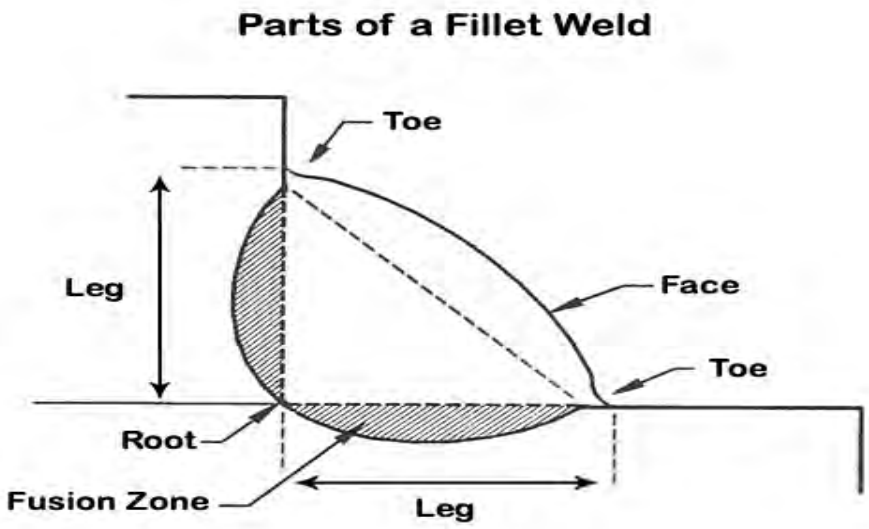
The majority of arc welding is done using a fillet weld. It is one of the most common welds because it can be used in a variety of situations. It is used most often for welding joints that meet at a 90 degree angle, such as the Lap, Corner and T-Joints.

A fillet weld is shaped like a triangle. The sides of the triangle join the two piece of base metal at right angles.




To create a fillet weld you will hold the gun at a 45 degree angle, bisecting the angle between the two pieces of metal.

It takes practice to be able to consistently make these welds the right size and shape. Many new welders make these welds too small.




*Root*: Where the weld meets the base metals

*Toe*: The top edge and bottom edge of the triangle

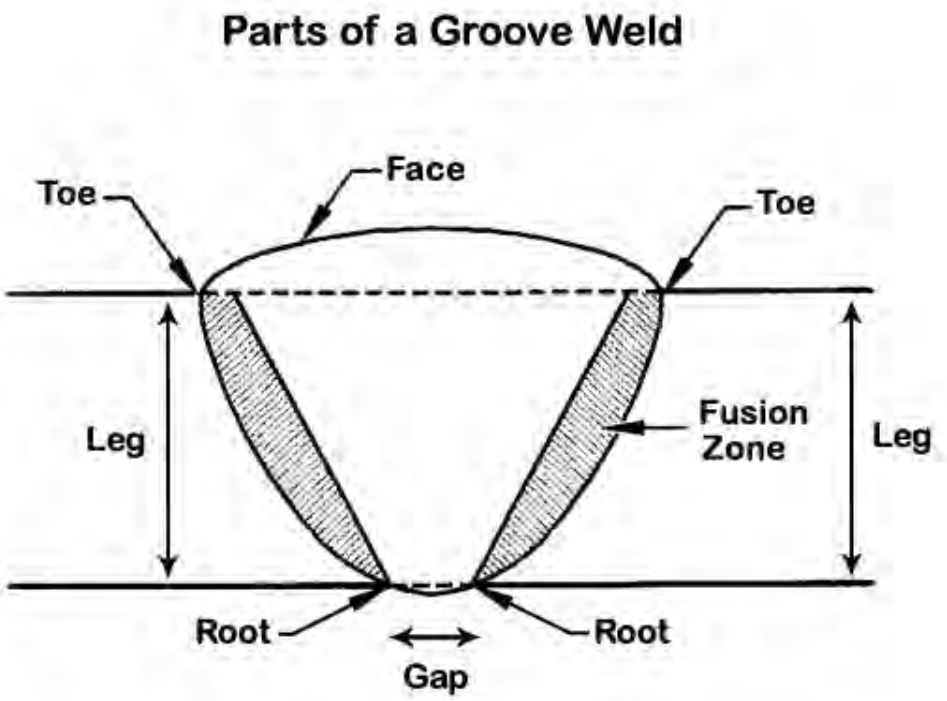
*Leg*: The distance from the root to the toe of the fillet weld

*Fusion Zone*: The area between the base metals that is heated to form the weld puddle

*Face*: The top/visual portion of the weld

Groove Weld

Groove welds are used to create butt and edge joints where a groove has been formed at the joint between the two pieces. There are different types of groove welds including single bevel, single V and J groove.




