Solar PV System Installation and Maintenance

Level-II

Learning Guide -19

Unit of Competence	**Perform Simple Welding**
Module Title	**Performing Simple Welding**
LG Code	EIS PIM2 M06 LO1 LG-19
TTLM Code	EIS PIM2 TTLM 0120V1

LO1. Prepare materials for SMAW welding process

Instruction Sheet	Learning Guide: - 19

This learning guide is developed to provide you the necessary information, knowledge, skills and attitude regarding the following content coverage and topics:-

- Identifying Weld requirements
- WPS requirements
- Inspecting correct size, type and quantity of materials/components
- Preparing Materials correctly with job specifications.
- Assembling/Aligning of materials.

This guide will also assist you to attain the learning outcome stated in the cover page. Specifically, upon completion of this Learning Guide, **you will be able to:-**

- Identify Weld requirements
- WPS requirements
- Inspect correct size, type and quantity of materials/components
- Prepare Materials correctly with job specifications.
- Assemble/Align of materials.

Learning Instructions:-

1. Read the specific objectives of this Learning Guide.
2. Follow the instructions described below 3 to 4.
3. Read the information written in the information Sheet 1, Sheet 2, Sheet 3, Sheet 4, Sheet 5, in pages 3,11,16,26 & 50 respectively.
4. Accomplish the Self-check 1,Self-check 2,Self-check 3,Self-check 4 and Self-check5 in pages 10,15,25,51,60 respectively

Information sheet -1	Identifying Weld requirements

1.1Definition of welding

To achieve safe working conditions in the metal fabrication and welding industry, all personnel should be able to recognize the hazards which apply to their particular occupation. Welding operators must also know the correct operating procedures for the equipment. An operator can be subjected to many safety hazards associated with the industry. As with any other industrial worker, they may be injured through incorrect lifting practices, falling or tripping, or incorrect use of hand tools and machines.

The operator will also encounter particular hazards associated with welding. A clean, tidy workplace, free from combustible materials, is an essential requirement for the safety of welding personnel. Additionally, others working in the vicinity of welding operations are at risk from hazards such as electrocution, fumes, radiation, burns or flying slag and noise. They too must be protected if their health and safety is not to be put at risk.

- **Requirements for good welding**
  - ✓ a. Cross - section of the added metal should be small and oxidation should be minimum.
  - ✓ b. Cross - section of the added metal should be small and oxidation should be maximum.
  - ✓ c. Cross - section of the added metal should be large and oxidation should be minimum

- **What makes a good weld?**

A key skill in manufacturing is welding and ensuring a good weld is vital for the integrity of a product. A brittle or porous weld presents a serious safety concern for industrial applications and the vast majority of manufacturers have rigorous procedures in place to ensure welds meet quality standards.

- **Here's a guide to factors that will ensure a good weld.**

✓ **Ensure a clean surface**

Metal surfaces need to be thoroughly cleaned of impurities like water, oil, and flux before they are welded while aluminum needs to have the outside layer of oxide removed before welding commences. The presence of impurities will cause porosity in the weld – that is tiny holes that weaken the join.

✓ **Mind the gap**

A factor that often results in welds failing is an incorrect gap or poor edge preparation between the two parts being joined. If the gap is too big there is a danger the weld bead will simply burn away the edges of the two parts, insufficient gap when joining thicker materials will result in lack of weld penetration. To ensure a good weld, you need to pay particular attention to the edge preparation and correct required gap.

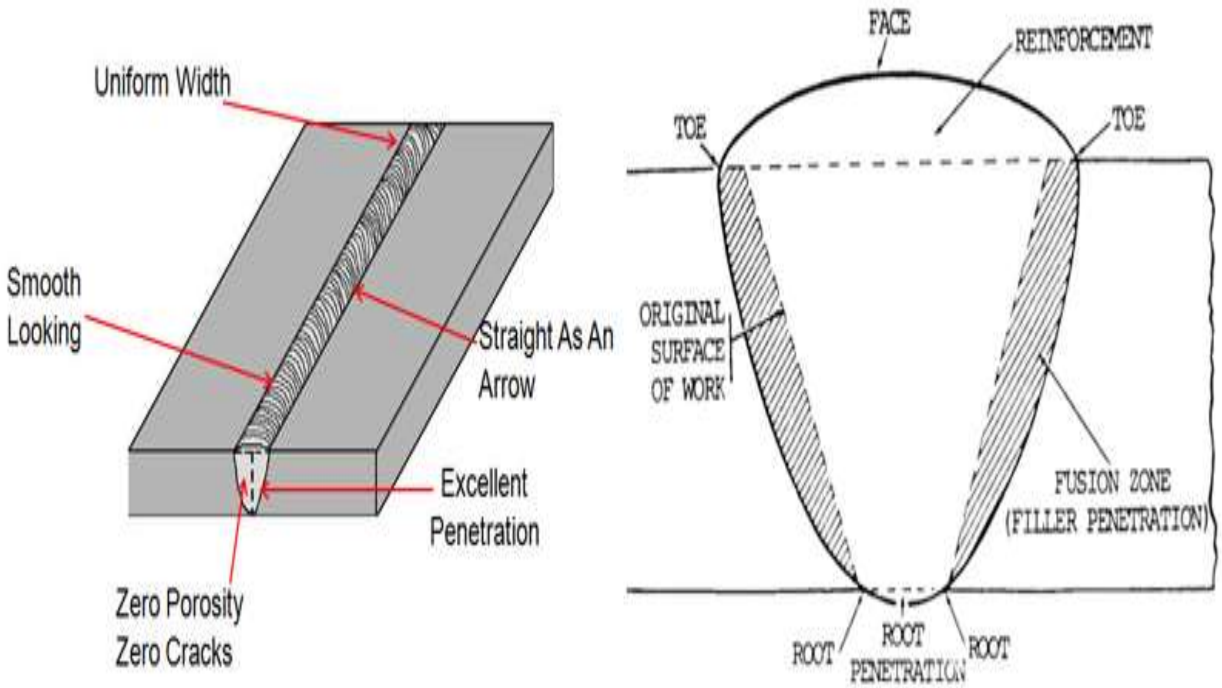


Figure 1: mind gap

- **Know the best process**

There are a number of weld processes, such as MIG, TIG, Stick (MMA) and Flux-cored, and knowing when to use each technique is an important factor in getting a good weld.

MIG, or metal inert gas, is a type of wire welding that is suited to production welding of mild steel sheet and plate, it uses an inert gas to protect the molten weld pool, which sometimes makes it difficult to use outdoors in windy conditions. Another type of wire welding is flux-cored welding, which takes place without gas and is therefore more suitable for outdoor work. Stick welding is typically the best choice for quick onsite repairs while TIG, or tungsten inert gas, welding works well on stainless steel and aluminum where the look and presentation of the weld is important.

- **Inspect the weld**

Once a weld is in place, it is important to check its quality. There are several ways of doing this. The simplest way is to check it by eye for cracks or inclusions in the weld and other problems. Welders also use a number of other so-called non-destructive testing (NDT) processes to inspect their work, such as liquid penetration and X-ray inspections. No matter what inspection is used, ensuring welds are strong and durable is an important step in the process and a vital part of quality assurance.

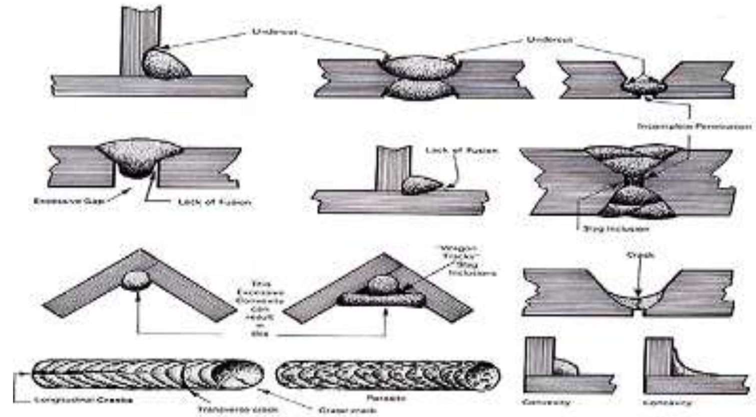
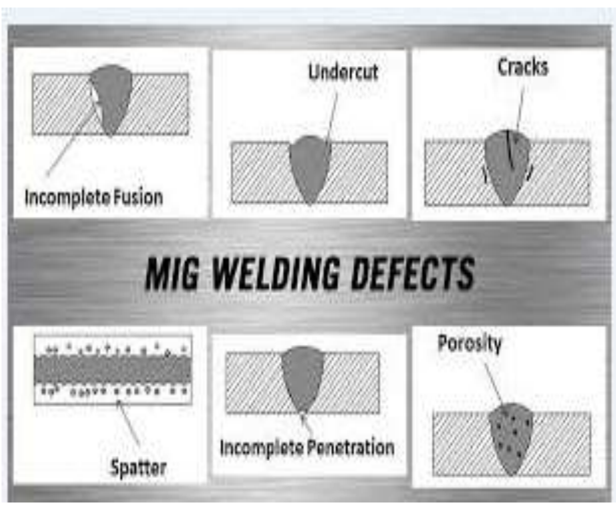
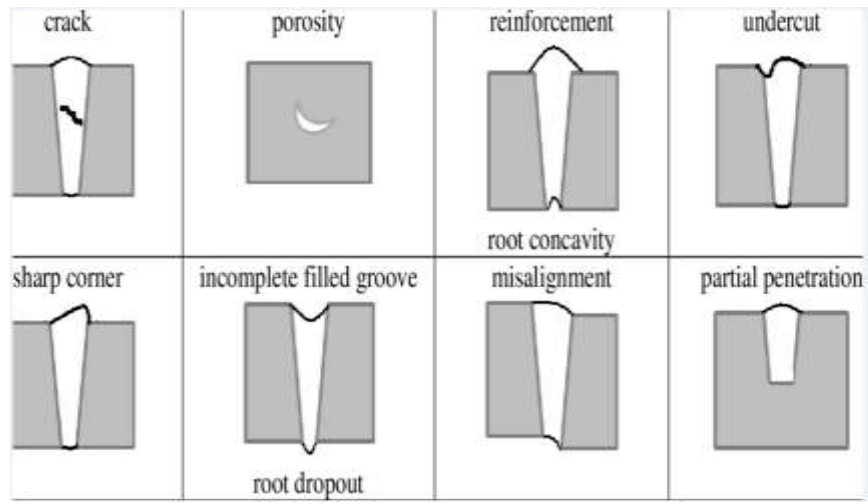


Figure 2: **Typical weld defects**





- **Design**

  Designing is the correct weld joint is important for cost, strength and visual appearance. The welding engineer has a number of options available, and selecting the correct joint and welding process for the job, along with accessibility is critical when designing a welded product.

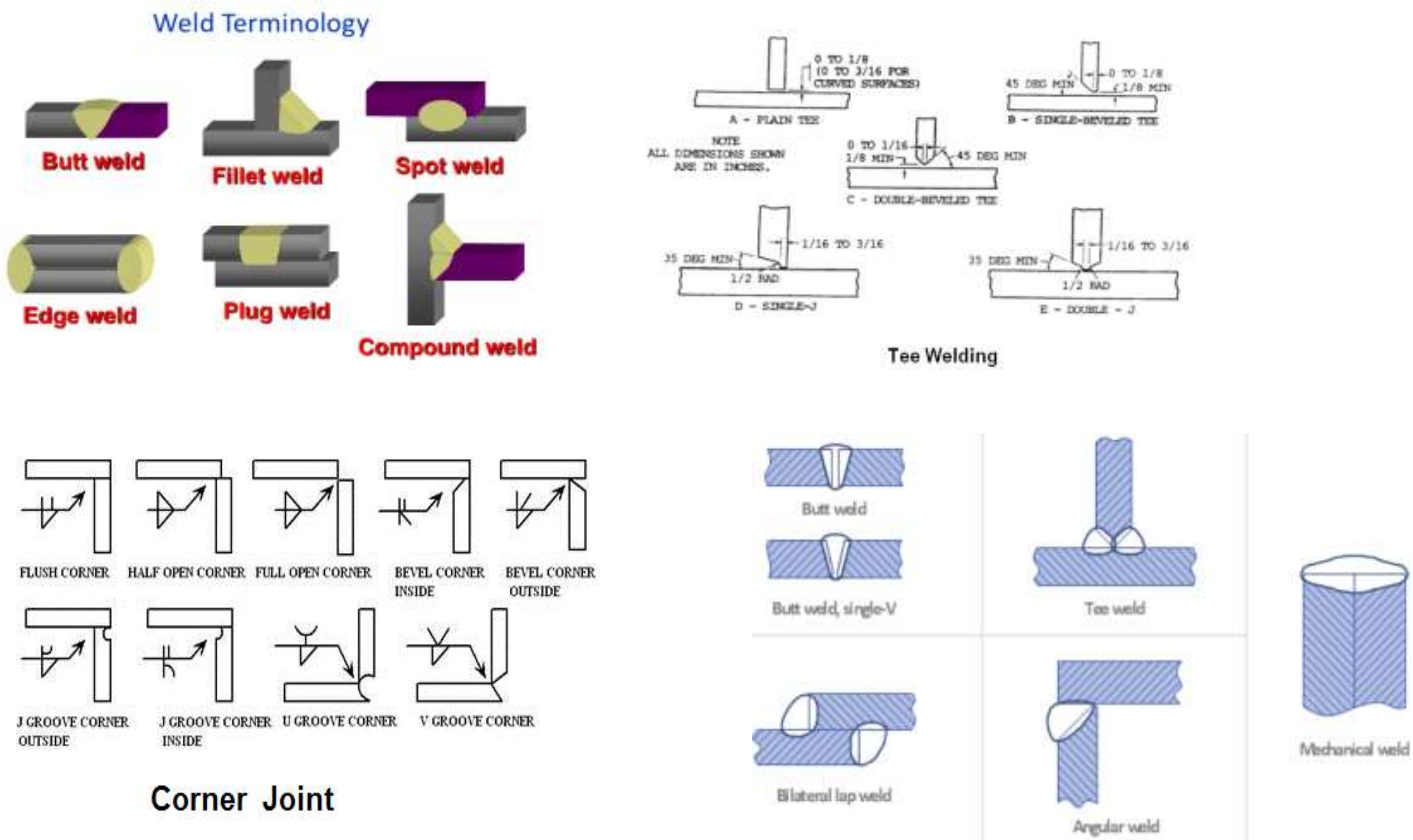


Figure 3: Different Joints

- **Welding** education requirements vary by employer. Some employers require welders to have a high school diploma and require completion of employer-based welding tests. Other employers look for a certificate or undergraduate degree from a technical school, vocational school or community college.

The following are typical requirements for the quality of weld products.

- ✓ The product is finished accurately in accordance with the design dimensions.
- ✓ The product offers the required functionality and strength (or safety).
- ✓ The appearance of the weld satisfies the required level.

The basic condition of welding quality to achieve products of such high quality includes the following:

- ✓ No cracks or holes found in the bead.
- ✓ The bead has uniform waves, width and height.
- ✓ The finished product satisfies the design dimensions and has almost no distortion.
- ✓ The welding meets the required strength.
- ✓ Full penetration welds that fuse and join the entire interface between the base materials or a weld joints including partial penetration welds should be used appropriately to ensure the necessary rigidity.

Self-Check – 1	Written Test

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

I. say true or false for the following question below

1. A Cross - section of the added metal should be small and oxidation should be minimum
2. MIG, or metal inert gas, is a type of wire welding
3. Designing the correct weld joint is important for cost, strength and visual appearance

Note: **Satisfactory rating - 2 points** **Unsatisfactory - below 1.5 point**

Answer Sheet

Score = ____________

Rating: _____________

Information sheet -2	Following Welding procedure specifications (WPS) requirements

2.1. Definition of welding Procedure

A Welding Procedure Specification (WPS) is the formal written document describing welding procedures, which provides direction to the welder or welding operators for making sound and quality production welds as per the code requirements. The purpose of the document is to guide welders to the accepted procedures so that repeatable and trusted welding techniques are used. A WPS is developed for each material alloy and for each welding type used. Specific codes and/or engineering societies are often the driving force behind the development of a company's WPS. A WPS is supported by a Procedure Qualification Record (PQR or WPQR). A PQR is a record of a test weld performed and tested (more rigorously) to ensure that the procedure will produce a good weld. Individual welders are certified with a qualification test documented in a Welder Qualification Test Record (WQTR) that shows they have the understanding and demonstrated ability to work within the specified WPS.

The following are definitions for WPS and PQR found in various codes and standards:

According to the American Welding Society (AWS), a WPS provides in detail the required welding variables for specific application to assure repeatability by properly trained welders. The AWS defines welding PQR as a record of welding variables used to produce an acceptable test weldment and the results of tests conducted on the weldment to qualify a Welding Procedure Specification. For steel construction (civil engineering structures) AWS D1.1 is a widely used standard. It specifies either a pre-qualification option (chapter 3) or a qualification option (chapter 4) for approval of welding processes.

2.1 Types of welding position

This chapter presents common types of welding position and various difficulties associated with them. Further, need for edge preparation and the rationale for selection of suitable groove design have also been presented. Keywords: Flat welding, horizontal welding, vertical and overhead welding, groove weld, edge preparation

Welding positions the welding positions are classified on the basis of the plane on which weld metal is deposited. Flat welding In flat welding, plates to be welded are placed on the horizontal plane and weld bead is also deposited horizontally (Fig. 23.1). This is one of most commonly used and convenient welding position. Selection of welding parameters for flat welding is not very crucial for placing the weld metal at desired location in flat welding.

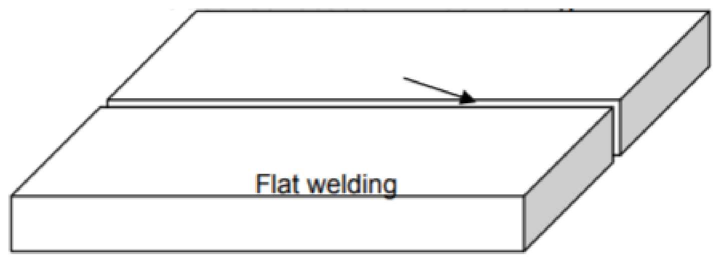


Figure 4: Flat Welding

- **Horizontal welding**
  In horizontal welding, plates to be welded are placed in vertical plane while weld bead is deposited horizontally (Fig. 23.2). This technique is comparatively more difficult than flat welding. Welding parameters for horizontal welding should be selected carefully for easy manipulation/placement of weld metal at the desired location.

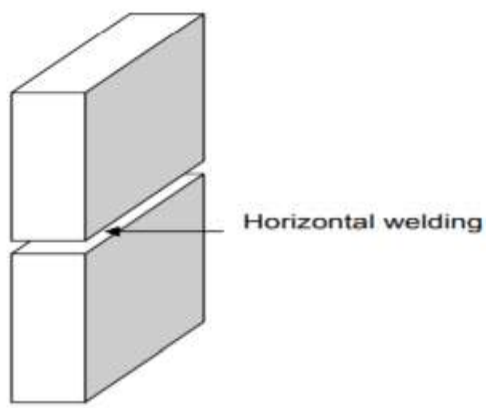


Figure 5: horizontal welding

- **Vertical welding**
  In vertical welding, plates to be welded are placed on the vertical plane and weld bead is also deposited vertically (Fig. 23.3). It imposes difficulty in placing the molten weld metal from electrode in proper place along the weld line due to tendency of the melt to fall down under the influence of gravitational force.

  Viscosity and surface tension of the molten weld metal which are determined by the composition of weld metal and its temperature predominantly control the tendency of molten weld metal to fall down due to gravity. Increase in alloying elements/impurities and temperature of melt in general decrease the viscosity and surface tension of the weld metal and thus making the liquid weld metal more thin and of higher fluidity which in turn increases tendency of weld metal to fall down conversely these factors increase difficulty in placing weld metal at desired location. Horizontal welding Therefore, selection of welding parameters (welding current, arc manipulation during welding and welding speed all are influencing the heat generation) and electrode coating (affecting composition of weld metal) dilution becomes very crucial for placing the weld metal at desired location in vertical welding.

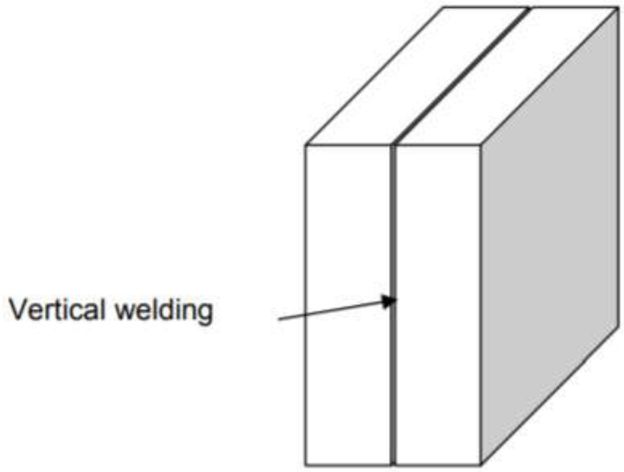


Figure 6: vertical welding

- **Overhead welding**

  In overhead welding, weld metal is deposited in such a way that face of the weld is largely downward and there is high tendency of falling down of weld metal during welding (Fig. 23.4). Molten weld metal is moved from the electrode (lower side) to base metal (upper side) with great care and difficulty hence, it imposes problems similar to that of vertical welding but with greater intensity. Accordingly, the selection of welding parameters, arc manipulation and welding consumable should be done after considering all factors which can decrease the fluidity of molten weld metal so as to reduce the weld metal falling tendency. This is most difficult welding position and therefore it needs great skill to place the weld metal at desired location with close control.

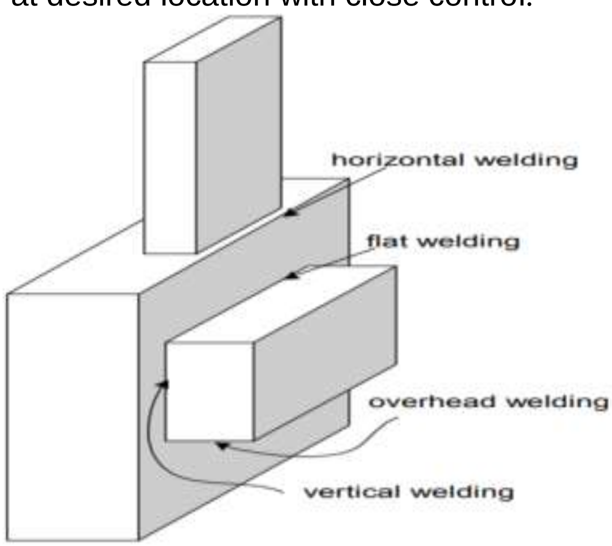


Figure 7: different types of welding positions including overhead welding

- **Rationale behind selection of welds and edge preparation**
    - ✓ **Groove weld** Groove weld is called so because a groove is made first between plates to be welded. This type of weld is used for developing butt joint, edge and corner joint. The groove preparation especially in case of thick plates ensures proper melting of the faying surfaces by providing proper access of heat source up to the root of the plates and so as to help in developing sound weld joint. It is common to develop grooves of different geometries for producing butt, corner and edge joint such as square, U (single and double), V (single and double), J (single and double) and bevel (single and double). Following sections describe various technical aspects of different types of groove welds.

    - ✓ **Single groove weld** Single groove means edge preparation of the plates to produce desired groove from one side only resulting in just one face and one root of the weld. While in case of double groove, edge preparation is needed from both sides of the plates which in turn results in two faces of the weld and welding is needed from both sides of the plates to be welded. Single groove weld is mainly used in case of plates of thickness more than 5 mm and less than 15 mm. Moreover, this range is not very hard and fast as it depends on penetration capability of welding process used for welding besides weld parameters, as welding parameters affect the depth up to which melting of plates can be achieved from the top.

    - ✓ **Double groove** weld Double groove edge preparation is used especially under two conditions a) when thickness of the plate to be welded is more than 25 mm, so the desired penetration up to root from one side is not achievable and b) distortion of the weld joints is to be controlled. Further, double groove edge preparation lowers the volume of weld metal to be deposited by more than 50% as compared to that for the single groove weld especially in case of thick plates. Therefore, selection of double groove welds helps to develop weld joints more economically, at much faster welding speed than the single groove weld for thick plates.

Self-Check – 2	Written Test

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

II. say true or false for the following question below

1. A Welding Procedure Specification (WPS) is the formal written document describing welding procedures
2. A WPS is developed for each material alloy and for each welding type used.

Note: **Satisfactory rating - 2 points** **Unsatisfactory - below 1 point**

Answer Sheet

Score = ____________

Rating: _____________

Information sheet -3	Inspecting correct size, type and quantity of materials/components

3.1. Definition of inspecting and Component

Many characteristics of a weld can be evaluated during welding inspection - some relating to weld size, and others relating to the presence of weld discontinuities. The size of a weld can be extremely important, as it often relates directly to the weld's strength and performance. For instance, undersized welds may not withstand stresses applied during service.

Depending on their size and/or location, weld discontinuities (imperfections within or adjacent to the weld) can prevent the weld from meeting its intended performance. Weld discontinuities are often referred to as welding defects, and they can sometimes cause premature weld failure due to a reduction of strength or added stress concentrations within the welded component.

Weld inspections are conducted for several reasons, the most common of which is to determine whether the weld is of suitable quality for its intended application. To evaluate the quality of a weld, you must first have criteria to which you can compare the weld's characteristics. Codes and standards developed specifically for a variety of welding fabrication applications are used during welding inspections to dictate what levels of weld discontinuities are acceptable. It is important to choose a welding standard that is intended for use within your industry or application.

Quality acceptance criteria can originate from several sources. The welding fabrication drawing or blueprint will typically provide sizes and other dimensional information, such as length and location of welds. These dimensional requirements are typically established through design calculations or are taken from proven designs known to meet the performance requirements of the welded connection.

3.2. The role of a welding inspector.

Welding inspection requires a wide variety of knowledge on the part of the inspector, including an understanding of welding drawings, symbols, and procedures; weld joint design; code and standard requirements; and inspection and testing techniques.

For this reason, many welding codes and standards require that the welding inspector be formally qualified. There are several welding inspection training courses and certification programs available. The most popular program used in the US is the Certified Welding Inspector (CWI) program, and it's administered by the American Welding Society (AWS). Certification as a welding inspector typically requires that you demonstrate your knowledge through a welding inspection exam.

3.3. Welding inspection methods.

- **Visual inspection.**

If performed correctly, a visual inspection is often the easiest and least-expensive method for many applications. However, a good-looking weld doesn't always ensure internal quality, and discontinuities aren't always visible to the naked eye. Thus, additional methods are available, including those listed below.

- **Surface crack detection.**

Used to detect fine cracks, seams, porosity, and other surface-breaking discontinuities, surface crack detection is usually applied using one of two methods: liquid penetrant inspection or magnetic particle inspection.

- ***Destructive weld testing.***

As the name suggests, this inspection technique involves the physical destruction of the completed weld to detect various mechanical and physical characteristics.

A quality welding operation requires the establishment and control of a sound welding inspection program. With the proper technique, the right quality requirements and acceptance criteria, and experienced welding inspectors, you can build such a program.

Destructive weld testing, as the name suggests, involves the physical destruction of a completed weld to evaluate its strength and characteristics. This method of testing is frequently used for the following applications:

- Welding procedure qualification
- Sampling inspection
- Research inspection
- Welder performance qualification testing
- Failure analysis work

Methods of destructive weld testing typically involve sectioning or breaking the welded component and evaluating various mechanical and physical characteristics. Check out some of the most common methods for executing a destructive weld test below.

3.4. Destructive weld testing methods.

- **Macro etches testing.**

This method requires the removal of small samples from the welded joint. These samples are then polished at their cross section and etched using a mild acid mixture, depending on the base material used. The acid etch provides a clear visual of the weld's internal structure.

Inspection of the etched sample reveals depth of penetration, as well as evidence (if any) of lack of fusion, inadequate root penetration, internal porosity, and cracking shown at the fusion line (which is the transition between the weld and the base material).

This type of inspection is a snapshot of the overall weld-length quality when used for sampling inspection of production welds. Macro etch testing is also used successfully in failure analyses to pinpoint welding problems such as crack initiation.

- **Fillet weld break test.**

This type of testing involves breaking a sample fillet weld that is welded on one side only. The sample has a load applied to its un welded side, typically in a press, and the load is increased until the weld fails. The failed sample is then inspected to establish the presence and extent of any welding discontinuities.

Fillet weld break tests provide a good indication of discontinuities within the entire length of the weld tested (normally 6 to 12 inches) rather than a cross-sectional snapshot, like the macro etch test. This type of weld inspection can detect such items as lack of fusion, internal porosity, and slag inclusions.

Though the fillet weld break test is often used on its own, it can also be used in conjunction with the macro etch test, as the two methods complement each other by providing information on similar characteristics but with different detail.

- **Transverse tension test**

Because a large portion of design is based on tensile properties in the welded joint, it is important that the tensile properties of the base metal, the weld metal, the bond between the base and the weld, and the heat-affected zone conform to design requirements.

The transverse tension test checks all this by pulling specimens to failure and then dividing the maximum load required during testing by the cross-sectional area. The result is in units of tension per cross-sectional area.

- **Guided bend test**

This is a test method that involves bending a specimen to a specified bend radius. Various types of bend tests are used to evaluate the ductility and soundness of welded joints. Guided bend tests are usually taken transverse to the weld axis and may be bent in plunger-type test machines or in wraparound bend test jigs. Face bend tests are made with the weld face in tension, while root bend tests are made with the weld root in tension. When bend testing thick plates, side bend test specimens are usually cut from the welded joint and bent with the weld cross section in tension.

The guided bend test is most commonly used in welding procedure and welder performance qualification tests. This type of testing is particularly good at finding liner fusion defects, which will often open up in the plate surface during testing.

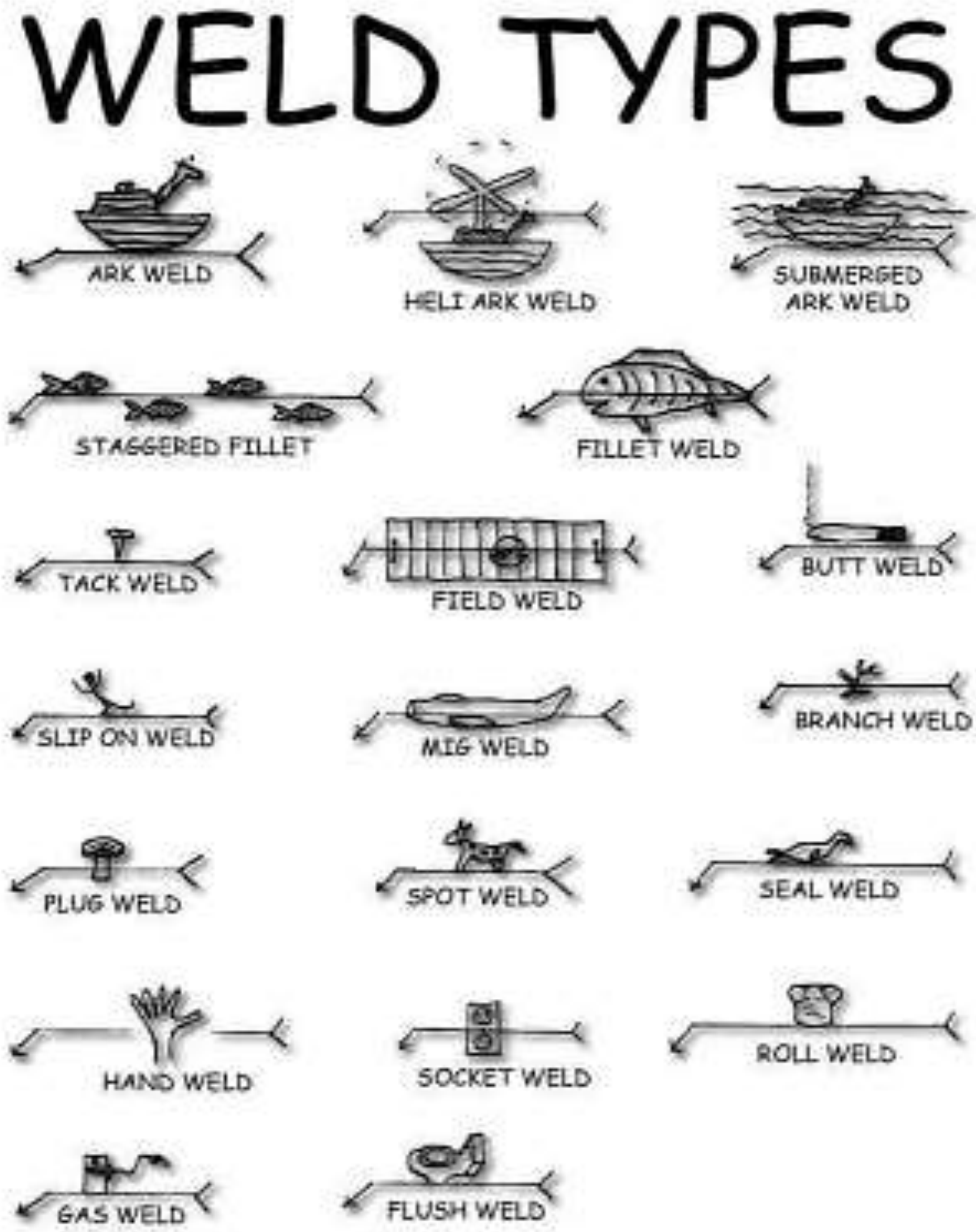


Figure 8: types of welding

3.5. Welding Equipment

Technology with no compromises: design and manufacturing of welding components accordingly to specific application requirements and parameters.

Welding controls to set parameters and display welding reports. Complete range of welding transformers with AC – DC and MF technology from 25 to 500 KVA. Welding cylinders and presses, seam welding heads for special and standard applications.

Figure 9:AC_DC measuring device

- ***Medium Frequency Welding:***
  Improve welding quality and reduce energy costs. Inverters and welding transformers 1000 Hz – 500V to assure constant system performances, improved parameters accuracy and reduced dimensions.

- **Ventilation**

Ventilation can remove heat from the environment and reduce exposure to fumes and other atmospheric contaminants in the work area.
There are three main types of ventilation:

- ✓ local exhaust ventilation
- ✓ forced dilution ventilation
- ✓ Natural dilution ventilation.

- The choice of ventilation system should take into account:
  - ✓ the amount and type of fumes and contaminants produced
  - ✓ the proximity and location of the welding process relative to the ventilation system
  - ✓ the level of ventilation, natural or mechanical, both for the whole workplace and the welding area – this will also depend on screens and partitions which may restrict cross-flow at the work area

✓ The proximity of the welder's breathing zone to the fume source.

Figure 10: welder's breathing zone to the fume

- **Local exhaust ventilation**

A local exhaust system may comprise the elements listed:

✓ a hood which captures the contaminant close to its point of generation
✓ a duct system to move contaminant away from the work area
✓ an air cleaning system to prevent pollution of the general atmosphere
✓ an exhaust fan to provide air flow
✓ a stack or other means of discharging the decontaminated air into the atmosphere.

Local exhaust ventilation systems should be designed to provide a minimum capture velocity at the fume source of 0.5m/second away from the welder. Inlets and outlets should be kept clear at all times. Air from a local exhaust ventilation system should not be re-circulated into the workroom. This air should be discharged into the outside air away from other work areas and away from air conditioning inlets or compressors supplying breathing air.

Examples of local exhaust ventilation suitable for welding operations include:

✓ fixed installations, such as side-draught or down-draught tables and benches, and partially or completely enclosed booths
✓ portable installations, such as movable hoods that are attached to flexible ducts
✓ low volume high velocity fume extractors attached directly to the welding gun

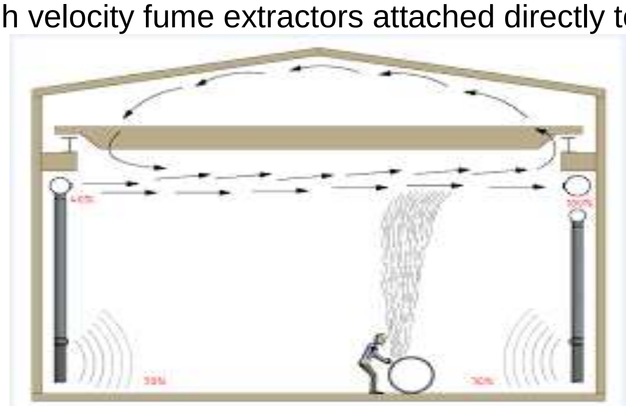


Figure 11: ***exhaust ventilation***

- **Forced dilution ventilation**

  An elevated concentration of atmospheric contaminants can be diluted with a sufficient volume of clean air. Successful dilution ventilation depends not only on the correct exhaust volume but also on control of the airflow through the workplace. Although forced dilution ventilation systems are not as effective in controlling atmospheric contaminants as local exhaust ventilation systems, they may be useful to control minor emissions of low toxicity contaminants.

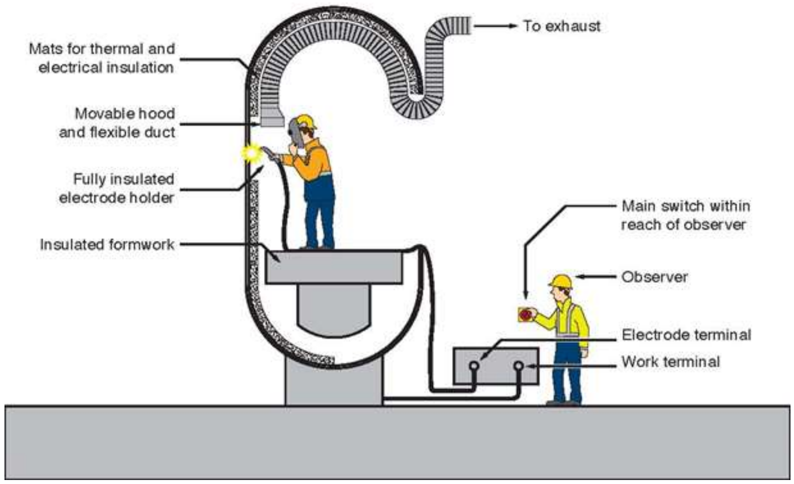


Figure 12: Local Exhaust ventilation in confined space welding

- **Natural ventilation**

Natural ventilation should only be used for general comfort not as an engineered control measure for atmospheric contaminants and fumes. Natural ventilation can assist with the transfer of contaminants from the work area however it is not a reliable way of diluting or dispersing contaminants. For example, if a worker is working in a fixed position and the natural wind velocity is mild or wind is in a direction towards the worker, the worker may remain exposed to contaminants that have not been removed from the worker’s breathing zone.

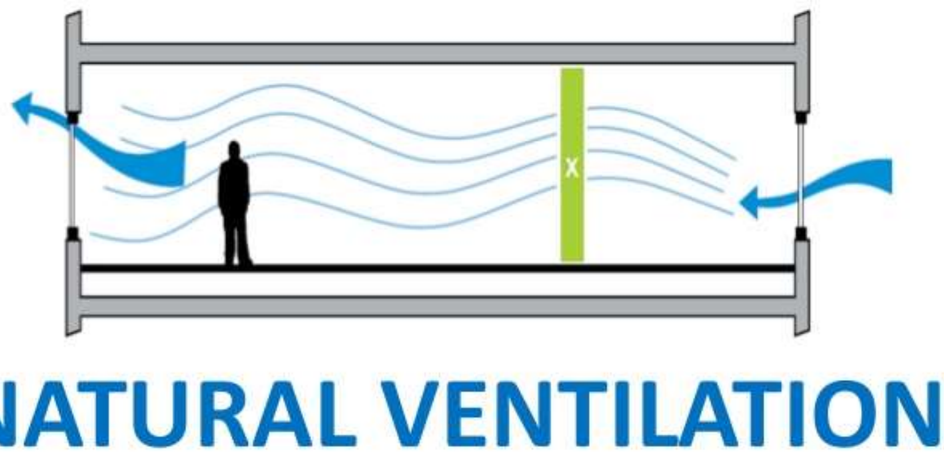


Figure 13: Natural ventilation

Self-Check – 3	Written Test

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

I. Say true or false for the following question below

1. Ventilation can remove heat from the environment and reduce exposure to fumes.
2. Natural ventilation should only be used for general comfort .
3. Guided bend test is a test method that involves bending a specimen to a specified bend radius.
4. Fillet weld break test is a type of testing which involves breaking a sample fillet weld that is welded on one side only.
5. Macro etch testing is a method which requires the removal of small samples from the welded joint.
6. A quality welding operation requires the establishment and control of a sound welding inspection program.

Note: **Satisfactory rating - 4 points** **Unsatisfactory - below 3 point**

Answer Sheet

Score = ____________

Rating: _____________

Information sheet -4	Preparing Materials correctly with job specification

4.1. Welding Tools and Materials

SMAW (Shield Metal Arc Welding) is simple and easy welding method, and possible to weld under strong wind. Shape of much type of these materials is steel rod, and including some elements. In addition, some materials are coated copper and the others have flux cored structure

Figure 14: Different Tools and Materials

Metal has been worked by humans for thousands of years. Over time, the techniques and technology used to produce and shape metal goods have been driven by the innovations of science and technology.

Before we dive into some of the technical processes available for welding metal together, let's first take a moment to define a weld. A weld is a fabrication process that joins materials, usually metals or thermoplastics, by fusion. Fusing materials is distinctly different than other kinds of lower temperature metal-joining techniques such as soldering, which do not melt the base metal.

Metal welding is the fusing of two pieces of metal to create one solid continuous piece. All welders work on the same principle: A gas torch or electric welder is used to generate precisely directed heat to melt material, and a filler material is introduced by the operator to complete the fusion.

With time has come innovation and accessibility, and now we've come so far that you - yes YOU! - can learn how to weld easily. Let's get started!

4.2. Welding Tools and Materials

- **Complete Consumables and Tool List for this Class**

  Power Tools

  - ✓ Angle grinder with a paddle switch
  - ✓ Sawzall (optional)
  - ✓ Metal Band Saw

- **Consumables**

  - ✓ Angle grinder wheels
  - ✓ Welding wire
  - ✓ Steel - more on this below
  - ✓ Shielding gas

- **Clamping, Measuring & Marking**

  - ✓ Soapstone
  - ✓ Squaring Tools
  - ✓ Welding magnets
  - ✓ Scribe
  - ✓ Welding clamps
  - ✓ Permanent markers

- **Hand Tools**

  - ✓ Welding pliers
  - ✓ Steel wire brush - specifically a steel brush, not a stainless steel or aluminum brush
  - ✓ Hack saw

- **Studio Safety**

  - ✓ Welding table
  - ✓ Welding curtain
  - ✓ Bricks - available at your local hardware store, or your driveway.

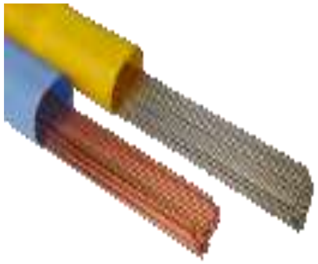
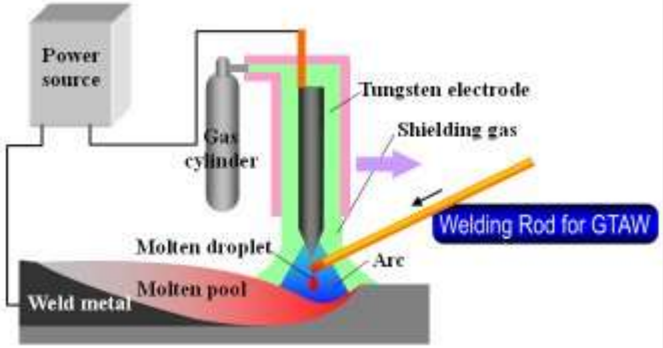
4.3. Personal Safety

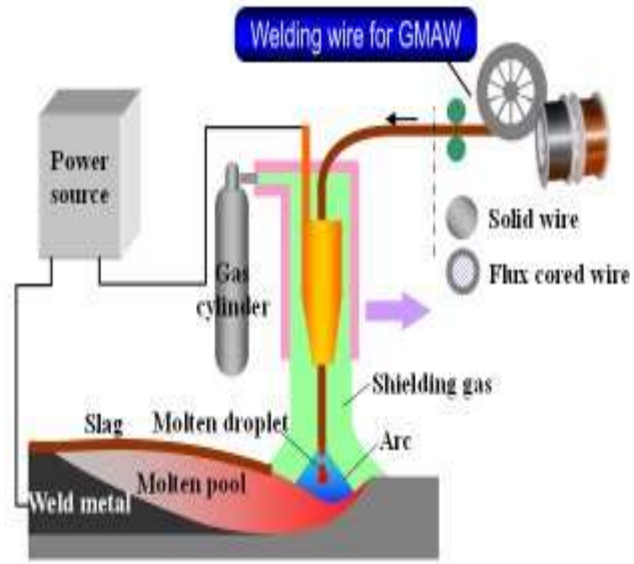
- ✓ Welding helmet
- ✓ Welding jacket
- ✓ MIG welding gloves
- ✓ Safety glasses
- ✓ Ear protection
- ✓ Grinding visor
- ✓ Face Mask
- ✓ Work shoes

- **Supplies for Projects**

  - ✓ 16 gauge cold-rolled sheet steel
  - ✓ 1" Square tube, 16 gauge
  - ✓ 2" Flat bar, 1/8th inch
  - ✓ 1" Flat bar, 1/8th inch

Kind of welding materials

Kind	Characteristic	Appearance	Mechanism
Covered Electrode	**[Structure]** These types of materials are painted and covered flux around core steel rod. **[Characteristics]** Shielding gas is unnecessary because of intercepting the atmosphere and the arc by resolute gas from coating flux. SMAW (Shield Metal Arc Welding) is simple and easy welding method , and possible to weld under strong wind.		
TIG Welding Rod	**[Structure]** Shape of many type of these materials is steel rod, and including some elements. In addition, some materials are coated copper and the others have flux cored structure. **[Characteristics]** GTAW(Gas Tungsten Arc Welding) is clean process because of generating non-spatter and non-fume, has good bead appearance and mechanical properties of weld metal, is able to apply to all kind of metals. Shield of the arc from atmosphere perform to blow inert gas i.e. Argon. GTAW is many used to pipe welding or repair welding.		

GMAW Solid wire	**[Structure]** Shape of these materials is small diameter steel wire including some elements. In addition, there is copper coated type and non-coated type. These wires are packed in spool(bobbin) or large drum-pack container. **[Characteristics]** These materials are most popular in Japan, and used to semi-automatic welding by human welder or automatic welding by robot. Shield of the arc from atmosphere perform to blow CO_2 gas or mixture gas of CO_2 and Argon.		
GMAW Flux Cored Wire	**[Structure]** These wires have dual structure that inner is flux and outer sheath is cylindrical thin steel plate. In addition, there is copper coated type and non-coated type. These wires are packed in spool(bobbin) or large drum-pack container. **[Characteristics]** These wires generate fewer spatter and better bead appearance than the solid wires at fillet or vertical form welding. These are many used to ship-building or bridge construction. In addition, there are unnecessary		

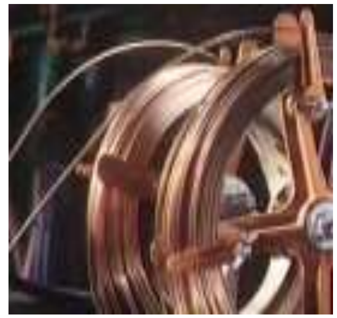
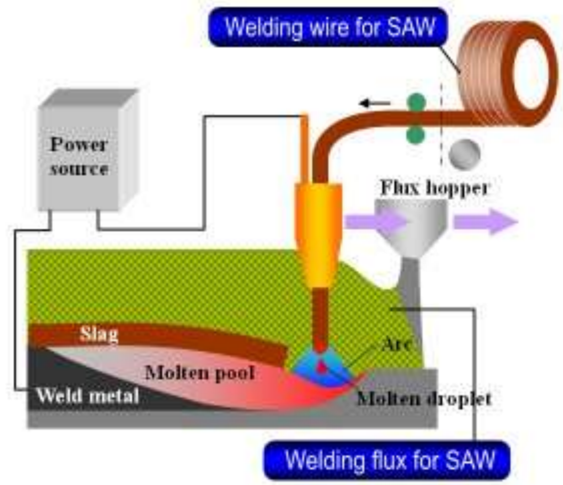
	types of shielding gas, too.		
SAW wire	**[Structure]** Shape of these materials is large diameter steel wire including some elements. But there are flux cored types in a part. These wires are mainly packed in non-spool (bobbin) coil type. These are used in combination with the following flux. **[Characteristics]** SAW(Submerged Arc Welding) can used in ultra high current range and become very high efficiency by more than two electrodes system. In addition, generates no arc rays, has good bead appearance and is not affected by the strong wind.		
SAW Flux	**[Structure]** The fluxes are mixed powdery materials contained some elements. And, soled in the steel drum or bag made by paper or cloth.. **[Characteristics]** The fluxes are filled in welded groove of base metal, and then covered the arc on welding. Kind of these have the melting type and the bonding type by the difference in manufacturing method.		