*Root*: Where the weld meets the base metals

*Toe*: The top and bottom edge of the triangle

*Leg*: The distance from the root to the toe of the fillet weld

*Fusion Zone*: The area between the base metals that is heated to form the weld puddle

*Face*: The top/visible portion of the weld

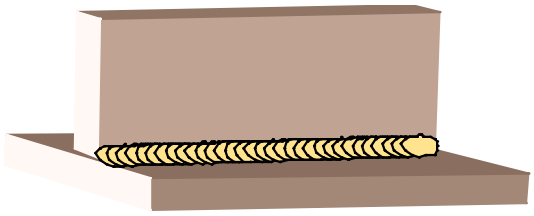
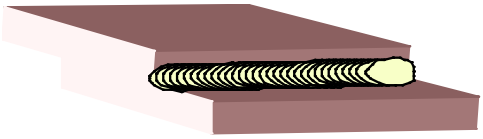
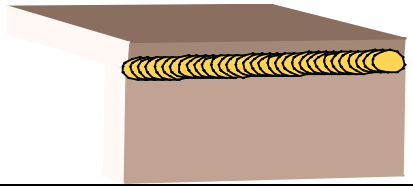
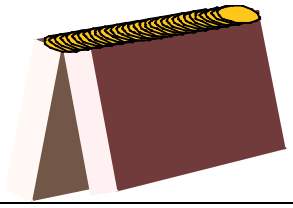
*Gap*: The space at the bottom of the weld between the two roots

## *JOINTS*

**Reading Text, Document Use**

As mentioned, a weld is made along the seam where two pieces of metal meet. The weld forms the weld joint. The five primary types of joints used in arc welding are summarized in the following chart.

## *JOINT SUMMARY CHART*

| *Joint* | *Definition* |
|---|---|
| **T-Joint**  | A t-joint joins two pieces of metal that are at right angles to each other (90 degree angle). They actually form a T shape.<br><br>There is a seam on either side, where the two pieces of metal meet. To make the weld stronger, you can weld along both seams. |
| **Butt Joint**  | A butt joint is a weld that joins two pieces of metal that meet end to end. The metal pieces will be on the same plane. They butted up against each other leaving a small gap along the seam. The weld fills the gap. |
| **Lap Joint**  | A lap joint is a weld that joins two pieces of metal that are overlapped. |
| **Corner Joint**  | A corner joint is a weld that joins two pieces of metal that meet at a corner to form a right angle (90 degree angle). The joint forms an L shape. |
| **Edge Joint**  | An edge joint is a weld that joins two or more pieces of metal that are parallel with each other. |

You will need to match the weld type with the joint you are welding.

| Joint | Weld Type |
|---|---|
| T-Joint | Fillet Weld |
| Butt Joint | Groove Weld |
| Lap Joint | Fillet Weld |
| Corner Joint | Fillet Weld |
| Edge Joint | Groove Weld |

**Note**: People learning to weld usually start with T-Joints and Butt Joints.

## *TOOLS*

**Reading Text, Document Use**

**Thinking Skills: Critical Thinking**

Vise

A vise allows you to hold metal in place as you work, leaving both of your hands free.

You can use a vise to hold the base metal you are welding. You will also need to use a vise to hold any metal you need to grind.

There are several types of vises you could use, including those that attach to the legs of the workbench and the kind that are mounted on the top of a workbench.

Hammers

Welders use a variety of hammers. The most common is a chipping hammer, used for cleaning slag from welds. One end has a chisel and the other end is pointed.