Figure 15

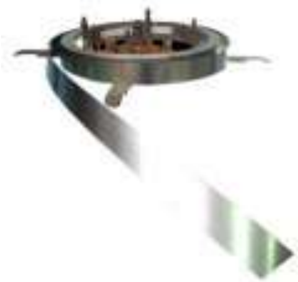
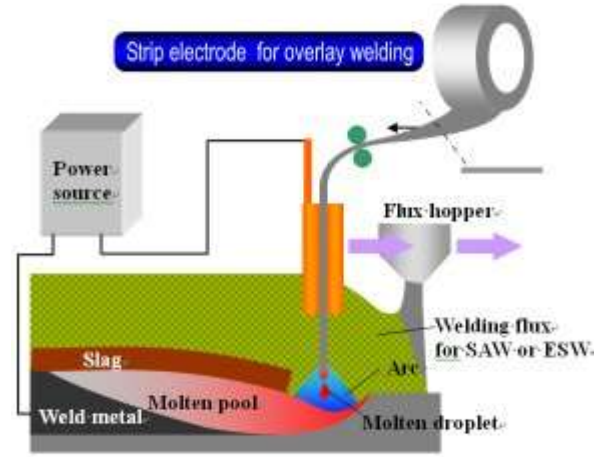
Strip Electrode	**[Structure]** These are welding materials of ribbon shape with suitable width. **[Characteristics]** Strip electrodes are used in the overlay welding on another base metal surface. High efficiency work is possible because of very wide bead. Kind of welding method has the submerged arc welding (SAW) or the electro-slag welding (ESW).		

Figure 16: different Components

- **Who This Class Is For**

Figure 17: Angle Welding

This class is designed for those who are completely new to welding. Throughout this course, amateur metalworkers will learn ideas and tips about how to become skilled welders, ready to push their making craft to the next level.

- **About Your Instructor**

Figure 18: Instructor when using Welding

I learned how to weld in college when I took a drop-in advanced sculpture class while constructing my thesis project. I learned primarily Oxy-Acetylene welding to do very fine wire work. To this day, I think Oxy welding is my favorite technique, but it's not practical for every application, and not as fast as MIG.

I learned MIG welding when learning how to repair bicycles in Reno, and my neighbor handed me the gun to their flux-cored 110v welder and said, 'Ok, now you do it'. I explained I had never used a MIG welder before and they turned to me and said: "It's just like using a really hot glue gun." That phrase shot down whatever fears I had about doing a bad job, and I found myself confidently wielding the torch within 20 minutes.

I've taken on large welding projects for Intractable builds, and have done structural welding on sculptures that have traveled around the world.

In short, I'm no pro or expert, but I'm self-taught, experienced and can provide a great pathway to get you metalworking and welding in no time.

- **Personal Safety Equipment**

  MIG welding can be safe as long as you follow a few important safety precautions. Welding metal requires us to protect ourselves from the many dangerous aspects of the trade with safety gear to prevent us from getting burned or blinded.

Figure 19: Safety Equipment

An auto-darkening welding helmet protects our eyes from the light that is generated by any form of arc welding but allows you to see when the arc of the torch is not active. Auto-darkening helmets are helpful if you are doing a bunch of welding and don't want to jerk the helmet off and on to see what you are doing in between welds.

Figure 20: Arc

If you work in a community shop with lots of people, protecting others from seeing the arc by using a welding screen. The screen protects potential on-lookers from getting blinded by the arc.

Having your skin covered is critical. Once you start grinding and welding, hot sparks and molten metal slag can shoot in all different directions. We protect ourselves by wearing heat-resistant leather and natural fiber; synthetic fabrics melt instead of burn, meaning they become molten and burn into the skin, yikes! But honestly, a leather jacket is really hot to wear for any extended welding project. If you're like me and heat up quickly, you can try a welding apron with a long sleeve flame-resistant cotton shirt.

Figure 21: Her wear safety close

Most of the time, I wear coveralls that have been rated for use with welding. They cover all my skin, and I can tuck the sleeves into my gloves when I'm welding, or easily roll them up when I'm grinding. This cover will not only protect your skin from the heat produced by welding, it shields your skin from the UV light produced by welder's arc.

Just like your welding clothes, you are going to want wear very sturdy **work shoes** that do not have any synthetic materials that could melt. Good work boots or even canvas slip-ons are fine - just no running shoes.If I'm going to be welding for more than 15 minutes, I'll even put on **sunscreen**. I've occasionally gotten sunburns on my neck from the small gap between my leathers and my helmet, but SPF 110 seems to do the trick.

Figure 22: Working Welding

When you are welding, you will be gripping and traverse your hands and forearms along some very hot metal. For this reason, we wear **MIG welding gloves**. Be warned, MIG gloves are the most uncomfortable gloves in the world. They should fit loose so that if they become too hot, you are able to quickly fling them from your arm on to the ground.

Wearing a **grinding visor** protects your face from flying particulate while you are using a grinder. If you are working to grind off paint, or any other kind of metal finish, consider wearing a face mask to protect you from potential fumes on the steel coating.

Figure 23: Eye Glass

I wear **safety glasses** under my welding helmet for the sole reason that I make sure I am wearing them once I start grinding metal. There are some terribly horrific stories about metal slag and shards coming into contact with eyeballs, I will spare you them and just reiterate - WEAR SAFETY GLASSES. The safety glasses I recommend have a Z87.1 rating. This rating ensures that your eyes are receiving some UV protection from other welders around you, and from flying sparks when you're grinding.

Figure 24: Complete After

You also want to protect your ears while welding and grinding by wearing ear muffs or **ear plugs**. When the fast-spinning grinding wheels come into contact with the steel it is super-duper loud, and prolonged exposure can cause pain or even temporary deafness.

It's important to weld in a well-ventilated area. MIG welding produces fumes which you shouldn't breathe in. If you are going to be welding and working for longer than 30 minutes, wear either a mask or a respirator that can protect you from metal fumes.

- **Even More Welding Safety**

Figure 25: Scarp

- **DO NOT WELD GALVANIZED STEEL**.

  Galvanized steel contains a zinc coating that is applied to industrial steel to prevent rust over a prolonged period of time. (Think streetlamps, and bridge supports) This zinc coating produces carcinogenic and poisonous gas when it is burned. Exposure to the immolated coating can result in heavy metal poisoning also known as 'welding shivers'. These are flu-like symptoms that can persist for a few days, but that can also cause permanent damage. This is not a joke. I have witnessed someone who has welded galvanized steel out of ignorance and immediately felt the effects and had to be rushed to the hospital, so don't do it!

Figure 26: Considering Fire Safety

Molten metal slag can splatter several feet from a weld. Grinding sparks can fly even further. Any sawdust, paper or plastic bags in the area can smolder and catch fire, so keep a tidy area for welding. Most often, your attention will be focused on the parts you are welding, and not the area around you, so it can be hard to see what's going on behind you if something catches fire. Reduce the chance of that happening by clearing away all flammable objects from your weld area. This is a good precaution for any shop, but keeps a fire extinguisher beside the exit door from your workshop. CO_2 extinguishers are the best type of extinguisher for welding. Water extinguishers are not a good idea in a welding shop since you are standing next to a machine which essentially transforms wall power into lightning.

- **Different Kinds of Welding**

  The main types of welding used in industry and by home engineers are commonly referred to as MIG welding, TIG welding, arc welding, and gas welding. Hands down, MIG welding is the most common form of welding practiced, but there are other options for fusing metal together.

- **GMAW** or **G**as **M**etal **A**rc **W**elding (more commonly called **MIG welding**) is the most widely used and perhaps the most easily mastered type of welding for industry and home use. The GMAW process is suitable for fusing mild steel, stainless steel as well as aluminum. A few years ago the full name - Metal Inert Gas (MIG) welding was changed to Gas Metal Arc Welding (GMAW) but if you call it that most people won't know what the heck you're talking about - the name MIG welding has certainly stuck.
- **MIG** (**M**etal **I**nert **G**as welding)is a semi-automatic arc welding process in which a consumable wire electrode and a shielding gas are fed through a welding gun, also known as the **torch**. The machine produces massive electrical current that travels through the consumable wire to your work pieces fusing and melting both the wire and the base metal together.

Figure 27: MIG welding

MIG welding was developed in the 1940's as a way to speed up the way production welders fuse materials in factories during and after WW2. Seventy years later, the general principle is still very much the same but most MIG welding equipment has been modernized with better parts and some even have onboard computers.

MIG welding uses an arc of electricity to create a short circuit between a continuously fed positive anode (the wire-fed welding gun) and a negative cathode (the base metal being welded). If you want a greater understanding of the core principles of electricity check out the Electronics Class.The heat produced by the short circuit, along with a non-reactive inert gas, melts the metals under the welding torch and allows them to mix together. Once the heat is removed, the metal begins to cool and solidify, forming a new piece of fused metal.

MIG welding is useful because you can use it to weld many different types of metals: carbon steel, stainless steel, aluminum, magnesium, copper, nickel, silicon bronze and other alloys. This class only goes over how to fuse mild steel, but your welder's manual will have advanced instruction on how to weld other materials.

Figure 28:Oxy welding part of ammunition boxes, 1943 - from the Flickr Creative Commons Public Domain Image Library provided by the State Library of South Australia.

- **Oxy-Acetylene Torch Welding**, more commonly **Gas Welding and Cutting**, are not used as widely for general welding of mild steel, but great for very delicate assembly of small ornate parts. This form of welding is one of the earliest industrial forms of welding. Gas welding consists of mixing oxygen and acetylene gas to create a flame capable of melting steels. The gas torch is commonly used for brazing softer metals such as copper and bronze, but can also be used for welding delicate aluminum parts such as refrigeration pipes.

Figure 29: Oxy-Acetylene

- **GTAW** (**G**as **T**ungsten **A**rc **W**elding), or more commonly **T**ungsten **I**nert **G**as (**TIG)** welding is comparable to oxyacetylene gas welding and needs quite a bit of hand/eye/foot coordination from the operator. TIG welds are best suited for out high-touch work, such as sculptures and architectural features. TIG welds provide a superior finish that needs minimal clean up by sanding or grinding.

- **TIG welding** provides a very clean way to weld. In one hand you wield a torch electrode and connect ground to your base material. You activate the flow of current with a foot pedal and control the amount of current on the welder. Instead of a consumable wire feed being burned from the torch, the person welding gently feeds filler material from a rod into the welding pool. Since you control the feed of material, slag splatter is minimal. If you are interested in learning more about TIG welding, check out this Instructable.

Figure 30: TIG welding

Arc Welding or **S**hielded **M**etal **A**rc **W**elding (**SMAW**) is more commonly referred to as stick or arc welding. Arc welding works by clamping a current producing electrode onto a coated consumable stick of material. An electrical arc travels from the tip of the consumable electrode to the base material underneath. The distance between the electrode tip and base material controls the amount of heat being generated by the super-hot electrical arc. Arc welding is best suited for structural manufacturing, construction, and large-scale repairs. Arc welds get very hot, and can burn out thin material easily; thinner materials are more suited to the MIG welding processes.

- **Pros and Cons of MIG Welding**

  Before going further in this class, please note that the lessons in this course only go over one of the kinds of welding listed above, MIG welding. MIG welding is the most common form of welding, albeit the price tag associated with a MIG welder can be high, it is the most accessible of welding skills to learn. More on that in our upcoming lessons.

Figure 31: Pros

- **Here are some advantages to MIG welding:**

  - ✓ The ability to join a wide range of metals and thicknesses
  - ✓ All-position welding capability, meaning you can weld on vertical and overhanging surfaces with ease
  - ✓ A good weld bead, with the right settings
  - ✓ A minimal amount of weld splatter (compared to industrial stick welding)
  - ✓ Easy to learn

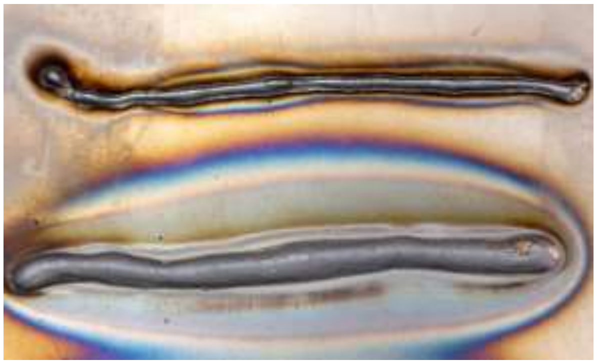


Figure 32: working by MIG welding:

- **Disadvantages of MIG welding**

  ✓MIG welding can only be used on thin to medium thick metals. Depending on the welder, I would say the thinnest would be 24GA steel, which is about .0239 inches, and medium thickness is about 1/4" or 5/16" - anything thicker than that, and it's on to stick welding.

  ✓The use of an inert gas makes this type of welding less portable than arc welding which requires no external source of shielding gas

  ✓Produces a somewhat sloppier and less controlled weld as compared to TIG welding

- **Measuring, Marking, Squaring, and Clamping**

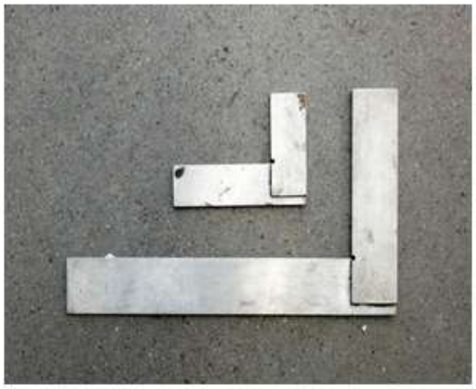


Figure 33: Measuring Tools

- **Measuring Tools**

Any good fabricator knows that improper measurement when working on any project is not advised and will lead to poorly crafted finished work. Be sure to invest in a number of reliable measuring and marking devices. The most common measuring tools you will need in your metalworking arsenal are tape measures, metal rulers, calipers, metal T-squares, and a marking tool of some kind. I often find myself doing a majority of my marking with a center punch or an extra-fine point permanent marker.

Figure 34: Clamps

- **Welding Clamps & Magnets**

  Tight joints are key when welding pieces of metal together. Using welding clamps and grips will allow you to set your work piece up firmly while welding it together. **Clamps and grips** come in all shapes and sizes, so be sure to find the right kinds of clamps for your job, I swear there is a clamp out there for every kind of job.

Figure 35: welding magnets

If you are wanting to work quickly, or don't need extensive jigging for holding your pieces together, consider using **welding magnets**. Welding magnets hold pieces at a variety of angles, but most commonly at 90, 45, 60, and 135.

Options for Cutting Metal

Figure 36: Cutting Metal

I had a shop teacher once tell me that with any tool you have three options: affordability, speed, and quality - but you only get to pick two. As we go over options in cutting metal, you will see what I mean. The cutting options presented below scale from least to most expensive.

Figure 37: Hacksaw

For cutting thin rod and tube affordably, look no further than a **hacksaw**. Be sure to use the right blade for your material in your saw. Mild steel requires a blade with fewer teeth per inch (commonly referred to as TPI), like this 18 tooth per inch blade . Softer metals like aluminum or copper will need a blade with more teeth per inch . The cuts that you get with a hacksaw are slow and often kind of chewed at the edges, making them not quite flush. You may want to use a miter box to try and get the squarest cuts possible.

Figure 38: angle grinder

Another option in cutting is using your trusty **angle grinder with a cut-off wheel**. The cut-off wheel will be rated for the kind of material you are cutting, as well as the thickness of the material you are cutting, so be sure to check the back of the wheel before you fit it to your grinder. Getting a square cut is a little tricky. You can achieve a squares cut in tube or rod by marking your material with a combination square, so you have a straight cutting guide, move your guard to the side of your grinder, then plunging the spinning wheel straight down into your material with the grinder perpendicular to your cutting plane. Cutting with an angle grinder goes fast, and leaves your material mostly smooth and very hot so allow it to cool.

If your studio has limited space, consider getting a grinder miter stand . These yield great results on a budget, are fairly portable, and can be stored easily.

Figure 39: Different materials

Another affordable power tool you can use to cut metal is a sawzall . **Sawzalls** with the correct blade for your material cut through a metal tube like butter. I find that if I score my material with a straight line using a cut-off wheel, this creates a groove for the sawzall's blade to follow. After scoring the grove, rotate the material 90 degrees and begin cutting with the blade following the grove. This yields a pretty quick, mostly square cut which will require minimal deburring.

Figure 40: CN machine

Lastly, let's go over band saws. Above you see a **vertical band saw** (left) and a **horizontal band saw** (right). The vertical band saw is great for making small cuts in solid material, but not advised for larger jobs, or hollow tube. The horizontal band saw is, in my opinion, the best tool a welder could invest in for cutting metal.

Figure 41: horizontal band saw

This band saw gives the operator the most control and reliability in making cuts. You are able to set the speed of the blade, the angle of the cut, and the speed of which the blade descends into the material. You almost never have to deburr a cut made on the horizontal band saw, and if you do, it’s because your settings are too fast.

Often, if I have to make cuts of the same length over and over again, I will clamp a piece of material to the out feed table at a set distance from the blade. This makes fast work for getting precise cuts over and over again. All I have to do is feed the material I am trying to cut until I hit the stop-block of the clamp, then I vice the metal and make the cut.

If you need to make accurate cuts on a jobsite, consider a port band saw. They yield straight cuts that require minimal deburring, and often have variable speed control so you can set the blade speed for your material. If you need to make custom shapes in sheet metal, check out this Intractable on plasma cutting. Plasma cutters are expensive tools, but lots of maker spaces are starting to purchase them for common use in their shop. For a more in-depth tutorial and explanation on cutting metal, check out the Cutting lesson from the Metalworking class.

Sourcing Steel

Figure 42: Arranging Sourcing Steel

Finding steel is easy! It's pretty much everywhere around us. A keen eye can observe steel fixtures and welded parts in every part of our modern world. You are able to source steel from up cycled parts, or start with raw material from hardware stores and steel distributors. Big box hardware stores carry common lengths and thicknesses of steel sheet, bar, and pipe, and is usually found near lumber or fasteners.

Figure 43: Metal workshop

If you are sourcing up cycled steel, pay extra attention to any possible coating that may be on your steel. Welding galvanized or powder coated parts can make you really sick, so be sure to grind off all finishes from parts before super-heating the base material with the welding torch, immolating whatever coating is on your steel to off gas toxic fumes.

When purchasing raw steel, you have to pay attention to whether or not the steel is hot rolled or cold rolled. Because steel is ductile, meaning that it is able to be stretched into shapes, raw iron is either shaped with heat or stretched over cold mechanical parts to be extruded into a shape. Let's go over the difference.

Figure 44: Rolled Steel

- **Hot Rolled Steel**

  Hot rolled steel is formed at temperatures over 1,000 degrees Fahrenheit. This steel recrystallizes its form during the cooling process, giving the finished product looser tolerances than the original metal because the material has gone through so much shrinkage during cooling. This shrinkage causes the material to **scale** as it cools. The scale needs to be ground off with an angle grinder before we weld on to the material.

Hot rolled steel is often used for the manufacturing of structural components, such as I beams.

Figure 45: Sheet metals

- **Cold Rolled Steel**

Cold rolled steel undergoes a processing and shaping at room temperature. This increases the strength of the finished product through the use of strain hardening by as much as 20 percent. Cold rolled steel usually feels smoother to the touch and is a brighter shade of silvery gray.

Steel formed by the cold rolled steel process include bars, strips, rods, and sheets. These shapes are usually smaller than the same products available through hot rolled methods, but more suitable for the home and craft welder.

Cold roll steel has no scale that needs to be ground off. Because this kind of steel is stretched and shaped by machines, it is coated with a film of oil that allows it to roll with less friction during processing. We remove this film with acetone or denatured alcohol before welding.

Self-Check – 4	Written Test

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

I. Say true or false for the following question below

1. SMAW(Shield Metal Arc Welding) is simple and easy welding method.
2. Metal welding is the fusing of two pieces of metals to create one solid continuous piece.
3. Galvanized steel contains a zinc coating that is applied to industrial steel to prevent rust.
4. MIG (Metal Inert Gas welding)is a semi-automatic arc welding process.
5. TIG welding provides a very clean way to weld.
6. Cold roll steel has no scale that needs to be ground off.

Note: **Satisfactory rating - 4points** **Unsatisfactory - below 3 point**

Answer Sheet

Score = ___________

Rating: ____________

Information sheet -5	Assembling/Aligning of materials

5.1. Assembling Pipes by Butt-Welding:

- The Different Types of Bevels and How to Make Them

  Welding thick parts together (plates and pipes) requires the weld be made over the total thickness of the part in order to guarantee the assembly's mechanical continuity. To achieve this, a bevel is made on the end surfaces of the elements to be assembled prior to welding them together.

  Butt-welding on pipes is special in as much as the welder does not generally have access to the inner face of the joint. Therefore, all the welding operations must be done from the outside. For this reason, the edges must be prepared accordingly.

  The different welding standards (ASME, AWS, ISO, EN, etc.) generally give the instructions to be followed in terms of bevel geometry. This article describes the preparations most frequently encountered in the industry, depending on the wall thickness of the pipes to be welded together.

- **Formation of a Bevel on a Pipe End**

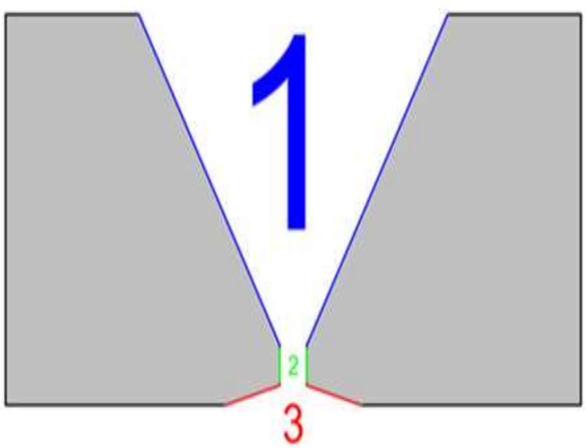


Figure 46: Bevel on a Pipe

- **Beveling**
  Beveling is the operation for creating a flat angled surface on the end of the pipe. The opening created by the beveling operation gives the welder access to the pipe wall's total thickness, and enables him to make a uniform weld that will guarantee the assembly's mechanical continuity. A root pass is made at the base of the bevels, which forms the base for filling the groove angle formed by the two bevels by successive welding passes.

- **Facing**

Figure 47: Facing

Facing is the term used for the operation to create a land, which consists of making a flat surface on the end of the pipe. Correct facing makes it easier to put the pipes in line with each other before welding and also contributes to having a constant root opening between parts. These are both essential parameters for maintaining a correct welding puddle and for ensuring that the root pass has penetrated the joint completely.

- **Inside Counter boring**

Figure 48: Inside Counter boring

Pipe production tolerances may lead to varying thicknesses over the pipe's circumference. This may lead in turn to variations in the thickness of the root face when the bevel is being made. This is why a counter boring operation is generally recommended in welding procedures.

The operation consists of lightly machining the inside surface of the pipe in order to guarantee that the land or root face has a constant width over the whole circumference of the pipe. Having a constant land width will make it easier to do the root pass. This parameter is essential when automated welding processes are used because a machine is not capable of assessing and compensating for any possible irregularity on the land, which obviously is not the case in manual welding.

- ✓ The Different Types of Bevels that are Used Depending on Pipe Wall Thickness

- ✓ Range of Thicknesses t ≤ 3mm (.118")

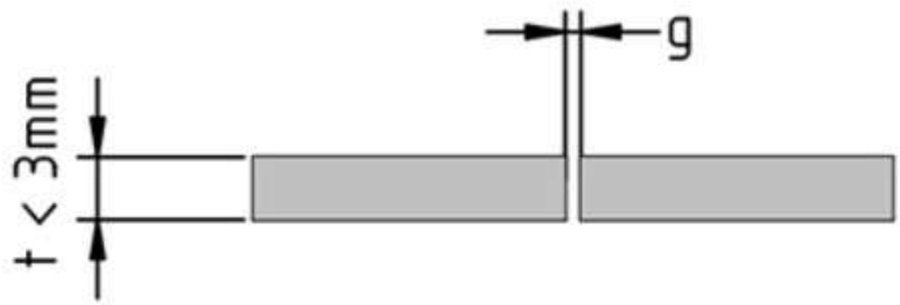


Figure 49: Pipe Wall Thickness

When butt-welding is required for pipes with walls less than 3mm (.118") thick, beveling the end of the pipe is generally unnecessary. Arc-welding technologies (111, 13x, 141) are capable of penetrating the whole depth of the pipe in a single pass.

When an automated welding technique is used (orbital welding or a process uses high-density energy sources), the end of the pipe must be faced to make sure that the weld edges are perfectly perpendicular. Depending on the application or the process used, the opening between the parts will be between g=1/2t and g=0 (especially for processes using high-density energy sources).

- **Range of Thicknesses 3 ≤ t ≤ 20mm (.787")**

When a welder can only access one side of the joint to be welded, preparing the parts with open square edges does not generally enable the weld metal to penetrate completely when wall thicknesses are more than 3mm (.787"). Therefore, a bevel must be made, so that the welder can make a root pass at the bottom of the joint, which will then be filled by one or more additional passes.

Usually the root pass is made using the 141 process for providing the best possible penetration (the root pass being used as a base for subsequent welding passes). For economic reasons, the following passes, called “fill” or “filling” passes, are made using a 13x or 111 process, which is more productive (the quantity of metal deposited, feed speed, etc.) than that of the 141 process.

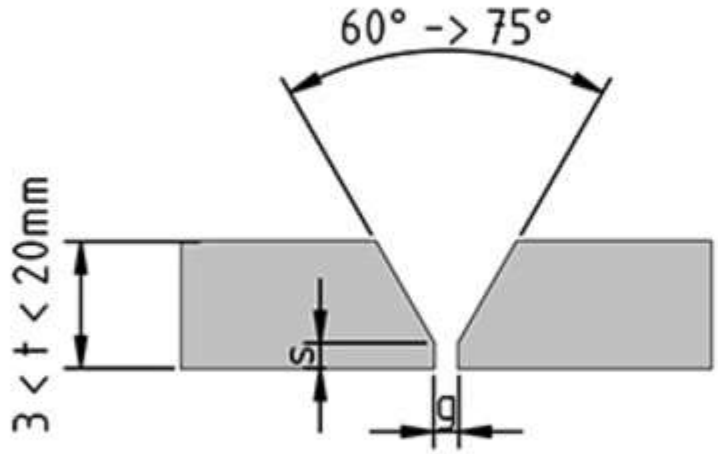


Figure 50: V grooves are 60° and 75°

The most common angles for V grooves are 60° and 75° ((2×30° and 2x 37.5°) depending on the standard to be applied. A land is generally required with a width (s) between 0.5 and 1.5 mm (.020 and .059”). The root opening between the parts to be welded (g) is between 0.5 and 1mm (.020 and .059”).

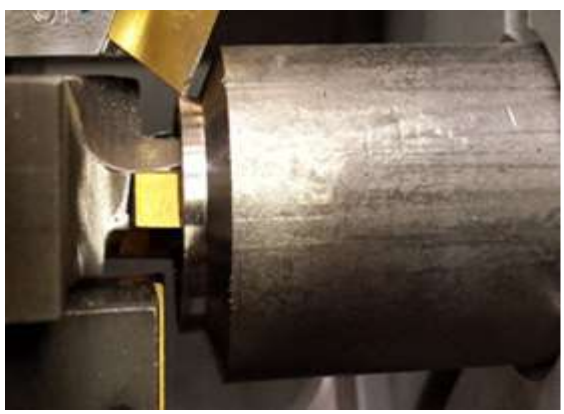


Figure 51: ‘J’ groove

However, ‘J’ groove preparations are required more often for this range of thicknesses (See details below). This is especially true when orbital welding processes are used. It is also the normal type of preparation when welding alloys, such as, duplex or Inconel.

- **Range of Thicknesses 20mm (.787”) ≤ t**

When wall thicknesses increase on the parts to be welded, the quantity of weld metal that needs to be deposited in the weld bead also increases in similar proportions. For avoiding welding operations that are too long and too costly from a labor and consumables point of view, preparations for welding joints with thicknesses of over 20mm (.787”) are made using bevels that enable the total volume of the bevel to be reduced.

- **Double Angle V Grooves (or Compound V Grooves):**

The first solution for reducing the size of the bevel is to make a change in the groove angle. An initial angle of 30° or 37.5° (up to 45°) is combined with a second angle, generally between 5° and 15°. The first 30° or 37.5° angle must be kept to avoid the groove becoming too narrow and preventing the welder from making the root pass.

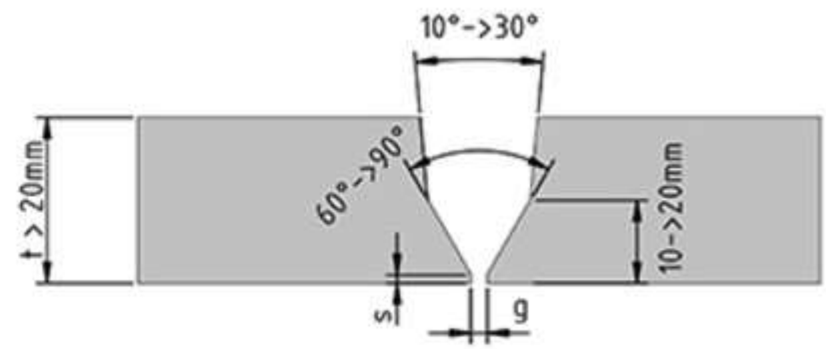


Figure 52: V grooves

Just like single V grooves, these preparations require a land from 0.5 mm to 1.5mm (.020 to .059”) wide and an opening between the parts (g) between 0.5 and 1mm (.020 and .039”). The hot pass for the land is usually done using the 141 process, and filling operations using the 13x or 111 processes.

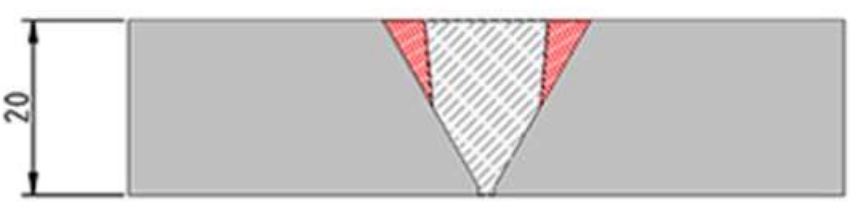


Figure 53: grey zone plus red zone

For example, in comparison with a 30° single angle bevel (grey zone plus red zone), a V bevel with a double angle of 30°/5° (grey zone) gives an economy of about 20% in terms of weld metal for a part 20mm (.787”) thick.

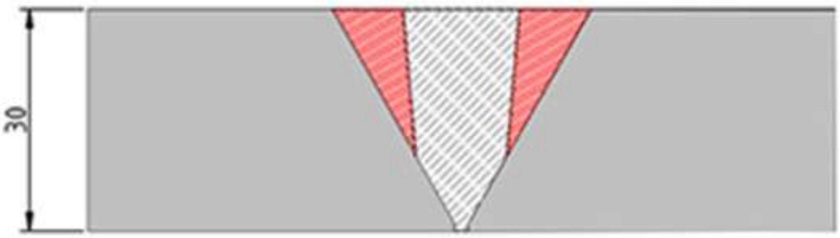


Figure 54: thick pipe.

The potential savings in terms of bevel volume increase in proportion to the wall thickness of the pipe to be welded. Consequently, savings will be over 35% on a 30 mm (1.181”) thick pipe.

- **Single and Double Angle J Grooves**

The second solution for drastically reducing the volume of the bevel and, consequently, the amount of weld metal in the ‘J’ groove preparation. Single angle ‘J’ grooves are comprised of an angle that is normally between 5° and 20°, a groove radius (r) and an increase in the land (e). The latter element makes the root pass easier to do by giving the welder better access to the land.

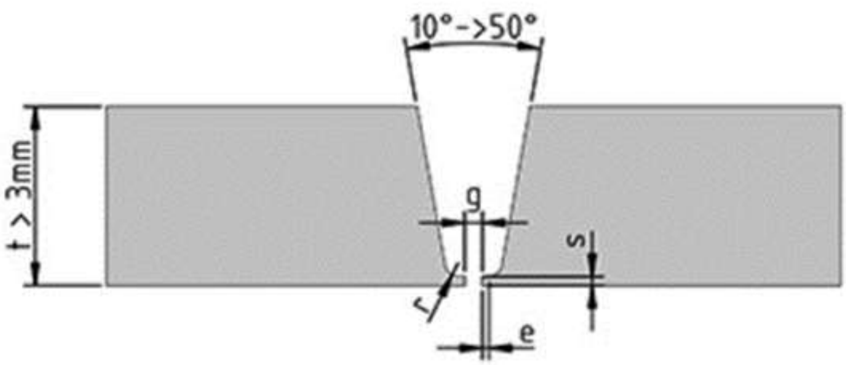


Figure 55: Single angle ‘J’ grooves

For cases with very thick walls, compound angle ‘J’ grooves can be made. Normally, the first angle is made at 20° and the second at 5°.

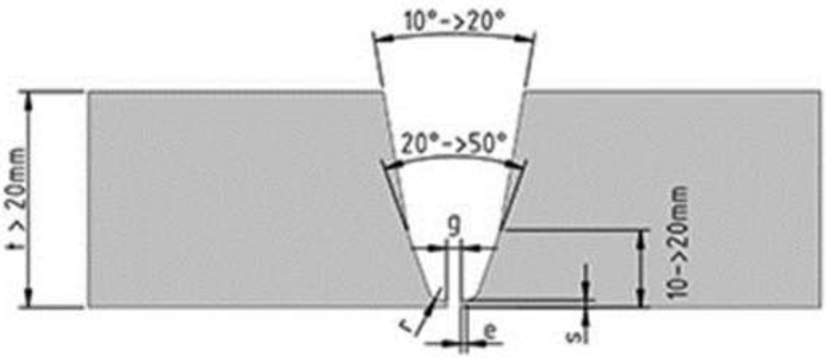


Figure 56: compound J grooves

J or compound J grooves are usually welded with either a very small or a zero opening (g) between the parts.

Figure 57: bevels avoiding cracking

From the point of view of geometry, bevels must be perfect to avoid cracking and other problems. As well as providing the accuracy to be guaranteed for this type of preparation, the machine used must also be capable of machining thick-walled pipes rapidly, in order to meet the production speeds required by manufacturers.

- **Narrow Gap Preparation**

  A variation on this type of bevel is narrow-gap preparation, which is used more and more in the oil industry due to the increase in pipe wall thicknesses and the high production rates to be maintained. The technique generally consists of making a single or compound angle ‘J’ bevel, with an opening as narrow as possible. This provides a very substantial reduction in the amount of weld metal used and an increase in productivity due to the decrease in welding times. For thicknesses of over 50mm (1.968”), the productivity factor can be over five times higher than on a weld made with a traditional bevel.

  Even so, a large number of constraints are to be found in the use of this technique. Two of them have a direct impact on the weld preparation process:

Firstly, bevel geometry and the opening between the parts must be controlled with the utmost accuracy. This is because the opening between the parts does not give the welder access to the bevel root. As a result, the whole weld, including the root pass, must be done using an automatic process. Automatic processes cannot accept any faults in alignment or irregularities in land width, contrary to the welder who is capable of adjusting the position of his torch for compensating any geometric faults in the groove.

The grade of the materials to be welded represents the second factor that must be taken into account. Every type of material possesses different shrinkage characteristics. Therefore, bevel geometry (the opening angle) must be studied beforehand for each different grade. The higher the shrinkage level of a material after welding, the more the angle has to be open, so as to prevent any cracks from appearing during solidification. A variation of a few tenths of a degree in the angle is liable to have a direct impact on the occurrence or absence of cracking, especially when welding nickel-based alloys.

These types of constraints require long and costly preliminary studies. Therefore, they need to be accompanied by a perfectly controlled bevel machining process. The description of the welding procedure (DMOS) resulting from preliminary studies requires lands to be accurate to one millimeter (.039”), for angles to be accurate to one degree and for the parts to be welded to be aligned perfectly so as to avoid any possible welding defects. Therefore, the equipment used for making the bevel must be capable of guaranteeing reliable repeat preparations under all conditions.

5.2. Machining a Bevel on a Pipe End

- **Axial Movement Machines**

Axial movement machines are equipped with a plate that moves in line with the axis of the pipe. Cutting tools are placed in position on the plate for making the required bevel shape. In the case of a compound bevel, tools will be used that have a shape identical to that of the required bevel or their shape is formed by combinations of simple shape tools. The most efficient machines on the market enable four tools to be used at the same time. This enables a bevel, a land and a counter bore to be made in one single operation.

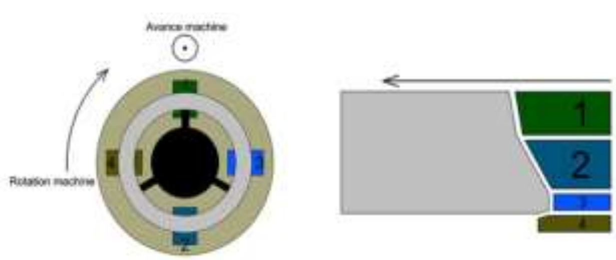


Figure 58: Axial

Here, tools No. 1 and 2 machine a compound bevel (the two tools can be combined to form one single tool). Tool No. 3 faces the land or root and tool No. 4 counter bores the inside diameter of the pipe. The tools move parallel to the axis of the pipe. For this reason, axial movement machines are essentially designed for beveling operations and are incapable of cutting a pipe into two separate parts. Example of application: Making a bevel on the end of a pipe that has been cut to the correct length beforehand.

5.3. Radial Movement Machines

Radial movement machines, called orbital machines, are generally held in place on the outside of the pipe. The tool-holder plate rotates while the pipe to be machined remains fixed. The tools move perpendicularly to the axis of the pipe by means of a mechanical transmission system. Unlike axial movement machines, radial movement machines carry out the beveling operation by separating the pipe into two parts. So, the latter type of machine can also be used for pipe cutting or length adjustment operations.

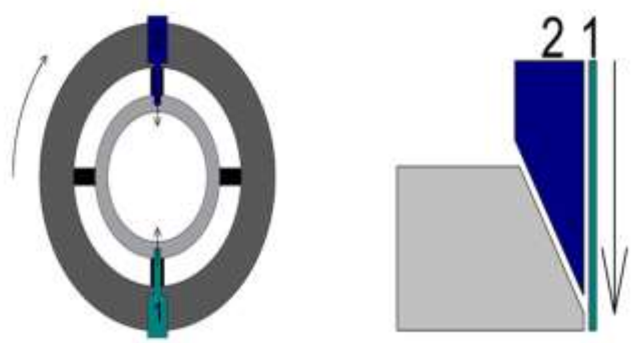


Figure 59: Radial Movement

Using beveling tools (No. 2, simple or compound shapes) combined with cutting tools (No. 1) enables the pipe to be cut in two and welding preparation (beveling) to be carried out in a single operation. The most efficient machines are capable of cutting and beveling several dozen millimeters in just a few minutes.

Example of application: Cutting lengths of pipe from an original base pipe. The parts cut off in this way are beveled at the same time as the cutting operation.

Self-Check – 5	Written Test

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

I. say true or false for the following question below

1. Beveling is the operation for creating a flat angled surface on the end of the pipe.
2. Facing is the term used for the operation to create a land.
3. Radial movement machines/ orbital are generally held in place on the outside of the pipe.

Note: **Satisfactory rating - 2 points** **Unsatisfactory - below 1.5 point**

Answer Sheet

Score = ____________
Rating: _____________

Reference

1. Bos, M.G. 1976. Discharge measurement structures. Publication 20, International Institute for Land Reclamation and Improvement (ILRI), Wageningen, the Netherlands.
2. Burt, C.M., Robb, G.A. and Hanon, A. 1982. Rapid evaluation of furrow irrigation efficiencies. Paper 82-2537 presented at the Winter Meeting of ASAE, Chicago, Illinois.
3. Busman, J.D. 1987. Optimizing control of surface irrigation using concurrent evaluation of infiltration. PhD Dissertation, Agricultural and Irrigation Engineering, Utah State University, Logan, Utah. Unpublished document. 209p.
4. Dedrick, A.R. and Erie, L.J. 1978. Automation of on-farm irrigation turnouts utilizing jack-gates. Trans. ASAE 21(1) 92-96.

Solar PV System Installation and Maintenance

Level-II

Learning Guide -20

Unit of Competence	**Perform Simple Welding**
Module Title	**Performing Simple Welding**
LG Code	EIS PIM2 M06 LO2 LG-20
TTLM Code	EIS PIM2 TTLM 0120V1

LO2:Set-up welding machine / equipment, accessories and fixtures

Instruction Sheet	**Learning Guide: - 20**

This learning guide is developed to provide you the necessary information, knowledge, skills and attitude regarding the following content coverage and topics:-

- identifying and selecting Welding machine settings, accessories and consumables
- Connecting Welding machine to power supply

- Adjusting Current and voltage fine-tuned
- setting Welding machine, accessories and consumables
- Providing Braces, stiffeners, rails and other jigs.
- Protecting Work items/materials from strong winds, drafts and rainfall
- Selecting appropriate distortion prevention measures for weld
- completing tasks without causing damage

This guide will also assist you to attain the learning outcome stated in the cover page. Specifically, upon completion of this Learning Guide, **you will be able to:-**

- Set accessories of Welding machine
- Connect Welding machine to power supply
- Adjust Current and voltage fine-tuned
- Procedures of Welding machine
- Provide Braces, stiffeners, rails and other jigs.
- Protect Work items/materials from strong winds, drafts and rainfall
- Select appropriate distortion prevention measures for weld
- complete tasks without causing damage

Learning Instructions:-

1. Read the specific objectives of this Learning Guide.
2. Follow the instructions described below 3 to 4.
3. Read the information written in the information Sheet 1, Sheet 2, Sheet 3, Sheet 4, Sheet 5, Sheet 6, Sheet 7, Sheet 8, in pages 64,73,76,80,85,91,95 and 101 respectively.
4. Accomplish the Self-check 1, Self-check 2, Self-check 3, Self-check 4, Self-check 5 , Self-check 6 , Self-check 7 and Self-check 8 in pages 73,75,79,84,89,90,100 and 108 respectively

Information sheet-1	Setting accessories of Welding machine

1.1. Setting accessories of Welding machine Cables & Connectors

CE-approved, fully insulated cable connections with neoprene rubber. Bayonet-type connection which locks firmly to provide safe and effective contact. The cable is fixed into a socket with two Allen screws.

Figure 60: Welding machine Cables

- **ZBK Cable Connection**
  Fully insulated with neoprene rubber. Sturdy and robust with low contact resistance. The cable is fixed into a socket with two Allen screws. The two halves of the connection in a ZBK connection are identical and can therefore be interchanged in any order.

Figure 61: **ZBK Cable Connection**

- **Electrode Holders**
  Electrode Holder ESAB 200, 400 and 500
  ESAB's CE-approved screw-type electrode holder offers many advantages including: Excellent current transfer between electrode and holder two whole positions at 45 and 90 for welding in different positions Electrode cable held in place by two Allen screws all electrode holders are fully insulated to provide maximum safety

ESAB 200, 200 A (35%)	0333 249 001
ESAB 400, 400 A (35%)	0369 849 880
ESAB 500, 500 A (35%)	0369 850 880

Figure 62: Holder

- **Electrode Holder optimum**

A closed head electrode holder allowing the electrode to be fitted either horizontally or vertically. The electrode holder is made of glass fibrereinforced plastic. All Optimums electrode holders are fully insulated.
Optimums 300, 400 A (35%) 0760 001 300
Optimums 400, 500 A (35%) 0760 001 400
Optimums 600, 600 A (35%) 0760 001 600

Figure 63: Electrode Holder

- Electrode Holder Samson

An open head electrode holder, the Samson is the 'classic' electrode tong design of electrode holder, made of a grassfire-reinforced plastic. All Samson electrode holders are fully insulated. Samson300, 300 A (60%) 0760 002 300
Samson 400, 400 A (60%) 0760 002 400
Samson 500, 500 A (60%) 0760 002 500

Return Clamps

MK 150, MP 200, MP 300 and MP450

The MK 150 is a fully galvanized earth clamp with a maximum opening of 50mm. The MP 200, MP 300 and MP 450 are robust earth clamps with strong gripping power for good contact. The maximum opening for the MP 200 is 50mm and 55mm and 60mm for the MP 300 and MP 450 respectively.
MK 150, 150 A (35%) 0682 103 801
MP 200, 200 A (35%) 0367 558 880
MP 300, 300 A (35%) 0682 103 803
MP 450, 450 A (35%) 0000 419 450

Eco Clamps

An earth clamp that provides good contact with the work piece and is available in two sizes.
Eco clamp 250, 250 A (35%) 0700 006 001
Eco clamp 400, 400 A (35%) 0700 006 002

- **Chipping Hammers**

Pneumatic Chipping Hammer HCB

This high impact speed chipping hammer produces virtually no vibration in the hand as a result of a built-in balance system, which absorbs recoil and counteracts shaking. A range of chisels are available for the HCB, they all have a tungsten-carbide tip and offer a long service life. Narrow chisel: 15mm wide for normal de-slagging and cleaning. Wide chisel: 35mm wide for removing spatter and de-burring after gas cutting.

Chipping Hammer HCB 0193 305 001

Figure 64: **Chipping Hammers**

- **Chipping Hammer SH2 and SH3**

  The SH2 chipping hammer is made of special high-quality steel, and has a user-friendly handle. The SH3 is a small hammer with a chisel and tip and steel handle with a plastic grip.

  Chipping Hammer SH2 0000 663 000

  Chipping Hammer SH3 0683 200 001

Figure 65: Chipping Hammer

- **Wooden Chipping Hammers**

  High quality tempered head and wooden handle. Chisel and point ends.

  Martellina Wood 0000 915 051

  Wooden Chipping Hammer TH/5 0701 380 106

Figure 66: Wooden Chipping Hammers

- **Murex Nozzle Cleaner Set**

  Prolongs the life of welding and cutting nozzles. Murex nozzle cleaner does not file the nozzle bore. Each set contains a range of nozzle cleaners from 0.46mm to 1.74mm.

  Nozzle Cleaner Set 0700 153 391

Figure 67: **Nozzle Cleaner Set**

- **Wire Brushes**

  Lightweight, easy-to-use steel brushes with wooden handles. Available with two, three or four rows of bristles.

Two-row mild steel brush	0760 024 100
Three-row mild steel brush	0760 024 200
Four-row mild steel brush	0760 024 300
Two-row stainless steel brush	0760 024 500
Three-row stainless steel brush	0760 024 600
Four-row stainless steel brush	0760 024 700

Figure 68: Wire Brushes

- **Welding gauge**

Correct groove preparation and sufficient weld deposit is required for a successful welded joint. The welding gauge type “J” provides the possibility to measure 60°, 70°, 80° and 90° groove angles, for measuring throat thickness (a-measure) up to 20 mm and reinforcement up to 10 mm

Figure 69: welding gauge

- **Consumable**

  The Unit standard electrode range contains electrodes for:
  - ✓ Mild and low alloy steels
  - ✓ Cast steel
  - ✓ Heat resistant steel
  - ✓ Low temperature steel
  - ✓ Weathering steel
  - ✓ Stainless and acid-resistant steels
  - ✓ Tool- and machine-part steels
  - ✓ Cast iron
  - ✓ Aluminum and aluminum alloys
  - ✓ Copper and copper alloys
  - ✓ Air-carbon-arc gouging
  - ✓ Gouging with standard equipment

5.4.What happens when the arc is struck?

The electrode is part of an electronic circuit. To strike an arc the electrode must first touch the work piece. This action causes a short circuit, and when the electrode is withdrawn slightly, the arc is formed.

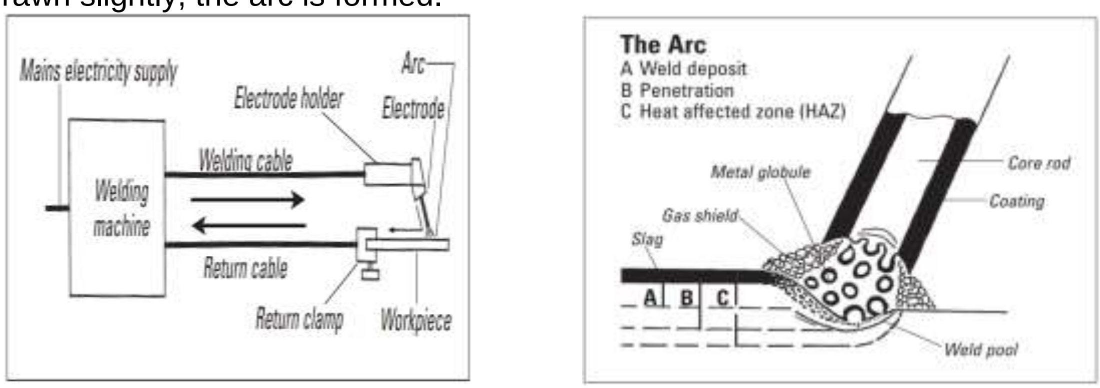


Figure 70: Arc Stuck

The arc will immediately melt some of the coating and core wire of the electrode tip, and the gas shield shown in the figure is formed. At the temperatures found in the arc (approx. 7000 °C) the gas will be ionized, providing good electrical conductivity in the arc.

The actual transfer of metal from the electrode to the work piece is in the form of molten globules of different sizes depending on the type of electrode used. Some electrodes produce globules that are so large that they actually short circuit the arc for a moment. In these cases it is of special importance that the welding power source has a fast dynamic response so that extreme currents and spatter are avoided.

- **Types of electrodes**

  When selecting an electrode, the first rule is to select one which produces a weld metal quality equal to or better than that of the base material and, when necessary, is approved for the material in question . Welding position and type of joint are other factors, which influence the choice of electrode, as different electrodes have different properties in different welding positions and types of joint .

  The most common types of electrodes are:

  - ✓ The Organic type (Cellulose)
  - ✓ The Rutile type
  - ✓ The Acid type
  - ✓ The Basic type (Low Hydrogen)

- **Organic** electrodes contain large quantities of organic substances such as cellulose. The metal transfer is referred to as explosion arc and the electrodes are well suited for vertical down welding.
- **Rutile**

  Electrodes contain large quantities of the mineral rutile (up to 50 %) or components derived from Titanium Oxide. Rutile electrodes can also contain cellulose. The rutile type of electrode has especially good welding properties both with AC and DC. The organic-rutile electrode is usually the cold welding type, characterized by a spray arc globular transfer, which is an advantage when welding in different positions. This type of electrode is when alloyed well suited for re- and hard surfacing because of its shallow penetrations and high weld build up. Big opening between plates can easily be bridged using this type of electrode. The rate of welding is not particularly high, but the deposit is of good quality and slag is easily removed.

  Unalloyed rutile electrodes are not normally recommended for welding steel with nominal tensile strength exceeding 440 Mpa. The impact values are low because of oxygen level in the weld metal. Rutile electrodes are relatively insensitive to moisture.
- **Acid**

  Electrodes produce an Iron Oxide / Manganese Oxide / Silica type of slag, the metallurgical character which is an acid. The coating contains oxides of the low pH value hence the term acid . Acid electrodes provide good fusion, a high rate of welding and are equally suitable for AC and DC. The arc is stable and slag is easily removable, even if it is the first bead in a Groove weld. Alloyed acid electrodes are suitable for welding steel with a nominal tensile strength of up to 440 Mpa .

- **Basic electrodes**

  Basic electrodes are often referred to as Low Hydrogen electrodes. After special heat treatment the coating has very low hydrogen content, hence the name. Basic electrodes with low moisture absorption (LMA) have lower initial moisture content and the speed of remoistening is much lower than of normal basic electrodes. Unalloyed basic electrodes give moderate welding speed in the flat position but are faster than other types when welding vertically up wards. The reason for this is that basic electrodes can be deposited at a higher current in the vertical position than other types of electrode In addition, the amount of weld metal deposited per electrode is greater than that of COATED ELECTRODES 132 other electrodes, which can be used in this position. This results in a smaller number of electrode changes. The normal result is therefore a higher fusion rate and higher arc-time factor when welding vertically upwards with basic electrodes compared with other types. The slag is normally not quite as easy to remove as the slag from acid or rutile electrodes, but, in spite of this, it can be classed as easily detachable. The slag from basic electrodes has a lower melting point than that from rutile or acid electrodes. The risk of slag inclusions during normal production welding is therefore unusually small when basic electrodes are used, even if the slag is not completely removed between beads during multi-run welding.

The weld metal from basic electrodes has low hydrogen content and usually has good toughness even at low temperatures. Basic electrodes are less likely to produce either hot cracks or cold cracks compared with other types of electrode. The superiority of basic electrodes from this point of view appears when welding manganese-alloyed structural steels, pressure-vessel steels and ship's plate with a nominal tensile strength of 490-530 MPa.

The higher the hardenability of the steel to be welded, the greater the necessity to use basic electrodes and the greater the need for low moisture content in the coating.

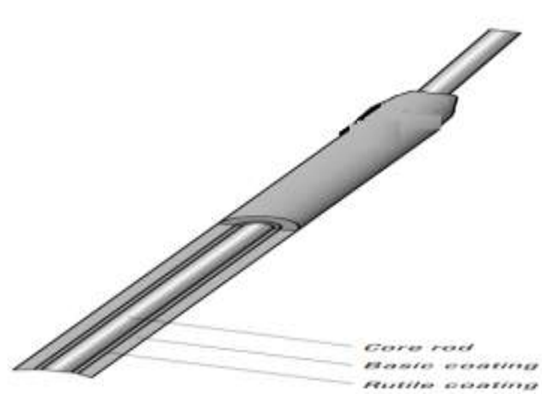


Figure 71: Basic Welding

Self-Check – 1	Written Test

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

I. say true or false for the following question below

1. Organic electrodes contain large quantities of organic substances.
2. The electrode is part of an electronic circuit.
3. Correct groove preparation and sufficient weld deposit is required for a successful welded joint.
4. An earth clamp that provides good contact with the work piece is available in different size.
5. The electrode holder is made of glass fiber reinforced plastic.

Note: **Satisfactory rating - 3 points** **Unsatisfactory - below 2 points**

Answer Sheet

Score = ____________

Rating: _____________

Information sheet-2	Connecting Welding machine to power supply

2.1. Define connecting Welding

Power sources will require either a single or three phase supply at the voltage of the country in which it is intended to be used. Most equipment is provided with a series of voltage tapings and these may need to be adjusted to match the supply voltage. In the UK and the rest of Europe the supply voltages are now 230V AC single phase and 400V AC three phase. In other parts of the world, different supply voltages occur and may vary between regions. In some countries, 220V AC three phases may be encountered. Three phase supplies may be limited to 30A, but higher power welding equipment may require a 45A or even a 60A supply.

From 1999, equipment started to appear with an effective current rating on the rating plate. This value should be used to determine the cable size and fusing requirements. However, national wiring regulations should always be followed.

Particular attention should be paid to the supply requirements for single phase equipment. In many parts of Europe the 230V supply is 16A, but in the UK the standard plug is only 13A. Therefore, the relatively low power output of this type of equipment is further reduced if a 13A plug is fitted, so a dedicated circuit may be required. In some parts of the world the single phase mains supply may be further limited in current, but generally in these countries, three phase supplies will be readily available. Another problem to be wary of is imbalance in the supply, if high powered equipment is connected between two phases of a three phase supply. If more than one power source is installed they should be connected between different phases.

Apart from the obvious hazards of overloading a supply, e.g. overheating and blowing fuses, problems with other equipment may be caused. If the supply has a high impedance (commonly known as soft) as may be the case in overhead cables, a high current draw may cause the voltage of the supply to fall below levels which may cause problems with other equipment.

The primary functions of the power source are to produce sufficient heat to melt the joint and to generate a stable arc and metal transfer. As the welding processes require high current (50-300A) at relatively low voltage (10-50V), the high voltage mains supply (230 or 400V) must be reduced by a transformer. To produce DC, the output from the transformer must be further rectified (Fig 1).

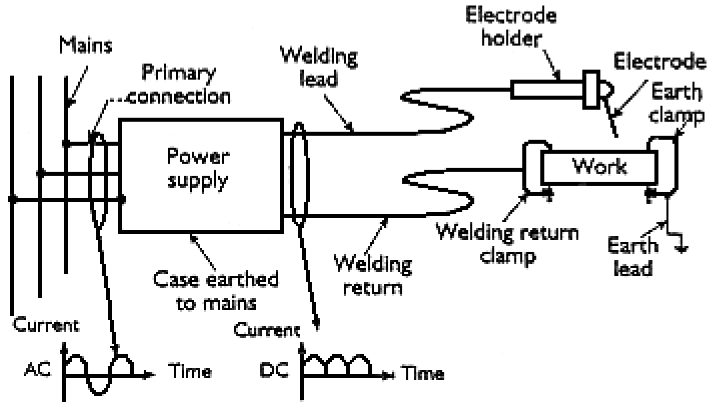


Figure 72: Five types of power source exist: AC transformer; DC rectifier; AC/DC transformer rectifier, DC generator and inverter.

The type of control, e.g. primary tapped, saturable reactor, thermistor and inverter is an important factor in the choice of power source. A simple primary tapped machine may be the ideal and robust choice for many MIG (GMA) welding jobs but it has its limitations. If there are insufficient steps, it may be impossible to tune the optimum condition and supply fluctuations will affect the output. Thermistor control allows continuously variable adjustment of the output is independent of supply voltage variations and can be controlled remotely. Thermistor power sources may be used for most welding processes, i.e. can have either a flat (MIG [GMA]) or drooping (MMA [SMA] and TIG [GTA]) output characteristic.

Inverter power sources offer all the advantages of thermistor control, but with additional performance, weight savings and efficiency. Transistors are used to convert mains AC (50Hz) to high frequency AC (>500Hz) before transforming down to a suitable voltage for welding and then rectifying to DC. Thus, the inverter is essentially a power block which may be controlled, often by software, to give the static and dynamic characteristics required for the selected welding process. Hence, most inverters offer multi process capability. Also, the response of modern inverters opens up the possibilities of high frequency pulsing as required for pulsed MIG (GMA) and dynamic feedback to control metal transfer as in dip transfer MIG.

Self-Check – 2	Written Test

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

I. say true or false for the following question below

1. Inverter power sources offer all the advantages of thermistor control.
2. AC transformer, DC rectifier & AC/DC are types of power source.
3. The primary functions of the power source are to produce sufficient heat to melt the joint.

Note: **Satisfactory rating - 2 points** **Unsatisfactory - below 1 point**

Answer Sheet

Score = ___________

Rating: ____________

Information sheet-3	Adjusting Current and voltage fine-tuned

3.1. Welding Amperage Selection

Trying to comprehend all of the dials and digital readouts on the welding machine can be intimidating. The few controls on a stick welding machine are going to be simpler than on a TIG machine. A top end TIG machine could have as many as 20 control knobs for various settings.

For the beginner welder, setting up a welding machine and adjusting the settings to however they are needed for a certain weld can be quite foreign. Stick welders, MIG welders, and TIG welders all have various controls on the front of the machine. These are to adjust the level of current needed for a weld.

But how do you know what amperage or voltage setting to set the machine to? Setting the amperage on a welding machine, whether Stick (SMAW), MIG (GMAW)(*typically uses voltage setting), or TIG (GTAW), depends on some key variables such as application and base material, welding process, and electrode.Once you determine these three main variables, you can set your welding machine and start laying a weld bead

- **Application and Base Material**

In this section, we will discuss the welding application, the base material and specifically how this applies to the amperage selection on a welding machine.

For the purposes of this article, the welding application (type of welding method) will be defined in a broader sense.

Welding application has a direct correlation with the amperage used in a weld. For example, a highly technical TIG weld on a helicopter exhaust manifold will have drastically different amperage needed than for say, an oil pipeline. The difference will be between welding thinner exotic metals and welding a three-foot diameter pipe to the next pipe in sequence.

Micro TIG welding and laser beam welding have similar applications where in the case of TIG welding the amperage is quite low. However, in the case of laser welding, there is no amperage at all since there is no electrical current flow within the work piece.In contrast, MIG welding and Stick welding (and sometimes TIG welding) can use very high amperage settings in order to achieve optimal penetration into the work piece.

Say for instance the welder is asked to weld a one-inch thick steel plate to a steel girder on a freeway overpass – this is a highly critical, structural weld and optimal penetration of the weld into the base metals must be achieved. In some applications, amperage is selected for convenience. For example, you might want to MIG weld a sheet of metal to another sheet of metal in your workshop, so you might be inclined to turn up your amperage to get the weld bead laid down as quickly as possible.

This is not to say rushing through a weld is a good practice but speeding up a weld bead in a non-critical application is very common. *Pro Tip: If you are interested in seeing all sorts of welding applications in one place, you should either get a tour at a shipyard, a fabrication shop, or your local technical or vocational school. Chances are, you might see a specific welding application which interests you and you might want to explore that application further in a career-oriented sense.*

- **Base Material**

The category of base material is quite broad. Therefore, we will focus on two main areas in the category of base material. And those are Type, and Thickness. Both of these areas have a very strong correlation with what amperage setting needs to be used on the welding machine.

The type of material used in different welding applications can vary widely from weld to weld, jobsite to jobsite, or even from welding technology to welding technology. Before even thinking of what amperage to set your welding machine to, you should ask yourself what type of metal you will be welding.

The main material types which standard welding methodologies can weld together are typically carbon steel, stainless steel, and aluminum. All three of these material types require different amperage selections on their respective welding machines. The most notable difference is between the ferrous and the non-ferrous materials, i.e. steel versus aluminum.

The reason why certain materials require higher or lower amperage settings is based on the raw material melting point. This is very apparent when looking at aluminum materials. Primarily since aluminum material melting point is typically around 1,200 degrees Fahrenheit.

When welding aluminum materials together, the current usually has to be switched from DC (direct current) over to AC (alternating current). In addition the amperage must be turned up to compensate for the higher melting temperature of aluminum. TIG welding aluminum is unique in that the current utilized is AC due to its cleaning characteristics. This is achieved due to the weld current alternating from one direction to the other.

Once the arc is struck in an aluminum TIG weld bead and the weld puddle is formed, the operator must move the bead relatively quickly. This is due to the aluminum base material having the tendency of "soaking up" the high amperage heat and potentially warping the base metals.

The adjustments to stick welding amperage to compensate for steel material thickness are similar to the processes necessary to compensate for material thickness with a MIG welder. The welding technology which has the most noticeable changeovers when switching from a thin work piece to a thick work piece is stick welding.

Stick welding is different from MIG and TIG welding in that the welding operator must select a different electrode which best suits the work piece thickness. The same electrode which works well for a thin piece of steel would not be as useful when welding a thicker piece of steel. This is due to the fact that a thicker piece of steel requires more penetration and a wider root to the weld.

A thinner electrode would not be up to the task – it would simply be consumed too fast.

Figure 73: thinner electrode

Self-Check – 3	Written Test

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

I. say true or false for the following question below

1. TIG welding aluminum is unique in that the current utilized is AC due to its cleaning characteristics.
2. MIG welding and Stick welding (and sometimes TIG welding) can use very high amperage settings.
3. Welding application has a direct correlation with the amperage used in a weld.

Note: **Satisfactory rating - 2 points** **Unsatisfactory - below 1 point**

Answer Sheet

Score = ____________

Rating: _____________

Information sheet-4	Procedures of Welding machine

4.1. Define Welding Procedure

A Welding Procedure Specification (WPS) is the formal written document describing welding procedures, which provides direction to the welder or welding operators for making sound and quality production welds as per the code requirements. WPS is supported by a Procedure Qualification Record (PQR or WPQR).

- ✓ Welding requires skill. Determining "how to weld" requires knowledge regarding the materials being welded and welding process, among numerous other factors. Because of huge number of variables involved, the knowledge of the welding engineer and the skill of the welder need to be validated by a series of tests. All this information is documented on Welding Procedure Specification (WPS), Procedure Qualification Record (PQR), Welding Procedure Qualification Record (WPQR), and associated Test Reports.

- **What is Welding Procedure Specification (WPS)?**
  - ✓ A WPS is a document that describes how welding is to be carried out in production. Its purpose is to aid the planning and quality control of the welding operation. They are recommended for all welding operations and most application codes and standards make them mandatory.
- **What is Procedure Qualification Record (PQR)?**
  - ✓ A PQR is required when it is necessary to demonstrate that your company has the ability to produce welds possessing the correct mechanical and metallurgical properties. A welding procedure must be qualified in accordance with the requirements of an appropriate welding procedure standard, such as ASME Sec IX, as follows:1. Produce a welding procedure specification (WPS) as stated above.2. Weld a test piece in accordance with the requirements of your specification. The joint set up, welding and visual examination of the completed weld should be witnessed by a certified welding inspector such as an AWS certified CWI or an Inspection Body. The details of the test such as the welding current, pre-heat etc., must be recorded during the test.3. Once the welding is complete the test piece must be subject to destructive and nondestructive examination such as radiography and mechanical tests as defined by the welding procedure standard. This work must be carried out in a qualified laboratory but the Inspection Body may require witnessing the tests and viewing anyradiographs.4. If the test is successful you or the test body completes the appropriate documents which the test body's surveyor signs and endorses.

- **How to Setup Welding Machine to Weld**

Before setting up your machine you need to prepare and research a few things before squeezing the trigger to striking an arc. Most of the weld quality relies on any welder settings or machine set-up and proper preparation. Before setting up you machine you need to get the answers to:

- ✓ What Type of Metal Will I Be Welding?
- ✓ What is the Metal Thickness That I Will Be Welding?
- ✓ How Will I Prepare the Joint?
- ✓ Do I Have The Right Gas and Electrode/Filler Wire?
- ✓ How is the Welder Set-Up?
- ✓ Where Can I Find a MIG Welder Setting Chart or Who Can I ask for Advice!

- **What Type of Metal Will I Be Welding?**

The type of metal that will be welded has a big impact on the machine setting, electrodes and gasses that will be used. Different metals have different melting temperatures and hold that heat differently. When setting up you MIG welder you need to know exactly what type of metal you are going to weld. There is no single setting that works on every metal type. The three most commonly MIG welded metals are:

- **What is the Metal Thickness That I Will Be Welding?**

The thickness of the metal has a major impact on the machine settings. When it comes to other processes like Stick or TIG welding you can use almost the same setting for a variety of metal thicknesses. For example you can weld ¼ in thick plate with the same setting used to weld a 1" inch thick plate and so on.

- **How Will I Prepare the Joint?**

Machine set-up only works right if you have a properly set-up joint. Ideally you want all rust, paint, oils, dirt’s and mill scale removed from the weld area. This is done for three reasons:

- ✓ The first is a clean joint produces a clean weld.
- ✓ The second is that the machine settings will vary between dirty Joints and clean one.
- ✓ Finally a dirty joint will spatter and spit increases the you getting

burns or starting a fire.

Figure 74: Joint

Do I Have The Right Gas and Electrode/Filler Wire?

A major part of setting up your machine is choosing the right gas and filler wire/electrode. This is an area that varies depending on all of the above factors and many more. the three most commonly used gas/ electrode variations or combinations are:

- ✓ Carbon Steel – ER70s Electrode with a C25 Gas (75% Argon and 25% Carbon Dioxide)
- ✓ Stainless Steel – ER308L with a C2 Gas (98% Argon and 2% Carbon Dioxide)
- ✓ Aluminum – ER4043 with 100% Argon gas

There are three settings or controls that set the welder and those three are:

- ✓ Voltage
- ✓ Wire Feed Speed
- ✓ Gas Flow Rate/Gas Type or Mixture

These three settings are what control the heat of the weld and depending what gasses are used the transfer type too. If you are not familiar with transfer types then please read up on MIG Welder Transfer Types because they have a big effect on your settings and how you will be welding.

Figure 75: Welding

Code adopted Standard Welding Procedure Specification (SWPS), Welder Performance Qualification Record (WPQR), and Independent Laboratory Test Report for the WPQR

PQR/ WPQR Testing

The following tests by Independent Test Laboratory may be required on your PQR and WPQR Coupons:

- ✓ Weld Visual Examination by a AWS Certified Welding Inspector
- ✓ Bend Test
- ✓ Hardness Test
- ✓ Transverse Tensile Test
- ✓ All Weld Metal Tensile Test
- ✓ Charpy Impact Test
- ✓ Weld Metal Chemical Analysis
- ✓ Macro etch Test
- ✓ Torque Test
- ✓ Peel Test
- ✓ Nick Break Test
- ✓ Radiography Test
- ✓ Ultrasonic Test

- **Weld Inspection and Testing**

In addition to the above, you may require independent inspection of the welds by the following qualified personnel:

- ✓ Visual Inspection by AWS Certified Welding Inspector (CWI)
- ✓ Radiographic Testing by Level II personnel certified as per SNT-TC-1A
- ✓ Ultrasonic Testing by Level II personnel certified as per SNT-TC-1A
- ✓ Magnetic Particle Testing by Level II personnel certified as per SNT-TC-1A
- ✓ Penetrant Testing by Level II personnel certified as per SNT-TC-1A AEIS can perform the above tests at your facility or at our laboratory.

Self-Check – 4	Written Test

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

I. say true or false for the following question below

1. A Welding Procedure Specification (WPS) is the formal written document describing welding procedures.
2. The thickness of the metal has a major impact on the machine settings.
3. The WPS purpose is to aid the planning and quality control of the welding operation.

Note: **Satisfactory rating - 2 points** **Unsatisfactory - below 1.5 point**

Answer Sheet

Score = ___________
Rating: ____________

Information sheet-5	Providing Braces, stiffeners, rails and other jigs.

5.1. Definition of braces, stiffeners, Rails

Gusset plates are used to transmit the applied forces from main elements (beams and columns) to bracing elements and vice versa. Figures 1 and 2 illustrate examples of gusset plate connections for an eccentrically braced frame and a special concentrically braced frame. Many research papers have addressed the analyses and designs of gusset plate connections. The stresses distributed along the edges and/or at the Whitmore effective sections of the gusset plates were the major topics discussed in these papers.
When a bracing member is subjected to a compressive force, the gusset plate, which is connected to the bracing member, will be stressed in compression and shear. However, since the vertical main member is deflecting away from the bracing member (refer to the lower left-hand quarter portion of the braced frame shown in Figures 3(a) & (b)), the angle between the vertical main member and the horizontal main member is enlarged. As a result, tensile stresses are also introduced to the gusset plate. The effects of frame deformation on gusset plates for diagonal bracing elements loaded in compression were investigated by Cheng, Grondin, and Yam using full-scale tests. Their tests found that the capacity of the gusset plate was reduced due to the effects of frame deformation on the gusset plate.

Similarly, for a reverse condition, when a bracing member is subjected to a tensile force, the gusset plate, which is connected to the bracing member, will be stressed in tension and shear. However, since the vertical main member is deflecting toward the bracing member (refer to the lower left-hand quarter portion of the braced frame shown in Figures 3(c) & (d)), the angle between the vertical main member and the horizontal main member is reduced. As a result, compressive stresses are also introduced to the gusset plate.

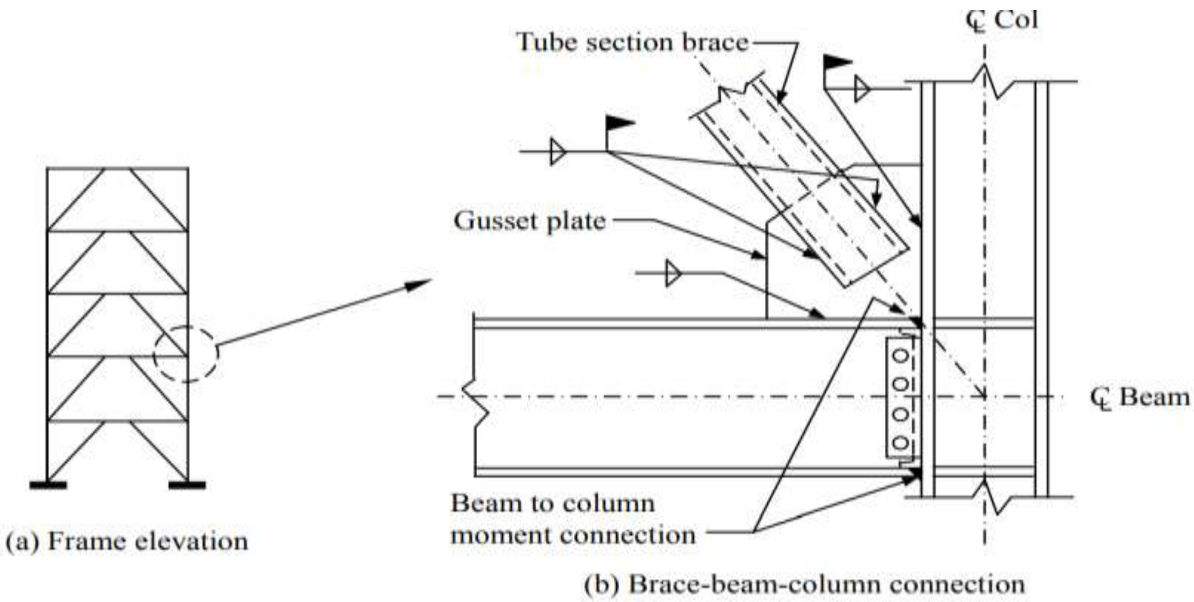


Figure 76: Brace- Beam Connection

Figure 1. Gusset Plate Connection Example for an Eccentrically Braced Frame

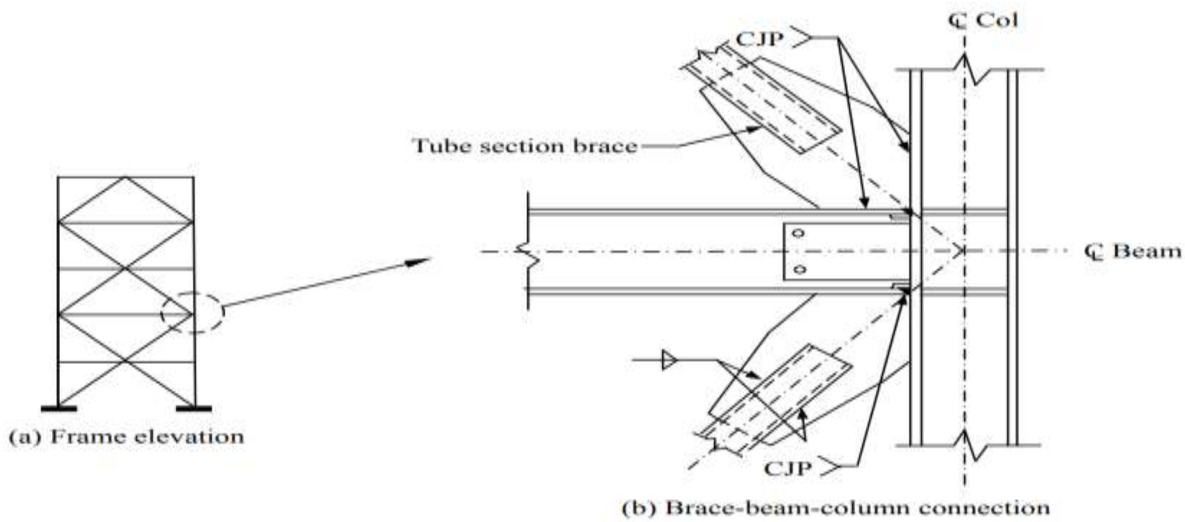


Figure 77: Gusset Plate Connection Example for a Special Concentrically Braced Frame

- **Stiffener**

  Stiffeners are secondary plates or sections which are attached to beam webs or flanges to stiffen them against out of plane deformations Deep beams sometimes also have longitudinal web **stiffeners**.

  Stiffeners are secondary plates or sections which are attached to beam webs or flanges to stiffen them against out of plane deformations.

Almost all main bridge beams will have stiffeners. However, most will only have transverse web stiffeners, i.e. vertical stiffeners attached to the web. Deep beams sometimes also have longitudinal web stiffeners. Flange stiffeners may be used on large span box girder bridges but are unlikely to be encountered elsewhere.

- **Types of stiffener**

  There are two principal types of stiffener:

  ✓Longitudinal web stiffeners, which are aligned in the span direction

  ✓Transverse stiffeners, which are aligned normal to the span direction of the beam.

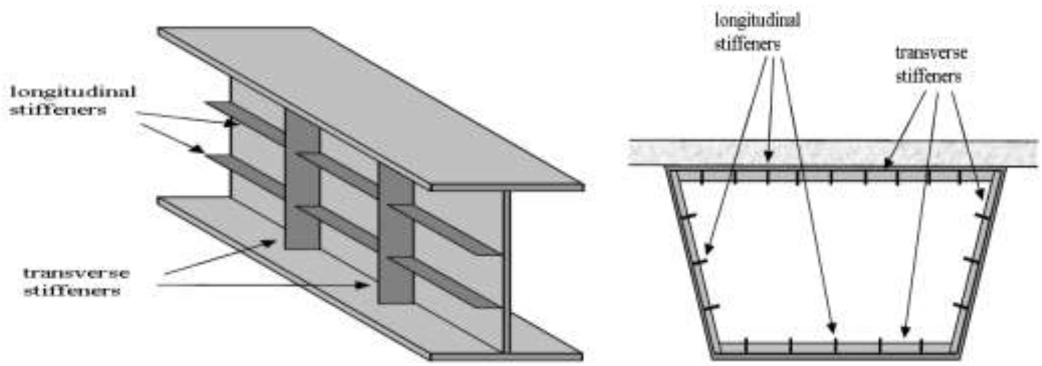


Figure 78: Longitudinal web stiffeners

A variety of sections have been historically used as stiffeners, however the simple flat stiffener is the type almost always used in modern designs. Stiffeners can be attached on one side of the plate (single sided), or on both sides (double sided). Usually bearing stiffeners are double sided, while intermediate web stiffeners are single sided. Stiffeners can also be doubled up, or even trebled, to form multi-leg stiffeners.

- **Controlling local buckling**

  Local buckling occurs when a cross section is slender enough for buckling to occur within the cross section, due either to compression or shear. The webs of bridge beams are usually vulnerable to local buckling, but flanges are usually much thicker and inherently more resistant to buckling.

  Local buckling can occur due to transverse compression load e.g. a web subjected to a bearing reaction, longitudinal compression load e.g. from bending, or from shear. In all cases the addition of a relatively small stiffener to a slender plate can increase the resistance to local buckling substantially.

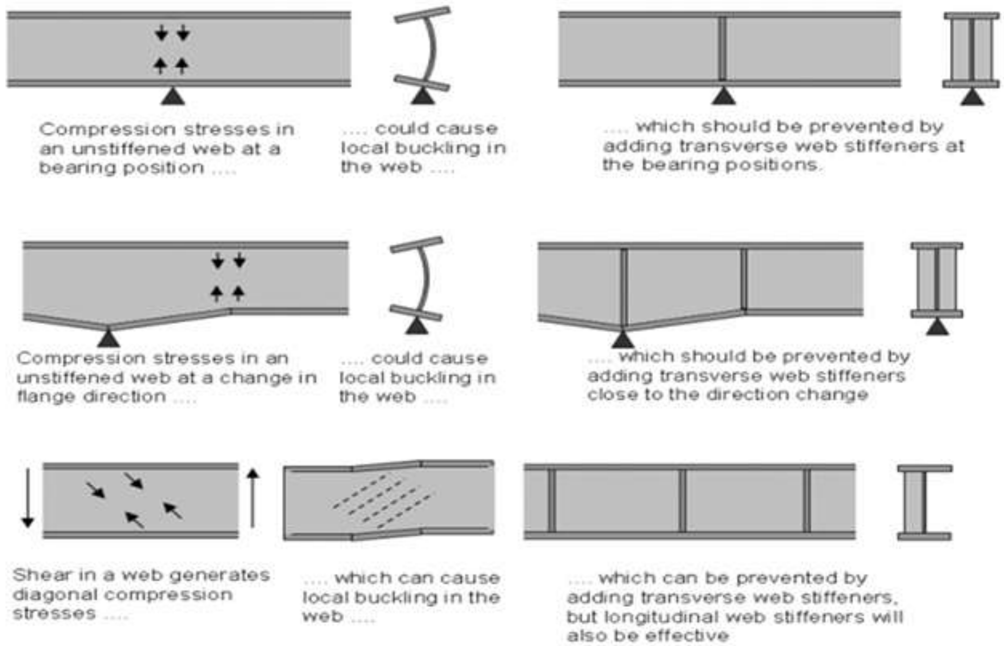


Figure 79: Local Bucking

- **Connecting bracing or transverse beams**
  The easiest way to brace steel beams together is by fixing the bracing to transverse stiffeners. Thus stiffener positions almost always coincide with bracing positions.
  In a ladder deck the webs of transverse beams can be connected directly to the main beam stiffeners, so stiffener spacing matches transverse beam spacing. In a multi-girder bridge with cross bracing the bracing members are usually connected to the main beam stiffeners, so that stiffener spacing is the same as bracing spacing.

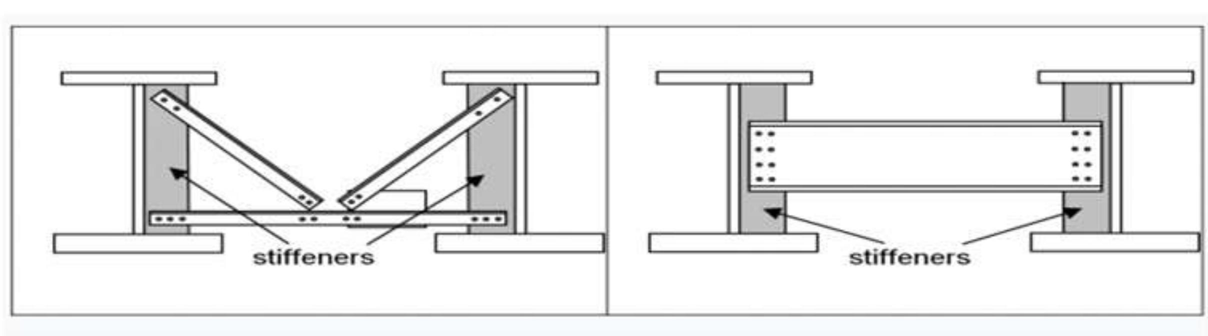


Figure 80: Stiffeners

Consider resisting F_S forces as given in PD 6695-2 clause 10, there may also be horizontal loading from the bearing if it is fixed. These loads may generate bending moments in the stiffener section.

Having determined the loading, verify the chosen stiffener size by checking the adequacy of the effective stiffener section to act as a column for combined axial load and bending moment as required by EN 1993-1-5 clause 9.4.

- **Rail joint**

  Rail joint, also called rail fish plate or joint bar, is one of several railway components. It takes on the task of connecting two rails and usually installed with fish bolt and nuts. Rail joint is one of the weak links in the whole railway track structure.

Figure 81: Rail Joint

Self-Check – 5	Written Test

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

I. say true or false for the following question below

1. Rail joint is one of the weak links in the whole railway track structure.
2. Local buckling occurs when a cross section is slender enough for buckling to occur within the cross section.
3. Stiffeners are secondary plates or sections which are attached to beam webs or flanges.
4. In a multi-girder bridge with cross bracing the bracing members are usually connected to the main beam stiffeners.

Note: **Satisfactory rating – 3 points** **Unsatisfactory - below 2 point**

Answer Sheet

Score = ____________

Rating: _____________

Information sheet -6	Protecting Work items/materials from strong winds, drafts and rainfall

6.1. Protecting Work items

Any wind most certainly will affect the welding process, assuming you are using shielding gas. TIG welding is a method often used for joining of light metals and high-alloy steels and it contains a number of risks as with other arc welding methods. If proper precautions are taken, safe working environment can be provided. Arc welding includes various hazards like dust, gas and smoke, compressed gas cylinders, harmful rays, high temperature and electric shock. These hazards can cause accidents which may occur before, during or after welding.

Especially breathing dust, gas and smoke or exposure to the harmful rays may lead to occupational diseases in long term. In this paper, physical and chemical risks that may arise during the TIG welding process are searched and safety measures that set by international and national standards are presented. Storage and use of compressed gas cylinders, safety instructions for TIG welding machine, workplace safety, personal protective equipment specifications and measures must be taken against occupational diseases constitute content of the post.

TIG is an abbreviation of “Tungsten Inert Gas”. The arc is created between a non-consumable tungsten electrode and work piece under the shielding atmosphere of argon, helium or argon helium mixture. For this process also filler metal is needed. A typical TIG welding set-up consists of welding power source, welding torch, clamp, shielding gas, foot control, cooling system with coolant in and out hoses as shown in Fig. 1.

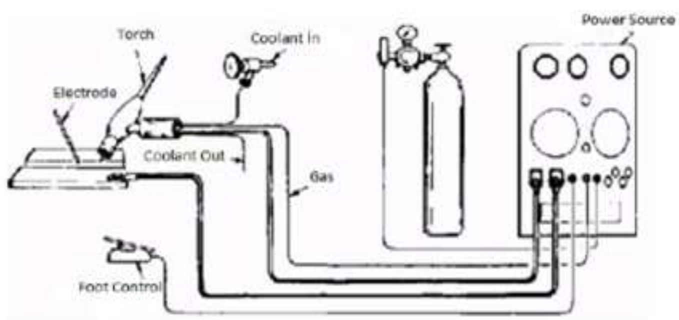


Figure 82: Typical TIG welding set up

TIG welding is suitable for all positions; almost any type of metal can be welded. High quality weld and low distortion next to the welding area is obtained and no flux is needed. Disadvantage of TIG welding is inert gas can be blown away by the wind in outdoor applications. Welders also must be well trained and expensive for thick walled parts; metal deposition rate is lower compared to other methods

General instructions for safe use of TIG welding machine:

- ✓ Proper installation, grounding, and operating of the TIG welding machine should be provided according to local codes.
- ✓ Check the welding machine and other equipment.
- ✓ Make sure that right gas cylinder mounted to the system.
- ✓ Turn on the main switch.
- ✓ Open the gas cylinder valve.
- ✓ Set the gas pressure and current according to welding type.
- ✓ Connect work piece to the apparatus.
- ✓ Press the start button and start welding process

- **Welder Safety and Choosing the Right Equipment**

For safe operations, welders must be suitable for the work and well-trained. Authorization to access welding equipment should be limited with the welders which are qualified to operate this unit. An employee checklist below can be useful for welders.

- ✓ Do you know how to use the controls properly?
- ✓ Use, maintain and store your protective equipment in accordance with instructions.
- ✓ Look for signs of leaks, wear and damage.
- ✓ If you find any problems, tell your supervisor. Don't just carry on working.
- ✓ Co-operate with health monitoring.
- ✓ Wash your hands before eating, drinking, or using the lavatory.
- ✓ Never clean your hands with solvents or concentrated cleaning products.
- ✓ Use skin creams provided as instructed

For manual welding, choosing the right welding set can avoid the muscle, joint and tendon disorders. It should be noted that welders usually have to lift, pull or push heavy equipment and materials. For moving or lifting heavy parts, cylinders and other equipment sufficient number of people is needed. Selecting the right welding set size may help to avoid;

- ✓ Personal suffering caused by injuries or ill health from musculoskeletal disorders,
- ✓ The financial burden of sickness absence and increased insurance premiums,
- ✓ Reduced productivity
- ✓ Welders being unable to come back to this type of work, which could affect their future earnings.

Welders should assure that proper personal protective is used and fire protection fire extinguishing equipment is properly located at the work site.

- **Shielded Metal Arc Welding**

Shielded metal arc welding (SMAW) is the simplest, least expensive, and mostly widely used arc welding process (Figure 2). It is often referred to as 'stick welding' or manual metal arc welding. This process produces coalescence of metals by heating them with an arc between a covered metal electrode and the base metal work piece. Shielding is provided by decomposition of the electrode covering. The main function of the shielding is to protect the arc and the hot metal from chemical reaction with constituents of the atmosphere. The electrode covering contains fluxing agents, scavengers, and slag formers (1). Pressure is not used in the process, and the filler metal is obtained from the electrode. All ferrous metals can be welded in all positions using SMAW.

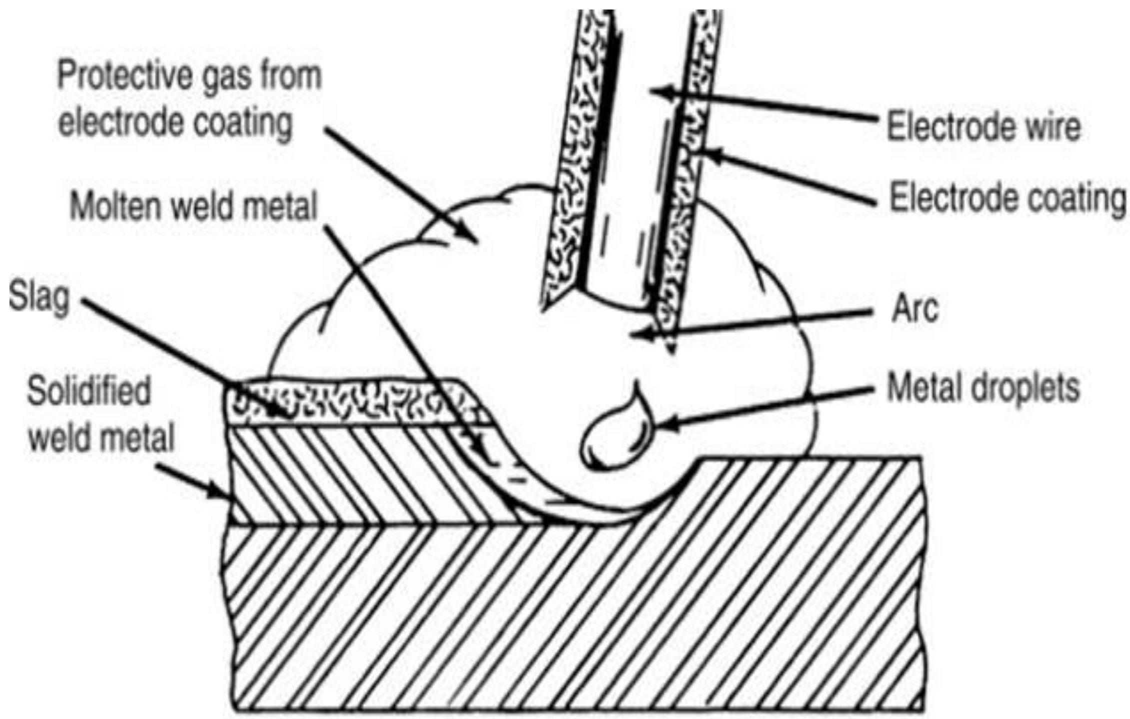


Figure 83: Shielded Metal Arc Welding

Self-Check – 6	Written Test

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

I. Say true or false for the following question below

1. TIG welding is a method often used for joining of light metals and high-alloy steels.
2. TIG is an abbreviation of “Tungsten Inert Gas”.
3. Welders should assure proper personal protectives.
4. Shielded metal arc welding (SMAW) is the simplest, least expensive, and mostly used arc welding process.

Note: **Satisfactory rating - 3 points** **Unsatisfactory - below 2 point**

Answer Sheet

Score = ___________

Rating: ____________

Information sheet -7	Selecting appropriate distortion prevention measures for weld

7.1. Thin steel hulls have become a standard in Naval Surface

- ✓ Incorporates thinner and higher strength steel panels and structures
- ✓ Designs increasingly becoming more light weight to increase mission capabilities
- ✓ Meet operational objectives and improve vessel performance
- ✓ Counteracts increase in weight due to automated equipment and weaponry Naval vessels will increasingly trend toward use of thinner, light weight/higher strength steel designs

Thin steel designs create new challenge production environment and fabrication difficulties such as:

- ✓ Distortion due to high heat input on thin on thin steel
- ✓ From traditional ship production processes
- ✓ Panel shrinkage and dimensional control issues
- ✓ Workforce unfamiliarity with techniques needed to ease construction difficulties

7.2 Distortion and Issues with Thin Steel

Distortion can be caused by almost every manufacturing process. This course will focus on distortion caused by locked-in residual (or left over) stresses that can come from four major sources:

- ✓ Steel mills rolling process, material handling, shipping and storage
- ✓ Poor fit-up caused by inadequate nesting and inaccurate cutting
- ✓ Over-welding, inadequate welding process and erection sequences
- ✓ Unrestrained, inadequate clamping and fixturing thin steel is difficult to weld because it is more prone to buckling distortion buckling

distortion as plate thickness decreases thickness decreases

- ✓ Flame straightening is commonly used to remove distortion
- ✓ Improper flame straightening has been found as the triggering mechanism for damage.

7.3.What is residual stress?

- ✓ Stress that remains after the original cause of the stresses has been removed.
- ✓ Due to the moving heat of a welding arc, the plate heats and cools at different rates in certain areas, leaving residual stresses in the material
- ✓ Distortion is closely related to the amount of residual stress and the degree of joint restraint during the welding process

What causes distortion?

- ✓ As welding heats the material, joints fuse together causing a highly localized heated area. This results in non-uniform stresses setting up cause of the expansion and contraction of the heated material

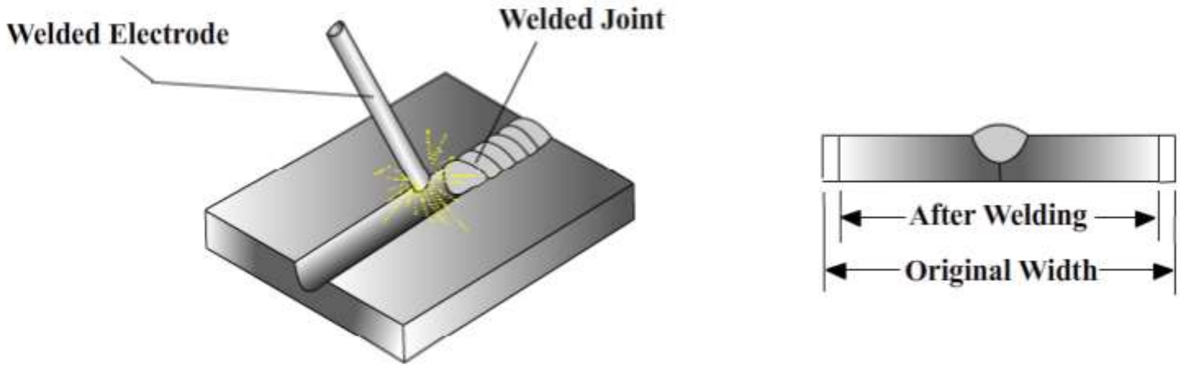


Figure 84: Welded Electrode

7.3. What causes distortion?

Initially, stresses are created in the surrounding cold metal when the weld pool is formed as the heat affected zone (HAZ) next weld pool. Additional stresses occur during the contraction of the weld metal and the cooling of the HAZ is resisted by the bulk of the cold metal

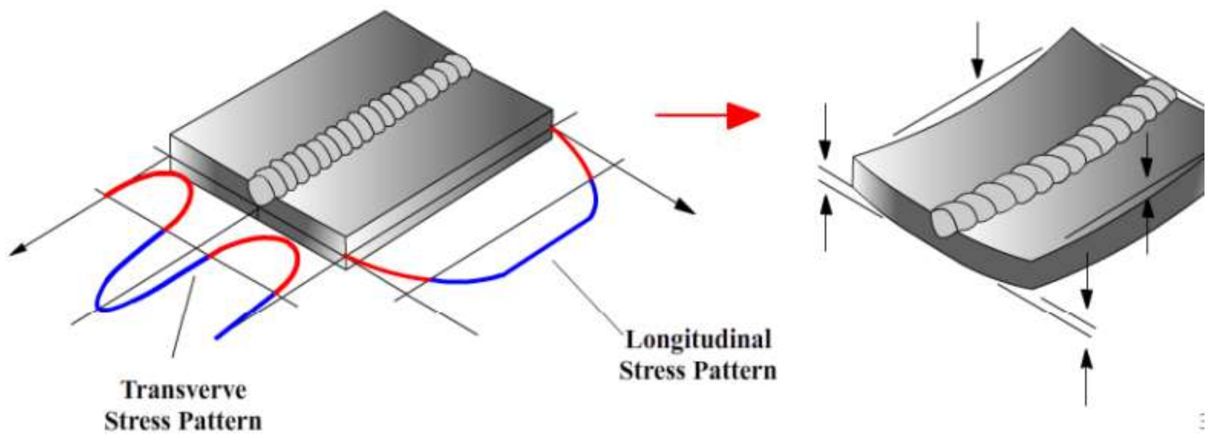


Figure 85: Longitudinal Stress Pattern

- **Types of Distortion**

  There are five forms of distortion. Two or more types of distortion may occur at the same time. The types of distortion are:
  - ✓ Transverse shrinkage
  - ✓ Longitudinal shrinkage
  - ✓ Angular distortion
  - ✓ Bowing and Bowing and dishing
  - ✓ Buckling

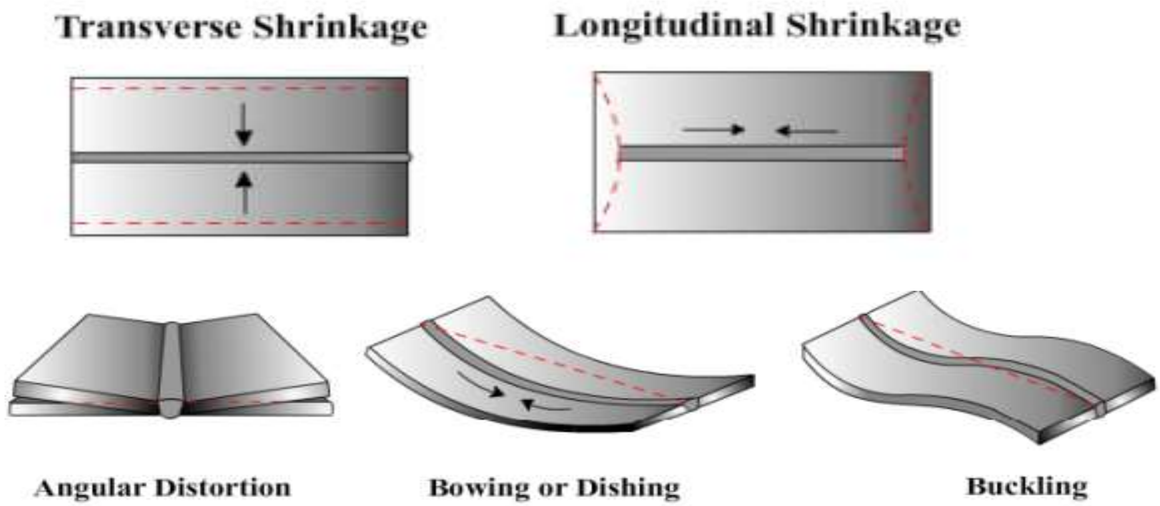


Figure 86: Transverse Shrinkage

What causes transverse shrinkage?

- ✓ The majority of transverse shrinkage is caused by welding in the longitudinal direction
- ✓ This type of distortion is primarily dependent on the cross- sectional area of the joint.
- ✓ The bigger the weld, the greater the shrinkage

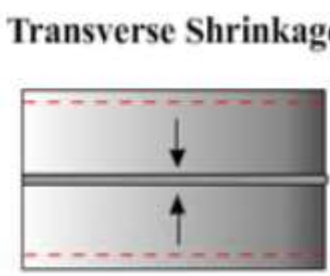


Figure 87: Shrinkage

- What prevention measures can be taken?
  - ✓ Lower heat input (reduce weld size, increase travel speed) will reduce the amount of shrinkage
  - ✓ Cannot be totally avoided but it isn't necessary bad if it is controlled
  - ✓ Balanced heat input using recommended weld sequences
  - ✓ Severe cases may require insert pieces added at the end joint, often late in construction

- **Angular Distortion**

What causes angular distortion?