Using a Hammer – General Tips:

- Inspect your hammer before you begin
- Don't use any cracked, chipped or pitted hammers
- Don't use any hammers with damaged handles
- Check that the head is on the handle tightly
- Hold the hammer with a light but firm grip near the end of the handle
- Swing your hammer in a controlled fashion
    - The control you have over the hammer stroke is more important than the strength you use
- Use your whole arm
- Keep your elbow close to your body

- Hold the hammer tight enough that you have control but not too tight that your forearm gets tired
- Use gravity and the weight of the hammer to gain momentum rather than using muscle
- Check that you are in a comfortable position
- Stand straight with your feet apart, with one foot ahead of the other
- Keep your shoulders square to your work
- Bend your knees slightly

## Band Saw

Band saws are table mounted. The blades are interchangeable. There are specific blades for cutting metal. The electric motor moves the blade up and down at a high RPM. With a band saw you can cut large pieces of metal.

### Tips for Using a Band Saw:

- Follow all safety guidelines, for example:
    - Keep your hands clear of the machine at all times
    - Don't catch the piece of metal that falls off
- Check with your instructor for the proper feed speed
- Clamp the work piece securely in a vise
- Lower the head of the saw so that it just clears the work piece
- Double check your dimension and ensure that the vise is secure
- Turn the saw motor on and open the valve slowly to lower the head
    - Allow the saw to do the work for you
- Lift the head of the saw before you remove the metal piece
- Hold the head in position with the hydraulic valve
    - Very little pressure is required to operate the valve lever

- Clean the saw
- Clean up your work area

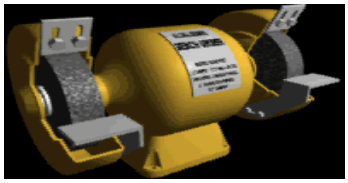
Grinders

An angle grinder is a handheld power tool. The motor, (either electric or pneumatic) spins a grinding disk at a high RPM.

Once the disk is spinning, you will press the grinder firmly against the metal surface. It is important to hold the grinder with two hands and keep your grip firm as you apply pressure. You can use a vise to keep the metal from moving.

A bench grinder is similar to an angle grinder, except that a bench top machine uses interchangeable grinding wheels, rather than disks.

When you are using a bench grinder, stand in front of the grinder and move the metal into the spinning wheel of the grinder, rather than moving the grinder into the metal. You need a firm grip on the metal.



Like sandpaper there are different grades of disks/wheels. You will need to assess the job so that you can make the right decision.

You can use a grinder to:

- grind, buff, sharpen, shape and polish metal
- remove metal flakes and rust
- smooth an area that has been welded
- sharpen the edges of metal tools
- remove rough/sharp edges to finish the metal
    - This is call de-burring, or removing the rough/sharp edges (burs) left after the metal has been worked

Tips for Using a Grinder:

- Follow all safety guidelines and keep your hands clear of the disc at all times
- Install the correct disc for the job, for example:
    - Use ¼" thick "hard disc" for fast metal removal and grinding jobs that don't need a smooth finish
    - Use 36 grit "flex discs" for finishing, when a smooth finish is needed
- Clamp the metal work piece securely in the vise
- Hold the grinder body horizontally with the disc flat on the metal you are working on
- Lift the 'tail' of the grinder about 1 inch to get the perfect grinding disc angle
- Practice applying the proper down pressure
    - Too much pressure will burn out the motor
    - Too little pressure does not remove the metal fast enough

If you are using an angle grinder:

- Hold the grinder firmly with both hands
- Brace your body against the wall or bench to support your upper body

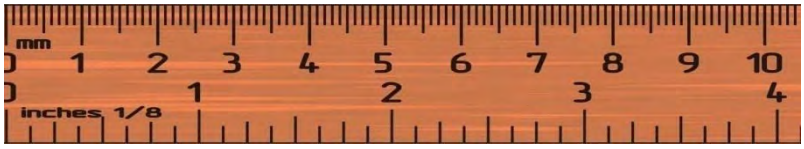
**Note**: Grinders will produce sparks. Ensure that there are no people nearby and that your area is clear of anything flammable.

## *MEASURING TOOLS*

As a welder, you will need to make precise measurements of the length, width and thickness of metal. You will also need to measure angles, for example, a T-Joint is made up of two pieces of metal that must create a right angle.

Rulers and Tape Measures

Welders use metal rulers and tape measures. In most cases, you will be using a ruler that has both Imperial (inches) and SI/Metric (centimetres) measurements. Ideally you will want to be able to use both systems of measurement.

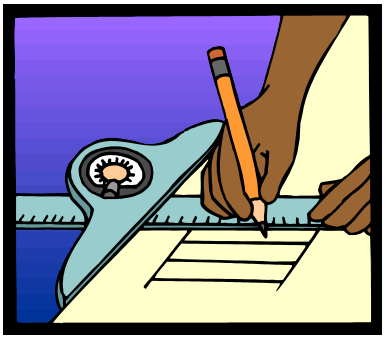



Angles

Welders need to use a number of tools to measure angles. For example weld gauges, angle gauges, angle finders and protractors. It is not possible to assess an angle visually.

Square

Welders need to be able to create right angles when they are welding joints. If there is a need to create a specific angle, a steel Square will be helpful. A Square will help you determine whether your corners are at perfect right angles.



## *WELD ASSESSMENT*

**Reading Text, Document Use**

**Thinking Skills: Critical Thinking**

It is important to be able to identify a good weld from a poor weld. As you develop your welding skills you will be able to assess and evaluate your welds and correct some common problems.

## *ASSESSING WELDS*

A Good Weld:

- Minimal spatter
- Uniform bead appearance
- Wide beads
  - A flatter weld usually means there is better penetration and fusion
- Moderate crater
- No overlap, undercuts, under fill, overfills or cracks
- Good penetration into base metals (depth of the weld)
- Good fusion (the join between metals)

**Crater**: the depression at the end of a weld.

**Overlap**: the filler material extends beyond the weld edges.

**Undercut**: a groove melted in the base metal and not filled by the filler materal.

**Underfill**: the fill is below the level of the base metal.

**Weld crack**: a crack in the filler or the base metal.

Poor Welds: One or more of the following:

- Large spatter deposits
- Rough, uneven beads
- High, narrow beads
- Large, shallow crater
- Overlap, undercuts, under fill, overfills or cracks
- Poor penetration (depth of the weld)
- Incomplete fusion (the join between metals)

# GMAW ADVANTAGES AND DISADVANTAGES

**Document Use**

GMAW Advantages:

- Fairly easy to learn
- You can create high quality strong welds
- The electrode is fed automatically so you don't need to stop and start your weld
- There is not a lot of slag produced so there is less to chip or grind off the finished weld
- Spatter is minimal, once you develop a good technique
- GMAW works on a wide variety of metals and alloys including ferrous and non-ferrous metals
- The process can be manual, mechanical or fully automated (robotic)
    - This makes it ideal for production settings
- GMAW can be used to weld in all positions

GMAW Disadvantages:

- The equipment is a bit more complicated to operate than the equipment used in some of the other welding processes
- Not ideal for working outside, so it has limited use in construction
    - The wind can interfere with the shielding gas
- The weld puddle may be hard to see because of the nozzle
- The equipment may be more expensive than other types of welding equipment

- The equipment may be less portable than other welding equipment
- You need access to a shielding gas cylinder

## Welding Resources Used Throughout Students Notes

http://www5.hrsdc.gc.ca/NOC/English/NOC/2006/QuickSearch.aspx?val65=7265

http://healthandfitness101.com/wp-content/uploads/2008/05/lifting-pic.jpg

http://www.muggyweld.com/melting.html

http://www.curbly.com/DIY-Maven/posts/2115-the-art-of-welding

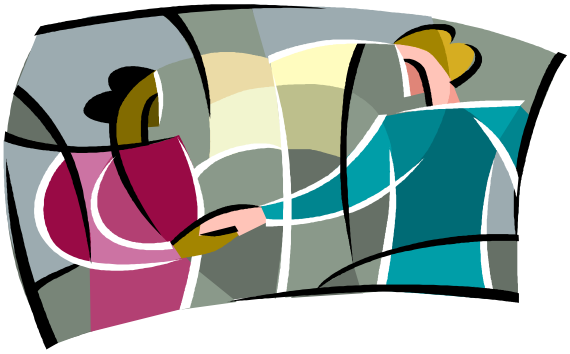
http://www.welding.com/edu_weld2.shtml

http://en.wikipedia.org/wiki/Gas_tungsten_arc_welding

http://en.wikipedia.org/wiki/Shielded_metal_arc_welding

http://en.wikipedia.org/wiki/Gas_metal_arc_welding

http://www.millerwelds.com/resources/basicelec/



**We hope you have enjoyed this welding course.**

**On behalf of Literacy Ontario Central South, Literacy and Essential Skills in Industrial Arts (L.E.S.I.A.) project, we would like to thank you for your participation.**

**Best of luck with your future endeavours.**