- ✓ The weld cross
- ✓ section is not balanced on the element perimeter causing features in the section to rotate with respect to each other

Figure 88: Angular Distortion

- **What prevention measures can be taken?**
  - ✓ Using tack welds to set up and maintain the joint gap
  - ✓ Identical components welded in a sequence that is balanced about the neutral axis
  - ✓ Process and technique should aim to deposit the weld metal as quickly as possible
  - ✓ Use of proper clamping
- What correction measures are necessary?
  - ✓ Mechanical straightening by adding strong backs or other supports where needed flame straightening

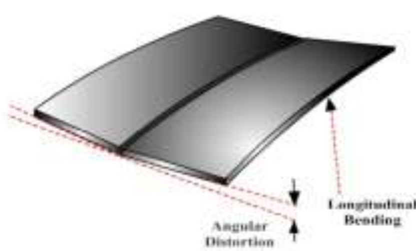


Figure 89: Angular Distortion

- **Bowing Distortion**

  Bowing distortion occurs when the weld is not balanced with respect to the neutral axis of the cross section affecting the straightness of the element so that longitudinal shrinkage in the welds bends the section into a curved shape

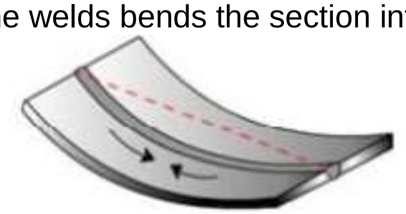


Figure 90: Bowing

7.4. What prevention measures can be taken?

Weld sequencing and back-step welding should be used to minimize bowing
– Adequate plate restraint prior to welding what correction measures are necessary?
– Correction measures can be mechanical or thermal
Mechanical is preferable when shrinkage from flame straightening is a concern. However, cracking formation need to be prevented Mechanical straightening requires using force (wedge, pneumatic ram, etc.) the o push the bowing area flat and a strong back or header is welded to hold the panel flat when the force is released   In the case of severe bowing on a T beam, the distortion needs to be corrected thermally with flame straightening as mechanically straightening it would cause a T beam to ripple and become unstable

Self-Check – 7	Written Test

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

I. say true or false for the following question below

1. Thin steel designs create new challenge production environment and fabrication.
2. Distortion can be caused by almost every manufacturing process.
3. The majority of transverse shrinkage is caused by welding in the longitudinal direction.
4. Bowing distortion occurs when the weld is not balanced with respect to the neutral axis of the cross section.

Note: **Satisfactory rating - 3 points** **Unsatisfactory - below 2 point**

Answer Sheet

Score = ____________

Rating: _____________

Information sheet -8	Completing tasks without causing damage

8.1Definition of Hazards

A hazardous manual task, as defined in the WHS Regulation, means a task that requires a person to lift, lower, push, pull, carry or otherwise move, hold or restrain any person, animal or thing involving one or more of the following:

- Repetitive or sustained force
- High or sudden force
- Repetitive movement
- Sustained or awkward posture
- Exposure to vibration.

These factors (known as characteristics of a hazardous manual task) directly stress the body and can lead to injury. Consequences of Poor Manual Handling. Consequences can be split into three main areas:

- Short term and superficial injuries
- long term injuries
- Mental health issues. For example: cuts, bruises, sprains, tears, small fractures, muscle strain, etc.

Having identified the hazard s in your work place, assessed their risks and reviewed the existing controls, all hazards must be managed before people are hurt, become ill or there is damage to plant, property or the environment. The management of risks in the work place requires eliminating risks so far as reasonably practicable in the first instance. Where elimination is not possible, then risks should be minimized, so far as reasonably practicable.

All hazards that have been assessed should be dealt with in order of priority. The most effective control option/s should be selected to eliminate or minimize risks. The Hierarchy of Controls (see diagram below) ranks control options from highest level of protection and re liability to lowest. This should be used to determine the most effective control/s.

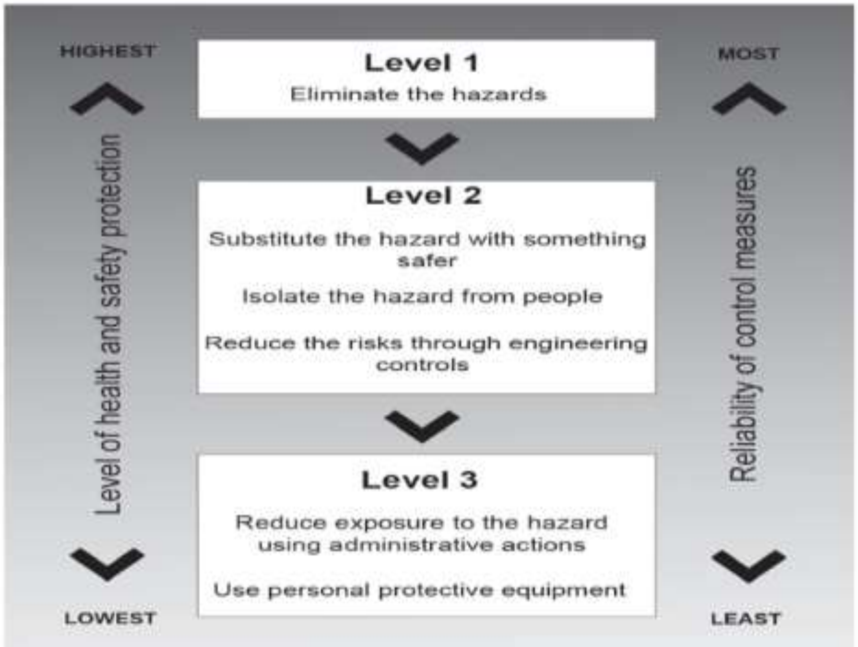


Figure 91: Hierarchy of Controls

- **Level 1 Control Measures** – Eliminate the Hazard The most effective control measures eliminate the hazard and associated risks. This can be achieved through removing the hazard or selecting alternate products or equipment to eliminate the risk. If a hazard cannot be eliminated then risks can be minimized by lower control measures.

- **Level 2 Control Measures** These are used to minimize the risks and involve on or a combination of the Following;
  (i) Substitute the hazard: substitute a substance, method or material to reduce the risk or the hazard
  (ii) Isolate the hazard: separate the hazard from the work place or people, For example;
    - ❖ Chemical store room, or a laboratory kept locked except to an authorized person.
    - ❖ Lock out procedures on faulty equipment.
    - ❖ Appropriate guarding for machinery.

  (iii) Use engineering control s: modify existing machinery or plant or purchase different machinery or plant to provide a physical solution. For example;
    - ❖ Trolleys, hoists or cranes.
    - ❖ Guard rails

- **Level 3 Control Measures**
  These are control options which should be considered last a s they do not control the source of the hazard but rely on human behavior or supervision and are therefore less effective. They include;
    - ✓ Administrative Procedures: develop work methods or procedures to reduce the conditions of risk, for example:
        - ❖ Written Safe Operating Procedures
        - ❖ Job rotation to restrict h ours worked on difficult jobs.
        - ❖ Staff trained in the correct operating procedures.
    - ✓ Use Personal Protective Equipment (PPE) and training in its use: offer the lowest level of protection and should only be used as a last resort to deal with the hazard, where the hazard cannot be removed or reduced by any other means, for example:
        - ❖ Handling of chemical s – gloves, safety glasses ,aprons.
        - ❖ Protecting eyes from flying particles.
        - ❖ Protecting feet – safety boots.

Consultation with workers is required in the selection and implementation of control measure in the workplace. Controls may need to be trialed to determine effectiveness and workers should be involved in the feedback process. Each measure must have a designated person and date assigned for the implement at ion of controls. This ensures that all required safety measures will be completed and document.

- **Monitor and Review**
  Hazard identification, risk assessment and control are an on-going process. Therefore, regularly review the effectiveness of your hazard assessment and control measures at least every 3 years. Make sure that you undertake a hazard and risk assessment when there is a change to the workplace including when work systems, tools, machinery or equipment change. Provide additional supervision when new employees with reduced skill levels or knowledge are introduced to the workplace. The effectiveness of control measures can be checked through regular reviews as well as consultation with workers. Maintaining records of the risk management process assists when undertaking subsequent reviews or risk assessments as it demonstrates decision making processes and informs how controls were intended to be implemented.

Hazard– A condition with the potential to cause personal injury or death, property damage, or operational degradation

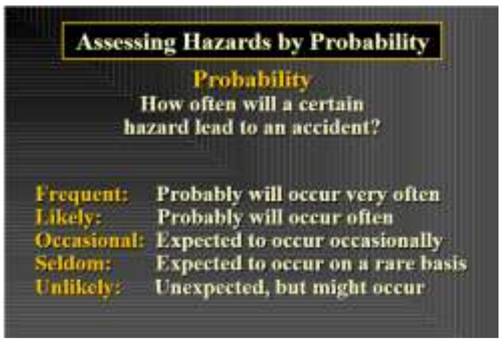
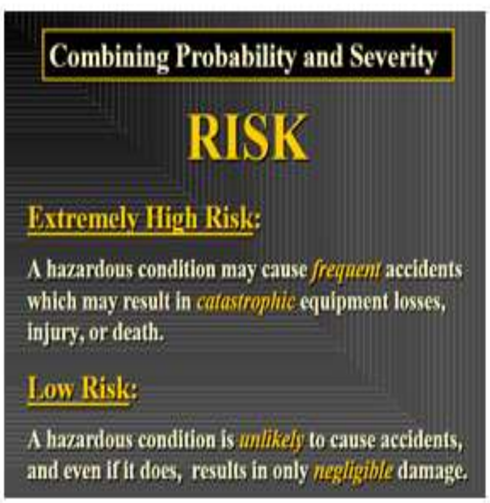
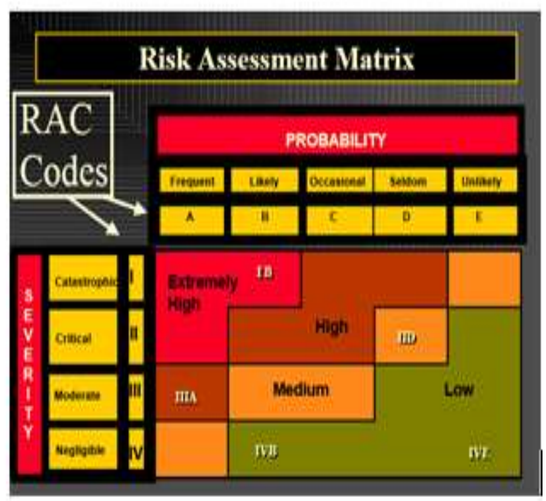


Figure 92: Assessing Hazard





8.2. Work Planning and Control Procedure

Purpose The purpose of this procedure is to ensure adequate protection of workers, the public, and the environment, through the consistent, effective, planning, authorization, and release of activity-level work. It covers the seven core functions of SLACs' integrated safety and environmental management system (ISEMS):

- Define the work
- Identify and analyze hazards
- Develop and implement controls
- Authorize work
- Release work
- Perform work within controls
- Feedback and continuous improvement

For all activity-level work performed in or on facilities managed by SLAC, including technical and administrative activities, experiments, operations, maintenance, and service. It does not cover project management, scheduling, or budgeting. For construction, see Work Planning and Control: Construction Work Planning and Control Procedure. It applies to all workers (including SLAC employees, subcontractors, and users); their supervisors; field construction and service managers; and area and building managers.

8.3. Procedures

Planning, Authorization, and Release Three key concepts of work planning and control are planning, authorization, and release. Before beginning actual work, all work must first be planned, then authorized, and finally released.

- **Planning**

  Planning consists of defining the scope of work, identifying and analyzing the hazards, and developing and implementing controls. Identifying and analyzing hazards and controls related to both the activity and the work area where the activity will occur are the responsibility of the person authorizing the work. A visit to the job site may be warranted, as well as a discussion with the area or building manager and review of any area hazard analysis (AHA). The results are documented in some form of work plan, which forms the basis for authorization and release.
- **Authorization**

  Authorization means that the person who authorizes the work

  - ✓ Is sufficiently knowledgeable of the hazards to plan and authorize such work
  - ✓ Has determined the work falls within his or her area of responsibility
  - ✓ Is satisfied with the content of the work plan
  - ✓ Has determined that the persons assigned to perform work are qualified
  - ✓ Has discussed hazards and controls with those persons

The person who authorizes work is accountable for its performance. Work is typically authorized by the supervisor of the person performing the work.

- **Documentation**
  Requirements for documenting authorization vary with the type of work. It is important to remember that the purpose of documenting authorization is to address and communicate to the worker unique or specific hazards resulting from the condition of the equipment being worked on, the location of the work, the significance of negative consequences if an intermediate step is omitted or performed out of sequence, and so on.

  When deciding how and whether to document authorization, the following factors should be considered, regardless of the type or location of the work:
    - Injury and illness rates at SLAC (see CAS Dashboards)
    - Potential to cause severe or disabling injuries or illness, even if there are no previous events
    - Possibility of one, simple human error leading to a severe event
    - Familiarity with the process/changes in process
    - Complexity of the task(s)
    - Frequency of encountering the hazards or controls
    - Existence of specific or unique personal protective equipment (PPE) requirements

7.4. Release

Release means permission to proceed with authorized work in a given area or on a given project. Release is granted after the person granting the release has made sure that

- Hazards unique to the area have been communicated
- Affected persons have been notified
- Work has been coordinated to avoid conflict and minimize risk

Work performed in a person's resident area is typically released by the supervisor; non-resident area work by the area or building manager. For work in a resident area not under the supervisor's control, release is also granted by area or building manager.

For construction work, the area or building manager typically transfers responsibility for daily release to the FCM, who then releases work to the subcontractor. (See Work Planning and Control: Construction Work Planning and Control Procedure for details.)

7.5. Authorization and Release by Type of Work

How work is planned, authorized, and released depends on the type (green, yellow, or red) and the location (office/non-office and resident/non-resident area).

- **Green work** is administrative or technical in nature and does not require any permits or special ESH training (for example, for fall protection). Green work is authorized by the completion of required new employee/worker safety training. Green work in office areas is released with the same required new employee/worker safety training. Green work in a non-office area (that is, an industrial area) requires release by the area or building manager, if required on the area hazard analysis (AHA) or other postings. Otherwise, if the worker is familiar with the area, has read the AHA, has no ESH concerns, and adheres to all postings, he or she may enter the area to perform green work.

- **Yellow work** in the worker's resident area is authorized and released with an up-to-date SLAC Training Assessment (STA) and supervisor acknowledgment of worker's ability to carry out assigned When a worker is dispatched outside his or her resident area, a JSA or SOP is typically required for authorization, and the work is released by the area manager, if there is one, otherwise by the building manager. (Release by an area or building manager is also required for work in resident areas, if the area is not under the control of the worker's supervisor.) For work involving subcontractors, a tailgate briefing is also required as a final release before beginning any activity. Some simple activities performed outside a worker's resident area may be authorized without a JSA or SOP, as determined by the supervisor. For example, climbing a ladder (which is yellow work) to perform green work.

- **Red work** is authorized at the activity level like non-resident yellow work (that is, by the supervisor of the workers involved, using a JSA or SOP). In addition, the planning efforts are documented by the work planner with a work integration plan (WIP); a coordination meeting is held to discuss the activities, timing, permits, and so on until the area manager is satisfied that release may be granted; and, unless all workers are present at the coordination meeting, a tailgate briefing is required to release work for each worker before beginning any activity. For work that is considered to have lab-wide impact, the associate laboratory director (ALD) of the planner must indicate concurrence of adequate planning by signing the WIP. For the authorization and release of construction work, see Work Planning and Control: Construction Work Planning and Control Procedure.

Self-Check-8	Written test

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

Say true or false for the following questions below

1. All hazards that have been assessed should be dealt with in order of priority.
2. Level 1 Control Measures is the most effective control measures to eliminate the hazard and associated risks.
3. Hazard identification, risk assessment and control are an on-going process.
4. Planning consists of defining the scope of work, identifying and analyzing the hazards, and developing and implementing controls.
5. Release means permission to proceed with authorized work in a given area or on a given project.

Note: **Satisfactory rating 3 and above points Unsatisfactory - below 2 points**

Score = ____________

Rating: _____________

Reference

1. Elliott, R.L. and Walker, W.R. 1982. Field evaluation of furrow infiltration and advance functions. Trans. ASAE, 25(2):396-400.
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Solar PV System Installation and Maintenance

Level-II

Learning Guide -21

Unit of Competence	**Perform Simple Welding**
Module Title	**Performing Simple Welding**
LG Code	EIS PIM2 M06 LO3 LG-21
TTLM Code	EIS PIM2 TTLM 0120V1

LO3:Set-up pre heating tools/ equipment

Instruction Sheet	Learning Guide: - 21

This learning guide is developed to provide you the necessary information, knowledge, skills and attitude regarding the following content coverage and topics:-

- Selecting appropriate Pre-heating equipment
- Operating equipment with the manufacturer's instructions

This guide will also assist you to attain the learning outcome stated in the cover page. Specifically, upon completion of this Learning Guide, **you will be able to:-**

- Select appropriate Pre-heating equipment
- Operate equipment with the manufacturer's instructions

Learning Instructions:-

1. Read the specific objectives of this Learning Guide.
2. Follow the instructions described below 3 to 4.
3. Read the information written in the information Sheet 1 and Sheet 2, in pages 112 and 121 respectively.
4. Accomplish the Self-check 1 and Self and check 2 in page 120 and 123 respectively

Information sheet-1	Appropriate Pre-heating equipment

1.1.Application

When welding, brazing, or soldering metals such as steel, aluminum, Inconel, stainless steel, and other ferrous or nonferrous alloys, joint failures and other defects can occur due to the extreme thermal stresses imposed by rapid heating and cooling at the connection area. Preheating and post-heating the connection area is done to better prepare the surfaces and slow the cooling process to reduce the potential for joint failure. It also drives out moisture which may also cause problems. As a result, there is less rework required and the finished piece performs better. Technicians in this field know, and governing bodies such as ASME, API, ASM, NAVSEA, in addition to proprietary entities, have codes that require preheating and post-heating many metals when welding, brazing, or soldering.

A preheating application Brisk Heat assisted with was a submarine manufacturer welding large steel beams to reinforce a nuclear reactor chamber within a nuclear submarine. The steel beams were 6 in thick x 12 in wide x 120 in long (152 mm thick x 305 mm wide x 3048 mm long). Preheating to 360°F (182°C) before joining was critical to prepare the surface, and post-heating to ensure a slow enough cooling rate to avoid failure was also required. Preheat temperatures can vary from metal to metal depending on carbon/alloy content and thickness but are generally 175°F to 500°F (79°C to 260°C). To be truly effective, preheating and post-heating must be uniform across the entire joining area. Depending upon the size and shape of the materials being joined, hours of manpower and large amounts of fuel could be wasted using other heating methods such as torching or steaming. Hotspots and uneven heating are likely to occur when preheating in these manners. Additionally, torching or steaming greatly increases the risk of technicians sustaining burns.

1.2.Solution

Brisk Heat BWH heavy insulated fiberglass heating tapes can deliver heat up to 1400°F (760°C). They have a high watt density of 13.1 W/in^2 (2.0 W/cm^2) which ensures a rapid thermal response and even distribution of heat. BWH fiberglass heating tapes are a safer, more efficient, and provide more even heat for pre and post-heating than other methods such as torching or steaming. They are exceptionally flexible and easily conform to complex shapes, making them ideal for a variety of difficult metal joining applications. For precise and accurate temperature control, a Brisk Heat X2 digital programmable PID temperature controller can be used to regulate the heat output of the heating tape. The X2 controller can be programmed to specify exactly how much heat is applied to meet the needs of the application.

In other applications where the required heat is never more than 450°F (232°C), Brisk Heat full line of BS0 silicone heating tapes or SRL silicone heating blankets are an effective solution.

1.3.Preheating is an important preparatory operation for certain welding jobs. As the name implies, it is the process of raising the temperature of a part before welding it. This preheat temperature has to be maintained throughout the welding procedure. In some cases it might be necessary to continue heating the part during welding, but sometimes the heat input from the welding itself maintains that temperature. The inter pass temperature, which is the base metal temperature maintained between the first and last welding passes, should not fall below the preheat temperature. Preheat is recommended for certain jobs for several reasons. Among these is that it helps stave off moisture from the base metal and weld, which in turn makes the completed part less susceptible to hydrogen cracking. It also reduces shrinking stresses in both the base metal and the weld joint. Generally speaking, preheating helps ensure that the weld has the mechanical properties it was designed to achieve.

1.4.Torch Heating

Essentially three methods commonly are used to preheat joints: propane (gas) torch, induction heating, and electrical resistance heating.

"Torch heating is certainly the most portable of the three methods," said Scott Fong, owner and general manager of KASI Technologies Inc., an Edmonton company that specializes in renting industrial heating, welding, and bolting equipment. "Basically, torch heating is like using a big barbecue lighter. It's just a torch and you simply monitor its temperature with temperature-indicating sticks. Once you see the sticks melt, you know you've reached the minimum preheat temperature and you start welding."

While Fong appreciates the portability and affordability of this method, he also notes that it is, by its very nature, not as accurate as the other technologies available.

"It is very easy to overheat the steel past your maximum inter pass temperatures," he explained. "You also don't get even heating all the way around the surface. You've got to manipulate the torch a lot. Once the welder starts welding, he may be able to keep the weld at the minimum preheat temperature via the welding process itself; however, on thicker sections of steel, the heat tends to bleed out very quickly. In situations like that, it's important to have a more controlled preheat process."

- **Proper Torch Setup for Thermite Welding**

  - ✓ Torch stand
  - ✓ Thermite torch tip
  - ✓ Thermite torch body
  - ✓ In-line pressure gages (At Torch Handle)
  - ✓ Non-Q.D. Flash-Back Arrestors (At Torch Handle, Recommended)
  - ✓ 3/8 I.D. Hose, Grade “T” ONLY, 50ft-100ft (Fuel Source, LP)
  - ✓ Non-Q.D. Flash-Back Arrestors at tanks (Required)

Figure 93: Thermite Welding

1.5.Induction Heating

A wide range of industries have long used induction heating, and the technology has been a success story for nearly two decades in industrial and construction welding applications, including refineries, petrochemical, pipeline, structural, shipbuilding, pressure vessel repair and mining.

Many welding applications require preheat, which minimizes the temperature difference between the arc and the base material. Preheating slows the weld cooling rate and lowers hydrogen — two factors that help reduce the risk of cracking and the potential for a failed weld.

When preheating or post-weld stress relieving are necessary, induction can save significant time and provide temperature consistency up to 1,450 degrees Fahrenheit — while also offering benefits for safety and weld quality.

The most common methods for achieving a more controlled preheat temperature are induction heating and electrical resistance heating.

“The equipment used for induction is considerably more expensive than that used for electrical resistance heating,” said Fong. “However it does get your steel hotter quicker. It still offers you much more control than what you achieve with a torch.”

The induction method of preheating can use either a liquid-cooled braided hose or an air-cooled premade blanket wrapped around the material to be heated to create a magnetic field. The magnetic field excites the molecules in the material, which creates heat that radiates from the center of the material outward in all directions.

With an induction heating system you attach a thermocouple to the weld. The thermocouple senses the temperature of the steel and sends a signal back to the controller on the induction machine. Once the steel reaches the preheat temperature, it will maintain that temperature until the controller is adjusted.

“It is very quick,” said Fong. “It has its ideal applications. For instance, when a shop is heating very thick sections of pipe and rotating them, this can be a good solution. Its limitation is that an induction machine can be used to heat just one weld joint at a time, and it has only a single point of control.”

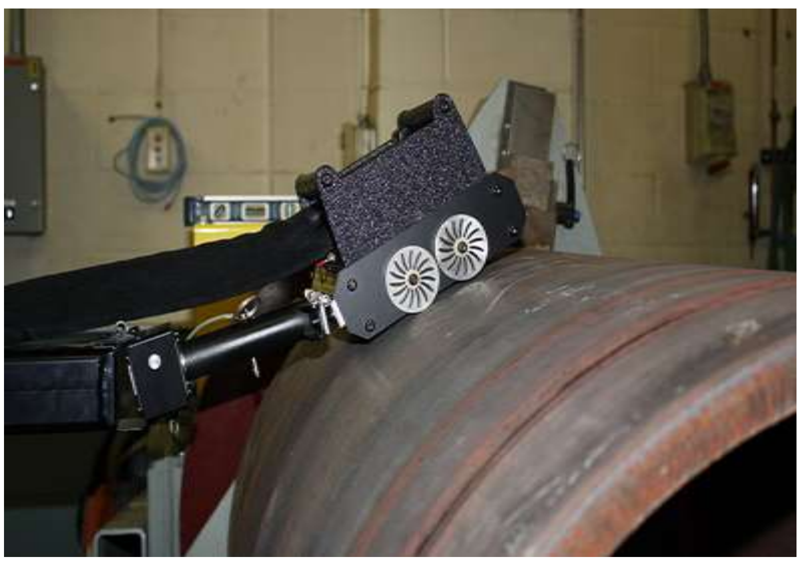

Figure 94: Induction Heating

1.6. Component options for induction heating

Induction is commonly used for heat treatment in pipe fabrication and welding. But many contractors don’t realize induction can deliver benefits in a wide range of applications, including welding flat plate, moving parts and other part geometries. The Miller Pro Heat Induction Heating System is available with numerous air- and liquid-cooled options, depending on the job requirements.

- **Air-cooled**

  Air-cooled blankets or air-cooled cables are easily laid onto or wrapped around the part. Designed with flexibility and efficiency in mind, air-cooled cables or blankets can fit almost any induction preheating application and don’t require a cooler and coolant, which can save time and eliminate some costs in welding preheat. Air-cooled systems can be used for preheating applications up to 400 degrees Fahrenheit.

- **Liquid-cooled**

  This type of system can be used for applications that require high-temperature preheating and stress relieving. Liquid-cooled induction offers the widest range of temperatures for preheat, hydrogen bake out and post-weld heating treatment — with the ability to heat up to 1,450 degrees Fahrenheit. The principle differences compared to air-cooled systems are the addition of a water cooler and the use of a flexible liquid-cooled hose that houses the induction coil. Liquid-cooled systems generally use a built-in temperature controller and outside temperature recorder, which are particularly important components in stress relieving applications.

- **Rolling induction**

  The majority of pipe welds completed in fabrication shops are rolled. Rotating pipe while welding provides many benefits, including ease of achieving quality welds by eliminating out-of-position welding, reduced welder fatigue, and improved productivity from higher wire feed speeds and increased deposition rates. The Pro Heat 35 Induction Heating System with Rolling Inductor allows fab shops to preheat work pieces — including moving parts — and delivers fast, consistent heat up to 600 degrees Fahrenheit.

  Induction heating benefits

  Compared to using open flame or resistance for preheating and stress relieving, induction offers numerous advantages. Some key benefits of induction include:

- **Temperature uniformity**

  Induction heating distributes heat energy evenly over the area where the coil is wound or the blanket is placed, providing even, consistent heat to the base material. In comparison, flame heating requires manual motion that is difficult to control, while resistance heating pads often do not touch the part consistently, causing uneven heat and stresses on the weld. Pro Heat systems use sensors to accurately report and record the joint temperature. Induction heating components also make cycle interruptions unlikely, which is critical to productivity in stress relieving.

- **Reduced cycle time**

  Induction provides significantly faster setup and time-to-temperature. Resistance heating often requires a preheating contractor, which can result in delays and long heating time that cause welder downtime. With induction, welders can heat their own parts, maximizing efficiency. And the time-to-temperature can be achieved in minutes compared to hours for resistance heating. On thick, thin and odd-shaped parts, it's not uncommon to expect a more than 50% reduction in total cycle time with induction.

- **Efficiency/utility costs**

  The induction heating process is very efficient, and most of the electrical energy used actually generates heat inside the part. Utility costs are typically much lower than other methods. With flame heating, the majority of the heat energy created is wasted in the open air. Resistance heating wastes electrical energy because of the large transformer in the power supply, and because only one side of the heating element sits against the cold part. Many customers who convert to induction heating can earn rebates from utility companies because of the efficiency improvements.

- **Versatility**

  Induction can be used on many shapes, sizes and types of parts, from pipe and flat plate to elbows and valves. One aspect of induction that makes it attractive for complex shapes is the ability to adjust the coils during the heating process to accommodate unique parts and heat sinks.

- **Minimized safety risks**

  Flame and resistance methods heat work pieces from the outside in, so they carry the risk of burn injuries. Resistance heating uses ceramic pads that stay hot long after the joint has been brought to temperature, while flame heating carries the risk of fires and even explosion. With induction, only the work piece gets hot; the cables, blankets and wraps don't, so there's less chance of injuries or accidents and the operator is less fatigued from the heat.

- **Decreased consumables costs**

  The insulation used in induction is easy to attach to work pieces and can be reused over and over. Also, induction coils are robust and don't require fragile wire or ceramic materials. Compare this to the ceramic fiber insulation used in resistance heating, which can be used only once or twice before it must be discarded, requiring a large inventory of insulation and significant costs for disposal of potentially hazardous material.

- **Ease of use**

  A major benefit of induction is its simplicity. Insulation, blankets and cables are simple to install, usually taking less than 15 minutes, and they can be easily adjusted.

- **Customer success stories**

  Induction is used in a wide range of applications and industries, including oil and gas pipelines, heavy equipment construction, and maintenance and repair of mining equipment. Read more about some success stories.

- **Electrical Resistance Heating**

  A standard electrical resistance preheating machine, on the other hand, is built as a six-way unit, which means it is equipped to heat three joints at the same time, while offering six points of control.

  Similar to the induction method, the pipe gets wrapped. However, the coils (flexible ceramic pads) that are used heat through conduction, and therefore heat from the outside going into the steel. The electrical resistance method (sometimes referred to as Cooper heat) also controls the pre heat by using the feedback of a thermocouple.

  “It allows you more control, in the sense that you can add more controlling thermocouples,” said Fong. “For materials like P91 alloy steel, where you need to tightly monitor your maximum inter pass temperature and your preheat temperature, the electrical resistance method gives you more control over that. P91 is becoming widely used in power plants and other high-temperature applications. So in circumstances where you are using this type of material, using electrical resistance allows you to control each 120 sq. in. of steel. It is also your most effective method of controlling maximum inter pass.”

  Fong also noted that the equipment is simpler and more durable for field applications.

  “It is a little slower with respect to actually setup, but when you are welding thick sections, that speed isn’t as big a concern because you can prepare for more welds at once,” he explained. “Preheat time could also be a half hour compared to five minutes. That depends on the power available and the setups, so it is harder to quantify.”

  Fong pointed to one company he worked with that saved enough money from switching from using torch heating to an electrical resistance system that the equipment paid itself off in about six months.

- **Track Your Heat**

Although both induction and electrical resistance monitor preheat temperature, Fong urges welders to continue to use temperature-indicating sticks to ensure they have reached the correct temperature.

"You should always use temperature-indicating sticks because, for instance, the thermocouple measures at only one point on that piece of pipe. You are responsible for having minimum preheat temperature on the whole area within 3 in. of where you are welding. If you are on an 8-in.-diameter pipe and you have two thermocouples, one on each side of the section of pipe you are going to weld – they are diametrically opposed you've got 6 in. of coverage there on 24 in. of circumference. You should be using temperature-indicating sticks. It's not worth slapping on a thermocouple every 3 in. That is just overkill.

"Welders should always carry temperature-indicating sticks in their pockets, one minimum for the preheat temperature, and one for the maximum interpass temperature as per the WPS/PRQ requirements," Fong continued. "The controller may say 350 degrees, but it's reading only that one thermocouple at that one spot."

Fong also encourages those using preheat equipment to get some proper training before engaging with the technology.

"We have field heat treatment technicians out there in the field," he pointed out. "It is a Designated Occupation in Alberta. However, with the right training, you can gain a great deal of time savings utilizing induction or electrical resistance preheat equipment and avoid the problems that can arise when you don't have the training."

Self-Check-1	Written test

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

Say true or false for the following questions below

1. Preheating is an important preparatory operation for certain welding jobs.
2. A wide range of industries have long used induction heating.,
3. Induction is commonly used for heat treatment in pipe fabrication and welding.
4. Induction provides significantly faster setup and time-to-temperature.

Note: **Satisfactory rating 3 and above points Unsatisfactory - below 2 points**

Score = ____________

Rating: _____________

Info.sheet-2	Operating equipment with the manufacturer's instructions

2.1. Welding Pre-Heating Ring Coils

One set is composed of two rings, usually connected in parallel, installed externally (ERC) or internally (IRC) of each pipe's terminal and connected with the generator through connection cables. Welding pre-heating ring coils guarantee uniform heating through the wall thickness of pipes, with extremely limited tolerance range. After the heating process is completed, coils are removed, pipes aligned and welded. These operations require quite some time, and with any other conventional system the pipes cool down.

Figure 95: Heating Ring

2.2. Welding Pre-Heating Clamp Coils - IWC

One set is composed by one clamp installed across the joint area. By using these clamps, pipes to be welded can be aligned before the heating process because the clamp will heat simultaneously 100 mm of one end and 100 mm of the other end.
The coil is connected with the generator by connection cables. Welding pre-heating clamp coils, as well as ring coils, guarantee uniform heating through the wall thickness of pipes, with limited tolerance range. In very cold environments, where the pipe temperature drops down quickly, this solution allows to start the welding process immediately after the heating cycle because the pipes are already aligned.

In some cases, when the welding process is handled in different steps (root weld + Inter pass fillings + cap weld), the clamp coil is used also to maintain the temperature during intervals

Figure 96: Clamp Coils - IWC

Self-Check-2	Written test

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

Say true or false for the following questions below

1. Welding pre-heating ring coils guarantee uniform heating through the wall thickness of pipes.
2. Welding Pre-Heating Clamp Coils composed by one clamp installed across the joint area.

Note: **Satisfactory rating 2 and above points Unsatisfactory - below 1 points**

Score = ____________

Rating: _____________

Reference

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Solar PV System Installation and Maintenance

Level-II

Learning Guide -22

Unit of Competence	**Perform Simple Welding**
Module Title	**Performing Simple Welding**
LG Code	EIS PIM2 M04 LO4 LG-22
TTLM Code	EIS PIM2 TTLM 0120V1

LO4. Perform tack welding

Instruction Sheet	Learning Guide: - 22

This learning guide is developed to provide you the necessary information, knowledge, skills and attitude regarding the following content coverage and topics:-

- Performing tack welding
- Accepting tack weld visually and dimensionally
- Tack on root for pipe as required
- Installing backing plate, stiffener, running plate
- Cleaning joints from dirt particles

This guide will also assist you to attain the learning outcome stated in the cover page. Specifically, upon completion of this Learning Guide, you will be able to:-

- Perform tack welding
- Accept tack weld visually and dimensionally
- Tack on root for pipe as required
- Install backing plate, stiffener, running plate
- Clean joints from dirt particles

Learning Instructions:-

1. Read the specific objectives of this Learning Guide.
2. Follow the instructions described below 3 to 6.
3. Read the information written in the information Sheet 1, Sheet 2, Sheet 3, Sheet 4 and Sheet 5 in pages 127,136,140,148 and 154 respectively.
4. Accomplish the Self-check 1, Self-check 2, Self-check 3, Self-check 4 and Self-check 5 in pages 135,139,147,151 and 158 respectively
5. If you earned a satisfactory evaluation from the “Self-check” proceed to Operation on page 152.
6. Do the “LAP test” on page 153

Information Sheet-1	Performing tack welding

1.1. Tack Welding

Tack welding is necessary to ensure that the pipes do not move during closure welding. Make sufficiently large tack welds and place them often enough around the diameter of the joint that the filler wire is smaller in diameter than the root gap. Grinding the tack welds to a feather edge may be helpful; it may prevent small defects that could be detected during radiographic examination from occurring when you make the closure weld.

1.2. Closure Welding

When closure welding, keep the joint sealed except in areas being welded. Maintain gas purge pressure for the first two passes to ensure that the root pass will not be tremendously oxidized during subsequent weld passes. Move your torch in a continuous motion from sidewall to sidewall, adding filler wire where the joint has not been tack-welded. Position the filler metal in the root gap opening. This reduces the possibility of the root gap closing up, limiting weld reinforcement at the root.

- **What Is Tack Welding?**
  After items to be welded together have been positioned as required, generally by clamping them on suitable fixtures, tack welds are used as a temporary means to hold the components in the proper location, alignment, and distance apart, until final welding can be completed.

  In short-production-run manual welding operations, tack welding can be used to set up the work pieces without using fixtures. Typically, tack welds are short welds. In any construction, several tack welds are made at some distance from each other to hold edges together.

  An advantage of this provisional assembly procedure is that if the alignment for final welding is found to be incorrect, the parts can be disassembled easily, realigned, and tack welded again.

  In general, tack welding is performed by the same process that is used for the final weld. For example, aluminum-alloy assemblies to be joined by friction stir welding are tack-welded by the same process using a small tool developed for this purpose. Or electron beam tack welds, created with reduced power, are used to supplement or replace fixturing and to maintain the correct shape and dimensions during final electron beam welding.

If the final welding is performed while the elements are still clamped in a fixture, tack welding must keep the elements in place and resist considerable stresses, not sufficiently contrasted by clamping devices, that tend to separate the components.

1.3. Why Tack Are Welds Important

The temporary nature of tack welds may give the false impression that the quality of these auxiliary joining aids is not as important as that of final weld and that this operation doesn't have to be properly programmed, performed, and inspected. This is not true.

Tack welding is real welding, even if the welds are deposited in separate short beads. It performs the following functions:

- Holds the assembled components in place and establishes their mutual location
- Ensures their alignment
- Complements the function of a fixture, or permits its removal, if necessary
- Controls and contrasts movement and distortion during welding
- Sets and maintains the joint gap
- Temporarily ensures the assembly's mechanical strength against its own weight if hoisted, moved, manipulated, or overturned

1.4. Defective Tack Welding Risks

When hoisted, improperly tack welded assemblies can rupture, and portions or subassemblies can fall and endanger people or damage property.

Tack welding must not interfere with or degrade the quality of final welding. It must not introduce weld defects, such as arc strikes, craters, cracks, hard spots, and slag left in place.

Many steels used in fabricating pipes and vessels are sensitive to rapid cooling or quenching, especially following short tack welds, because of the limited heat input required to tack weld. *Note:* Higher heat input slows the cooling rate, which minimizes the occurrence of hard and brittle microstructures.

Hard, brittle, and crack-sensitive microstructures can be formed in the heat-affected zone (HAZ) if the metal is rapidly quenched. In this case, even removing the whole tack weld by grinding may leave dangerous, invisible cracks in the base metal.

The brittle metal can crack during solidification of the weld metal or when stressed. Under bead cracks cannot be readily detected by visual inspection, and more thorough non-destructive tests may not be performed if they are deemed unimportant for such limited welds. However, these small cracks can cause the whole structure to fail.

- **Controlling Tack Weld Quality**

  To ensure quality, most codes require that tack welding be performed only according to qualified welding procedures by welders fully certified in the process used for the final weld. The requirements are applicable for any welding process used.

- **Distortion Control Procedures**

  In all fusion welding processes, the sequence and the direction of the tack welds are important for distortion control. Besides maintaining the joint gap, tack welds must resist transverse shrinkage to ensure sufficient weld penetrations.

  For a long seam, tack welding should start at the middle and proceed along the joint length, alternating in both directions, in proper back step or skip sequence to avoid stress build up and deformation.

  Tack welds also can be placed at the joint ends and then added in the middle of each resulting distance between those already done, until the whole length is covered with the required number at the needed spacing.

  Why tack weld in sequences such as these? Because if tack welds are placed progressively from one end to the other, shrinkage can close the gap at the opposite end and might even cause one sheet end to overlap the other.

  Because of greater thermal expansion in austenitic stainless steels, the spacing between tack welds on these materials should be much shorter than for mild steel.

- **Special Requirements**

  Tack welding is an essential step in preparing pipes for welding. Thorough attention should be given to obtain adequate alignment and consistent root opening (joint gap) that control the success of the most important root pass. Although this work could be assigned to fitters, it should be supervised closely to make sure that the workers are properly qualified.

The number and size of tack welds depend on pipe diameter and wall thickness. Tack welds with complete fusion should be the same quality as the final weld.All tack welds must be thoroughly cleaned before proceeding with the final weld.

Both ends of each tack weld, representing start and stop (which are weak points often having unacceptable defects), must be ground to remove possible flaws and to present a very gradual slope that blends the weld's sides into the metal.

- **Additional Precautions**

When tack welding is used as fixturing for brazing, the area surrounding the tack must be thoroughly cleaned to remove oxides developed during welding.

In semiautomatic and automatic welding, the meeting points of the final weld electrode with tack welds can impair arc voltage control and filler wire feeding, making manual assistance especially important for maintaining quality.

Tack welding is an essential ingredient in a successful welding project, be it simple or complex. It is therefore very important to perform the process properly and minimize the risks associated with poor tack welding.

Figure 97: Tack welding

- **Tack-welds functions**

Tack-welds perform the **following functions**:

- ✓ Hold in place the assembled components,
- ✓ establish their mutual positioning and alignment,
- ✓ Set and maintain the prescribed joint gap,
- ✓ Complement the function of a fixture, and permit the assembly removal from it, if necessary,
- ✓ Control and contrast component movement and distortion of the structure during welding,

- ✓ Temporarily ensure the assembly's mechanical strength when *hoisted, moved, manipulated or overturned*, if designed for this purpose. tack- welds must be made strong enough to sustain the stresses affecting them during fabrication.

The welding operations that follow must be so *planned and conducted* that existing Tack-welds are either completely remelted or suitably blended to become indistinguishable from the following weld passes.

They are called remelted or incorporated depending on the technique used to embed them in the final welds. In the first case it is assumed that the considerable heat input employed (say by Submerged Arc Welding) will reheat also the Heat Affected Zone (HAZ) left around the original Tack-welds, so that **no additional attention** is required.

To make sure that these are indeed remelted, their **size must be limited by design**, while their length may be increased if necessary to provide sufficient strength. In the second case the residual presence of the original Tack-welds must be taken into account, so that their **quality must be equal** to that needed in the final welds.

Special attention therefore must be devoted to process, filler metal, composition compatibility, removal of slag traces and original HAZ (Heat Affected Zone) extent.

The precise technique to be used in each case must be **thoughtfully prepared and carefully applied**, to avoid expensive repair operations if not successful.

Tack-welds may be needed also **outside the proper structure welds**. That is the case for Temporary welds. In general they should be removed **without affecting** the base material, to make sure they **will not be used** to sustain loads exceeding their actual capacity.

Good practice would require to use always suitable non-destructive inspection to look for **under-bead cracks** that might have been introduced while applying Tack-welds.

For statically loaded structures only, the responsible Engineer may decide to leave temporary welds in place. For structures subject to alternating loading, and therefore under *fatigue stressing*, the attention to all details, including sound Tack-welds, should be pushed to the highest level.

Although specifications may be *clear and precise* as to tack-weld requirements, implementation must be enforced on the job site, lest a sloppy work is performed.

Good workmanship must be assured by having inspection committed to check proper execution. It is not fair to leave to the fitters the responsibility on the number; dimensions and quality of tack welds. Welding management must take full responsibility to specify all requirements in a special WPS.

1.5. Additional prescriptions

Must be included as to *filler metal* to be employed, *preheating* if necessary, and *hoisting instructions*, if the tack welded assembly has to be hoisted before welding completion.

Tack welds are an essential part of all successful welding projects, simple or complex alike. It is therefore very important to know and to perform the process properly to minimize the risks associated with poor tack welding.

1.6.The Steps

1. **Lay it all out.** In this case, on a flat, non-combustible surfaces the shop floor. Now square up the pieces of the frame and lightly tack-weld them together. Some clamps or weights will hold everything in place.

Figure 98: Lay it all out

2. **Cut here.** You could hacksaw these pieces of ¾-in. angle iron easily enough, but you can save some time by using an abrasive metal-cutting blade as the wheel in a chop saw. A slow, steady feed cuts fast without making excess heat.

Figure 99: Cutting

3. **Proper tacking is important.** Weld just enough to pin the parts together. As you add more parts, adjust to keep everything square. Never finish-weld any joints until you have a fairly complete subassembly that's well tacked; measure diagonally to square things up.

Figure 100: Proper tacking

4. **Cope it out.** We used a plasma cutter to trim part of the angle iron at the joints. This is known as coping, and it allows the pieces to fit more closely. You can achieve the same thing with a grinder or even a hacksaw

Figure 101: Cope it out

5. **Keep adding parts.** After you assemble the front and rear frames, add the horizontal frame elements. Another pair of hands can help here. Tack everything together, and check that it's all square before attempting full welds.

Figure 102: Keep adding parts

6. Good posture helps. If you're not comfortable, the weld bead is going to wander. Use both hands to hold the welding gun, and brace at least one elbow against your torso. Rehearse the movement in longer beads with the welder shut off.

Figure 103: Good posture

7. **Measure, and measure again.** As you build up, constantly check the assembly for squareness by measuring across diagonals. Use a few light hammer taps to correct to within 1/8 in. before you finish the weld.

Figure 104: Measuring

8. End result: We added a handle, a rack for clamps and ground cables at the rear and, of course, wheels and casters. Shelves are made of expanded metal, so they won't collect dust or slag. Then we sandblasted the slag off the welds and finished with Hammer tone silver paint. The cart is topped with a plasma cutter--one that cuts 1/4 in.-thick steel plate like warm tofu.

Figure 105: Final Result

Self-Check-1	Written test

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

Say true or false for the following questions below

1. Tack welding is an essential step in preparing pipes for welding
2. Tack welding is necessary to ensure that the pipes do not move during closure welding
3. Tack-welds perform to hold in place the assembled components,

Note: **Satisfactory rating 2 and above points Unsatisfactory - below 1 points**

Score = ____________

Rating: _____________

Information Sheet-2	Accepting tack weld visually and dimensionally

2.1. Definition of Accepting Tack Welding

Tack welding is a vital part of a pressure vessel fabricated by welding. This is why the ASME Boiler and Pressure Vessel Code require qualification of the welding procedure used for tack welding. The code requires the tack welding procedure to be qualified in accordance with the referencing book section and Section IX the same as for other weldments.

Many metals used in code fabrication are very sensitive to rapid quenching including many of the basic P-No. I metals. Very hard, brittle, crack sensitive micro structures, such as martin site and upper bainite, are formed in many metals when rapidly quenched from an elevated temperature. The brittle micro structures are likely to crack during the solidification of the weld metal or when highly stressed during operation of the pressure vessel.

The cracks are usually an under bead crack not detectable by visual or dye penetrant examination and difficult to detect by radiographic or magnetic particle examination. Yet these small cracks may lead to the product failure, if not at hydro test, at some future time due to cyclic fatigue of the pressure vessel. There are many preventive measures to circumvent this problem such as preheat, high heat input processes, subsequent Post Weld Heat Treated (PWHT), etc.

How does this apply to tack welds? Unfortunately tack welds are usually given little attention if any and are seldom controlled rarely specified. Herein lies the problem.

A high heat input process may be selected for the welding, but the tack is applied by the shielded metal arc welding process. The tack is a very rapid quench application and a brittle, crack sensitive micro structure results usually at the root of the weld. The tack may be subsequently pulled and stressed during the fit-up operation with a resultant under bead crack in the pressure retaining material at the root of the weld. Subsequent weld passes with the high heat input process do not, generally, remove the cracks. In fact, the cracks may propagate further into the base metal and/or weld metal during the subsequent welding operations.

Tack welds are important! If the vessel is to be Post Weld Heat Treated (PWHT) the Welding Procedure Specification (WPS) for the tack welding shall be qualified with PWHT. If the welding process is qualified with preheat, the tack weld shall be applied within the preheat range qualified.

The code requires the tack welding to be applied following a qualified WPS whether it is removed, left in place or incorporated into the weld. Tack welding to a qualified WPS is required for any code tack weld including attachments such as backing strips, legs, saddles, lifting lugs, reinforcing rings, thermometer wells, etc. There is at least one exception to this. Section VIII, UW-28 and Section I, PW-28 state in part that procedure qualification testing is not required for any machine welding process used for attaching non-pressure bearing attachments to pressure parts which have essentially no load carrying function. Section IV has exceptions for stud welding.

- Other areas of confusion on tack welding include the following:
  - ✓ Removal of a tack weld means removal of the deposited weld metal essentially flush with the parent base metal. **NOTE:** This leaves the heat affected zone and some weld metal/base metal mixture which may contain brittle, crack sensitive structure. Removal may also be complete, as in the case of back gouging to sound metal. **NOTE:** All rules apply even when removed in this manner.

  - ✓ Feathering of tacks, or their starting and stopping ends, shall be properly prepared by grinding or other suitable means so that they may be satisfactorily incorporated into the final weld. This does not require complete grinding of the entire tack, just the start and stop so it may be smoothly incorporated into the final weld. If a tack is made with Gas Tungsten Arc Welding (GTAW) for example, and is smoothly contoured at the start and stop, the tack need not be ground. **NOTE:** A workmanship sample is usually made to demonstrate which tacks may be satisfactorily incorporated into the final weld to determine an acceptance standard.

  - ✓ Tacks shall be visually examined for defects and, if found, the defects shall be removed. Defects are the normal entrapped slag, gas pockets, lack of fusion, cracks, etc. **NOTE:** Tacks are often pulled and stressed to failure, cracking or tearing away base metal. These defects must be removed before making the final weld.

  - ✓ Tack welds may be long or short. Some fitup operations require 12" long tacks fully fused into the root of the weld. I have seen some tacks cover more than half the length of the root. This is why a welder who is tack welding the root of a single welded butt joint needs to be qualified for welding without backing. When tack welding the root of a stay weld in a boiler, in the 5G position, the tack welder needs to be qualified for the 5G position. After all, he is putting in the most critical part of the weld.

- The next time you meet a code tack weld, bear it with respect. Qualify the tack weld procedure, qualify the tack welders performance and control the application of the tack in accordance with your quality control program. A respected tack weld may pay you back with dividends of which you may never have been aware. The dividends may be no x-ray repairs, no leaks and no product failure.

Self-Check-2	Written test

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

Say true or false for the following questions below

1. Tack welding is a vital part of a pressure vessel fabricated by welding.
2. Removal of a tack weld means removal of the deposited weld metal.
3. Tack welds may be long or short.
4. A high heat input process may be selected for the welding.

Note: **Satisfactory rating 3 and above points Unsatisfactory - below 2 points**

Score = ____________

Rating: _____________

Information Sheet-3	Tack on root for pipe as required

3.1. Definition of Root

This is the most common type of arc welding. Sometimes called MIG welding, Metal Inert Gas Welding is a form of arc welding which is great for mild steel, stainless steel and aluminum. The process involves a wire feed which goes through a wire electrode inside a welding.

Figure 106: Root Pipe

Pipelines are used to transport fluids, including vapors, gases, slurries and powders which flow through pipes at various pressures and temperatures. The transmission of these materials invariably subjects the pipe to intense stresses and strains and this demands the highest possible performance from the pipe. All pipework must be designed and fabricated in a way that ensures the safety of plant operators, the plant, the public and the environment.

Figure 107: Pipe

The fabricator is responsible for the quality of the pipework and pipe fabrication must be carried out in accordance with all relevant standards and specifications. One faulty weld could lead to damage costing millions of dollars, personal injury and in serious cases even death. Welded pipe systems demand the highest degree of excellence in materials and quality of work. Because high standards are required, the cost of pipework is extremely high.

Table 1: Specification Of Component

Name	**Welded pipe / welded steel pipe / straight seam pipe 6m / root**
Size Range	1-8 inch
Outside Diameter	21.3-630mm
Wall Thickness	1.8-22.2mm
Thickness	0.5-8.0mm
Appearance	Generally smooth, bright
Packing	Export standard packing or according to customers' requirement
Certificate	ISO9001:2008,SGS
Shipment	Within10-15 workdays,25-30days when the quantity beyond 1000tons

Figure 108: Consumables for Pipe Welding

Currently, there are four categories of consumables available for welding pipes of various strength levels.

- ✓ **SMAW** (Shielded Metal Arc Welding) Cellulosic Electrodes Vertical Up, Low Hydrogen Electrodes Vertical Down, Low Hydrogen Electrodes
- ✓ **FCAW** (Flux-Cored Arc Welding) Self-Shielded (Inner shield) Electrodes Gas-Shielded (Outer shield) Electrodes
- ✓ **GMAW** (Gas Metal Arc Welding) Solid Wire Electrodes Root Pass Welding with STT Power Supply
- ✓ **SAW** (Submerged Arc Welding) Solid Wire Electrodes with Flux for Double Ending for any grade of pipe, there are possibilities for both process and the consumable to be used. The table below gives various electrode choices for different strength pipes. These are for fill and cap pass-es. Lower strength electrodes commonly are used for root and hot passes.

  Consumables for High Strength Pipe the mechanical requirements

(1) The weld metal exceeds the specified minimum tensile strength of the pipe (with the root pass and cap pass reinforcement intact).
(2) The pipe material breaks first. Because the reinforcement is left intact, the weld metal does not necessarily need to be as strong as the pipe. A level of ductility in the weld metal is required to pass a guided bend test, but there are no explicit requirements for the tensile test.

Table 2: Pipe Grades

Strength Requirements for Pipe Grades

Pipe Grade	Minimum Yield Strength		Minimum Tensile Strength		Maximum Ultimate Tensile Strength	
	psi	MPa	psi	MPA	psi	MPa
X-42	42,000	289	60,000	413	—	—
X-46	46,000	317	63,000	434	—	—
X-52	52,000	358	66,000	455	—	—
X-56	56,000	386	71,000	489	—	—
X-60	60,000	413	75,000	517	—	—
X-65	65,000	448	77,000	530	—	—
X-70	70,000	482	82,000	565	—	—
X-80	80,000	551	90,000	620	120,000	827

3.2.Vertical up Welding

- **Pipe End Cleaning**

  Pipe may be covered with a variety of coatings, which include primers, epoxy, tar, paper, varnish, rust, scale, moisture or organic contaminants. Failure to recognize and properly clean these joints can contribute to rejected welds and costly repairs. Joint cleanliness is especially important in welding pipe.
  Follow these guidelines to minimize welding defects such as root pass hollow bead:
  - ✓ Moisture and condensation of any type must be removed prior to welding.
  - ✓ Clean both ends of the pipe on the inside and outside surfaces. The area to be cleaned should extend at least 1” (25mm) from the end of the bevel on both the inside and outside surfaces.
  - ✓ A recommended method for cleaning pipe is the use of a heavy duty straight shaft grinder with a rubber expanding wheel and a carbide coated sleeve. The small shaft and reduced overall weight allow easy access to both the inside and outside pipe surfaces. Pipe End Preparation with No Backup Ring the dimensional requirements for welding vertically up are shown below. A 1/8” (3.2mm) gap must be maintained accurately all the way around the joint. When no backup

ring is used a 1/8” Fleet weld 5P or5P+ are recommended for the root pass.

- **Pipe End Preparation with No Backup Ring** the dimensional requirements for welding vertically up are shown below. A 1/8” (3.2mm) gap must be maintained accurately all the way around the joint. When no backup ring is used a 1/8” Fleet weld 5P or5P+ are recommended for the root pass.

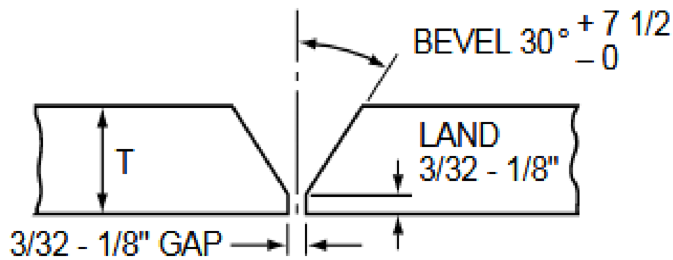

Figure 109: Backup Ring

- **Pipe End Preparation with Backup** Ring Alloy pipe is often welded vertically up using a low hydrogen electrode. When a low hydrogen electrode is used for the first pass aback up ring maybe used. With a backup ring, the pipe ends are made with a feather edge. The gap should be about the same as the diameter of the electrode with coating and must be consistent all the way around.

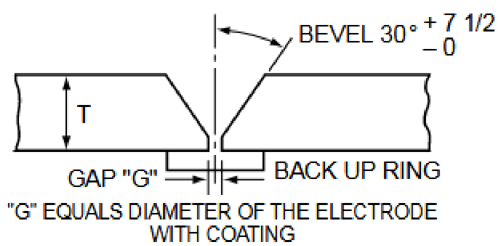

Figure 110: Backup Ring Alloy pipe

- **Features and Benefits**

  Conforms To AWS Code

  SoluShim SS-2-38-16 and SS-4-38-16 provide 1/8″ minimum gap for plate/pipe projects as required by AWS Code D1.6/D1.6M Stainless Steel Structural Code, eliminating need for measurement and guesswork.

  Experience Contaminant-Free Welding Made from EPA Approved Aquasol Water Soluble Composite Board100% biodegradable and environmentally friendly Compatible with any metal highly durable, incompressible, pre-sized and uniform in thickness Flexible structure can be manually shaped to form any angle with ease.

- **Consistent Pipe & Seam Installation** Maintains required root gap during plate and pipe welding applications Highly Incompressible Eliminates holding rod while simultaneously welding Eliminates root gap from shrinking with each tack weld Sticks stay firmly in place throughout welding process

- **Simple Spacer Removal**
  Is fast and effortless using a light application of water to moisten and dissolve sticks, achieving a contaminant free weld leaves behind no harmful trace elements that can lead to post-weld contamination Eliminates costly and timely post-weld grinding to remove metal spacers Spacer Installation & Removal

Figure 111: Different Pipe

When the pipe system designer has determined that the use of backing rings is unacceptable and that complete joint penetration, and a continuous root surface is needed, butt joints may be made from one side without backing using special groove designs and techniques described in this document. Although gas tungsten arc welding (GTAW) is commonly used for precise control in root pass welding, shielded metal arc welding (SMAW) and gas metal arc welding (GMAW) are also widely used to achieve complete joint penetration and an acceptable root surface.

- ✓ **Cleanliness**

  Cleanliness is important in all welding, and it is especially so in root pass welding. This includes groove faces and aminimum of 1 in. (25mm) from the groove on both inside and outside surfaces of the pipe. Grinding or other mechanical means should be used to remove all paint, scale, rust, and dirt. In addition, all parts of the joint should be free of grease and oil; these may be removed by use of a suitable solvent. A suitable solvent is one that does not leave a residue and is not harmful to the welder or the weldment. Most solvents require good ventilation, and many are flammable; therefore, proper precautions should be taken. Grinding and cleaning operations should be done just prior to welding. After cleaning, the pipe should be handled with clean gloves to preserve cleanliness.

- ✓ **Preparations for Purging**

  The highest quality root welds are obtained by using GTAW either with or without consumable inserts. A purge (displacement of air at the inside surface of the weldment with a suitable gas) is required for stainless and non-ferrous piping systems, except aluminum, if a smooth root surface is to be obtained. Carbon steels and most low alloy steels can be welded, using an open root groove, without the use of an internal gas purge.

  - ❖ **Purging Gases.** Welding grade argon is the gas most often used for internal purging. For some applications, nitrogen, carbon dioxide, helium, and mixtures of these gases are suitable purge gases. These gases can be used at lower cost than argon for specific applications, but they should be demonstrated as suitable by testing prior to use in production. The purity of purging gases is important and should be included in the welding procedure specification. Argon, helium, and nitrogen of better than 99% purity are available commercially and should be used. The moisture content should be controlled by specifying a dew point of-40°F(-40°C) maximum. The purging procedures described in this document are based on the use of argon as the purging gas. If nitrogen or helium is used, modifications to the purging procedure maybe necessary because both gases are less dense than air and argon.

  - ❖ **Purge Gas Containment**. Purging requires entrance and exit openings through which the purge gas can enter and leave the weld joint area at controlled rates. For piping where both ends can be capped, properly-sized wood or plastic disks can be taped to the pipe ends. Plastic caps that are used to prevent damage to pipe ends during shipment are commonly used as purge caps. The cap on the entrance side requires a hole to receive the purge gas. The other cap requires a hole large enough to prevent build-up of gas pressure. Since air is lighter than argon, the exit hole should be at a higher elevation to minimize the entrapment of air. Precautions should be taken to ensure that all leak paths are blocked and that branch.

3.3. Tack welding pipe

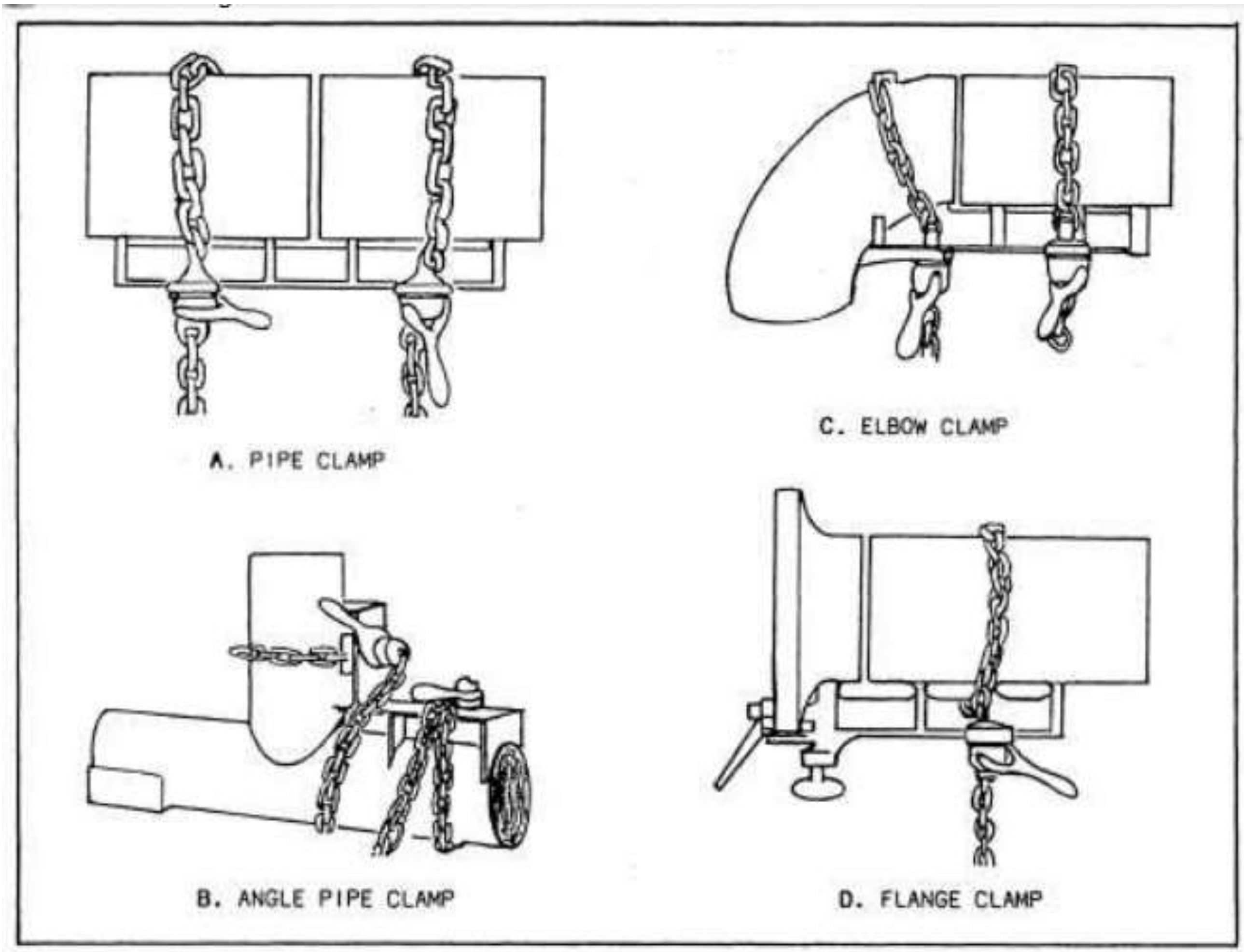

Figure 112: Tack welding pipe

Self-Check-3	Written test

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

Say true or false for the following questions below

1. Metal Inert Gas Welding is a form of arc welding which is great for mild steel.
2. Pipe welding applications Highly Incompressible Eliminates holding rod.
3. Cleanliness is important in all welding
4. The highest quality root welds are obtained by using GTAW.
5. Welding grade argon is the gas most often used for internal purging.

Note: **Satisfactory rating 3 and above points Unsatisfactory - below 2 points**

Score = ___________

Rating: ____________

Information sheet -4	Installing backing plate, stiffener, running plate

4.1. Definition Installing Backing Plate

Back strip support is a metal strip fixed by tack welding on the back side of the plates to be welded or inside the pipes to be welded covering the weld groove. This is required to achieve proper penetration of the weld metal and to ensure that the weld edges are welded properly and there is no undercut. Backing strip is generally required where the root gap is higher.

Backing strip is widely using as a back support for molder weld metal in order to achieve a good weld profile and bead. It is used to weld a grooved joint which as a groove opening from 1~6 mm. It helps the molten weld metal to remain within the lower grooves and to avoid causing excess groove penetrations and undercuts. This backing strips will be later removed in most of the cases and re weld the area after grinding or gouging.

There are different types of backing strips such as ceramic, metallic etc

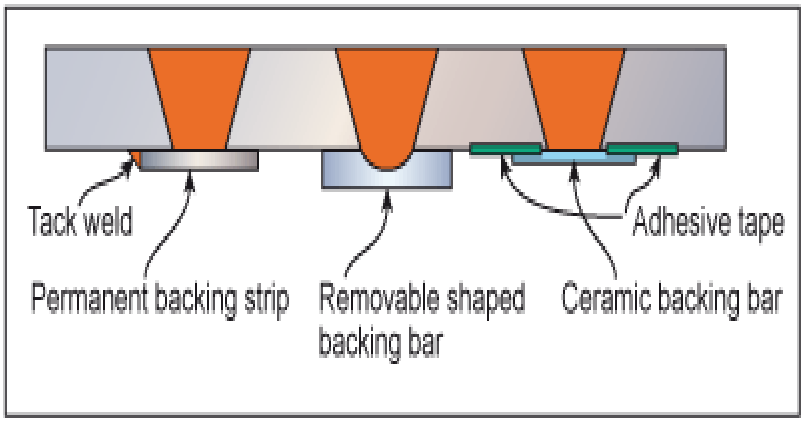

Figure 113: Tack Welding

The stiffness, k, of a body is a measure of the resistance offered by an elastic body to deformation. For an elastic body with a single degree of freedom (DOF) (for example, stretching or compression of a rod), the stiffness is defined as

- **Stiffeners**

It is defined as the property of a material which is rigid and difficult to bend. The example of stiffness is rubber band. If single rubber band is stretch by two fingers the stiffness is less and the flexibility is more. Similarly, if we use the set of rubber band and stretched it by two fingers, the stiffness will be more, rigid and flexibility is less

Stiffness is very important to be considered, since it measures the resistance to deformation. A stiffer material will stand load without big deformation. All materials are deformed under the action of applied load to some extent. For structures like trusses, one can use parts to increase its stiffness, these parts are called STIFFENERS.

Stiffening agents and fillers are applied to add weight, firmness and bulk to fabrics or binder chemicals to add strength and abrasion resistance by spot welding of adjacent fibers. Spot welding also gives some control over dimensional stability. Polymer dispersions are applied by padding, slop padding, foam, spray and knife coating. For example, micro-dispersed anionic polystyrene copolymer is applied to needle punched carpet fabrics as a stiffener. Self-crosslinking anionic acrylate polymers are applied to needle punched fabrics and other nonwovens to improve dimensional stability and wash resistance.

Glass fabrics and polyester spun bonds are sometimes finished with self-crosslinking anionic polystyrene acrylate dispersions and have excellent thermal resistance and dimensional stability. Thermoplastic binders are important in the manufacture of nonwoven fabrics intended for molding operations. Other binding chemical finishes include anti-dust finishes, which bind and depress dust in applications such as mats.

The stiffener welded with tack welds and side heating shows bowing and angular distortion in the stiffener and bending of the web plate. The amount of bowing distortion is at a maximum (5.2) at the stiffener midspan. As a result of heating, the web plate tends to expand. However, the tack welding does not allow this expansion. As a result, the web plate has bending distortion as well. Figure 6.11 shows the web plate bent out of plane near one end of the stiffener. The web plate is bent on the end of stiffener which was welded last. Table 6.3 lists the amount of bowing distortion in this case.

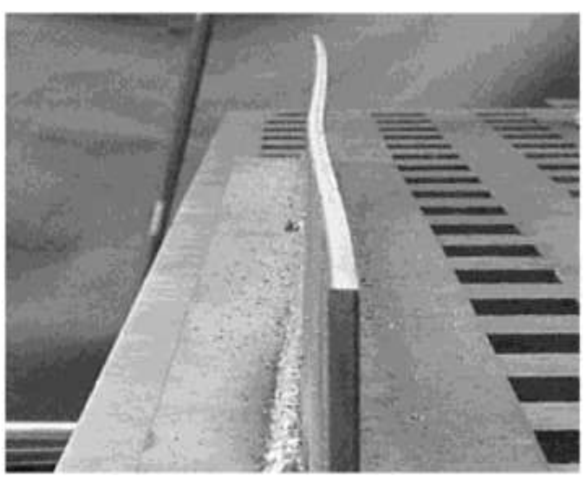

Figure 114: Stiffened and corrugated tubes

Stiffened tubes, in which external stiffeners is used with a circular tube, as shown in were considered as efficient energy absorbers [55]. Such tubes have enhanced energy absorbing properties such as EA and SEA, improved crushing stability and less sensitive to loading characteristics such as direction and uniformity [55]. Most of these improvements were achieved through the capability of externally stiffened tubes to develop an axisymmetric deformation mode during the axial collapse where the plastic deformation occurred in the regions between the stiffeners and the stiffeners worked as a stabilization tool for the whole structure.

(a) (b) (c)

Figure 115:(a) Externally stiffened tube [55], (b) laterally corrugated tube [56], and (c) corrugated tube

Similar to externally stiffened tubes, researchers also evaluated corrugated tubes as effective energy dissipating devices. Introducing corrugations in the axially loaded tubes forced the plastic deformation to take place at specific places along the length of the tube. This behavior enhanced the uniformity of the force-displacement response and allowed for predicting and controlling the collapse mode of the tubes [57]. Arameh et al. [56] conducted an experimental study into the EA performance of aluminum tubes with corrugations that were varied in geometries and directions. The authors observed that tubes with corrugations had better crashworthiness characteristics, uniform crush responses without high initial peak loads, and predictable collapse mode. They reported that corrugated tubes with their predictable EA performance can be considered as reliable energy absorbers.

- Several ways can be used to minimize distortion caused by shrinkage:

  - ✓ Do not over weld
  - ✓ Use intermittent welding
  - ✓ Use as few weld passes as possible
  - ✓ Place welds near the neutral axis
  - ✓ Balance welds around the neutral axis
  - ✓ Use back step welding
  - ✓ Anticipate the shrinkage forces
  - ✓ Plan the welding sequence

Self-Check-4	Written test

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

Say true or false for the following questions below

1. Back strip support is a metal strip fixed by tack welding on the back side of the plates to be welded.
2. Stiffeners is defined as the property of a material which is rigid and difficult to bend.
3. The stiffener welded with tack welds and side heating shows bowing and angular distortion in the stiffener and bending of the web plate.
4. Stiffened tubes, in which external stiffeners is used with a circular tube.

Note: **Satisfactory rating 3and above points Unsatisfactory - below 2 points**

Answer sheet

Score = ____________

Rating: _____________

Operation Sheet 4	Procedure to perform tack welding

Operation Title: Tack Welding

<u>The Steps</u>

Step 1. Square up the pieces of the frame and lightly tack-weld them together. Some clamps or weights will hold everything in place.
Step 2.Cut these pieces of ¾-inch with hacksaw but you can save some time by using an abrasive metal-cutting blade as the wheel in a chop saw.
Step 3. Weld just enough to join the parts together.
Step 4. Use a plasma cutter to trim part of the angle iron at the joints. You can achieve the same thing with a grinder or even a hacksaw
Step 5. Add the horizontal frame elements after you assemble the front and rear frames.
Step 6. Tack everything together, and check that it's all square before attempting full welds.
Step 7. Use both hands to hold the welding gun and brace at least one elbow against your torso.
Step 8. Check the assembly for squareness by measuring across diagonals. Use a few light hammer taps to correct to within 1/8 in. before you finish the weld.

LAP Test	Practical Demonstration

Name: ______________________________ Date: ________________

Time started: ________________________ Time finished: ________________

Instructions: Given necessary materials, tools and measuring instruments you are required to perform the following tasks within 1 hour.

Task1. Perform tack welding for the following project as shown bellow

Information Sheet-5	Cleaning joints from dirt particles

5.1 Definition of Cleaning

One of the first steps in making any sound field weld, regardless of type, will be to properly pre-clean the joint. One of the most desirable tools is a stiff wire brush

Figure 116: Cleaning Brush

All surfaces to be welded must be free from all paint, loose or thick scale, slag, rust, moisture, grease or other foreign material by Code. Mill scale that can withstand a vigorous wire brushing may remain. All finished welds are to be cleaned as well. Multiple pass welds should be cleaned between every pass. This is typically accomplished by using a stiff wire brush in conjunction with a chipping hammer. The chipping hammer removes slag and splatter. The grinder is also a very common and useful tool for cleaning. Grinders are to be used with care to avoid doing more harm than good to both finished welds and the base metal

Figure 117: Welding Cleaner

Slag is a by-product of welding. It typically adheres to the weld surface. Slag must be removed between passes and upon weld completion. A finished weld should have a clean appearance.

PRE-WELD & INTERPASS HEATING

Heating is an important part of welding. Preheating the joint helps remove any moisture. It also allows the joint to cool at a slower rate which will allow additional time for hydrogen to diffuse out of the molten weld metal. Preheating is the required practice of providing localized heat to the weld zone. The most common method is by use of a manual torch.

Figure 118: PRE-WELD

Required preheat is to be applied for a distance of 3" in all directions from the weld joint. Minimum preheat and inter pass temperatures are to be in accordance with

Table 3: Thickness welding component

	Thickness of Thickest Part at Point of Welding in inches (millimeters)			
Welding Process & Base Metal	To 3/4" (20 mm)	Over 3/4" (20 mm) to 1 ½ " (40 mm) Incl.	Over 1 ½" (40 mm) to 2 ½" (60 mm) Incl.	Over 2 ½" (60 mm)
SMAW A36, A572 (A709 - Gr. 36, 50, 50W)	50 deg. F (10 deg. C)	70 deg. F (20 deg. C)	150 deg. F (65 deg. C)	225 deg. F (110 deg. C)

In accordance with Standard Specification 724.03(a), No welding is to be allowed when the ambient air temperature around the weld joint is lower than 20 deg. F (-6 deg. C), when surfaces are wet or exposed to rain, snow, harmful wind or when operators are exposed to inclement conditions that will hamper good workmanship.

Before you do anything else, remove any oil, grease, or water vapour from the surface. Some people try to do this with a wire brush, but this practice is wrong because a wire brush won't remove these materialist only spreads them around and creates small scratches and other nooks and crannies on the surface that hold oil and grease, making them impossible to remove later. Never wire-brush first. Always remove oil, grease, and other contaminants first.

So how do you remove such contaminants? Two classes of liquids make effective degreasers: organic solvents such as acetone and mild alkaline solutions such as strong soaps.

The most common method for checking preheats is by using a temperature crayon. Using temperature crayons becomes more essential when welding thicker members.

Figure 119:Pre-Heating Agent

Typically, temperature crayons will be labeled for a specific temperature. If the weld joint has reached the label temperature, the temperature crayon will melt when rubbed across the base metal.

Alcohol isn't a good degreaser and shouldn't be used to clean aluminum. In the past vapor degreasers often were used to clean aluminum, but they emit volatile compounds into the air. Most of them have been prohibited over the years for environmental reasons. For the same reason, many shops have stopped using many organic solvents. Because of that, the question sometimes changes from "What solvent should I use?" to "What solvent *can* I use?" The choice of degreasing solvent often can vary from facility to facility. Acetone, methyl ethyl ketone, lacquers thinner, and toluene all make good solvents.

Once you choose a solvent, wipe the parts to be welded with a clean, lint-free rag dipped in the solvent. The solvent will evaporate rapidly from the part. Make sure the solvent has evaporated completely before fitting the parts together, and never pour solvent into a weld joint that already is fit together. Allowing a welding arc to impinge on any of these solvents can release poisonous gases.

To summarize, take the following steps before welding aluminum:

- ✓ Remove oil, grease, and water vapor using a solvent or mild alkaline.
- ✓ Remove surface oxides with a wire brush or strong alkaline or acid.
- ✓ Assemble the joint. If it won't be welded immediately, cover the joint with brown Kraft paper to prevent dirt and grit in the air from getting into the joint.
- ✓ Keep the joint dry.
- ✓ Weld within a few days. Clean the joint again if it isn't welded within that time.

Figure 120: work Shop

Self-Check – 5	Written Test

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

I. say true or false for the following question below

1. One of the first steps in making any sound field weld, regardless of type, will be to properly pre-clean the joint.
2. Preheating the joint helps to remove any moisture.
3. The most common method for checking preheats is by using a temperature crayon.

Note: **Satisfactory rating - 2 points** **Unsatisfactory - below 1 point**

Answer Sheet

Score = ____________

Rating: _____________

Reference

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Solar PV System Installation and Maintenance

Level-II

Learning Guide -23

Unit of Competence	**Perform Simple Welding**
Module Title	**Performing Simple Welding**
LG Code	EIS PIM2 M04 LO5 LG-23
TTLM Code	EIS PIM2 TTLM 0120V1

LO5: Check gap and alignment

Instruction Sheet	Learning Guide: - 23

This learning guide is developed to provide you the necessary information, knowledge, skills and attitude regarding the following content coverage and topics:-

- Performing root gap
- Accepting alignment within the range of code and standard.
- Fitting materials visually free from stresses

This guide will also assist you to attain the learning outcome stated in the cover page. Specifically, upon completion of this Learning Guide, you will be able to:-

- Perform root gap
- Accept alignment within the range of code and standard.
- Fit materials visually free from stresses

Learning Instructions:-

1. Read the specific objectives of this Learning Guide.
2. Follow the instructions described below 3 to 6.
3. Read the information written in the information Sheet 1, Sheet 2 and Sheet 3, in pages 162,166 and 170 respectively.
4. Accomplish the Self-check 1, Self-check2 and Self-check3, in pages 165,169 and 173 respectively

Information Sheet-1	Performing root gap

1.1. Introduction to root gap

Acceptable tolerances for alignment should be specified in a yard or workshop standard. This in turn should reflect a recognized industry standard, for example as given by the classification societies or IACS guideline number 47, “Shipbuilding and Repair Quality Standard”.

A root gap is provided to facilitate the escape of gases generating during the process to avoid defects of blow holes in welding. Also, the narrow opening at the bottom of the mating plates ensures the full penetration of the arc and profiled **root** bead penetration, which indicates a sound welding joint

In general the gap has to be large enough to ensure proper side wall fusion through the entire member thickness. The gap shall however not be larger than necessary to avoid excess use of filler material from an economical point of view as well as possible problems with distortion of members and residual stress in the weld. Figure1 shows a fit-up where the gap is too large. The proper way to handle this would be to release enough of the completed weld so that the elements can be adjusted and the gap reduced, or if this is not possible use an insert piece.

Figure 121: large gap

Edges of members are to be parallel and with a specified gap which is important for the later straightness and overall tolerances of the construction. In general plate edges shall be as parallel as possible and distance “d2-d1” shown in Figure2 shall be as small as possible.

Figure 122: alignment of member edges

Importance of root gap when joining parts during welding

To ensure adequate full joint penetration, without a gap you would need to tack on a backing bar, which takes forever as far as prep before the weld, and cleanup after the weld (including cutting the backing bar off with a torch)

The purpose of say a beveled V groove with a 1/8th gap and a 1/8th landing is a very efficient setup for ensuring FJP (full joint penetration) as the closest sides of the gap are also the thinnest so as you weave cross the gap filler metal will drop into the gap and along the landings, this is called your root pass, all it takes is a visual inspection of the other side of the groove to determine whether or not FJP was achieved. Another thing about welding rods, consumable inserts, and filler metals is depending on the rod the weld materials will always a higher tensile strength than the two pieces it is joining together. Like 7018 rods are rated at 70,000 lbs of tensile strength. More than the carbon steel your joining this ensures that should there be another failure, it will not be because of inadequate weldment strength. excessive root gap by welding is neither advisable nor permitted in the codes. Following are the remedies:

- ✓ If dismantling the joint and closing the gap to permissible limit (Grinding zero gap area) is feasible, it is the best alternative. But sometimes excess gap is only local and maintenance of dimensions does not permit grinding rest of portion to close the gap. Dismantling the joint is sometimes expensive as well. Under the situation follow one of the two options given below.

- ✓ Misalign the thickness temporarily by wedging in the excess gap area. Thus one of the two mating surfaces becomes accessible for work. Deposit welds metal on this edge (build up) slowly allowing cooling in between. After sufficient metal is deposited to cover excess gap, grind and re-prepare the edge, realign by removing the wedge, tack and proceed with normal welding.
- ✓ If permissible, you can use ceramic or copper backing in the excess gap area and start building up one of the two edges to reduce the gap. After sufficient build up prepare the edges and continue with normal welding.

Self-Check -1	Written Test

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

Say true or false for the following questions

1. Acceptable tolerances for alignment should be specified in a yard or workshop standard
2. Misalign the thickness temporarily by wedging in the excess gap area
3. the gap has to be large enough to ensure proper side wall fusion through the entire member thickness

Note: **Satisfactory rating - 2points** **Unsatisfactory - below 1points**

Answer Sheet

Score = ____________

Rating: _____________

Information Sheet-2	Accepting alignment within the range of code and standard.

2.1. Introduction of code and standard. In alignment

- Joint design and setup affect the safety and quality of completed weldment.
- Because joint design and setup are so important, they are covered by written codes and specifications that must be followed.
- Special tools to measure and aid fit-up are also available

2.2. Job Code Specifications

- Whenever a bridge, building, ship or pressure vessel is welded, the manufacturer and the buyer must reach agreement on how each weld will be made.
- To eliminate the need to write a new code for each job, government agencies, societies, and associations have developed codes.
- These codes are used universally to ensure safety and quality when welds are made.

2.3. **Governing Codes and Standards**

- A welding code or standard is a detailed listing of the rules and principles that apply to specific welded products.
- Codes ensure that safe and reliable welded products will be produced and that persons associated with the welding operation will be safe.
- In addition, when codes are specified, the use of these codes is mandated with the force of law by one or more government jurisdictions.
- Here are some of the more common codes and standards:
- *API 1104-Standards for Welding of Pipeline and Related Facilities*- used for pipelines
- *ASME Boiler and Pressure Vessel Code* – American Society of Mechanical Engineers
- *ASME B31.1, Power Piping* – used for pressure piping
- *AWS D1.1 – Structural Welding Code – Steel*

2.4. Code Changes

- Codes are periodically reviewed and updated.
- Addendum sheets (new pages) for the areas of the code affected by the changes are issued.
- The ASME issues yearly addendums.
- The yearly addendum is identified by placing the letter A in front of the year on the cover of the code.

2.5. Accepting alignment within the range of code and standard

Alignment of members before welding is very important for the quality of the weld and for the stress concentrations in and around the welding. For distributing the stresses in a structure the most efficient way, the path of the stress shall be as smooth as possible. Abrupt changes in sectional properties will lead to stress concentrations and subsequently possible cracks depending on the actual loading of the joint. In general distance “dt” given on Figure 4.1-9 and Figure 4.1-10 shall be as small as possible and for highly stresses areas “dt” shall be close to zero.

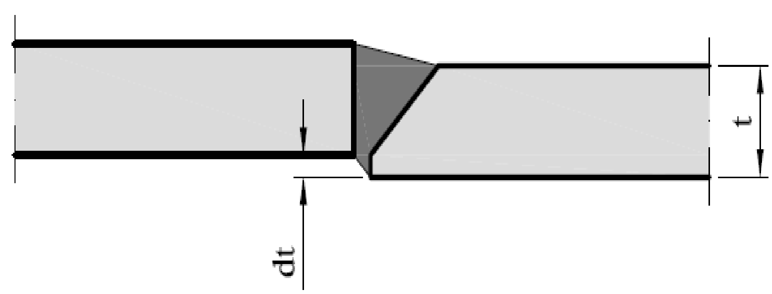

Figure 123: Alignment of Members at Butt Joint

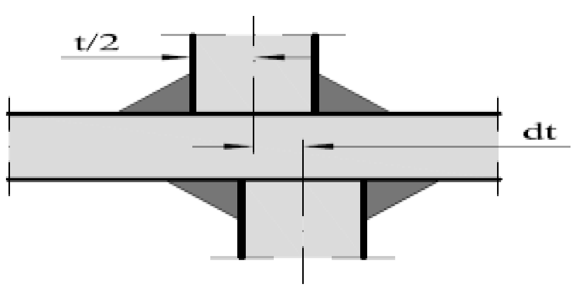

Figure 124: Alignment of Members at Cruciform Joint

In addition to the gap and linear alignment as described above, angular alignment must be checked. Angular misalignment is when there is misalignment between two welded pieces such that their surface planes are not parallel with each other or at the intended angle. It is often caused by inaccuracies in the assembly procedures or distortion from other welds.
Angular misalignment can also be caused by local deformation of the edge of a plate if it is not properly supported or has been distorted by heating due to welding.
Gap and alignment of plates shall be secured by fixation of the members to be welded. Use of tab pieces for this purpose is described later in this section.

Two examples of poor alignment are shown in Figure 4.1-11 and Figure 4.1-12. Figure 4.1-11 shows a misalignment of a butt joint also shown in Figure 4.1-9. The actual misalignment was measured to 8 mm compared to 3 mm allowed misalignment. Figure 4.1-12 shows misalignment of a butt joint of the welded flange of a stiffener.

Figure 125: Poor Butt Joint Alignment and Poor Alignment of Stiffener Flange

Self-Check -2	Written Test

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

Say true or false for the following questions

1. A welding code or standard is a detailed listing of the rules and principles that apply to specific welded products
2. Alignment of members before welding is very important for the quality of the weld and for the stress
3. Joint design and setup affect the safety and quality of completed welding task

Note: **Satisfactory rating - 2 points** **Unsatisfactory - below 1.5 points**

Answer Sheet

Score = ___________

Rating: ____________

Information Sheet-3	Fitting materials visually free from stresses

3.1. Introduction to Fitting Materials

When proper edge preparation, beveling, gap and alignment is in place, it is essential that the members up for welding are fixed to secure proper quality and strength of the weld, smooth transfer of stresses from member to member and straightness and tolerances of the finished structure.

Fit-up of smaller structures to ensure acceptable gap and alignment can be done by clamps whereas larger structures are normally fit-up using welded strong backs (see Figure 3.1) and wedges (see Figure 3.2) or hydraulic jacks

Figure 126: Fit-up with Welded Strong back and Wedges

Fit-up can also be designed to take account the deformations the welding will impose on the connection of members due to the shrinkage of the filler material when cooling off. Figure 126 show an example of such a fit-up. The example of the sandwich deck construction shown in Figure 126 did not allow such an angled fit up, which could have reduced residual stresses considerably. For the case only one-sided welding was possible.

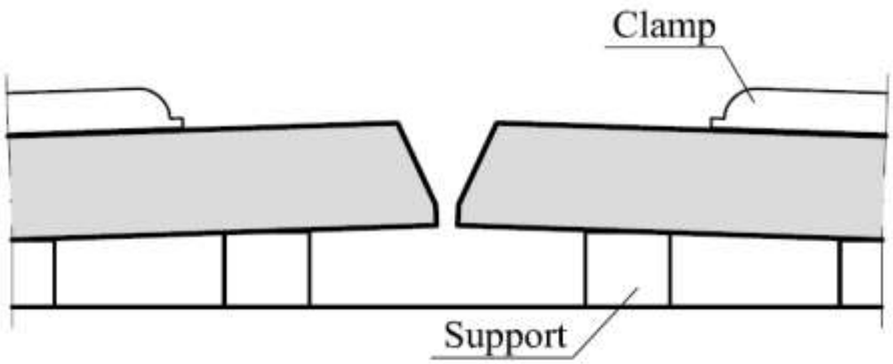

Figure 127: Fit-Up of Butt Joint in Angle

Tab pieces are fitted to ensure a good “end” of the weld. As ends of welds are often prone to have defects tab pieces at the ends of the weld are introduces to extend the welding. As a rule of thumb a tab piece should extend as far out from the plate or stiffener as the thickness of the plate or stiffener. After welding of the member the tab piece is removed and the area properly cleaned and ground.

In Figure 3.4 and Figure 3.5 the correct use of tab pieces is shown. The tab pieces have an adequate length and the shape of the tab piece matches the beveling of the members.

In Figure 3.6 and Figure 3.7 the incorrect use of tab pieces is shown. In Figure 3.6 the tab piece is missing and in Figure 3.7 the weld is not extended sufficiently over the tab piece.

Figure 128: Correct Use of Tab Piece

Figure 129 Missing Tab Piece

Self-Check -3	Written Test

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

Say true or false for the following questions

1. Tab pieces are fitted to ensure a good "end" of the weld.
2. Fit-up of smaller structures to ensure acceptable gap.
3. The tab pieces have an adequate length and the shape.

Note: **Satisfactory rating - 2 points** **Unsatisfactory - below 1 point**

Answer Sheet

Score = ____________

Rating: _____________

Reference

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Solar PV System Installation and Maintenance

Level-II

Learning Guide -24

Unit of Competence	**Perform Simple Welding**
Module Title	**Performing Simple Welding**
LG Code	EIS PIM2 M04 LO6 LG-24
TTLM Code	EIS PIM2 TTLM 0120V1

LO6: Weld to job specification

Instruction Sheet	Learning Guide: - 24

This learning guide is developed to provide you the necessary information, knowledge, skills and attitude regarding the following content coverage and topics:-

- Performing root pass
- Cleaning root pass with procedures
- Performing subsequent filling procedures
- Capping with specifications and procedures
- Ensuring Weld deposit within specifications
- Welding materials using SMAW process
- Cleaning joints from discontinuities
- Cleaning welds using appropriate tools and techniques
- Avoiding weld defects or porosity

This guide will also assist you to attain the learning outcome stated in the cover page. Specifically, upon completion of this Learning Guide, you will be able to:-

- Perform root pass
- Clean root pass with procedures
- Perform subsequent filling procedures
- Cap with specifications and procedures
- Ensure Weld deposit within specifications
- Weld materials using SMAW process
- Clean joints from discontinuities
- Clean welds using appropriate tools and techniques
- Avoid weld defects or porosity

Learning Instructions:-

1. Read the specific objectives of this Learning Guide.
2. Follow the instructions described below 3 to 6.
3. Read the information written in the information Sheet 1, Sheet 2, Sheet 3, Sheet 4, Sheet 5, Sheet 6, Sheet 7, Sheet 8 and Sheet 9 in pages 177, 182, 188, 194, 199, 206, 221, 224 and 229 respectively.
4. Accomplish the Self-check 1, Self-check 2, Self-check 3, Self-check 4, 5, Self-check, 6, Self-check , 7, Self-check , 8, Self-check and 9, Self-check in pages 179, 181, 193, 198, 205,218,223,228 and 246 respectively
5. If you earned a satisfactory evaluation from the “Self-check” proceed to Operation on page 180 and 219
6. Do the “LAP test” on page 181 and 220

Information -1	Performing root pass

1.1. Definition of Root Pass

Root pass simply refers to the 1st pass in any weld process, which makes the two members being welded, one structure. Subsequent passes increase the weld depth to the desired thickness, yielding the necessary strength

A method for root pass welding steel plate and pipe is provided that uses pulse arc welding having a current pulse waveform exhibiting a low constant background current and fixed frequency.The welding process may be performed without a backer or backing material.

- **We claim:**

- ✓ A method for pulse arc welding a root pass of a butt weld joint, comprising providing first and second joint members with first and second facing edges tapered to form an included angle; positioning the first and second facing edges to define a channel; moving only a single electrode within the channel; applying current that passes between the single electrode and the first and second facing edges to form a complete root pass between the first and second facing edges from a single side of the first and second joint members, the root pass forming a weld bead along a bottom surface opposite the first and second facing edges, and being formed exclusively by the single electrode and between the first and second facing edges without a weld bead supporting medium; said current having a waveform comprising a constant background current level and fixed frequency current pulses, wherein a stable background current level is about 5 amps to about 40 amps, and the waveform is configured to produce a stable focused arc that penetrates a root pass area of the first and second facing edges.
- ✓ The method of claim 1 wherein the joint comprises a plate or pipe joint and is formed between edges that are in the range of about one-eighth inch thick to about two inches thick or greater.
- ✓ The method of claim 1 wherein each of the first and second facing edges is tapered to a knife edge.
- ✓ The method of claim 1 wherein the root pass is welded using a GMAW-Pulse process in a generally horizontal position.
- ✓ The method of claim 1 wherein the single electrode has a diameter in the range of about 0.02 inch to about 0.07 inch.
- ✓ The method of claim 1 comprising the step of performing a fill welding process after the root pass weld is formed wherein the fill welding process is performed using a submerged arc welding process, GMAW fill welding process or flux core fill welding process.
- ✓ The method of claim 6 wherein said fill welding process is performed during but delayed from the root pass welding process.
- ✓ The method of claim 1 wherein each of the first and second facing edges comprises a land.

- ✓ The method of claim 1 wherein front ends of the first and second facing edges are separated by a gap of up to about ⅛ inch prior to welding.
- ✓ The method of claim 1 wherein the first and second facing edges are in contact with each other prior to welding.
- ✓ The method of claim 1 wherein the frequency of the fixed frequency-current pulses is in the range of about 60 Hz to about 300 Hz.
- ✓ The method of claim 1 wherein the first and second facing edges are tapered to an included angle of about 3 degrees to about 80 degrees.
- ✓ The method of claim 1 wherein the welding process is performed with moving the electrode at a travel speed in the general range of about 5 inches per minute to about 25 inches per minute.
- ✓ The method of claim 1 wherein the welding process is performed with a wire feed speed in the general range of about 300 inches per minute to about 600 inches per minute for a 0.045 inch electrode wire.
- ✓ The method of claim 1 wherein the electrode is oriented at a push angle of about 0 degrees to about 40 degrees.
- ✓ The method of claim 1 wherein the welding process is performed at a stick out distance of about ⅜ inch to about 1½ inches.
- ✓ The method of claim 1 wherein said current comprises an average value DC voltage in the range of about 16 volts DC to about 25 volts DC.
- ✓ A method for pulse arc welding a root pass of a butt weld joint, comprising:
- ✓ providing first and second joint members with first and second facing edges tapered to form an included angle;
- ✓ positioning the first and second facing edges to define a channel;
- ✓ moving only a single electrode within the channel;
- ✓ applying current that passes between the single electrode and the first and second facing edges to form a complete root pass between the first and second facing edges from a single side of the first and second joint members, the root pass forming a weld bead along a bottom surface opposite the first and second facing edges, and being formed exclusively by the single electrode and between the first and second facing edges without a weld bead supporting medium; said current having a waveform comprising a constant background current level and fixed frequency current pulses, wherein said waveform is configured to produce an arc voltage within a range of about 16 VDC to about 25 VDC, to produce a stable focused arc that penetrates a root pass area of the first and second facing edges.
- ✓ The method of claim 18 wherein the root passes is welded using a GMAW-Pulse process in a generally horizontal position.
- ✓ The method of claim 18 wherein the welding process is performed with moving the electrode at a travel speed in the general range of about 5 inches per minute to about 25 inches per minute.

Self-Check -1	Written Test

Directions: Answer all the questions listed below.

I. Say true and false for the following question below

1. Pulse arc welding a root pass of a butt weld joint, comprising providing first and second joint members with first and second facing edges tapered to form an included angle.
2. Root pass welding steel plate and pipe is provided that uses pulse arc welding having a Voltage pulse waveform exhibiting a low constant background current and fixed frequency.

***Note:* Satisfactory rating - 2 points** **Unsatisfactory - below 1 point**

Answer Sheet

Score = ___________

Rating: ____________

Name: _________________________ Date: _______________

Operation Sheet-1	Clean root pass

Operation Title: Procedure to clean root pass

Step 1. Using the angle grinder, clean root pass free from slag.

Step 2. Clean all trapped slag and porosity

Step 3. Redefine the groove face to serve as outline your filling pass

Step 4. Repair porosity or pinholes

Step 5. Clean root pass until shines

LAP Test	Practical Demonstration

Name: ______________________________ Date: ________________

Time started: ________________________ Time finished: ________________

Instructions: Given necessary materials, tools and measuring instruments you are required to perform the following tasks within 1 hour.

Task1. Perform cleaning of root pass

Information -2	Cleaning root pass with procedures

1.1. Definition Cleaning Procedure

Weld Metal Cleaning Slag or flux remaining after a pass shall be removed before applying the next covering pass. After the final pass all slag and weld spatter shall be removed. Arc strikes shall be removed by grinding or other suitable means. Cracks or blemishes caused by arc strike shall be ground to a smooth contour and examined visually to assure complete removal.

2.2. Treatment of Underside of Groove Prior to depositing weld metal on the underside of a welding groove, the root shall be gouged to sound metal unless otherwise specified on an applicable Welding Procedure Data Sheet, accepted by the Canadian Welding Bureau.

2.3. Root pass treatment

When welding double-sided joints, ensure that grinding is done to remove the root pass from the first side to sound metals before welding the first pass on the second side

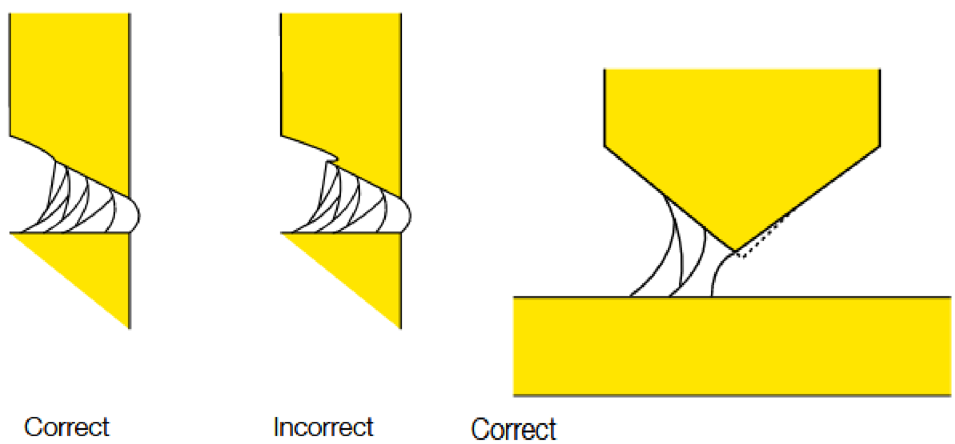
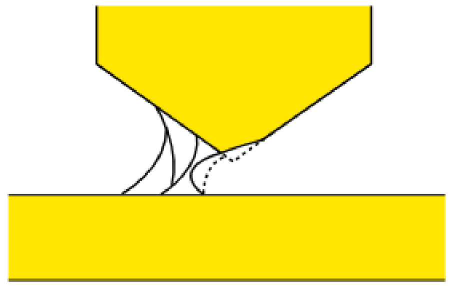


Figure 130: Root pass Treatment



Incorrect.
Grinding wheel pushed into root, resulting in a deep groove. The narrow joint is almost inaccessible to the torch.

2.4. Inter pass cleaning

Following the root pass, it is necessary to grind the weld to ensure proper penetration for the next pass or hot pass. This can be done using a 1/8-inch grinding wheel along the root pass, which helps create a flat or u-shape in the bottom of the weld.
With subsequent welds laid down after the hot pass, use a wire brush to clean away any imperfections or slag. This prepares the metal for each weld layer. A narrow-faced wire wheel works well for this. If the v-groove of the weld joint is wider, such as filler passes with larger-diameter pipes, choose a brush with a wider face that is designed to clean larger areas.

When two welders work on opposite sides of the pipe on larger-diameter pipes, the starting and stopping points for each welder are typically at the 12 o'clock and 6 o'clock positions. The point where the welds join and overlap is called the button. While this area can be more difficult to clean, avoid banging the wire wheel on the button, as this will damage the wires. Use normal pressure and allow the brush more dwell time to clean this area.

The same wire wheel used for inter pass cleaning can also be used to clean the weld and remove any slag from the cap pass. Some wire wheels use a dual-hex nut design that simplifies periodic flipping of the wheel to help promote the self-sharpening ability of the wire tips. Choosing a wheel with this design helps deliver maximum cleaning action, long life and safer use.

An encapsulated stringer bead wheel is another option for cleaning between weld passes. Only the wire tips are exposed from the encapsulation. These brushes offer several advantages, including longer product life and aggressive cleaning action. And because there are no long wires outside of the encapsulation, long wire breakage is eliminated. Be aware that the operator has less flexibility with an encapsulated wire brush because of the short trim length of the wires. When choosing this option, look for an encapsulated wheel that uses a heat-stabilized encapsulation that gradually wears away to expose a consistent short trim. This makes it suitable for cleaning hot welds without overheating.

2.5. Prepping pipe for welding

The first step is to prepare the bevel. Pipe is generally delivered to the jobsite with a bevel already created. However, it will require cleaning and shoring up the land, which is the flat portion at the end of the bevel, using a grinding wheel. This flat area allows for proper spacing between the two pipe ends so they can be aligned and tacked together for welding.
A notching wheel or 1/4-inch grinding wheel work well for this task. When using a grinding wheel, don't dwell too long in any one spot, as this can gouge the material. Instead, keep the wheel in motion and travel the circumference around the land, while keeping the wheel as flat as possible.
Once the land has been created, the bevel and interior diameter of the pipe opening should be cleaned for welding. The right tool for cleaning the bevel depends on how much rust is on the pipe. Operator preference also plays a role. The most common way to clean a bevel is with a wire wheel, but it depends on the condition of the pipe.

- **Cleaning the pipe**

  Base material condition can vary greatly when pipes arrive on the jobsite. There is typically some rust on the pipe how much depends on the length of time since manufacturing and the pipe storage conditions. The more time that passes between manufacturing of the pipe and preparing it for welding, the greater the chances more rust has accumulated. If the pipe has only light surface rust, it requires a different conditioning product than if it has heavier rust.

- **Wire brushes and wheels:** Light surface rust can typically be removed with a hand wire brush or wheel. Wire brushes efficiently remove loose material on the surface of the pipe without changing the base metal. Product options in this category include hand wire brushes for small-diameter pipe or power wire wheels, such as a stringer bead wheels, and wire cup brushes for larger-diameter pipe and faster cleaning.

  Wire wheels can be used to clean the pipe surface prior to welding and for cleaning the welds between passes. Cup brushes tend to clean more surface area and often clean faster, but they also tend to create a kickback if the cup hits the wrong part of the pipe. Both products clean effectively. While the choice often comes down to operator preference, wire wheel brushes are most commonly used.

  Note, wire products also work well to remove any burrs that may have formed while creating the land. Because wire wheels and brushes are designed to let the wire tips do the work, it's important to orient the tool so only the wire tips hit the work surface. This promotes the most effective cleaning action, reducing the urge for the operator to push harder. It also helps extend product life and reduce the risk of wire breakage. With a wire brush, apply light pressure just slightly more than the weight of the grinder to let the wire tips do the work.

- **Flap discs:** If the base material has more than light surface rust perhaps even pits in the steel it requires a more aggressive product to clean the metal. The bevel must always be completely cleaned and any rust or pits removed from the material. Flap discs are a good option in this situation especially a 60-grit flap disc to efficiently grind out any rust, pits and imperfections on the pipe, while also minimizing the potential for gouging that can occur with a grinding wheel. Flap discs are available in many different material types. A disc with an aluminum backing is more rigid, which is ideal for maintaining the edge of the bevel without rounding the material. Rounding the edges of the bevel during cleaning can be detrimental to properly filling the weld.

Self-Check -2	Written Test

Directions: Answer all the questions listed below.

I. Say true and false for the following question below

1. Weld Metal Cleaning Slag or flux remaining after a pass shall be removed before applying the next covering pass.
2. Flap discs: If the base material has more than light surface rust perhaps even pits in the steel it requires a more aggressive product to clean the metal.
3. Wire brushes and wheels light surface rust can typically be removed with a hand grinding machine.
4. Inter pass cleaning the root pass, it is necessary to grind the weld to ensure proper penetration for the next pass or hot pass.
5. Root pass treatment when welding double-sided joints, ensure that grinding is done to remove the root pass.

Note: **Satisfactory rating - 3 points** **Unsatisfactory - below 2.5 points**

Answer Sheet

Score = ___________

Rating: ____________

Name: ___________________________ Date: ________________

Information Sheet -3	Performing subsequent filling procedures

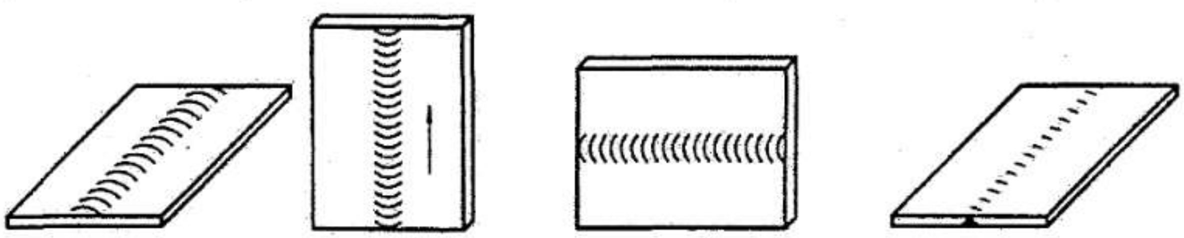
3.1. Primary purpose for procedure qualification

- To verify compatibility of materials and techniques to result in a sound weld with acceptable mechanical properties
  - ✓ WPS qualified by mechanical testing
  - ✓ PQR is documentation to prove that a weld can be made using the procedure and have acceptable mechanical properties

PRELIMINARY WELDING PROCEDURE

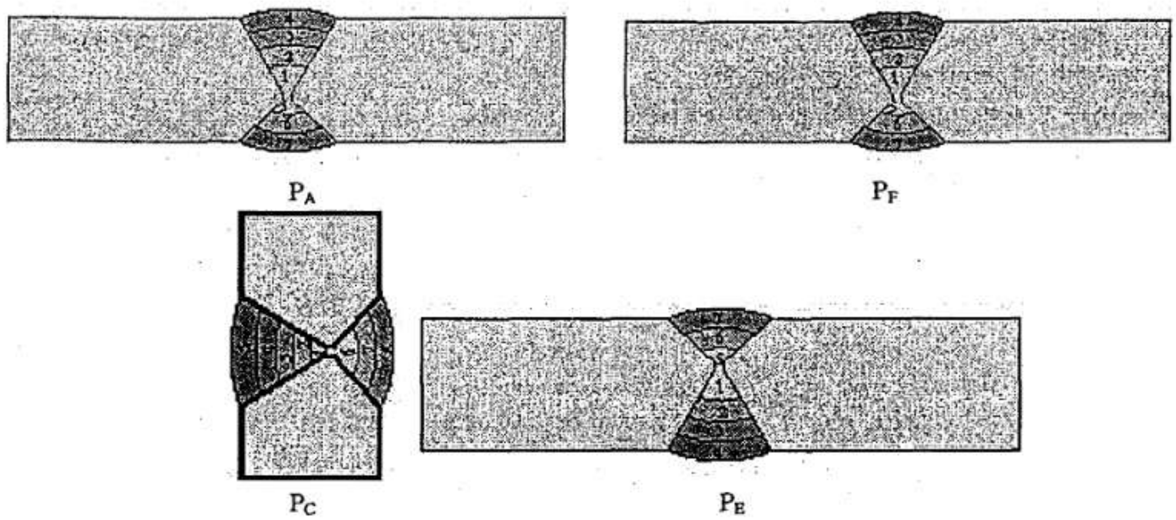
- ✓ The preliminary welding procedure specification was prepared in accordance with EN 288-2. It specs tolerance range for all the relevant parameters. The base material are plates with thickness 30 mm, made of St 52-3N steel. This steel belongs to first group of steels, according to EN 288 as can be seen below: Steels with minimum yield strength Reh < 360 N/mm2 and with analysis not exceeding, in %:

C =	0,24 (0,25 for castings)
Si =	0,60
Mn =	1,70
Mo =	0,70
S =	0,045
P =	0,045
Any other single element =	0,3 (0,4 for castings)
All elements total =	0,8 (1,0 for castings)



Welding positions for different specimens (Butt welds)

Figure 131: Welding Position for different Specimens



Numbers of runs and order of Filling out the Groove for different Welding Position

Figure 132: Runs and Filling Welding Position

Table 4: Filling out the groove Welding position

Numbers of runs and order of Filling out the groove for PA Welding Position

Run	Process	Electrode diameter	Current [A]	Voltage [V]	Type of current / polarity	Travel speed [mm/min]
1	Traveling	EVB50 ϕ 3.2	110 - 120	19-20	DC/inverted polarity	100 - 105
2	Traveling	EVB50 ϕ 4	180 - 190	22-23	DC/inverted polarity	105 - 110
3	Traveling	EVB50 ϕ 5	230 - 240	23-24	DC/inverted polarity	90 - 95
4	Traveling	EVB50 ϕ 5	230 - 240	23-24	DC/inverted polarity	95 - 100
5	Traveling	EVB50 ϕ 4	180 - 190	22-23	DC/inverted polarity	105 - 110
6	Traveling	EVB50 ϕ 4	180 - 190	22-23	DC/inverted polarity	105 - 110
7	Traveling	EVB50 ϕ 4	180 - 190	22-23	DC/inverted polarity	120 - 125

- **Weld Procedure Qualification**

  Understand the intended application for which the WPS will be used

  Things to know prior to qualifying a welding procedure

  - Know the application for the welding procedure
  - ❖ What welding process(es) are going to be used during construction
  - ❖ What materials are going to be used during construction
  - The types and grades
  - The thicknesses of each material
  - Are there dissimilar welds including welds between different P-No.
- Know the design requirements for the application

- Does the design require specific material toughness requirements?

Table 5: Procedure Qualification

Procedure Qualification – Filler Metal Variables

Paragraph		Brief of Variables	Essential	Supplementary Essential	Nonessential
QW-404 Filler Metals	.12	φ Classification		X	
	.14	± Filler	X		
	.33	φ Classification			X
	.50	± Flux			X

- Qualified welding procedures are based on the PQR
  - ✓ The number of welding procedures
  - ✓ The range of variables

Table 6: Filler metal Variables

Procedure Qualification – Filler Metal Variables

Filler Metals (QW-404)	
SFA Specification:	SFA 5.28 for GTAW SFA 5.18 for GMAW
AWS Classification:	ER80S-D2 for GTAW ER70S-6 for GMAW
Filler Metal F-No.	6 for GTAW and GMAW
Weld Metal Analysis A-No.:	11 for GTAW 1 for GMAW
Size of Filler Metal	1/8-in. for GTAW 0.035-in. for GMAW
Weld Metal Thickness:	1/4-in. for GTAW 1/2-in. for GMAW
Other:	

Table 7: Procedure qualification Test

Procedure Qualification – Testing

Tensile Test (QW-150)						
Specimen No.	Width	Thickness	Area	Ultimate Load, lb	Ultimate Stress, psi	Type of Failure and Location
Tensile 1						
Tensile 2						

- The tensile strength must exceed 58 ksi

Guided-Bend Test (QW-160)	
Type	Results
Side Bend 1	
Side Bend 2	
Side Bend 3	
Side Bend 4	

- No open weld or HAZ discontinuity greater than 1/8-in.

Self-Check -3	Written Test

Directions: Answer all the questions listed below.

I. Choose the best answer

1. Qualified welding procedures are based on the PQR
   - A. The number of welding procedures
   - B. The range of variables
   - C. Both
2. Know the application for the welding procedure
   - A. What welding process are going to be used during construction
   - B. What materials are going to be used during construction
   - C. The types and grades
   - D. The thicknesses of each material
   - E. All F. None
3. To verify compatibility of materials and techniques to result in a sound weld with acceptable mechanical properties
   - A. WPS qualified by mechanical testing
   - B. PQR is documentation to prove that a weld can be made using the procedure and have acceptable mechanical properties
   - C. The thicknesses of each material
   - D. A & B

Note: **Satisfactory rating - 2 points** **Unsatisfactory - below 1.5 point**

Answer Sheet

Score = ____________

Rating: _____________

Name: ____________________________ Date: ________________

Information -4	Capping with specifications and procedures

4.1. Definition of welding procedure specification

A welding procedure specification (WPS) sets broad guidelines for the shop and field welding practice of the fabricator for each anticipated combination of essential variables. Welding parameters and ranges are specified and used to prepare the associated welding procedure data sheets.

4.2. Welding Procedure Data Sheet (WPDS)

A welding procedure data sheet (WPDS) is a document, used in conjunction with a WPS, detailing the welding parameters and ranges for welding a specific joint, over a range of thicknesses and weld sizes, as illustrated on the data sheet. The following is the standard welding procedure data sheet form suggested by the CWB, however, other welding procedure data sheet formats may be used. Each item on the data sheet will be described and guidance on the completion of the form will be given. Common errors in completing the form will be identified.

Capping Material Capping material can have multiple applications. Notwithstanding, a layer of capping material must be placed directly below the ballast layer in all instances. Capping material shall be a well-graded natural or artificially blended gravel/soil. It is required to have sufficient fines to allow for compacting to high densities by static or vibratory steel-tyred rollers or by ballasted pneumatic-tyred rollers. Capping material must be capable of providing structural support to the ballast layer and shedding water from the ballast away from the formation.

Structural Fill Material Structural fill must be a material with properties which when placed, provides a gradational support zone over the underlying material. Structural fill is typically used to provide a stable embankment for the support of the track infrastructure and a stable construction platform for the placement, compaction and maintenance of the capping layer and track.

4.3. Welding Procedure Specification

(WPS) is the formal written document describing welding procedures, which provides direction to the welder or welding operators for making sound and quality production welds as per the code requirements. The purpose of the document is to guide welders to the accepted procedures so that repeatable and trusted welding techniques are used. A WPS is developed for each material alloy and for each welding type used. Specific codes and/or engineering societies are often the driving force behind the development of a company's WPS. A WPS is supported by a Procedure Qualification Record (PQR or WPQR). A PQR is a record of a test weld performed and tested (more rigorously) to ensure that the procedure will produce a good weld. Individual welders are certified with a qualification test documented in a

Welder Qualification Test Record (WQTR) that shows they have the understanding and demonstrated ability to work within the specified WPS.

1.4 . Appropriate welding procedure standard, as follows

- ✓ Produce a welding procedure specification (WPS) as stated above.
- ✓ Weld a test piece in accordance with the requirements of your specification. The joint set up, welding and visual examination of the completed weld should be witnessed by a certified welding inspector such as an AWS certified CWI or an Inspection Body. The details of the test such as the welding current, pre-heat etc., must be recorded during the test.
- ✓ Once the welding is complete the test piece must be subject to destructive and non-destructive examination such as radiography and mechanical tests as defined by the welding procedure standard. This work must be carried out in a qualified laboratory but the Inspection Body may require witnessing the tests and viewing any radiographs.
- ✓ If the test is successful you or the test body completes the appropriate documents which the test body's surveyor signs and endorses.

1.5.Procedure Specification (AWS)

- Welding Procedure Specification (WPS)νWritten document that provides direction to the welder for making production welds in accordance with Code requirements
- Rules for qualification of procedures vary by referencing Code
  - ✓ Qualified by testing (ASME, AWS)
  - ✓ Pre-qualified (AWS)–Standard Welding
  - ✓ AWS Standard Welding Procedure Specification (SWPS)
  - ✓ Procedures that have been qualified by the Welding Research Council accepted and published by AWS for use as a qualified welding procedure

4.6.Welding Procedure Qualification (PQR)

- A test that is performed to demonstrate that the contractor can make satisfactory welds as specified in the Welding Procedure Specification
- Mechanical testing is required and NDE may be required, depending on the Code being qualified to
- Impact testing may be required by the referencing Code

Performance test which determines the welder's ability to make acceptable production welds under a given set of conditions (essential variables)

- ✓ Process
- ✓ Joint type
- ✓ Base metal
- ✓ Filler metal
- ✓ Position
- ✓ Gas
- ✓ Electrical characteristics

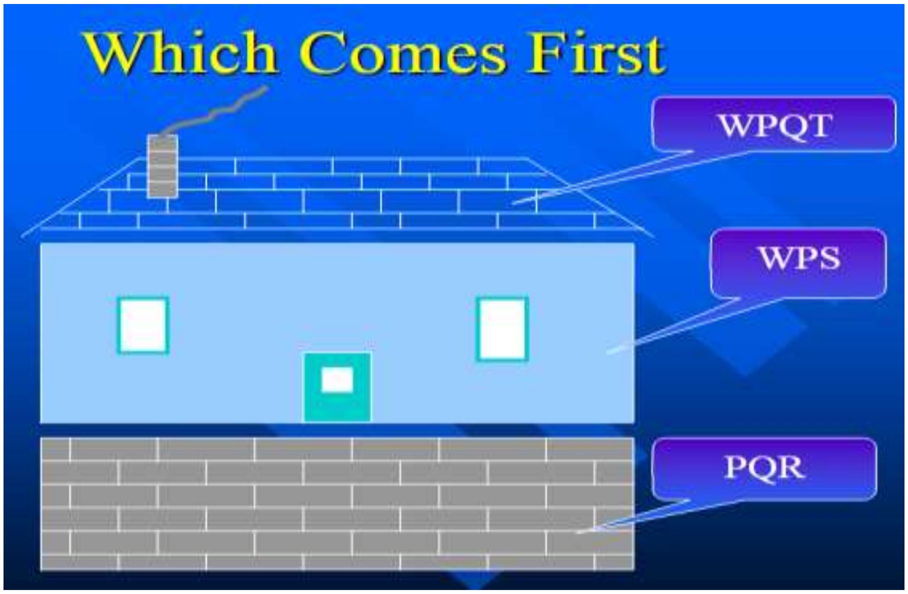


Figure 133: Electrical characteristics

4.7. Which Comes First

- To frame a house you need to know the size of the foundation
- To build a foundation you need to know the size and shape of the house
- The roof does not have to cover the house but should be fully supported by the framing

Self-Check -4	Written Test

Directions: Answer all the questions listed below.

I. Choose the best answer

1. Performance test which determines the welder's ability to make acceptable production
   A. Process
   B. Joint type
   C. Base metal
   D. Filler metal
   E. Position
   F. Non
   G. All
2. Welding Procedure Qualification
   A. test that is performed to demonstrate that the contractor can make
   B. Mechanical testing is required
   C. Impact testing may be required by the referencing
   D. A&B E All
3. Rules for qualification of procedures vary by referencing Code
   A. Qualified by testing
   B. Pre-qualified Standard Welding
   C. AWS Standard Welding Procedure Specification
   D. All

Note: **Satisfactory rating - 2 points** **Unsatisfactory - below 1.5 point**

Answer Sheet

Score = ____________

Rating: _____________

Information Sheet -5	Ensuring Weld deposit within specifications

5.1. Definition of Ensuring Weld deposit

Introduction In a mature industry such as welded steel construction, it is reasonable to believe that the role of the various individuals involved with a given project will be well understood and well defined. Unfortunately, experience indicates that there is a great deal of confusion in this area. Perhaps this is a reflection of misperceptions about the technology itself.

Too many other-wise knowledgeable people still regard welding as a “black art,” rather than a science that can be understood and controlled. The level of understanding among many Engineers regarding this important construction process is limit-ed. Regardless of the reason, Engineers frequently do not perform their professional responsibilities as they relate to welding.

Too often, they delegate this authority to Inspectors. Over-zealous Inspectors frequently overstep their role, making judgment calls that should be the purview of the Engineer. Furthermore, Fabricators do not always take full advantage of code-provided latitude for the resolution of many problems. In the end, Owners often pay too much for structures that have been plagued by delays, unnecessary repairs, and extraneous activities that add little or no value to the project.

Many problems result when the proper roles of the various individuals on the project are not understood. The most serious infractions occur when people accept responsibility for areas in which they have no authority or qualifications. This can result in disaster, but fortunately such cases are rare. More frequently, key individuals fail to carry out all of their appropriate responsibilities, causing costly delays.

Many problems result when the proper roles of the various individuals on the project are not understood

5.2. Structural Welding Code - Steel, defines such roles as they relate to welded construction. In addition to restating sections of the code itself, this paper will outline a philosophy that is conducive to increased cooperation and communication, and will foster the creation of higher quality products while minimizing fabrication costs.

Figure 134: Effective visual inspection requires that the Inspector be present when welding is being performed.

5.3. Various Roles Defined

At the heart of the issue are the proper definition of the roles and the Responsibilities of various individuals involved in welded fabrication. The following are taken from the AISC Code of Standard Practice and/or the AWS D1. 1-98Structural Welding Code – Steel

- **Owner:** The owner of the proposed structure OR that individual's designated representatives, who may be the Architect, Engineer, General Contractor, Public Authority, or others.
- **Architect/Engineer**: The Owner's designated representative with the full responsibility for the design and integrity of the structure.

- **General Contractor**: The Owner's designated representative with the full responsibility for the construction of the structure.
- **Fabricator:** The party responsible for furnishing fabricated structural steel.
- **Erector:** The party responsible for the erection of the structural steel.
- **Verification Inspector:** The duly designated person who acts for, and on behalf of, the Owner or the Engineer in all inspection and quality matters within the scope of the con-tract documents. (In some codes, such as AASHTO/AWSD1.5-96 Bridge Welding Code, this Inspector is known as the Q.A. Inspector, that is, the Quality Assurance Inspector.)
- **Fabrication/Erection Inspector:** The duly designated person who acts for, and on behalf of, the Contractor in all inspection and quality matters with-in the scope of the contract documents. (In D1.5, this Inspector is known as the Q.C. Inspector, that is, the Quality Control Inspector.)
- **Inspector:** When the term Inspector is used with-out further qualification, it applies equally to both the Verification and Fabrication/Erection Inspector. For the purposes of this paper, comments directed toward the Fabricate or apply equally to the Erector. Since most or all of the welding will be per-formed by either the Fabricator or Erector, the General Contractor will not be considered in this discussion. The term Engineer will be used in lieu of Architect/Engineer.

5.3. Responsibilities

The Engineer has the ultimate and full responsibility for the integrity of the structure. It is the Engineer who must establish the required quality level for all welded fabrications.

The emphasis is placed on acceptance and compliance to the specification

Important to note that the emphasis is placed on acceptance and compliance to the specification. A prevailing but mistaken impression of Inspectors is that their primary responsibility is to reject out of compliance work. This is more than an issue of semantics. The ability to reject a particular weldment is ultimately the Engineer's responsibility. The Inspector's responsibility is to accept materials that are in compliance.

While this approach may seem new or revolutionary to some people, the author believes that it is the primary philosophy presented in codes. And, to eliminate any dispute or potential misrepresentation of code intentions, it is the author's opinion that this should be the philosophy of the code even when it is not, because it will result in optimum value to the Owner.

Fabricators must know the entire code and understand what is mandatory, what is permitted, and what can be changed.

Welding processes or those of welding codes, it is imperative to consult a Welding Engineer, another profession-al, separate and distinct from the Inspector. The Inspector must under-stand how to enforce the application of the code, accept work that conforms to code requirements, and report to the Fabricator deviations from these requirements. The Inspector must know the whole code, and apply it to the situation, not "interpret" it

This statement endorses the power of an effective visual inspection. The checklist of items to inspect after welding includes the following:'

- Final weld appearance.
- Final weld size.
- Weld length.
- Dimensional accuracy.
- Amount of distortion.
- **Post-weld heat treatment**. The importance of these issues is self-evident. The appearance of the welds a strong indicator of the suitability of the actual welding procedure used, and the ability of the individual welder. More than merely a cosmetic issue, weld appearance provides some insight into how the weld was made.

5.4. Welding Procedure Specification.

The Welding Procedure Specification is a required document for all code welding. Your customer either directly or indirectly specifies to what code your company must qualify. The WPS outlines all of the parameters required to perform your welding operation.

The welding engineering standards typically include:

- Illustrated profiles of each typical joint intended for use, showing:
  - ✓ The type of joint (eg, butt, lap, tee, corner, edge);
  - ✓ The type of weld;
  - ✓ The geometry of the preparation and fit-up;
  - ✓ The standard welding symbol;
  - ✓ The range of thickness; and
- Minimum permissible sizes of fillet and partial penetration groove welds.

A welding procedure specification (WPS) sets broad guidelines for the shop and field welding practice of the fabricator for each anticipated combination of essential variables. Welding parameters and ranges are specified and used to prepare the associated welding procedure data sheets.

The company shall have welding procedure specifications for each welding process in use, outlining the general welding procedure to be followed in the construction of weldments built in accordance with the governing design or manufacturing standard, or both.

5.5. Welding Procedure Data Sheet (WPDS)

A welding procedure data sheet (WPDS) is a document, used in conjunction with a WPS, detailing the welding parameters and ranges for welding a specific joint, over a range of thicknesses and weld sizes, as illustrated on the data sheet. The following is the standard welding procedure data sheet form suggested by the CWB, however, other welding procedure data sheet formats may be used. Each item on the data sheet will be described and guidance on the completion of the form will be given. Common errors in completing the form will be identified.

- **Welding Procedures and Welder Performance Qualification**

- **Welding Procedure Qualification Record**

The Welding Procedure Qualification Record is the document that qualifies the Welding Procedure Specification. In order to qualify your WPS, a procedure qualification plate is welded the code requirements. The actual test parameters are recorded at the time of welding to ensure the WPS was being followed. Generally any supporting documentation, such as material specifications, electrode specifications and shielding gas specifications, are included as part of the WPQR. All required testing, both non-destructive and destructive, is recorded as well. These tests typically include X-Ray examinations, ultrasonic examinations, tensile testing, bend testing and when required impact testing.

The WPQR combines all of the information of the WPS and adds the test results to provide a complete document that certifies the welding specification. This document is also required by all codes unless you are qualifying under American Welding Society (AWS) specifications. Under certain conditions the WPS may be considered prequalified in which the WPQR is not required.

- **Welder Performance Qualification**

  This document is required by all codes for all welders. It details and summarizes the following information: Indicates the WPS referenced during the qualification test Identifies the welder by name and/or clock number Lists what the essential parameters were during this test Reports the results of the required qualification tests Specifies qualified limits for welder For most codes there is a time limit associated with the welder qualification test.

  However, the American Welding Society provides an unlimited qualification period if certain conditions are met. As with the WPS and WPQR, each code has a recommended format.

Self-Check -5	Written Test

Directions: Answer all the questions listed below.

I. Choose the best answer(5)

1. The checklist of items to inspect after welding includes the following:’

   A. Final weld appearance.

   B. Final weld size.

   C. Weld length.

   D. Dimensional accuracy.

   E. Amount of distortion   E. All   F. Non

II. Say true and false for the following question below(2 Each)

1. A welding procedure data sheet (WPDS) is a document, used in conjunction with a WPS, detailing the welding parameters and ranges.
2. The Welding Procedure Qualification Record is the document that qualifies the Welding Procedure Specification.
3. The Welding Procedure Specification is a required document for all not available any code welding.
4. The Engineer has the ultimate and full responsibility for the integrity of the structure.
5. When the term Inspector is used with-out further qualification, it applies equally to both the Verification and Fabrication/Erection Inspector.

Note: **Satisfactory rating - 10 points   Unsatisfactory - below 7.5 point**

Answer Sheet

Score = ____________

Rating: _____________

Information Sheet-6	Welding materials using SMAW process

6.1. Definition of Shielded Metal Arc Welding

Shielded Metal Arc Welding, otherwise known as manual metal arc welding or flux shielded arc welding, is a process that uses a flux-coated electrode to form the weld. As electricity passes through the electrode, the flux forms a gas, which shields the electric arc in the space between the electrode and the metal being welded, preventing contamination from atmospheric gasses in the weld. This process is fairly simple and doesn’t require much in the way of specialized equipment, making it very popular.

6.2. SMAW Welding Techniques

When welding, you want to form a neat, clean weld. To make this process easier, it’s important to pick steel that will work well with SMAW welding techniques. Steel that conforms to AISI-SAE 1015 to 1025 requirements will work well, as this steel has silica content under 0.1% and sulfur content under 0.035%. Alloy steels with content above this range can have problems with cracking.

Once you’ve selected your steel, be sure to clean up the edges to get a neat weld. This means removing paint, rust, moisture, scale and oils. If you’re not able to clean the joint, use an E6010 or E6011 electrode with a slow travel speed to make sure the gasses bubble out before the puddle solidifies.

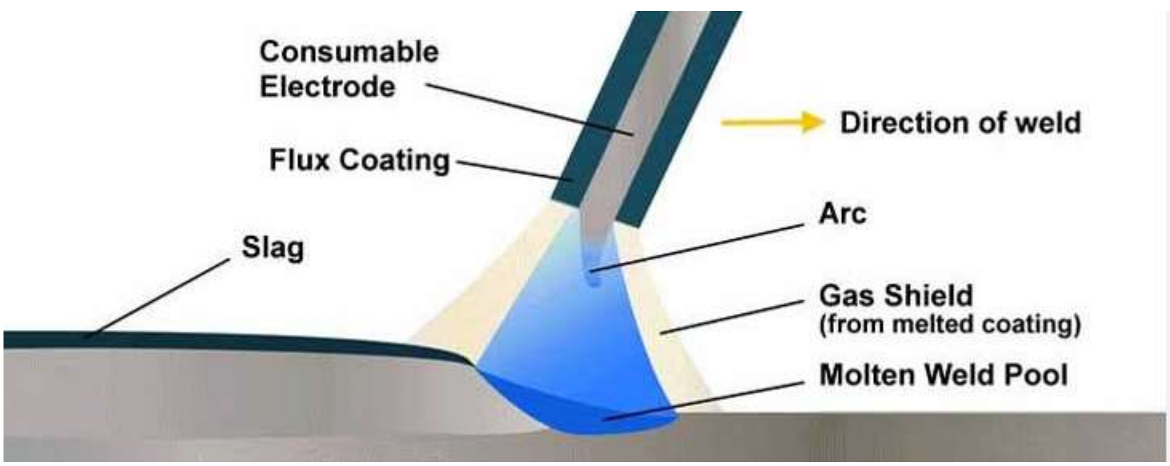


Figure 135: SMAW Welding

6.3. Joining Materials

Ways of joining materials In order to choose the best way of joining any combination of materials in any situation which is likely to arise, we must have a good general knowledge of methods of joining. Joints can be classified in several ways such as temporary and permanent, flexible and rigid, and hot and cold formed. In the pages which follow we have given enough details of the common ways of joining for you to be able to choose the best

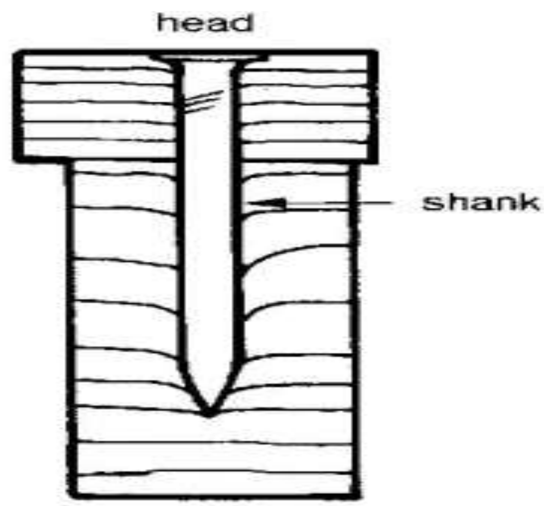


Figure 136: Joining Nill

Nails

Nailing is the quickest way of making a permanent joint in wood. Nails cannot be removed easily or without damage, and therefore should not be used as temporary joints. The nail punches the fibers of the wood away from the nail head. They grip the shank of the nail and resist attempts to withdraw it. The serrations round the shank, below the head, give extra grip. The treaded pattern on the head stops the hammer from slipping. Always nail through the thinner piece of wood into the thicker piece. The nail length should be about 2.5 to 3 times the thickness of the thinner piece.

NB: Nails are sold by length, type, material and weight (not number).

Common types:

- **Round wire nails** have a round shank and a flat head. They are made from steel wire and can be galvanized to stop rusting. The usual sizes are from 12 mm to 150 mm long and they are used for general joinery work.

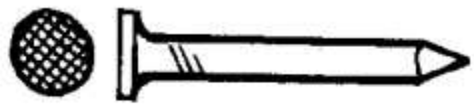


Figure 137: Round wire nails

- **Oval wire nails** have an oval shank and a narrow head which is driven below the surface. Turn the long axis of the oval shape in line with the grain to prevent splitting. They are made from steel wire and can be galvanized. The usual sizes are from 12 mm to 150 mm. Because they have no heads they do not hold the wood as firmly as round wire nails, but they are neater and are therefore used for interior joinery. The nail holes can be hidden by filling.

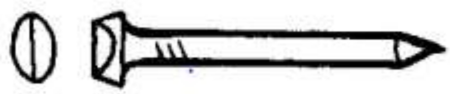


Figure 138: Oval wire nails

- **Standard panel pins** have a thin round shank and a small head which is driven below the surface with a nail punch. The usual sizes are from 12 mm to 50 mm and they are used for strengthening joints and fixing thin sheets.

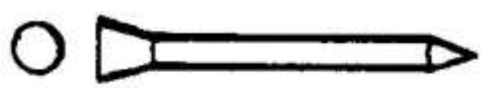


Figure 139: Standard panel pins

- **Hardboard pins** have a hard square shank to penetrate hardboard without bending and a pointed head which does not need punching below the surface.

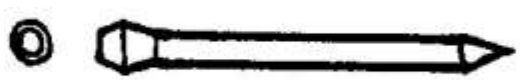


Figure 140: Hardboard pins

- **Clout nails** are short nails with extra-large heads for fixing roofing felt, canvas chair webbing, etc. They are usually galvanized to prevent rusting.

Figure 141: Clout nails

- **Hardened fixing pins** are hard, round shanked nails designed to withstand persistent hammering and to penetrate bricks, etc. They should be long enough to go through the job being fixed, any plaster on the wall, and then 15 mm to 20 mm into the wall.

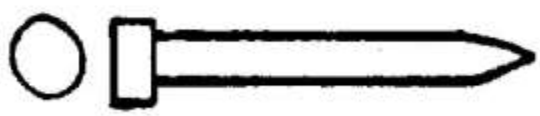


Figure 142: Hardened fixing pins

- **Staples** are square for crate-making and upholstery, and round for holding wire. Square staples are usually fired in by a staple gun. Round staples are heavier and are hammered in

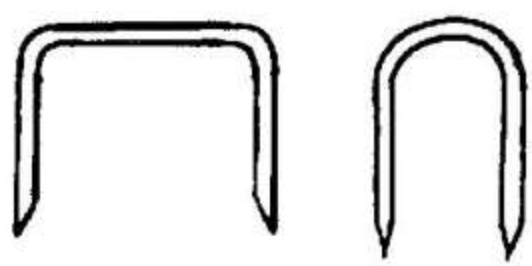


Figure 143: Staples

- **Dovetail nailing.** To give extra strength to a joint, drive in pairs of nails towards each other dovetail fashion.

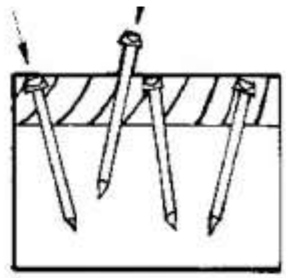


Figure 144: Dovetail nailing

- **Staggered nailing**. When nailing a frame together stagger the nails across the width of the wood to avoid splitting the grain. If the wood is brittle or tough, bore a small hole and blunt the nail point. These precautions help to prevent splitting, especially when nailing close to the end of a plank

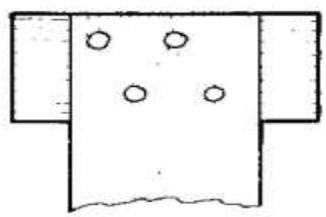


Figure 145: Staggered nailing

- **Clinched nailing** this is used to prevent nails being easily pulled out when nailing into thin wood. The process is shown right. Note that the usual rule is still used to calculate the length of the nail (3 x thickness of piece A). A convenient round bar, such as one handle of a pair of pincers, is used to help in turning the nail point back into the wood to give a strong, safe joint. Simply bending the nail over leaves a dangerous point exposed.

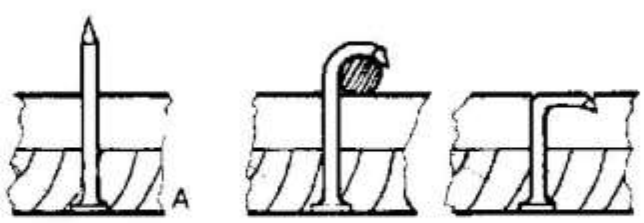


Figure 146: Clinched nailing

Nails for upholstery

- **Gimp pins** are small wire nails, often of brass, with a large head used in upholstery where the nail heads will show.

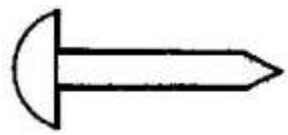


Figure 147: Gimp pins

- **Cut tacks** are short, sharp-pointed, flat-headed nails, usually with a blued or black mild steel finish. They are used in upholstery where the nails will be hidden.

Figure 148: Cut tacks

- **Corrugated fasteners** are short strips of corrugated steel with one sharp corrugated edge, used to make crude joints in cheap work. They are hammered in across the joint lines at each corner to hold the frame together.

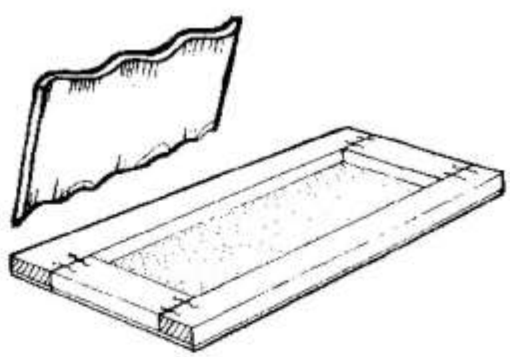


Figure 149: Corrugated fasteners

- **Screws for wood** Screws are an effective way of making a permanent or temporary joint in wood. The thread of the screw becomes enmeshed with the grain fibers to make a strong joint. Screws are stronger, neater and more accurate than nails, and can be taken out without causing damage.
- **Using screws**
  - ✓ Select the correct length of screw. This is 2.5 to 3 times the thickness of the top piece of wood. Always screw through the thinner piece of wood into the thicker.

- ✓ Drill the pilot hole to slightly less than the screw length. A bradawl hole may be enough in softwood, but in hardwood and for large diameter screws, use a drill equal to the core diameter. Failure to drill properly causes chewed up screw heads and split wood.
- ✓ Drill a clearance hole for the shank.
- ✓ Countersink for the screw head if needed.
- ✓ When using brass screws which easily break, screw in a stronger steel screw first to cut a thread, and in hardwood, lubricate the screw with soap or wax.

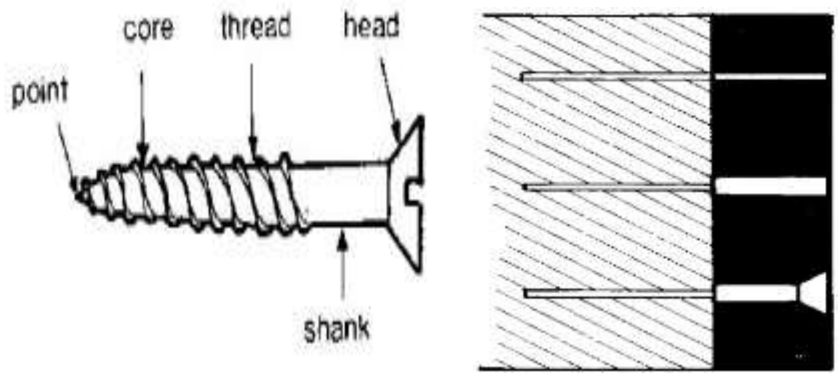


Figure 150: screws

6.4. Common types of screws

- **Countersunk head screws** are used to join wood to wood where the head has to be flush with the surface, and for fitting hinges. They are the most commonly used type..

Figure 151: Countersunk head

- **Round head screws** are used to screw thin metal fittings to wood (e.g. tee hinges and shelf brackets), and for joinery work where the head need not be flush. They are often of black japanned steel to resist rusting

Figure 152: Round head screws

- **Raised countersunk head screws** are less common and are used to screw fittings to wood. They are often of chrome plated brass to look attractive or plated to match fittings such as door furniture.

Figure 153: Raised countersunk head

- **Twin fast screws** have two threads instead of one, so that fewer turns are needed to screw them in. They have more holding power than ordinary screws, and this is especially useful for joining difficult materials such as chipboard and block board.

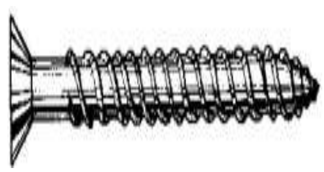


Figure 154: Twin fast screws

- **Coach screws** are large heavy duty screws with a square head onto which a spanner is fitted to turn them. They are used to join large pieces of wood such as bench tops.

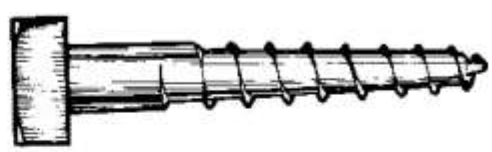


Figure 155: Coach Screws

- **Screw caps and screw cups** are used where appearance is important or where the screw must be removed frequently.

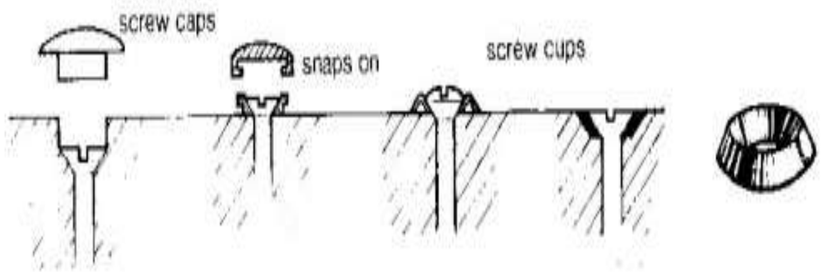


Figure 156: Screw caps and screw cups

6.5. Types of screwdriver slots

- **Straight slot.** A screwdriver can slip out of a straight slot and damage both screw head and wood.
- **Phillips slot.**
- **Pozidriv slot.** The main advantage of Phillips and Pozidriv slots is that the screwdriver blades do not slip out of the slots so easily

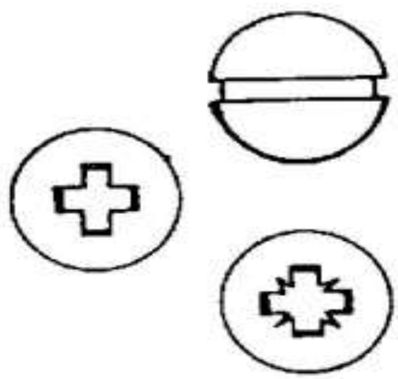


Figure 157: screwdriver slots

The common materials are steel and brass, and screws are often plated with chrome, Zink, nickel, or black japanning.

Steel screws are the strongest and cheapest. Brass screws look better and do not rust, but are not very strong.

The common sizes of steel countersunk screw are 6 mm to 150 mm long and 0 to 22 gauge number sizes. The gauge number indicates the diameter of the shank and the size of the head. The higher the number, the thicker the screw.

6.6. Screws are sold by:

- Quantity (How many?)
- Length (How long?)
- Gauge (How thick?)
- Material (What is it made from?)
- Type of head (What shape? What sort of slot?)

e.g. 100, 25 mm x No. 6 steel countersunk.

6.7. Some common glue and their uses

Scotch glue is animal glue made from bones and hide which is used hot to stick wood. It is available in slab or pearl (bead) forms. To use it, break a slab wrapped in cloth into small pieces and soak these in water overnight to form a jelly. Put the jelly and more water into the inner pot of a glue kettle, half fill the outer pot with water, and heat slowly until the glue melts into a liquid. The water in the outer pot prevents overheating. Pearl glue is ready for heating after a short soaking.

The glue is ready for use when it just runs from the brush and a thin skin forms on top. Remove the skin.

- **Advantages:**

  It is cheap, does not stain wood, is very strong if the joints fit well, and there is no waste because it can be reheated several times.

- **Dis advantages**:

  It must be used quickly before it cools, leaving little time to fit the job together and the job must be left in cramps overnight to set. It is not heat or water resistant

- **Rivets**

  Rivets are used to make permanent joints in metal, to join metal to soft materials and for joining soft materials to each other.

- **Solid rivets**
  - ✓ **Snap or round head rivets** are used for general purposes where a flush finish is not important and countersinking would weaken the job.

Figure 158: round head rivets

- ✓ **Countersunk head rivets** are used for general purposes where a flush surface is needed. They are the most commonly used type.

Figure 159: Countersunk head rivets

- ✓ **Flat head rivets** are used for joining thin plates which cannot be countersunk.

Figure 160: Flat head rivets

6.8.A bolt is a form of threaded fastener with an external male thread

- **Common types of bolts**

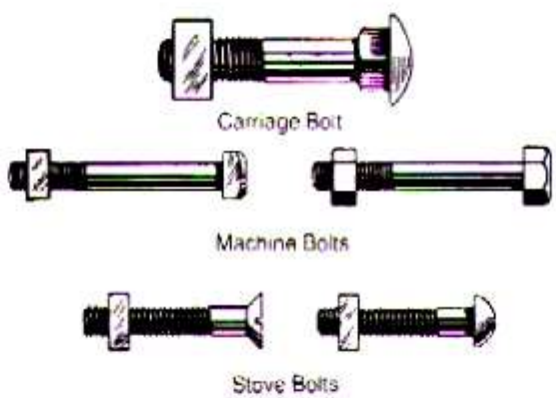


Figure 161: Bolts

- **Stages in counter sunk riveting.**
  - ✓ Drill and countersink both plates. Clean off any burrs.
  - ✓ Put in the rivet and press the rivet and the plates together with a set. Support the countersunk head on a flat block.
  - ✓ Swell the rivet with the flat face of a hammer until it is tight in its hole.
  - ✓ Use the ball-pein to fill up the countersink.

- ✓ Finish with the flat face and file the head smooth. A good countersunk rivet should be almost invisible.

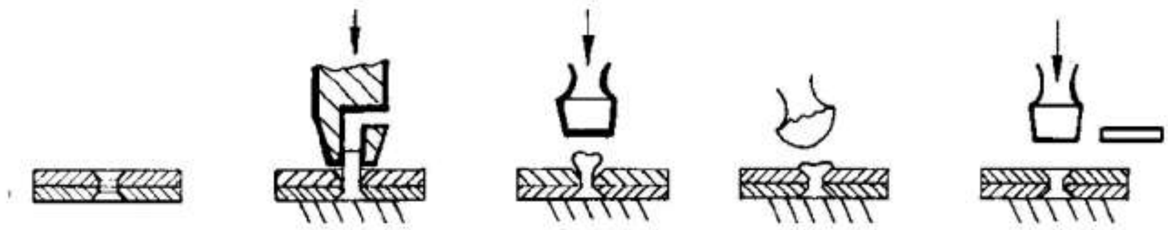


Figure 162: sunk riveting

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Self-Check-6	Written test

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

Say true or false for the following questions below

1. Nailing is the quickest way of making a permanent joint in wood
2. Round wire nails have a round shank and a flat head
3. Staples are square for crate-making and upholstery, and round for holding wire
4. Rivets are used to make permanent joints in metal, to join metal to soft materials and for joining soft materials to each other
5. Screw caps and screw cups are used where appearance is important or where the screw must be removed frequently.

Note: **Satisfactory rating 3 and above points Unsatisfactory - below 2 points**

Score = ____________ Rating: _____________

Operation Sheet 6	Procedure to perform welding

Operation Title:

Step 1.Use a soft face hammer and ANSI approved (z87.1) eye protection during cutting and bending procedures.
Step 2. Ensure that the surface to which the wear part will be attached to, is as flat as possible and the area to be welded is clean;
Step 3. Clamp and tack weld wear part into position;
Step 4. Stitch weld, laying 50 mm max length on each run, alternating ends or sides to minimize heat input. Does not deposit weld within 2 mm from the joint line between wear parts?
Step 5.Do not welds continuously - continuous welding may cause war page, layers delamination and cracking. use thermal crayons to check temperature, maximum allowed 200°c;
Step 6. If a complete peripheral weld is required, use stitch weld method as per step 3;
Step 7. Welding rods we recommend low hydrogen weld rods or gas covered core wire

LAP Test	Practical Demonstration

Name: ______________________________ Date: ________________

Time started: _________________________ Time finished: ________________

Instructions: Given necessary materials, tools and measuring instruments you are required to perform the following tasks within 1 hour.

Task1. Perform welding for the following project as shown bellow

Information Sheet -7	Cleaning joints from discontinuities

7.1. Definition of Cleaning Joints

Cleaning is the process of removing unwanted substances, such as dirt, infectious agents, and other impurities, from an object or environment. Cleaning occurs in many different contexts, and uses many different methods. Several occupations are devoted to cleaning.

7.2.A Welding Discontinuity

Technically, a welding discontinuity is the lack of a mechanical, physical or metallurgical harmony in the weld. This could be manifested in terms of

- Varied porosity
- Incomplete fusion or joint penetration
- Unacceptable profiles
- Subtle tears and cracks

All welding defects are developed discontinuities. If a discontinuity renders a weld incompetent or lowers its quality, it would be classified as a defect. Defects make the product risky to use or substandard. It is up to the quality control to decide whether the discontinuity qualifies as a defect or not.

7.3.The Differences between Discontinuities and Defects

Since the line between discontinuities and defects varies from one industry to another, only a generalized explanation can give a good guide to isolating defects from discontinuities.

- Any weld would be a defect if the welder or the quality control department rejects it and blacklists the product.
- A defined list of acceptable discontinuities will list the number or type of discontinuities allowed on a product before labeling it a defect.
- A discontinuity will survive a field test while a defect won't. A crack on a water pipe would be a defect since the water will leak while an unacceptable profile could pass as a discontinuity as long as the pipe doesn't leak.

Discontinuities can be ignored since they are always well within the acceptable production error margins. Defects, on the other hand, must be repaired. If the defect is irreparable, the product should get a red reject tag and head to the junk bin.

It's important to understand the distinction between a weld defect and discontinuity to understand the quality of a weld, and if an imperfection is a safety concern or merely cosmetic. A perfect weld is a precarious achievement that requires meticulous care in the preparation of materials, a work area and careful adherence to welding techniques

Table 8: Principal gases causing porosity and recommended cleaning methods

Material	**Gas**	**Cleaning**
C-Mn steel	Hydrogen, Nitrogen and Oxygen	Grind to remove scale coatings
Stainless steel	Hydrogen	Degrease + wire brush + degrease
Aluminum and alloys	Hydrogen	Chemical clean + wire brush + degrease + scrape
Copper and alloys	Hydrogen, Nitrogen	Degrease + wire brush + degrease
Nickel and alloys	Nitrogen	Degrease + wire brush + degrease

- **Detection and remedial action**

  If the imperfections are surface breaking, they can be detected using a penetrant or magnetic particle inspection technique. For sub surface imperfections, detection is by radiography or ultrasonic inspection. Radiography is normally more effective in detecting and characterizing porosity imperfections. However, detection of small pores is difficult especially in thick sections.

  Remedial action normally needs removal by localized gouging or grinding but if the porosity is widespread, the entire weld should be removed. The joint should be re-prepared and re-welded as specified in the agreed welding procedure.

Self-Check-7	Written test

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

I. Say true or false for the following questions below

1. Cleaning is the process of removing unwanted substances.
2. A Welding Discontinuity includes, Varied porosity, Incomplete fusion or joint penetration, Unacceptable profiles, Subtle tears and cracks.
3. Discontinuities can be ignored since they are always well within the acceptable production error margins.
4. If the imperfections are surface breaking, they can be detected using a penetrant or magnetic particle inspection technique.

Note: **Satisfactory rating 3 and above points Unsatisfactory - below 2 points**

Score = ____________

Rating: _____________

Information Sheet -8	Cleaning welds using appropriate tools and techniques

8.1. Types of Welding and the Tools You Need

Welding is the way that pieces of metal are permanently joined together. Almost everything around you was either welded or made by some piece of equipment that was welded. You know that stainless steel coffee pot? That was welded. Your car? That was welded, too. And while your work boots and utility gloves probably weren't, you can safely bet they were made by machines that were.

There are several different types of welding, each used for a specific type of metal or seam. Every method uses different tools, equipment and techniques. Additionally, while there is a large variety of welding methods to choose from, there are four which are most commonly used.

- **Choose the Right Welding Helmet for the Job**

Figure 163: Helmet for the Job

Whether your welding takes you out on an oil rig or into a mechanic's garage, you need the right protection for your eyes in every work environment. Many welders find that if they invest a little more in their helmet, it can make a big difference in comfort and overall welding ability, while also helping to provide better protection. That said, welding helmets come in a wide variety of price ranges and are made for different applications. Here are 5 important considerations before you invest.

A standard welding helmet, also sometimes referred to as a passive helmet, features a viewing lens with a static ultraviolet (UV) and infrared (IR) filter, usually a #10 shade. This filter offers the same level of protection no matter how many amps the light gives off from the weld. When a welder is ready to work, he will need to lower this kind of helmet with a quick nod or snap of the neck to flip the helmet down while keeping the torch in position. When work is complete, the welder has to lift the helmet to see.

While standard helmets with fixed lenses are often less expensive, they have some drawbacks. For an inexperienced welder, it can take some practice to keep the torch steady and in the right location after snapping the welding helmet into place. Also, if you're welding in a restricted area or confined space, there isn't always room to maneuver or to flip a helmet up or down. Lifting and lowering a helmet also adds to your work time, which can have an impact on productivity.

However, if most of your welding tasks only involve one kind of material, at the same thickness, and if you're always using the same process at a fixed amperage, then there's really no need to buy anything more than a fixed shade #10 standard helmet.

Variable Shade welding helmets feature auto-darkening filters with an electronic filter lens. An auto-darkening filter or ADF, is a liquid crystal display that features light sensors mounted near the lens to detect the welding arc. When the lens is not activated, the LCD filter will typically have a #3 or 4 shade, similar to sunglasses so it's easy to see with the helmet in place. Once a welding arc is started, sensors on the helmet will darken the lens to a shade from #9 to #13. The advantage of this helmet is that it can stay in place before you start work allowing you to set up a welding joint with the helmet in position. You can also keep the helmet in place for the length of the task, with no lifting or lowering needed.

Welding different materials of varying thickness requires different welding processes, such as stick, MIG or TIG. With these variables the amperage from a weld can range from 40 to more than 200 amps. If your job requires varying techniques and materials, you will need a variable shade lens for adequate eye protection.

7.2. What About Switching Speed?

The lens switching speed or reaction time is how fast a lens will switch from its natural state to a shade 3 or 4 when welding begins, and is usually expressed in ratings of 1/3,600 of a second to as high as 1/25,000. If your job requires welding for several hours at a time, an entry-level switching speed may cause eye fatigue by the end of the day. If this is the case, consider going to an intermediate or professional level switching speed.

7.3. Battery, Solar Power or Both?

Auto darkening helmets offer a variety of power options. Some feature internal non-replaceable batteries and solar assist panels. Others have replaceable batteries with solar assist panels. Some offer lithium batteries, which are great for extended battery life, but they also aren't as widely available as AAA batteries. Lithium batteries also cost more. Some helmets with solar assist panels require a charging period in direct sunlight before they can be used. The decision here is probably a personal one, but for wide availability and economical battery replacement cost, choose AAA battery operated. For extended battery life, choose lithium.

7.4. Does Helmet Weight Matter?

Yes. A lighter weight helmet will minimize neck strain and reduce fatigue with extended use. Choosing your helmet weight will really depend on the combination of all of the other factors along with how long each day you plan on using it. Again, if welding is your primary task, choose the lightest weight possible for your budget.

7.5. What about Personal Preference?

All welding helmets are designed to protect workers from the ultraviolet and infrared dangers emitted from welding arcs. Still there are many options on the market. Knowing whether you will be using the helmet for one specific task or many is the first consideration. Aside from that there is budget, weight, viewing lens and more. Most of all choose a helmet that's most comfortable for you and that you can wear for an extended period of time if needed. Taking the extra time to choose the right fit can pay off in terms of productivity and weld quality.

7.6. Basic Equipment for Welding:

To get started in the basics of welding, you need:

- ✓ a welder,
- ✓ electrodes,
- ✓ feeds and
- ✓ safety gear

7.7. TIG and MIG Welders

The most common welder used in basic projects by homeowners and hobbyists is the stick welder. Also known as the shielded-metal arc welder, most people prefer it due to how easy it is to buy and the lack of a special environment needed to use it. But the electrodes in a stick welder require frequent replacement compared with other forms of welding. These include the gas tungsten arc machines, TIG and gas metal arc welder, known as MIG welders. You will also need some sort of gas feed with this type of welder.

- **Charged Electrode**

An electrode is the tip of the tool that passes the current from the welder to the material being welded; making it so hot it becomes liquid. In the cases of the stick and MIG welders, the type of metal and the heat to melt it drives the type of electrode tip needed. But in a TIG welder, the electrode tip is made of non-consumable tungsten, and does not require replacement.

- **Wire and Electrode Feeds**

Some welds require a feed to strengthen the joint due to the geometry or weakness of the weld. Stick welding uses the electrode to feed; MIG welding often uses a wire feed. And TIG welding likewise uses a feed due to its non-consumable nature.

- **Other Tools**

Most welders also use an angle grinder to help smooth out joints, wire brushes, to clean metal surfaces or abrade them before welding, a chipping slag hammer, C-clamps, ball peen hammer, electrode tip cleaners, flint strikers, needle nose and linesmen cutting pliers. Other tools to have on hand: cold chisels, flat-head and Phillips screwdrivers, round and flat files, levels and squares.

Self-Check-8	Written test

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

I. Say true or false for the following questions below

1. The most common welder used in basic projects by homeowners and hobbyists is the stick welder.
2. An electrode is the tip of the tool that passes the current from the welder to the material being welded, making it so hot it becomes liquid.
3. To get started in the basics of welding, you need, welder, electrodes, feeds and safety gear

Note: **Satisfactory rating 3 and above points Unsatisfactory - below 2 points**

Score = ____________

Rating: _____________

Information-9	Avoiding weld defects or porosity

9.1.Welding defects

Welding defects can be defined as weld surface irregularities, discontinuities, imperfections, or inconsistencies that occur in welded parts. Defects in weld joints could result in the rejection of parts and assemblies, costly repairs, significant reduction of performance under working conditions and, in extreme cases, catastrophic failures with loss of property and life.

These defects originate from various sources. In most cases, the defects occur as a result of improper weld design and unsuitable welding processes and choice of incompatible materials. In addition, a lack of knowledge of the process, poor workmanship, and inadequate training of the welder can also contribute to these defects. Furthermore, there are always certain flaws in the welding due to the inherent weakness in welding technology and the characteristics of metals.

Critical welding quality assessment can control the welding defects to within acceptable levels. Non-destructive evaluation or non-destructive testing (NDT) methods can be used to indirectly quantify the weld quality without destroying the material or component. It is important to evaluate the weld quality, as welded joints are often the locations of crack initiation due to inherent metallurgical geometrical defects, as well as heterogeneity in mechanical properties and the presence of residual stresses. Various NDT methods have been developed, each having advantages and limitations in terms of applications, detectable defects, required skills, and costs. A combination of different NDT tests can be used to provide assurance that the component is fit for use.

In practice, it is practically impossible to obtain a perfect weld and, in most circumstances, it is not necessary to provide the adequate service functions required. Thus, for many industries, the specifications and tolerances for welds have been established to determine what is acceptable and fit for service. These are specified as codes or standards, and permit a variety of flaw types, sizes, and frequencies. Since some codes are more strict than others, the same weld might be acceptable under one code but not under another code.

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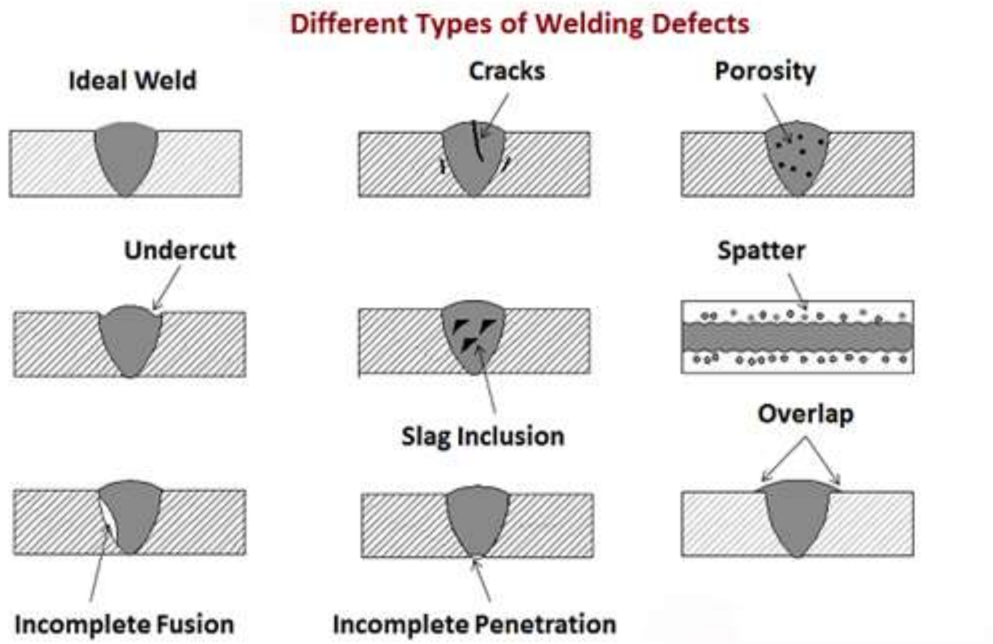


Figure 164: Different Welding Defects

Defects in weld joints could cause the rejection of parts and assemblies, an increase in the cost of maintenance, a reduction in performance and could cause catastrophic failures posing the risks of loss of life and property

- **Porosity**

Figure 165: Porosity

Porosity usually occurs as a result of weld contamination. This happens when gas is trapped inside or along the surface of the weld metal. Just like other weld defects, Porosity results in weak welds that may easily collapse.

9.2. Causes of weld porosity and their practicable prevention

- **Moist Electrodes**

It is recommended to use baked electrodes in Stick welding process in order to avoid involvement of moisture content in the weld metal. In worst, steam can be driven out, during the heat of welding which creates small cavities in the weld metal. Porosity eventuates when stainless steel electrodes or low hydrogen electrodes are not properly kept in dry condition. Although in low hydrogen electrodes some moisture is required within a limit, for better performance but is some case if moisture exceeds from the limit, the weld metal will prone to porosity. For prevention following are the steps to follow;

- ✓ Parent metal must be preheated in order to remove any moisture.
- ✓ The electrodes must be stored in dry conditions.
- ✓ Apply final backing before use.

Electrodes must not be oven baked before use because a little amount of moisture is required for better performance and weld-ability of the electrode.

Figure 166: Welding Effects

- **Contaminated Surface**
  Parent metal or electrodes may be subjected to atmospheric contamination. Any grease, oil or moisture content on surface contribute to gas formation when exposed to welding temperature and may cause porosity problems in your weld. In order to fix it, clean the material by specified surface preparation procedures.
- **Improper Gas Shield**
  The possibility of air entrapment due to inconsistent gas shield may also cause porosity problems. For this, the welder must check gas hose attachment with the equipment and remove hose contamination if any. Correct connection prevents any loss of gas shield and consequently no air entrapment. Moreover, airflow and

draughts in the shop can cause the restriction in gas flow. Some sort of screening is required to avoid such kinds of restrictions in the gas flow.

- **Too High Gas Flow**
  The High flow rate of the gas shield may cause turbulence due to which air can be drawn into the weld metal. Optimize gas flow, provides quality welds with no gas loss. Moreover, it saves cost on the other side.
- **Inadequate Electrode DE oxidant**
  During solidification, the excess oxygen comes out from weld metal due to reduced solubility and may undergo carbon monoxide formation that may cause porosity too. For this, some DE oxidants are added in electrodes, filler metals and even in parent metals to remove the oxygen content (which is so-called DE oxidation). Therefore inadequate DE oxidants may result in poor DE oxidation and are responsible for weld defects. In order to prevent this, use electrodes with adequate DE oxidants.
- **Too High Arc Length**
  Too much longer arc length (in other words high voltage) is also a cause of weld porosity. If the welding gun is held away from the joint keeping arc length longer, the magnitude of shielding is reduced which may lead to air entrapment from atmosphere. Correct arc length is recommended primarily to avoid draughts/breezes.
- **Incorrect Surface Treatments**
  The release of gases, during painting/surface treatments, can impair weld characteristics. Treatments like zinc coating or galvanizing produce gas and other unwanted particles. In an endeavor to fix this problem, make predictions about the outcome of chemical reactions before specific surface treatments.
- **Openwork Surface**
  Any surface which is open to atmospheric air can be contaminated. Air introduction from the back side through root opening gets entrapped in the weld puddle. Make sure that weld joint is protected from such kinds of air crevices.
- **Laminated Surface**
  Laminated surface also creates a disturbance in welding. In case of welding a laminated work piece, prepare un-laminated parent metal to conduct quality weld procedure.
- **In-Appropriate Flux**

  Welding flux must be treated with great care as they have the capability to absorb moisture (granular SAW flux). They must be supplied in dry condition. On the other hand, use of low activity flux results in surface porosity. That is why it is recommended to use high activity flux which offers quality welds with no porosity.

- **Prevention**
  - ✓ The gas source should be identified and removed as follows:
- **Air entrainment**
  - ✓ seal any air leak
  - ✓ avoid weld pool turbulence
  - ✓ use filler with adequate level of DE oxidants
  - ✓ reduce excessively high gas flow
  - ✓ avoid draughts
- **Hydrogen**
  - ✓ dry the electrode and flux
  - ✓ clean and degrease the work piece surface
- **Surface coatings**
  - ✓ clean the joint edges immediately before welding
  - ✓ check that the weld able primer is below the recommended maximum thickness

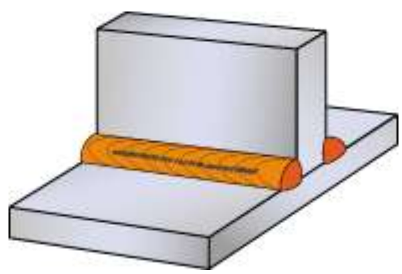


Figure 167: Elongated pores or wormholes

6.3. Cause

Wormholes are indicative of a large amount of gas being formed which is then trapped in the solidifying weld metal. Excessive gas will be formed from gross surface contamination or very thick paint or primer coatings. Entrapment is more likely in crevices such as the gap beneath the vertical member of a horizontal-vertical, T joint which is fillet welded on both sides.

When welding T joints in primed plates it is essential that the coating thickness on the edge of the vertical member is not above the manufacturer's recommended maximum, typically 20µm, through over-spraying.

- ***Prevention***

Eliminating the gas and cavities prevents wormholes.

6.4. Gas generation

- ✓ clean the work piece surfaces at and adjacent to the location where the weld will be made
- ✓ remove any surface contamination, in particular oil, grease, rust and residue from NDT operations
- ✓ remove any surface coatings from the joint area to expose bright material
- ✓ check the primer thickness is below the manufacturer's maximum

- **Joint geometry**
  - ✓ avoid a joint geometry which creates a cavity

6.5. Crater pipe

A crater pipe forms during the final solidification of the weld pool and is often associated with some gas porosity.

Cause

This imperfection results from shrinkage on weld pool solidification. Consequently, conditions which exaggerate the liquid to solid volume change will promote its formation. Extinguishing the welding arc will result in the rapid solidification of the weld pool. In TIG welding, autogenously techniques, or stopping the welding wire entering the weld pool before extinguishing the welding arc, will effect crater formation and may promote the pipe imperfection.

Prevention

Crater pipe imperfection can be prevented by controlling the rate at which the welding arc is extinguished or by welder technique manipulating the welding arc and welding wire

6.7. Defects may occur due to the following reasons;

- Incorrect welding parameters
- Inappropriate welding procedures
- Poor process condition
- Inappropriate selection of filler metal and parent metal
- Unskilled welder or welding operator
- Incorrect job preparations

6.8. Classification of Defects:

Defects can be classified as:

- **External defect** (also known as visual defect or surface defect):- found on the surface itself and
- **Internal defect** (also known as hidden defect or subsurface defect):- exist in the material at some depth.

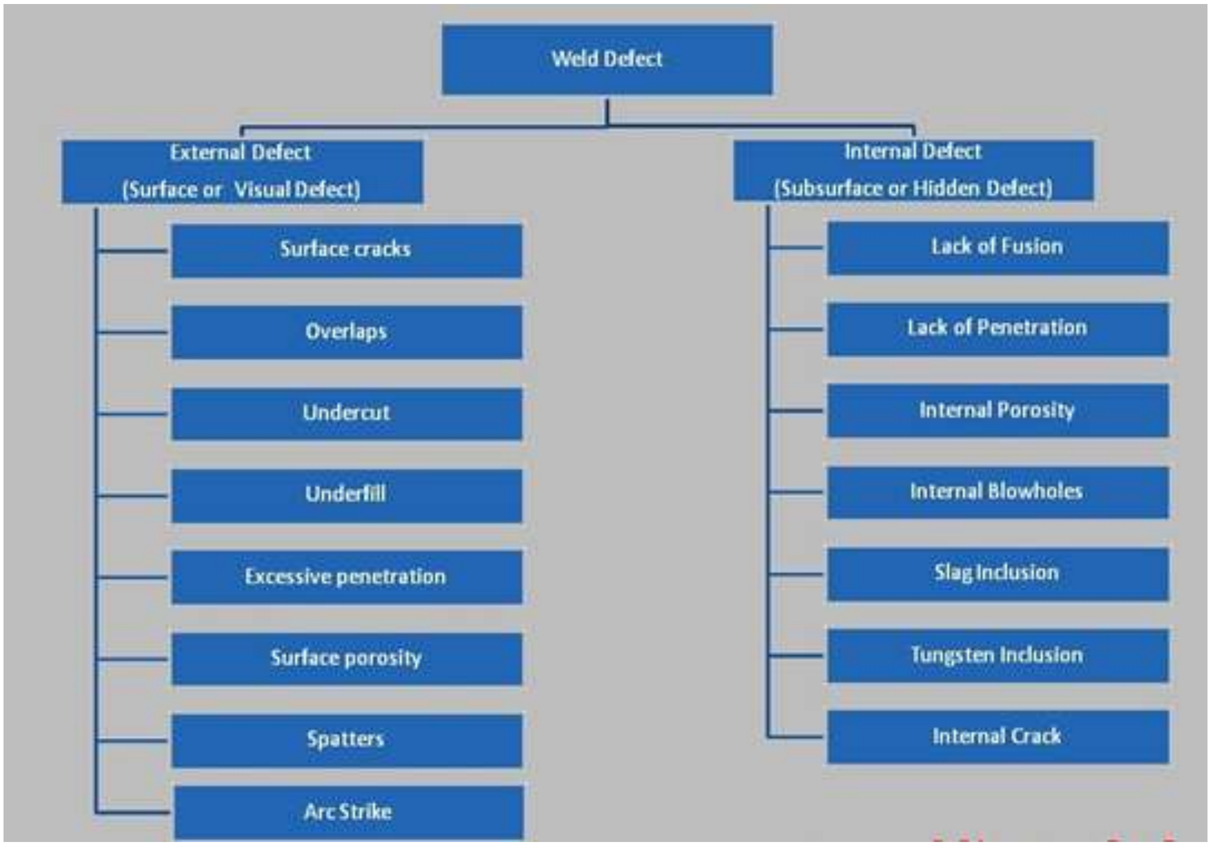


Figure 168: Weld Defects

- **CRACKS:** It is the most dangerous of all defects. Cracks may be of any size or shape; it can be either microscopic or macroscopic. Cracks may appear anywhere i.e. on the surface, subsurface, at any depth or at the root.

NB: Crack occurs when the localized stress exceeds the ultimate Tensile Stress (UTS) of the material. It may propagate within the material.

- **Cracks are of two types;**

  - ✓ **Hot Crack**
  - ✓ **Cold Crack**

HOT CRACK: Hot cracks occurs during welding or soon after completion of welding, it is most likely to occur during the solidification of the molten weld pool. Hot cracks mostly occur in the weld metal but it may occur at the Heat Affected Zone (HAZ) region too. When hot crack occurs on the weld metal then it is termed as **Solidification Crack** and if it occurs in the HAZ then called as **Liquation crack.**

Causes of Hot Crack:

- High concentration of residual stress
- Rapid cooling of weld pool
- High thickness of base material
- Poor ductility of welded material
- High welding current
- Inadequate heat treatment

Prevention:

- ✓ Preheating and post heating to avoid rapid cooling
- ✓ Using right filler metal

COLD CRACK: Cold cracks occur after the solidification of weld metal; it can even develop several days after completion of welding. Most of the time it develops in the HAZ but may occur on the weld metal too. It is often associated with non-metallic inclusion.

Causes of Cold Crack:

- ✓ **Diffusion of Hydrogen atoms:** Hydrogen atoms cause cold cracking. These hydrogen atoms may be induced in the weld metal from the surrounding, electrode, base metal or any contamination present on the root face.
- ✓ **Lack of Preheating:** Due to inadequate preheating, microstructural changes may take place. Microstructural crystals may re-structure itself to form marten site. Maten site is very prone to cracks. Preheating also helps in reducing diffusion of hydrogen atoms and ensures no moisture on the joint before welding.

Prevention:

- ✓ Preheating and post welding the weld metal
- ✓ Using low Hydrogen electrode

- **STAR CRACK (CRATER CRACK):**

Star crack is a type of hot crack and it develops at the crater on the weld metal. A crater is a depression formed on the weld bead where arc gets broken or when electrode is changed. It develops when center of the weld pool solidifies before its surrounding and due to this the center pulls the outer weld and thus star cracks are formed.

- **POROSITY/BLOW HOLES:**

Porosity is a small pore or void whereas blowholes are comparatively larger hole or cavity. It may be present on the surface or inside the weld metal. Porosity can occur individually or it may occur in groups also (mostly), group of porosity is known as **cluster porosity**.

Figure 169: Porosity

- **Causes of Porosity:**

  Porosity occurs due to the entrapment of gases in the molten weld pool, these entrapped gases doesn't get a chance to release and hence causes porosity or blowhole. Gases which are entrapped are mostly Hydrogen, Carbon mono oxide, Carbon dioxide, Nitrogen and Oxygen. Source of these gases are fluxes present on the welding electrode, Moisture, Oil, Grease other foreign contaminants present on the joint etc.

- **Prevention:**

  ✓ Use low Hydrogen electrode
  ✓ Baking of electrodes before welding as per the recommended procedure
  ✓ Through cleaning of joint surface and adjacent area before welding
  ✓ Preheat the joint before welding
  ✓ Ensure sufficient flow of shielding gases if using TIG or MIG welding

- **UNDERCUT:** Undercut appears as a narrow groove on the base metal adjacent to the weld metal along the edge. Undercut always runs parallel to the weld metal. It acts as a stress raiser during fatigue loading.

Figure 170: undercut

- **Causes of Undercut:**
  - ✓ High welding current and arc voltage
  - ✓ Large electrode diameter
  - ✓ Incorrect electrode angle
  - ✓ Longer arc length

- **UNDERFILL:** When the weld metal surface remains below the adjacent surface of the base metal then it is called as an under fill. Under fill is an undersized welding.

Figure 171: Under fill

- **LACK OF PENETRATION:** When the weld metal doesn't completely penetrate the joint, then it is called as Lack of Penetration of Incomplete Penetration. It is one of the most dangerous defects, since it acts as a stress raiser and hence crack may originate or propagate from here.

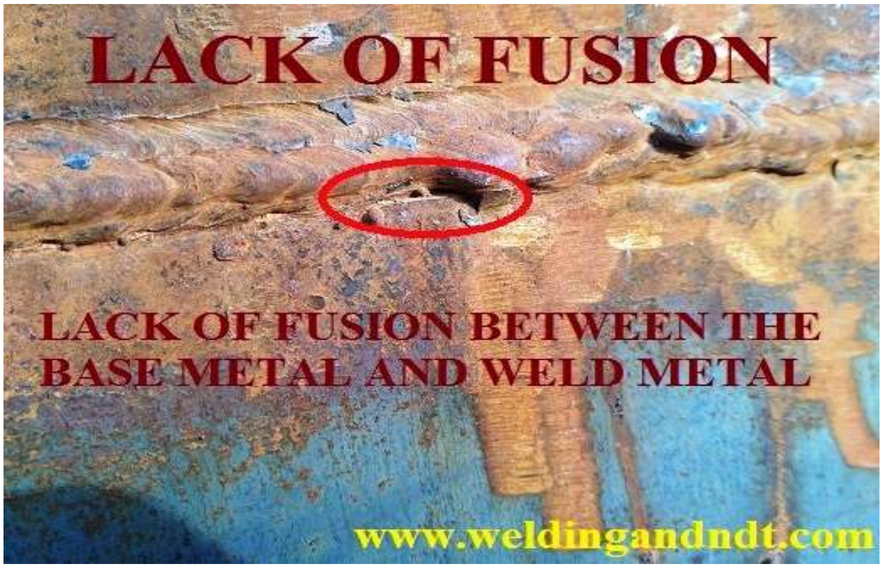
Figure 172: Lack of Penetration

Causes of Lack of Penetration:

- ✓ Root gap too small
- ✓ Fast travel speed
- ✓ Low heat input
- ✓ Too large an electrode diameter

- **Prevention:**
  - ✓ Proper joint preparation i.e. providing a suitable root gap.
  - ✓ Proper heat input
  - ✓ Correct travel speed
  - ✓ Using electrode of suitable size
  - ✓ Lack of penetration can be repaired by proper back gouging.

- **LACK OF FUSION:** It is the lack of proper melting (or proper fusion) either between the weld metal with the base metal or one layer of the weld with the other layer. Lack of fusion is also called as **cold lapping or cold shuts**. One of the most prominent reasons for the cause of lack of fusion is poor welding technique. Lack of fusion is an internal defect, but it can occur on the external surface too, if the sidewall of parent metal doesn’t get properly fused with the base metal, as shown in the below figure and for this case lack of fusion can also be called as **‘lack of sidewall fusion.**



Causes of Lack of Fusion:

- ✓ Low welding current
- ✓ Travel speed to high or too low
- ✓ Unfavorable heat input

- **SPATTERS:** Spatters are small globular metal droplets (of weld metal) splashed out on the base metal during welding. Spatters stick on the base metal hence can be removed by wire brush or buffing.

Figure 173: Spatters

- **Causes of Spatters:**
  - ✓ Excessive arc current
  - ✓ Excessive long arc
  - ✓ Improper shielding gases

- ✓ Electrode with improper flux
- ✓ Damp electrodes

- **OVERLAP:** Overlap occurs due to the overflow of weld metal on the surface of base metal. During welding, molten metal overflows on the base metal without fusing with the base metal.

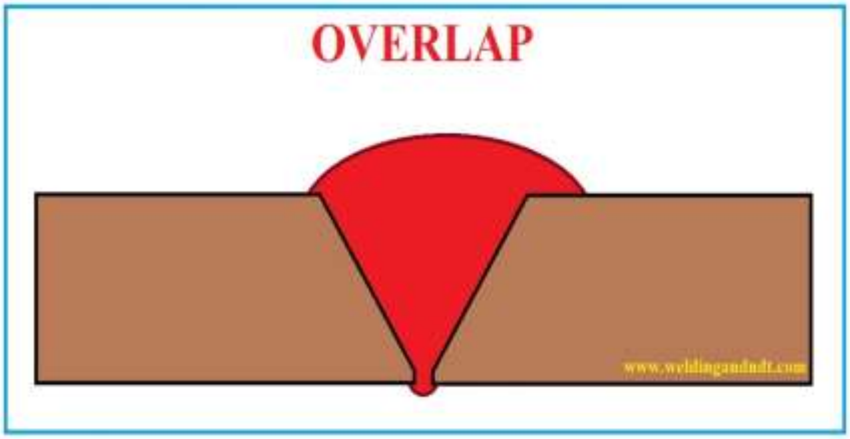


Figure 174: Overlap

Causes of Overlap:

- ✓ Current too low
- ✓ Large deposition in a single run
- ✓ Longer arc
- ✓ Slow arc travel speed

- **EXCESSIVE PENETRATION:** When the penetration of weld metal is too high through the joints then it is called as excessive penetration. It acts as notch where stress concentration takes place. In addition to this it results in economical wastage.

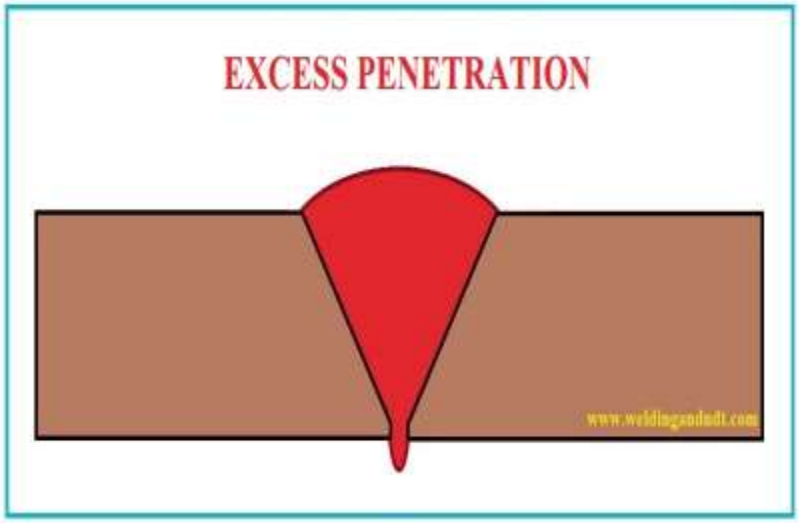


Figure 175: Excess Penetration

Causes of Excessive Penetration:

- ✓ Too wide a root gap
- ✓ High welding current
- ✓ Slow travel Speed

- **INCLUSION:** Entrapment of any foreign material (either metallic or nonmetallic) in the weld metal is called as inclusion. If slag doesn't get a chance to float over the surface of molten weld pool, then it gets entrapped within the weld metal such inclusion is called as slag inclusion. Similarly, sometimes droplets of tungsten get entrapped within the weld metal resulting in tungsten inclusion (in TIG welding). Sulphides, oxides and silicates also get entrapped resulting in inclusion. Inclusion acts as a stress raiser hence should be avoided.

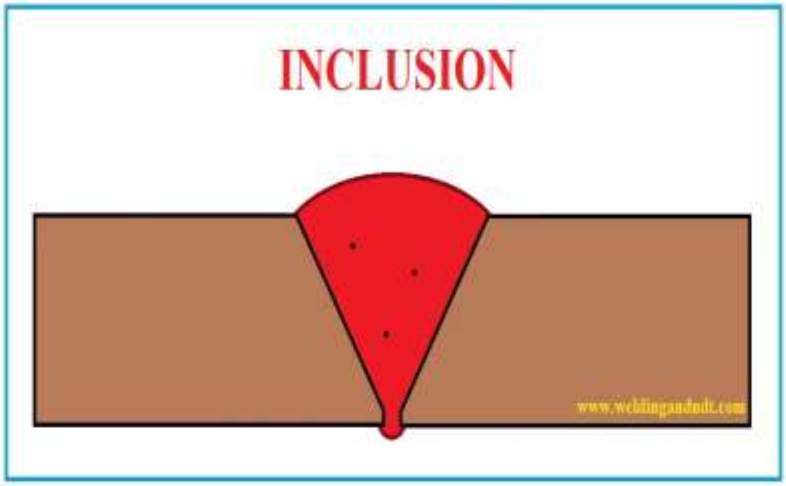


Figure 176: Inclusion

- **WAGON TRACKS:** Linear slag inclusion along the axis of the weld is called as wagon tracks. During **root pass** a groove is formed at the toe, due to wrong welding techniques, and that groove is filled by slag (especially Hydrogen which has been trapped by the solidified slag) and thus wagon tracks are formed. It is also known as **worm tracking.**

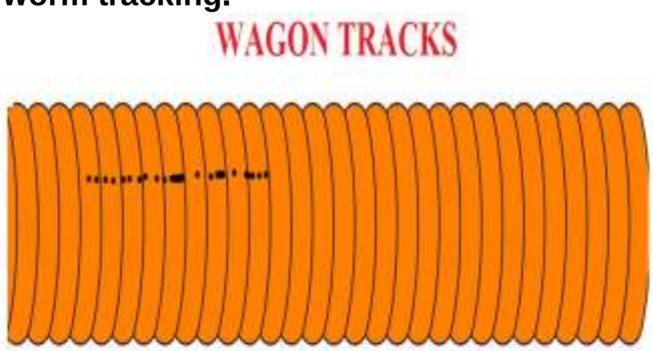


Figure 177: Wagon Tracks

- **ARC STRIKE:** When the electrode or the electrode holder, unintentionally or accidentally strikes with the work piece, an unwanted arc is generated causing arc strike. Arc strikes may initiate failure in bending and cyclic loading. In addition to this is affects the aesthetics of the work piece.
- **SHRINKAGE CAVITY:** During solidification of the molten weld pool, metal shrinkage occurs. Due to the shrinkage of weld metal a cavity is formed known as shrinkage cavity.

Please click here, to read the acceptance/rejection criteria for weld defects.
Please watch this video lecture (given below) for a better understanding of welding defects:

Self-Check-9	Written test

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

Say true or false for the following questions below

1. Welding defects can be defined as weld surface irregularities, discontinuities, imperfections, or inconsistencies that occur in welded parts.
2. Parent metal or electrodes may be subjected to atmospheric contamination.
3. The High flow rate of the gas shield may cause turbulence due to which air can be drawn into the weld metal.
4. Too much longer arc length (high voltage) is also a cause of weld porosity.
5. Welding flux must be treated with great care as they have the capability to absorb moisture (granular SAW flux).
6. Cracks may be of any size or shape; it can be either microscopic or macroscopic.
7. Hot cracks occurs during welding or soon after completion of welding, It is most likely to occur during the solidification of the molten weld pool.

Note: **Satisfactory rating 5and above points Unsatisfactory - below 3 points**

Score = ___________

Rating: ____________

Reference

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Solar PV System Installation and Maintenance

Level-II

Learning Guide -25

Unit of Competence	**Perform Simple Welding**
Module Title	**Performing Simple Welding**
LG Code	EIS PIM2 M06 LO7 LG-25
TTLM Code	EIS PIM2 TTLM 0120V1

LO7: Ensure weld conformance

Instruction Sheet	Learning Guide: - 25

This learning guide is developed to provide you the necessary information, knowledge, skills and attitude regarding the following content coverage and topics:-

- Removing defects with minimum loss of sound metal
- Inspecting Weld joints visually
- Completing weld records and completion details
- Observing OHS procedures

This guide will also assist you to attain the learning outcome stated in the cover page. Specifically, upon completion of this Learning Guide, **you will be able to:-**

- Remove defects with minimum loss
- Inspect Weld joints visually
- Complete weld records and completion
- Observe OHS procedures

Learning Instructions:-

1. Read the specific objectives of this Learning Guide.
2. Follow the instructions described below 3 to 6.
3. Read the information written in the information Sheet 1, Sheet 2, Sheet 3, Sheet 4, in pages 250,264,277 and 283 respectively.
4. Accomplish the Self-check 1, Self-check 2, Self-check 3, Self-check 4 in pages 263,274,282 and 290 respectively
5. If you earned a satisfactory evaluation from the "Self-check" proceed to Operation in page 275
6. Do the "LAP test" on page 276

Information Sheet-1	Removing defects with minimum loss

1.1 Definition of defects

- **Defect** In other words, a **defect** is an error in coding or logic that causes a program to malfunction or to produce incorrect/unexpected results. A program that contains a large number of bugs is said to be buggy. **Defect removal** is one of the top expanse elements in any software project.
- **Effective defect removal leads to:**
  - ✓ Reduced development cycle time
  - ✓ Reduced product cost
  - ✓ Improved product quality
  - ✓ Increased customer satisfaction
- **How to control welding defects**

  Remedies:
  - ✓ Preheat the metal as required.
  - ✓ Provide proper cooling of the weld area.
  - ✓ Use proper joint design.
  - ✓ Remove impurities.
  - ✓ Use appropriate metal.
  - ✓ Make sure to weld a sufficient sectional area.
  - ✓ Use proper welding speed and amperage current.
  - ✓ To prevent crater cracks make sure that the crater is properly filled.
- **Prevention and repair**

  Most defects in various hard chromium deposits arise from defects in the basis metal. These defects may be in the original metal surface or may be caused by pre plate finishing. Homogeneous hard chromium deposits can be produced only by eliminating these defects. The final segment of this article describes visual and provocative methods of detecting defects. Also discussed are prevention techniques and repair operations.

  Welding procedure review is necessary to ensure welding production is in compliance with all applicable standards and codes.
  - ✓ Verify proper material based on test reports and certificates furnished.
  - ✓ Witness, inspect and certify that all structural steel, including fasteners, have been fabricated in accordance with the requirements of the contract documents.
  - ✓ Review fabricator’s welder certifications, CWI certifications, and NDT certifications.

- ✓ Verify compliance though visual inspection of base metal surfaces and edges for conformance to applicable ASTM specifications. Verify heat numbers and proper storage procedures of base metal.
- ✓ Perform dimensional inspection.
- ✓ Monitor and review reports of nondestructive testing, if applicable, performed by fabricator for compliance to project specifications
- ✓ Perform visual welding inspection of joint preparations, proper use of consumables, and compliance to approved procedures and codes

1.2. Inspection

The type and degree of inspection depends on the following factors:

- ✓ The size, volume and value of the parts.
- ✓ Specifications for the plated product.

Particularly on large parts, one of the most satisfactory and least costly inspection systems requires that each operator examine his own work. Thus, the grinder, polisher, blaster or honer will not spend valuable time finishing a defect-exhibiting work piece detrimental to the final product. Similarly, the degreaser, racker and plater all have an obligation to spot defective surfaces and poor workmanship, and, most importantly, to report them.

The plater's inspection is of paramount importance because it is the last before the finish is applied. If he can pinpoint a defect that might cause the plated work to be rejected, he will have saved the cost of plating, stripping, refinishing, re-stopping off, and re-racking. Even more important is the possible erosion of customer goodwill, the loss of valuable production capacity, and the delay in processing other work. All of these drawbacks could be avoided if management or the plating department would insist on thorough inspection immediately before electro deposition.

Not all defects can be spotted with the naked eye, so it is sometimes necessary to resort to tools or special procedures such as:

- ✓ Visual inspection without magnification but under good light.
- ✓ Inspection with low-power magnification.
- ✓ Microscopic examination of critical or suspicious areas. (For example, engraved rolls and plates are normally inspected microscopically before plating to detect the presence of ink or defects.)
- ✓ Magnetic particle inspection" for cracks.
- ✓ X-ray inspection, primarily for weld assessment.
- ✓ Ultrasonic flaw detection, chiefly for sub-surface voids and laminations.
- ✓ Dye-penetrant examination to expose pits and cracks (several commercial products are available).
- ✓ Etching to detect cracks (see "Provocative Detection Methods").
- ✓ Hydrogen charging to detect blisters and lamination (see "Provocative Detection Methods").
- ✓ Checking for pits or cracks by noting dark bleed out spots as the work dries after degreasing, alkaline cleaning, acid pickling or electrolytic etching
- ✓ Measuring to determine surface roughness.
- ✓ Examining after polishing, buffing, vapor blasting or fine-grit blasting

- **Repair of basis metal**

After detecting basis-metal defects and determining that they must be corrected and that the customer or management will pay for all repair work, the plater must select the best means of reparation. Among these is dot welding, plugging, welding, sealing, and resin-filling.

- **Dot welding**

The least expensive and usually the fastest of the various basis-metal repair methods is dot welding. Skilled workmen can perform 20 to 40 such repairs per hour. For most ferrous alloys other than the stainless steels, a low-carbon steel ball is preferred. For stainless steels or chromium-plated surfaces, a 410-grade SS ball is recommended. Pure nickel balls are required for welding on nickel electrodeposits.

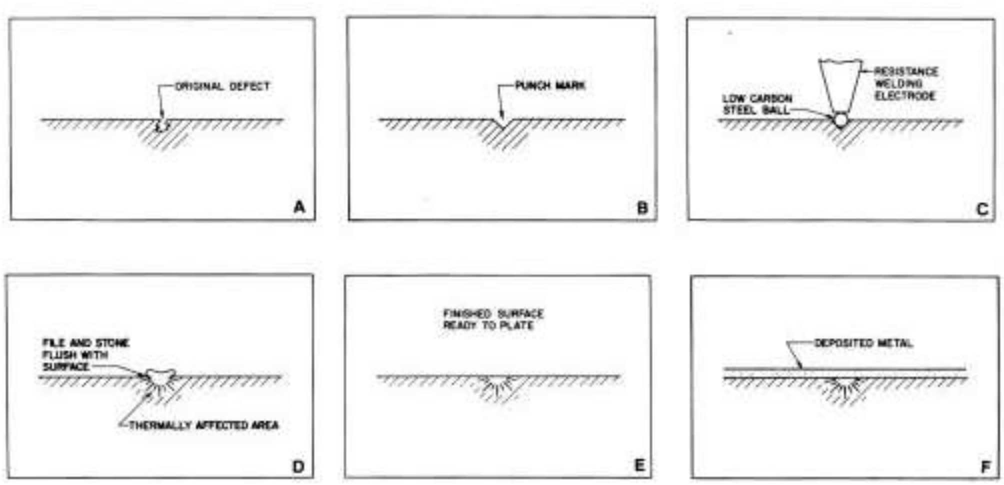

Figure 178: Steps for repairing basis-metal defects using dot welding.

When repairing some high-strength or hardened dies and molds, it may be advantageous to use a ball of an alloy as similar to the basis metal as possible. Either 1.5- or 3.0-mm-diameter (0.062- or 0.125-in.-diameter) bails are adequate for most repairs. The welding operation is performed with a low-power electrical resistance welder.

- **The repair procedure is as follows**:

  - ✓ Prick-punch or grind a small depression to remove the defect (Figs. 1a and b).
  - ✓ Place the ball in the depression.
  - ✓ Electrically ground the work to the welder.
  - ✓ Place the electrode firmly on the ball (Fig. 1c) and press the switch (Fig.1d).

The current and timer settings must be selected prior to welding by determining the correct transformer setting for the bail size on a test piece. The same current normally can be used with the same ball diameter.

- ✓ File the weld close to the surface using a "safe" file (*i.e*., a smooth, diagonally cut file with taped or rounded edges).
- ✓ Finish the weld by smoothing it flush with the surface (Figs. 1d and 1e) using a strip of aluminum oxide cloth wrapped around a smooth file or with an appropriate hand stone - each with rounded edges. The stone or abrasive covered file should be held at an angle of 45 degrees to the direction of the grinding or polishing scratches; the motion of hand finishing should be in the direction of the grinding pattern. Usually, 120-grit abrasive is satisfactory. A relatively coarse abrasive removes the weld quickly and a finer abrasive can then be used to remove the original scratches if necessary.
- ✓ Inspect with a 10X magnifying lens to be sure the weld is free of pits or cracks. If the weld is not perfect, repeat the process.
- ✓ Repolish the entire repaired area to remove all traces of scratches from hand polishing

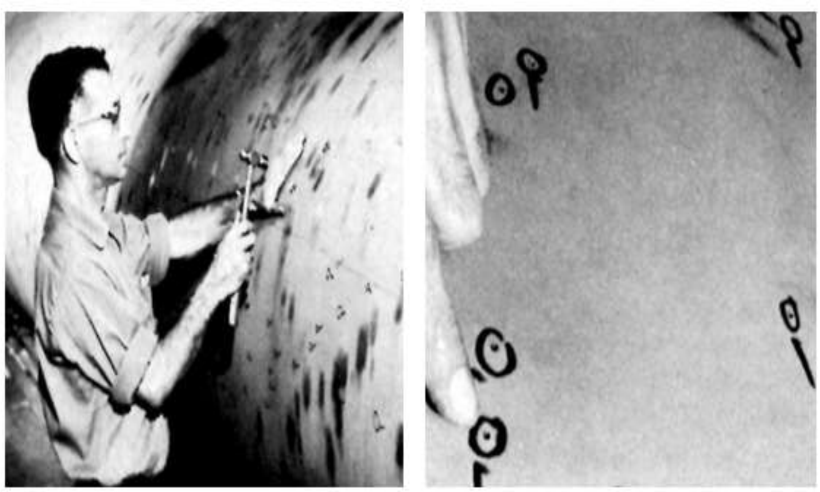

Figure 179: Plugging defects in the surface of a large cast-iron drum.

- **Plugging**

This procedure is more costly and slower than dot welding (10 to 30 plugs/hr in "soft" metals with noncritical finishing requirements) but is capable of providing perfect repairs consistently. It can be used on all ferrous (Fig. 2) and most non-ferrous basis metals. Oil hardening drill rod plugs are suitable for all non-stainless ferrous alloys. Precision ground cold-rolled steel may be used for very large plugs (*e.g*., larger than 6 mm, or 1/4 in., in diameter). Stainless-steel rod of the same grade as the basis metal is preferred for SS alloys. Phosphor-bronze rod is the best selection for plugging copper and most copper alloys because of its stiffness and desirable malleable characteristics. Hard-drawn copper wire or rod may be used in large sizes if desired, but it may be too soft to use for holes smaller than 3 mm (0.125 in.) in diameter. Hard drawn pure nickel wire (grades 200 or 201) should be used for repairing nickel electrodeposits. The procedure for plugging any basis metal is as follows:

- ✓ Prick-punch the defect and drill a hole approximately 5 to 2.5 times the drill diameter in depth (Fig. 3). The ratio of depth to diameter decreases with increasing diameter. For example, a hole diameter of 6 mm (0.25 in.) requires a ratio of only 0 to 1.5. Most plugging is performed with Drill #'s 52 through 30, ranging in diameter from 6 to 3.26 mm (0.0635 to 0.1285 in.). Although plugs as large as 12.5 to 19 mm (0.5 to 0.75 in.) have been used successfully, they are rarely required.
- ✓ Fit an appropriate rod, one drill size smaller than the tool, into the drilled hole loosely in such a manner that it rests firmly against the bottom. The hole must be clean, without any debris. The edge at the surface must be uniformly sharp and free of burrs. The end of the rod inserted into the hole must be fiat or tapered to the shape of the drill point (Fig. 3c).
- ✓ Snip or saw the rod about 6.4 to 12.7 mm (0.25 to 0.5 in.) above the surface and file the end flat.
- ✓ Swage the rod tightly into the hole with a series of firm hammer blows. A 2- to 4-oz ball peen hammer is large enough for the commonly sized rods. It is essential that the hammer be heavy enough to transfer the force of the blow through the rod to the bottom end, which must expand first if the hole is to be completely filled by the plug. The space provided by the slightly loose plug permits all air to escape as swaging progresses (Fig. 3d).
- ✓ If necessary, shorten the length of the rod that extends above the surface, before swaging is complete, to avoid bending the plug and to provide a perfectly tight seal between the plug and the basis metal at the surface.
- ✓ When swaging is complete, cut the rod off close to the surface and file it as close as possible with a "safe" tool. Finally, smooth the rod flush with aluminum oxide cloth on a file or with an abrasive hand stone as described under the section on dot welding.

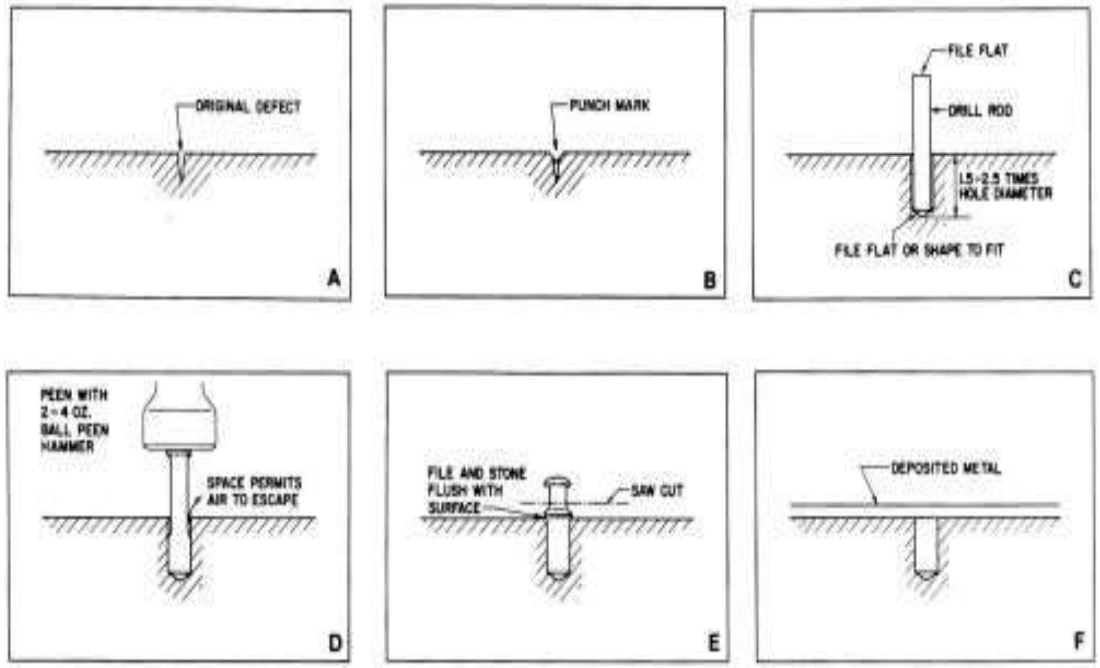

Figure 180: Steps for repairing basis-metal defects by plugging.

Large plugs are occasionally "fitted" by shrinking them in dry ice or liquid nitrogen and dropping them into holes drilled slightly smaller than the plug, usually 0.025 to 0.037 mm (0.001 to 0.0015 in). The plug must be left slightly longer than the depth of the hole so that it can be peened and finished in the manner described above after the plug was fully expanded. Very large plugs may be threaded and screwed into tapped holes that have been counter bored to remove the top two or three threads. The plug or rod should be threaded for a distance just long enough to fit firmly in the bottom of the hole. The unthreaded portion of the plug then may be cut off slightly above the surface after the rod has been screwed tightly into the hole with a pipe wrench. The unthreaded end must fit the counter bore snugly. The plug then may be swaged tightly into the hole. It is customary on large threaded plugs to insert a small plug in the edge of the large one. This dissects the circumference of the plug and acts as a key to lock it securely. The method may be useful in filling unwanted holes drilled inaccurately or made obsolete by design changes.

- **Welding**

Large cracks, deep blisters, defective welds, large damaged areas and similar defects often can be repaired by heliarc or submerged arc welding. The welder should be certified and licensed to repair high-pressure vessels. The work should be prepared for welding by grinding out the defect. This type of repair must never be undertaken by a plater without the full knowledge and approval of the customer or the metallurgical and engineering departments.

Brazing or silver soldering may be used successfully on copper and copper alloys but is not recommended for repairs to ferrous alloys unless they are to be plated with a seal coat of 0.025 to 0.05 mm (0.001 to 0.002 in.) of cyanide copper before chromium plating.

- **Sealing with undercoat**

It may be cheaper to apply a suitable undercoat of copper, iron, nickel or chromium beneath the final layer of chromium if the basis metal is very porous, as typified by some cast metals, sprayed metallic coatings or components formed by powder metallurgy.

Electrodeposited copper is suitable for sealing many non-ferrous basis metals, and has been used successfully on a variety of ferrous castings or porous steel components not subjected to severe pressure or stress. A cyanide strike must be used to cover ferrous base metals; thereafter, an acid copper sulfate bath is employed to fill minute pits and pores because of its excellent micro throwing power. Typical thickness may range from 0.075 to 0.75 mm (0.003 to 0.030 in.). The heavier copper deposits are usually precision ground before chromium plating to avoid distorting the contours of the work and/or cutting through the chromium as it is being finished. Typical applications for copper undercoats include conductor rolls for continuous strip plating and printing rolls and plates. Copper is not recommended as an undercoat for tools, dies, bearings or most hydraulic applications.

Iron and nickel are also considered excellent under coatings for functional chromium deposits. The under coatings must be deposited from physically clean, chemically pure plating baths without brighteners. Both Watts and sulfamate nickel baths are used successfully. Iron may be plated from the chloride, sulfate or mixed chloride/sulfate baths. Deposits usually range from 0.13 to 1.3 mm (0.005 to 0.050 in.) although a minimum of 0.25 mm (0.010 in.) should be deposited on roils and other simple shapes to seal most of the porosity. Obviously, any decision to utilize an undercoating must include dimensional clearance for the extra deposit thickness before plating. The cost of such an undercoating is frequently insignificant when compared with the value of the work being plated. The pore free finish obtainable by this type of repair is not achievable by any other means at a comparable cost.

- **Resin filler materials**

Very porous basis metals are sometimes filled with a suitable resin prior to chromium plating. Vacuum impregnation with epoxy or polyester resins may be beneficial for sealing pores in sprayed or powder formed metals. The technique is limited to relatively small articles, due to the requirement that they be completely evacuated in a vacuum chamber. When the pores have been filled and the resin has set, the excess resin must be removed from the surface by polishing or grinding. Because the open pores are completely sealed, hydrogen gas cannot be evolved. Chromium will readily bridge the nonconductive steel resin if the width of the defect is significantly smaller than the thickness of the deposit. Figure 4 shows a defect that is wider than the thickness of the deposit and that has been partially plated over with chromium. The possibility of having bleed-out or staining problems will be either eliminated or greatly reduced.

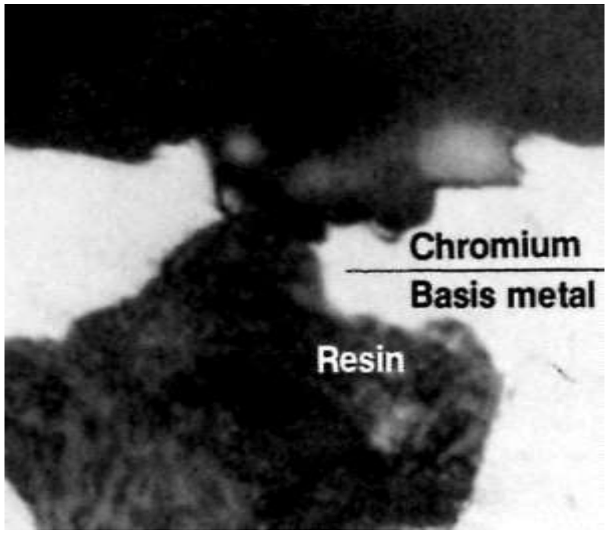

Figure 181: Chromium deposit partially bridging a resin-filled void.

There are metal-filled resins on the market that may be of some value for filling small voids before chromium plating. However, the strong oxidizing action of chromium plating solutions will attack many otherwise chemically resistant resins. Therefore, most metal-filled resins are better suited for use prior to depositing under coatings of copper, nickel or iron than for direct deposition of chromium. The technique must be limited to very small defects to avoid the presence of inadequately supported chromium. If the area is sufficiently small (*e.g.*, less than 0.13 mm, or 0.005 in., in diameter) the chromium will withstand normal thermal and mechanical stress without failure when plated at a thickness greater than 0.13 mm.

- **Repair of plated deposits**

In spite of careful basis-metal preparation and clean, well-balanced plating solutions, defects occasionally appear in the finished work. Improper handling of a plated part in the customer's plant or in the plating shop, or an accident in the functioning of a component in service, may result in a minor defect on an otherwise perfect chromium-plated surface. The cost of removing a large part from service, plus the expense of stripping and completely refinishing, makes local repair of the damage or defect a very attractive alternative.

To be able to make satisfactory local repairs adds an important new dimension to a functional-chromium plater's capabilities. It provides a relatively inexpensive, usually completely satisfactory method of puffing the part back into service with a minimum loss of production. It also offers a superior technique of providing flawless surfaces by permitting repairs to a preliminary deposit of chromium, which can then be given a final flawless deposit. The repair of finished surfaces requires highly developed skills because the possibility of accidental damage during processing prevails.

- **The procedure for repairing a pit originating in the basis metal of a chromium-plated surface is summarized below:**

  ✓ Protect the surface not involved in the repair from mechanical and chemical damage.

  ✓ Grind the defective area to the basis metal, using a small high-speed hand grinder with an aluminum oxide ball point, 3 to 6 mm (1/8 to 1/4 in.) in diameter, or a suitable conical abrasive point. The initial grinding may be performed with a relatively coarse abrasive, but it may be necessary to finish with a fine grinding point or a cloth abrasive wheel. This will produce a sufficiently smooth surface so that the defect can be seen when the basis metal is exposed. A change in the sparks from the bright white of chromium to the distinctive yellow or orange spark of a ferrous metal will reveal the exposure of steel. For confirmation, the ground depression may be wiped with a mildly acidic solution of copper sulfate.

  ✓ Copper will deposit by immersion on any non stainless ferrous alloy, clearly showing the extent of the exposed basis metal. A dial type depth gage, divided into units of 5 or 5.0 μm (0.0001 or 0.0002 in.), and mounted in a V-block, can be used to measure the depth of the hole from the plated surface or the deposit/basis-metal interface. If the defect is quite shallow (less than 0.08 mm, or 0.003 in.), it may be removed by grinding. If the defect obviously cannot be removed at this depth, it is usually advantageous to repair the defect by plugging or welding before attempting plating.

  ✓ After the repair has been made and the plug or weld has been ground flush with the surface of the basis metal, shape the edges of the chromium by grinding with a 3-mm-diameter (1/8-in.-diameter) ball point or cylindrical stone to provide a contact angle of approximately 60 degrees between the basis-metal surface and the wail of the depression (Fig. 5). The purpose of providing this steep angle is to minimize the breadth of the exposed interface between the original deposit and the repair deposit. Because the surface is etched for better adhesion before the repair layer of chromium is applied, a low angle (*e.g.*, 15 degrees) will show an unsightly (etched) ring after the final grinding step.

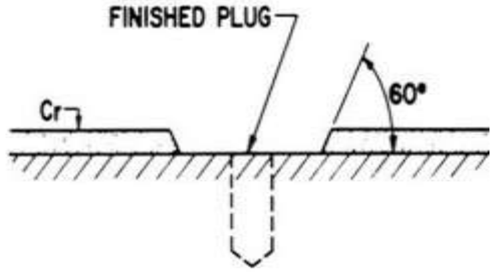

Figure 182: Repaired surface prior to spot chromium plating.

- ✓ Carefully inspect the area to be plated with a 10 or 20× magnifier to be sure that no pits or imperfections remain. The area surrounding the prepared spot should be washed thoroughly with lacquer thinner and masked with a thinned (50%) stop-off lacquer. The thinned prime coat is then followed by several layers of un thinned lacquer. The area of each spot to be plated must be measured carefully by tracing the spot on 1.0-mm (0.1-in.) square-grid graph paper or by checking the area against the size of a dowel that will just cover it. The areas must be recorded for use in calculating the plating current to be used.
- ✓ (**A).** Construct a cell with PVC plastic pipe, vinyl plastisol-coated steel, a well-lacquered paper cup (or ice cream carton), or by welding sheets of PVC plastic. A single spot cell normally would measure 7 to 12 cm (3 to 5 in.) in diameter. The bottom of the cell must be carefully fitted to the contour of the work surface by shaping it against a piece of coarse abrasive cloth taped to the surface. The bottom edge of the cell must then be coated with thinned (50%) lacquer. As soon as the lacquer is dry, the cell is centered over the stopped-off area and lacquered to the work surface with several coats of un thinned lacquer applied to both the inner and outer edges of the cell and adjacent lacquered surface (Fig. 6).

Figure 183: Cell with surface thermostat and strip heaters ready for local repair by plating.

- ✓ (**B)** An alternate type of cell is a permanent unit containing an anode, inlet and outlet connections through which plating solution may be pumped. The cell is fitted with a resilient gasket of Viton or Hyperon to make a liquid-tight seal when the cell is clamped tightly against the work. The gasket can be provided with a hole shaped precisely to fit the area to be plated or it can be oversized and applied to a surface stopped-off as described in Step 5 above.
- ✓ Heat the work surface. Hollow parts such as drums and many rolls can be heated by flowing steam or hot water through them. The surface also can be heated by the application of electrical strip heaters; in any event, it is advisable to control the temperature of the surface automatically with surface-mounted thermostats connected to the heat source through control switches or valves.

  In the system described in Step 5, the heat can be controlled by a thermostat in the plating solution. This method is generally satisfactory but the response to the thermostatic signal is a little slower than that attainable with surface-mounted thermostats. Separate control of surface and solution temperature is required when the method described in Step 5A is selected. If both the solution and surface temperatures are not controlled, a relatively large volume of metal in the work could act as a heat sink, preventing the work from reaching the desired plating temperature. The result of this condition might be poor adhesion and/or sub-par deposit quality.

- ✓ Using the system described in Step 5, fill the cell with clean water and apply heat to the work surface. Using the Step 5A system, apply heat to both the solution reservoir and the work surface.

- ✓ While the work is heating, position the anode in the cell, approximately 6 mm (0.25 in.) above the center of the area to be plated. (The anode is normally a piece of 3-mm-diameter, 6-percent antimony/lead alloy or 40-60 tin-lead solder wire, but never acid or resin-cored solder.) The size of the anode and its exact location are not critical unless several spots are to be plated in one cell or in several connected to the same power source. In either case, it then becomes essential that the anode size, anode-to-cathode distance, and depth of the various defects be considered carefully when positioning each anode. If all of the spots are approximately equal in diameter and length, the anodes can be equal in diameter and spacing. When the spots vary considerably in diameter and depth, the plating rate can be equalized within reasonable limits by spacing the anode closer to a deep hole than to shallower ones or farther away from small-diameter holes and closer to larger spots of approximately the same depth. In this manner, it is possible to connect several repair spots to a single current source and have them all plated within 1 or 2 hr of one another. In Step 5A, it is customary to use only one cell per current source because the method lends itself to rapid deposition.

- ✓ Make electrical connections to the work and the anode from the power source. A small dc rectifier (10 to 20 A, 6 to 12 V) carefully filtered to provide an ac ripple no greater than 1 or 2% and having a continuously variable transformer, an ammeter that has divisions no larger than 0.1 A, and a voltmeter with 0.1-V divisions are recommended. Many of the rectifiers supplied to perform plating tests in beakers or Hull Cells may be suitable, but it might be necessary to install a small, accurate bench-type ammeter (*e.g.*, the Weston Model No. 281) to the circuit.
- ✓ When the water in the cell has reached the desired plating temperature, adjust the thermostat to shut off at that figure - normally, 52 to 60°C (125 to 140°F). Maintain the temperature within ±1.0°C (±2°F) of the chosen setting. The water then may be replaced with room temperature chromic acid plating solution. The most commonly used formulation contains 250 g/L of chromic acid and 2.5 g/L H_2SO_4.
- ✓ When the solution temperature reaches the etching temperature (43°C, 109°F) apply current to the work anodic ally for 10 to 30 sec at 15 to 30 A/dm^2(1-2 A/in.^{2}) to etch the exposed chromium and the basis metal. Higher temperatures result in shorter etching times, but special pretreatment of either the basis metal or the chromium may be required to assure that each metal receives an adequate etch. Spots to be repaired using the cell described in Step 5A should be given this pretreatment.

  Either type of cell can be constructed from a transparent plastic material that facilitates centering the cell over the spot to be plated. When all electrical and solution connections have been made to the cell, the pump may be started and the heaters on the surface and in the solution reservoir turned on at approximately the same time, depending on the volume of solution and the mass of the part to be plated. Introducing ambient-temperature solution to the cell before the plating temperature has been reached will prevent etching. Yet the plating solution will do some minor cleaning and activating while it is in the cell. There are many techniques that have been used successfully, and any skilled worker will soon develop preferences, depending on the type of work he is required to repair and his experience.

- ✓ Following etching, reduce the rectifier current to zero with the variable transformer. The voltage should be set at 2.0 V and increased in increments of 0.1 V every 15 sec until the calculated plating current has been reached. The current density can range from 20 to 90 A/dm^2 (1.5 to 6.0 A/in.^{2}), depending on the temperature. Average current densities are 20 to 45 A/dm^2(1.5 to 3.0 A/in.^{2}) at 45-60°C (113 to 140°F). Higher current densities may be used with Step 5A. Excessively high current densities cause rapid treeing or nodule development at edges of the spot, resulting in lower effective current densities, reduced plating speed and possible shorting of the anode/cathode circuit. The deposition time must be calculated from a conventional plating-speed table to permit overplating by 2.5 to 5 µm (0.001 to 0.002 in.). The deposit must be plated to the minimum thickness or heavier to avoid reworking the repair. The solution level should be maintained with water to compensate for evaporation; very little chromium is consumed. It is desirable to cover the cell with a plastic bag to prevent mist from escaping to the air.

- ✓ When plating is complete and the cells removed, grind the excess chromium close to the surface using the stop off lacquer as a gage. Next, remove the lacquer and stone the remaining chromium flush with the surface. Use the same diagonal stone angle recommended for hand-stoning plugs or welds. Silicon carbide stones (60 to 120×) lubricated with kerosene or light oil are commonly employed.
- ✓ Prepare for additional finishing, which is always required - even if the repair is in the first of a multiple-layer chromium deposit - in order to blend the repaired deposit into the old chromium. Grinding, belt polishing, and buffing are commonly used although honing, super finishing, lapping and other methods are sometimes employed.

Self-Check-1	Written test

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

Say true or false for the following questions below

1. Effective defect removal leads to reduced product cost.
2. Remedies welding defects preheat the metal as required.
3. Defect removal is one of the top expanse elements in any software project
4. The least expensive and usually the fastest of the various basis-metal repair methods is dot welding.
5. Plugging is more costly and slower than dot welding.
6. Electrodeposited copper is suitable for sealing many non-ferrous basis metals.
7. Iron and nickel are excellent under coatings for functional chromium deposits.

Note: **Satisfactory rating 5 and above points Unsatisfactory - below 4 points**

Answer Sheet

Score = ____________

Rating: _____________

Information Sheet-2	Inspecting Weld joints visually

2.1. Definition of Inspecting Welding

- **Visual Inspection Procedure of Weld Joints.** Visual examination is the most important and the most universally accepted method of inspection. This procedure covers the visual examination of welding in components such as plates, welds, etc. by using Visual and Optical aids and Gauges.

Visual inspection is probably the most underrated, and often misused, method of welding inspection. Because of its simplicity, and the absence of sophisticated equipment, the potential of this method of inspection is quite often underestimated. Visual inspection of welding can often be the easiest to perform and is usually the least expensive to conduct. If carried out correctly, this type of inspection can often be an extremely effective method of maintaining acceptable welding quality and preventing welding problems. There are many areas within the welding operation that can be verified and evaluated by this method of inspection.

When designing an inspection plan, we need to establish the most appropriate areas to apply our inspection. We need to consider the possibility of preventing welding related problems, rather than finding problems which may have already occurred. Non- destructive testing (NDT), which is typically used for the inspection of completed welds, is usually designed and conducted to find welding problems after the fact, when the weld is completed. Visual inspection can often be utilized to prevent welding problems from happening in the first place. The welding inspection function is often divided into three areas.

First, and often the least utilized, is pre-weld inspection. This type of inspection can often provide us the opportunity to detect and correct unacceptable conditions before they develop into actual welding problems. Second, inspection during the welding operation can often prevent problems in the completed weld through verification of the welding conditions and procedural requirements. Third, post-weld visual inspection is a relatively easy method of conducting completed weld quality evaluation. We shall consider each of these inspection stages in more detail.

2.2. Pre-Weld Inspection

This inspection is conducted prior to the start of the welding operation. This type of inspection is typically associated with checking the preparation of the welding joint and verification of parameters that would be difficult or impossible to confirm during or after welding. This is the area of inspection where we can best introduce controls that may prevent defective welding. Some areas of pre-weld inspection are joint preparation inspection/pre-weld setup. This may involve the dimensional inspection of root openings. Root openings that are too tight can cause inadequate root penetration. Root openings that are too large can cause over- penetration.

Groove weld bevel angles, if too small, may cause lack of fusion, and if too large, can result in distortion of the weld joint from overheating and excessive shrinkage stress. Joint alignment (misalignment of the weld joint) can result in difficulty in producing a sound weld and stress concentration at its location, resulting in a reduction of fatigue life. Plate surface condition and cleanliness, pre-cleaning prior to welding, can often be of extreme importance. Improper or inadequate cleaning can result in unacceptable levels of porosity in the completed weld. Other pre-weld inspections may include preheat verification, temperature and heating method, presence and location of heat treatment monitoring devices, and type and efficacy of gas purging, if applicable.

Pre-weld inspection may also include evaluation and verification of documentation, material certification; filler alloy certification, welder performance qualification, welding procedure qualification, and welder and weld identification, for traceability, if applicable.

2.3. Inspection during Welding

This is the inspection that is carried out during the welding operation and is concerned mainly with the requirements of the welding procedure specification (WPS). This inspection includes such items as inter pass cleaning methods, inter pass temperature control, welding current settings, welding travel speed, shielding gas type, gas flow rate, and welding sequence, if applicable. Also, any environmental conditions that may affect the quality of the weld such as, rain, wind, and extreme temperatures.

2.4. Post-Weld Inspection

This inspection typically conducted to verify the integrity of the completed weld. Many non-destructive testing (NDT) methods are used for post-weld inspection. However, even if the weld is to be subjected to NDT, it is normally wise to conduct visual inspection first. One reason for this is that surface discontinuities, which may be detected by visual inspection, can sometimes cause misinterpretation of NDT results or disguise other discontinuities within the body of the weld. The most common welding discontinuities found during visual inspection are conditions such as undersized welds, undercut, overlap, surface cracking, surface porosity, under fill, incomplete root penetration, excessive root penetration, burn through, and excessive reinforcement.

In most welds, quality is tested based on the function for which it is intended. If you are fixing a part on a machine, if the machine functions properly, then the weld is often considered correct. There are a few ways to tell if a weld is correct:

- **Distribution**: Weld material is distributed equally between the two materials that were joined.
- **Waste**: The weld is free of waste materials such as slag. The slag after cooling should peel away from the project. It should be removed easily. In Mig welding, any residue from the shielding gas should also be removed with little problem. Tig, being the cleanest process, should also be waste free. In Tig, if you see waste, it usually means that the material being welded was not cleaned thoroughly.

- **Porosity**: The weld surface should not have any irregularities or any porous holes (called porosity). Holes contribute to weakness. If you see holes it usually indicates that the base metal was dirty or had an oxide coating. If you are using Mig or Tig, porosity indicates that more shielding gas is needed when welding. Porosity in aluminum welds is a key indicator of not using enough gas.
- **Tightness**: If the joint is not tight, this indicates a weld problem. In oxyacetylene welding if using autogenously welding, where there is no filler material, the weld must be tight. Same for Tig autogenously welding. The gap is not as critical in other types of welds since any gap is filled in by the filler material. That said, gaps in general indicate a potential quality problem.
- L**eak Proof**: If you are repairing an item that contains liquid, a leak is a sure fire way (and obvious way) to see that there is a problem. Same for something that will contain a gas. One testing method is to use soap bubbles to check for problems (can be easily applied with a squirt bottle.
- **Strength**: Most welds need to demonstrate the required strength. One way to ensure proper strength is to start with a filler metal and electrode rating that is higher than your strength requirement.

Other checks using visual methods include checks before (root face, gap, bevel angle, joint fit), during (electrode consumption rate, metal flow, arc sound and light), and after welding (under cut, root fusion issue, pin holes, excessive spatter, weld dimensions)

2.5. Visual Inspection (VT)

Visual inspection is a non-destructive testing (NDT) weld quality testing process where a weld is examined with the eye to determine surface discontinuities. It is the most common method of weld quality testing.

- **Advantages of non-destructive weld quality testing:**

  - ✓ Inexpensive (usually only labor expense)
  - ✓ Low cost equipment
  - ✓ No power requirement

- ✓ Quick identification of defects and downstream repair costs due to issues that weren't caught early

- Disadvantages:

  - ✓ Inspector training necessary
  - ✓ Good eyesight required or eyesight corrected to 20/40
  - ✓ Can miss internal defects
  - ✓ Report must be recorded by inspector
  - ✓ Open to human error

- ***Visual Weld Quality Testing Steps***

  - ✓ Practice and develop procedures for consistent application of approach
  - ✓ Inspect materials before welding
  - ✓ Weld quality testing when welding
  - ✓ Inspection when weld is complete
  - ✓ Mark problems and repair the weld

- ***Visual Weld Equipment***

Fillet Weld Gauge

Several pieces of equipment are required for visual weld quality testing:

- ✓ Weld hand held fillet gauge: measure -
  -flatness of the weld

- convexity (how the weld is welded outward)
- concavity (how the weld is rounded inward)

- ✓ Protective lenses with pocket viewer and shade lens for use when observing the welding process
- ✓ Magnifying glass per the code in your area
- ✓ Flashlight
- ✓ Chisel and hammer for spatter and slag removal before the weld is inspected
- ✓ Temperature device (Tempe stick, Pyrometer) to determine the preheating, interpass and post-heating temperatures.
- ✓ Magnet to indicate the type of material being welded
- ✓ Tape measure
- ✓ Calipers

Fillet Weld Gauge Diagram

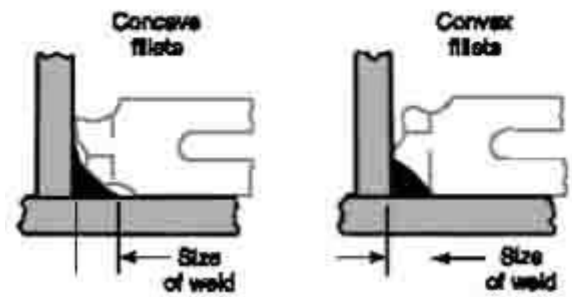

Figure 184: Fillet Weld Gauge

- ***Visual Inspection before Welding***

  - ✓ Check drawings
  - ✓ Look at weld position and how ti corresponds to the specification. Watch the vertical direction of travel
  - ✓ Check welding symbols
  - ✓ Does procedure align with local codes and the weld specification

- **Weld Material Inspection**

  - ✓ Do the materials purchased match the specification for base metal size and type? Check electrode size, gas selection and grade.

- ✓ Check materials for defects. Look for contaminants such as rust, scale, mill, lamination etc.
- ✓ Are materials prepared for correct angles

- **Assembly Inspection**

Follow these weld quality testing steps for assembly inspection:

- ✓ Check for fit
- ✓ Alignment of fixtures and jigs. Check cleanliness (look for spatter from previous jobs)
- ✓ Check quality if tack welds are used. The tack weld must be made with the same electrode as the main weld (s).
- ✓ Check use of pre heat to slow the cooling rate and to minimize distortion

- **Equipment Inspection**

- ✓ Check for damage (cables, ground clamps, electrode holder).
- ✓ Check arc voltage
- ✓ Check amperage meter for range against specification

- **Visual Inspection during Welding**

- ✓ Check electrodes for size, type and storage (low hydrogen electrodes are kept in a stabilizing oven)
- ✓ Watch root pass for susceptibility to cracking
- ✓ Inspect each weld pass. Look for undercut and required contour. Ensure the weld is cleaned properly between each pass.
- ✓ Check for craters that need to be filled
- ✓ Check welds sequence and size. Gauges are used to check size.

- ***Inspection after Welding***
  - ✓ Check weld against code and standards
  - ✓ Check size with gauges and prints
  - ✓ Check finish and contour
  - ✓ Check for cracks against standards
  - ✓ Look for overlap
  - ✓ Check undercut
  - ✓ Determine if spatter is at acceptable levels

- **Inspection Criteria**
  - ✓ Surfaces to be welded or thermally cut shall be cleaned of all foreign material such as grease, oil, dirt, scale, slag, and paint that would be detrimental to either the weld or base material. Weld preparations shall be machined (1000 RMS maximum surface roughness), grit blasted (near white blast), wire brushed, or ground to bright metal prior to welding.

  - ✓ Groove weld dimensions shall be verified by measuring the groove dimensions prior to welding. All weld preps shall meet drawing specified dimensions (whether provided via dimensions on the drawing or in a welding specification). If no dimensions are provided as part of the drawing or ordering documents, the dimensions shall meet dimensions specified by approved welding procedures (WPS). Tolerances specified in the welding specification or approved WPS shall apply. Measurement will be conducted with instruments suitable for the applied tolerances.

  - ✓ All completed weld surfaces shall be visually inspection for the entire weld length, unless an audit frequency is permitted by the applicable welding or quality specification. The inspected surfaces shall be inspected in accordance with the requirements of this procedure and evaluated to the applicable acceptance criteria, unless alternate inspection attributes or criteria are specified in the ordering documents communicated to the supplier or in the internal EC processing documents. A minimum light intensity at the inspection site of 100 foot-candles (1000 Lux) is required.

- ✓ Welds shall be dimensionally inspected for compliance to drawing tolerance a minimum of one (1) place per weld in every three (3) feet of weld. The weld location selected for examination shall be the least favorable as determined by visual examination.

- ✓ The inspection area shall include the weld and the accessible adjacent base material for a distance of 1.2 inch from the toes of the weld of edge of the base metal whichever is less.

- ✓ Material thickness shall be the nominal or actual thickness as specified on the engineering drawing or material specification. The material thickness used for the acceptance criteria for welds shall be based on the thickness of the thinner member joined except as follows:
- ✓ For upgrade or repair welds, the material thickness of the area of the base metal being welded is considered to be the material thickness.
- ✓ For weld deposited cladding, buttering, hard surfacing, wear surfacing, etc., the material thickness is the thickness of the weld deposit specified on the engineering drawing.
- ✓ Fillet welds shall be examined for size using standard weld profile gages or customer profile gages for sizes not covered by standard gages. Maximum fillet dimensions may be exceeded to meet minimum throat dimensions.
- ✓ The weld inspection surface shall be in the final heat treated condition and be free of all coatings and other surface conditions such as paint, plating, corrosion, etc. When blending or contouring is not required, welds shall be inspected in the as-welded condition.
- ✓ Weld contour and size attributes may be verified prior to stress relief treatments. All other attributes shall be verified after post weld heat treatments

- ✓ For welds that will be subsequently machined, the weld size shall be verified prior to machining and the machined surface shall be visually inspected relative to all of the other attributes contained herein.

https://www.youtube.com/watch?v=Ncguc7THEUY

Self-Check-2	Written test

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

Say true or false for the following questions below

1. Visual examination is the most important and the most universally accepted method of inspection.
2. Pre-Weld Inspection This inspection is conducted prior to the start of the welding operation.
3. Post-Weld Inspection This inspection typically conducted to verify the integrity of the completed weld.
4. Weld material is distributed equally between the two materials that were joined.
5. Groove weld dimensions shall be verified by measuring the groove dimensions prior to welding.

Note: **Satisfactory rating 4 and above points Unsatisfactory - below 3 points**

Answer Sheet

Score = ____________
Rating: _____________

Operation Sheet	Inspection during welding

Operation Title: Procedure inspection during welding

Step1. Check welding variables for compliance with welding procedure.

Step2. Check quality of root pass

Step3.Check quality of individual weld passes

Step4. Check inter pass cleaning

Step5.Check inter pass temperature

Step6.Check placement and sequencing of individual weld passes

Step7. Check back gouged surfaces

LAP Test	Practical Demonstration

Name: ______________________________ Date: ________________

Time started: ________________________ Time finished: ________________

Instructions: Given necessary materials, tools and measuring instruments you are required to perform the following tasks within 1 hour.

Task1. Perform inspection during welding

Information sheet-3	Completing weld records and completion

3.1. Definition of Record

A weld record sheet is used to track the critical information for each specific weld completed in a piping system. Figure 1 below illustrates a typical weld record sheet which is sub divided into 4 main sections these being:

- Header section
- Weld information section
- Material information section
- Test information section

The weld record sheet is used in conjunction with the weld isometric drawing and is often printed on the back of the drawing or attached to the drawing. Where possible the design office should fill in the common information before printing to increase efficiencies and minimize the risk of error. The pipe fitter can fill out the material information section as the spool is being tacked together. The welder then generally fills out the weld information section and the weld inspector completes the final test information section. Once complete the project engineer reviews it and verifies that all welds are completed, tested and accepted it can then be signed approved and included in the overall handover documentation package.

3.2. Weld Information Section

- **Weld No**: Unique number given to each weld in sequence so that there is complete traceability for every weld in the system Welder No.: Unique number given to every welder in a company. This number is recorded on the Welder qualification record after a welder performs and passes their qualification tests. This number is then recorded for every weld completed on both the weld record sheet and marked on the pipe beside each weld completed.

- **Weld Size:** Size of the weld being completed. This is used to tie back to weld coupon log to ensure that only these size welds were completed once the correct size weld coupons were completed.
- **Weld date:** The date the weld was completed.

- **Location:** Where the weld was completed, i.e. in the workshop or out on site. Shop welds are usually much easier as they are completed on a bench with good access and minimum purging, while field welds are usually more difficult as access is usually more difficult and the complete system needs to be purged which is harder to achieve. In critical systems a reduced percentage of shop welds may be inspected while the client may insist that 100% of all field welds are inspected.

- **Process:** Automatic or manual, most welds should be automatic which are more consistent and therefore more likely to pass inspection. Manual welds are only used where the fitting to fitting distance is reduced to a point where the automatic weld heads will not fit and therefore a manual weld is required. These are only usually allowed by prior approval of the client and usually require 100% inspection

3.3. Record of Weld Repair

A full record of all repairs shall be maintained by contractor. The record shall include the following:

- Weld number
- Type and size of defect
- Circumferential location (defined to an approved system)
- Estimate of the depth (assessed by ultrasonic test where possible)
- Where possible, the name of the welder who produced the defect
- Repair welding procedure number
- Name of repair welder
- Copy of the inspection reports for the repair
- Date of repair

3.4. Welding Procedure Certification

Our Independent Certification service comprises a complete package in respect of producing Welding Procedure Qualification Records / Procedure Qualification Records (WPQRs/PQRs). Our fully trained and qualified surveyors will attend your site and through a unique company-welder interaction method, collate all of the required data to produce the relevant certification. We then coordinate the required testing with our independent UKAS accredited laboratory, with results produced within a maximum of

3-5 days. Our experience and knowledge ensure minimum input from our customers and minimum disruption to their operations. In an industry where lead times are ever decreasing, we guarantee to provide a service that will not disappoint, with our unique certification seal recognizable as a world-class guarantee of highest quality performance.

3.5. Welder Performance Qualification

Our Surveillance Department can independently witness and verify welders, who follow detailed written instructions to produce test pieces (usually in the form of a Preliminary Welding Procedure Specification – PWPS – or a Welding Procedure Specification – WPS). We then coordinate testing of these pieces through our independent UKAS-accredited laboratory to enable qualification or coding to a National, European or Internationally recognized standard.

We also offer a programme for managing the on-going qualification/requalification of welders and for organizing documentation of evidence that can be used to support certificate prolongation.

3.5. Welding Procedure and Welder Qualification Testing

Through our Head Office UKAS accreditation, we hold a Department for Business Energy and Industrial Services (BEIS) appointment as a recognized Third Party Organization (RTPO). This allows us to witness Welding Procedure and Welder Qualification tests for work to be used under the Pressure Equipment Directive (PED) category.

Our comprehensive and independent third party surveillance services operate Nationwide, across Europe and even further afield. All of the work that we perform is in accordance with National, European and internationally recognized Standards, including, but not limited to:

We can also perform surveillance and issue certification to meet the requirements of specific companies or industry sectors, such as:

- ✓ Rolls Royce
- ✓ West lands
- ✓ DGS Shipping
- ✓ NSSS (National Steel Structure Specification) for more information about our services or to make an enquiry, please get in touch with Code a Weld.

Key Learning Points:

- ✓ Identify the main sections of a weld record sheet
- ✓ Identify the component parts of each section in the weld record sheet
- ✓ Be able to identify the information required to complete a weld record sheet.

3.6. Weld Record Sheet Information

A weld record sheet is used to track the critical information for each specific weld completed in a piping system. Figure 1 below illustrates a typical weld record sheet which is sub divided into 4 main sections these being:

- Header section
- Weld information section
- Material information section
- Test information section

The weld record sheet is used in conjunction with the weld isometric drawing and is often printed on the back of the drawing or attached to the drawing. Where possible the design office should fill in the common information before printing to increase efficiencies and minimise the risk of error. The pipe fitter can fill out the material information section as the spool is being tacked together. The welder then generally fills out the weld information section and the weld inspector completes the final test information section.

Once complete the project engineer reviews it and verifies that all welds are completed, tested and accepted it can then be signed approved and included in the overall handover documentation package.

Table 9: typical weld record sheet

Client : ________ FAS Project No.: ________ System: ________

Client Project No.: ________ Machine Serial No.: ________ Line / Iso. No. : ________

Approved By : ________ Machine Model No.: ________ Sheet : ____ of ____

Weld Information								Material Information				Test Information				
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Weld No.	Welders No.	Weld Size	Weld Date	Location		Process		Component /	Component	Cast No. /	Cast No.	NDT Report No.	NDT Type	NDT Date	Accept or Reject	Inspectors Initials
				Shop	F.W.	Auto	Man.									
1																
2																
3																
4																
5																
6																
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10																
11																
12																
13																
14																

3.7. Header Section

- **Client:** The company name who the work is being completed for.
- **Client project No**: A unique number assigned by the client for the work being completed.
- **Approved by:** Signature of the person approving the weld record sheet
- **Project No:** A unique number assigned by the contractor for the work being completed. It is usually used to track costs and progress on a particular project.
- **Machine Serial No:** The serial number of the welding machine used to carry out the welding. It is unique to each machine and if faults are discovered and linked back to this machine, it makes it easier for all welds completed by this machine to be tracked and re-inspected after the fact.
- **Machine model No:** The type of model of welding machine used to complete the welding.
- **System:** The name of the system being welded, e.g. Pure steam, product etc..
- **Line/Iso. No:** This is the isometric drawing number or the line number for which the welds that are being recorded are on.
- **Sheet No**: Sometimes there may be 3 or 4 isometrics for one line therefore they are grouped together as sheet 1 of 5, 2 of 5 etc.

3.8. Material Information Section

- ✓ Component / Component: This identifies the different components either side of a weld, e.g. Pipe/elbow or elbow/tee etc..
- ✓ Cast No. / Cast No.: Also known as the heat number it identifies the batch of material that the component was manufactured from. It was once a requirement that the cast number had to be the same each side of the weld to ensure consistent welding, however due to improved manufacturing techniques it is now possible for mills to repeatedly produce material which is consistent and which has tightly tolerance ingredient amounts. This consistency in the materials of the components ensures that the finished welds are of a high quality.

Self-Check-3	Written test

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

Say true or false for the following questions below

1. A weld record sheet is used to track the critical information for each specific weld completed in a piping system.
2. The weld record sheet is used in conjunction with the weld isometric drawing.
3. Client is the company name who the work is being completed for.
4. Weld number is a unique number given to each weld in sequence.

Note: **Satisfactory rating 3 and above points** **Unsatisfactory - below 2 points**

Answer sheet

Score = ___________

Rating: ____________

Information-4	Observing OHS procedures

4.1. SAFETY IN WELDING

Welders must be protected from electric shock, welding fumes, fire, and injuries that can be caused by insufficient PPE. Safety supplies and protective equipment keep work sites secure and help companies ensure full compliance with safety regulations.

Protective clothing, helmets, goggles, and other safety gear help guard employees from injury or infection. Safety signs warn employees and others of potential hazards, alert workers to the location of safety equipment and exit routes, and offer safety-related instructions in a concise and attention-getting format. Fall-protection safety products help prevent people working at heights from falling or decrease the risk of injury if they do fall. Traffic safety equipment can be used to keep traffic moving in the right direction and block off potential hazards.

4.2. PPE and Training Requirements

Burns and eye injuries are the most common types of injuries for welders. The right PPE protective clothing, gloves, welding helmets, respiratory protection are the addressed in both 1910.252(b)(3), which says employees engaged in welding, cutting, or brazing tasks shall wear protective clothing, and by 1910.132, the general OSHA PPE standard. The PPE standard says step one is the employer's hazard assessment, followed by PPE selection and worker training. Once trained, workers should understand when PPE is needed and what types of PPE are needed; how to put on and take off their PPE properly; the limitations of their PPE; and the proper care and maintenance of this protective equipment.

There are several hazards central to welding that must be accounted for in welders' training, equipment, and set-up for a job. These include electric shock, welding fumes, fire, and injuries that can be caused by wearing PPE that is not sufficient to protect against the level of hazard encountered during the task. Most welding equipment has a voltage that presents a risk of electric shock. "The most common type of electric shock is secondary voltage shock from an arc welding circuit, which ranges from 20 to 100 volts. Bear in mind that even a shock of 50 volts or less can be enough to injure or kill an operator, depending on the conditions," an article *OH&S* published three years ago pointed out.

Exposure to welding fumes and gases is a primary hazard. Welders must be acquainted with safety data sheets for the welding consumable products they are using, as well as the use of ventilation to ensure exposures are minimized. Permissible exposure limits come into play here, limits established by OSHA and the American Conference of Governmental Industrial Hygienists. Welders rely on respiratory protection, ventilation, and a variety of products for fume extraction.

Welding and related thermal processes utilize compressed gas and/or electric current to provide a concentrated heat source which melts or burns away steel and other metals. Proper safety precautions are required to avoid accidents related to the gas and power supplies, to the sparks, heat, fumes, and visible and invisible rays from the heat source.

Authorities in most countries have laid down regulations and guidelines related to welding and other hot work processes, their application onboard ships, the equipment to be used and the protection of the operator. These regulations must be available onboard, and be known and adhered to when hot work is to be done. A welded component that fails may represent a safety hazard to crew, ship and cargo. Classification societies and other authorities have consequently issued regulations and welding procedures for a number of applications onboard. These should be known and followed wherever applicable, and welding should be performed by qualified personnel under proper supervision.

In this chapter as well as in other parts of the handbook, you will find guide-lines on safe handling of equipment, how to protect yourself, and safety precautions that should be observed when welding and related thermal processes are used on board a ship. You will also find extensive information on how and where to use filler materials, and some guidelines as to identifying metals. This handbook, however, cannot be considered to be a complete manual for each of these areas, dealing in detail with all the aspects of the various items.

- **Do not install,** operate or repair equipment for welding or related thermal processes unless you are thoroughly familiar with:
  - ✓ The Instruction Manual for the equipment to be used.
  - ✓ Rules and regulations relating to the handling and installation of the equipment.
  - ✓ Rules and regulations relating to hot work onboard.
  - ✓ Proper use of protective equipment and accessories related to the hot work, like fire extinguishers, fume extraction equipment, etc.
  - ✓ Proper use of the filler material and fluxes for the job.
- **How to use the Handbook**
  Read this first Familiarize yourself with the chapter you are now reading, and follow the advice given here whenever you weld. If you know little about welding and your objective is to become familiar with the welding processes on a self-study basis, start with the chapters at the back of the book and follow the processes from gas to flame, from primary power to arc and then through consumables to solutions. If, on the other hand, you have a basic understanding of welding, read the book from the beginning, starting with the chapter on solutions.

- **When facing a problem** consult the solutions chapter. Here you will find quick guides to cutting, joining, rebuilding and coating, as well as information on how to identify metals, descriptions of the most common metals, and a number of examples on welding applications. You will also find tables for calculating filler material consumption.

- **Use the consumables correctly** when a solution is found you should check the specifics of the consumables you are going to use. The descriptions given in the chapter on consumables will not only give you technical information on the consumables, but also advise if special procedures should be followed for the particular product at hand.

The process before commencing work, take the time to check the details of the equipment and the technique you should use from the section on processes. You should also read through the special instruction manuals for the process and equipment you are going to use.

Power and gas supply Safe operation and successful results depend on you being familiar with these chapters, and also the instruction manual on the specific power source you have onboard. Ensure that the gas supply is in proper order and correctly maintained, that the welding machine is suited for the process at hand, and that the cables are of correct size. Cold repair components require no outside energy. The energy is built into the products and is released when the base and activator is mixed together. In order for the chemical reaction to take place, the temperature must be above +5°C.

4.3. Welding instruction and training

As the world's leading welding supplier to the marine industry, Wilhelmsen Ships Service has designed and certified a number of well recognized welding academies around the world. These academies offer tailor made solutions for maintenance and repair welding onboard vessels. It is crucial that pressurized gases and arc welding equipment are handled in a safe and secure way, and safety related issues are always a top priority for running the vessel.

The consequences of not adhering to correct safety procedures can be both hazardous for the crew and damaging to the vessel. Therefore, health and safety issues are an essential and an important part of the welding training offered. Welding and related processes are complex and require hands-on training, which teaches skills that are otherwise difficult to obtain. By attending approved training academies, the vessel's crew will be certified and trained to perform quality welding repairs onboard. Working in the ship's operating environment, in awkward positions, and with the numerous kinds of metals onboard, can be very challenging.

These are all elements the crew must take into consideration in order to work effectively. The Wilhelmsen Ships Service approved academies offer both practical and theoretical training as to how to select the correct welding methods and filler materials. These courses aim to help shipboard welders overcome the daily maintenance challenges onboard. In order to meet world fleets logistical time challenges and requirements, we endeavor to offer flexible solutions, and can therefore arrange courses throughout the year. The pupils can be enrolled and trained at short notice, and courses may be tailor-made to fit the pupil's individual needs. Over the years, thousands of seafarers have completed our courses, ensuring that high quality workmanship is carried out onboard the world's fleets. The courses offer training in the following processes:

- **Protection against** burns may be caused by hot work pieces, sparks, molten metal, red-hot electrodes etc.
- **Protection against ultraviolet and infrared light** Many welders have experienced the discomfort of arc-eye or "sun-burnt" skin on unprotected parts of the body, usually due to insufficient or incorrect protective equipment.
- **Protections against chemicals** Most of the products in the Unit or Cold Repair Component range are to be considered harmless. Nevertheless we always recommend that one does the mixing and application in a ventilated area and always wear the gloves supplied with the set, when handling polymer products.

- **Protection against flying** chips when using a chipping hammer to remove slag from the weld, there is always a risk of flying chips which are a potential danger. The chips are sharp and can cause serious damage to the eyes.
  General body protection a welder at work is isolated from his surroundings. He must concentrate on the welding operation and cannot see what may be happening in the surrounding area. He must therefore always wear a safety helmet, safety shoes etc. which will offer him protection against accidents beyond his control. A welder must always use complete personal protection equipment – but it is also important that he uses the correct type of equipment for the job. Wilhelmsen Ships Service, who supplies a full range of welding equipment all over the world, can offer correct and complete protection equipment which will provide maximum safety for the welder in all situations.
  Work site protection In order to protect the surrounding area from sparks and spatter, ultra violet and infrared light, welding curtains and/or blankets should be used

4.4. Arc welding faces shields and glasses

A welder should bear in mind that proper protection is absolutely necessary to guard him against the danger of electric shocks, burns, ultra-violet rays and bits of welding slag in the eye. Unit or face shields for welding are made from a lightweight, robust plastic material which is unaffected by heat, cold or moisture, and both glasses and shields conform to relevant EN standards.

- **The Auto vision Plus Fresh** Air Welding Shield This Shield is the Auto Vision Plus with respiratory unit. It gives the user clean, filtered air inside the helmet, and prevents inhalation of welding fumes. The airflow will keep the user fresh and let him concentrate on the work. The kit is CE approved and conforms to EN 12941:2009.The fan battery recharges in 2-4 hours and will provide up to 220 liters of air per minute for at least 8 hours.

Fresh air kit for face shield

Figure 185: Fresh air kit

- **The Auto Vision plus Welding face shield** the basis is a lightweight well designed shield which allows good air flow for the welder, and a head band that allows unique possibilities for adjustment:
    - ✓ Distance to face
    - ✓ Angle in relation to face
    - ✓ Height on head
    - ✓ Head diameter
    - ✓ Stay-up friction

  Replaceable inside and outside protective lenses, headband and sweatband for the headband is available as spares. The shield is equipped with a light powered quick automatic darkening glass that switches from low shade (4) to selected dark state within 0,4 milliseconds (0,0004 sec). The low shade state allows for good vision while chipping slag, grinding and repositioning for next arc striking. Dark mode is adjusted with a knob at the side of the shield.

The AutoVision Welding face shield

The Flip-Vision Welding face shield

Figure 186: Auto Vision and Welding face shield

- **Safety helmet with face shield** the Flip-Vision face shield is also available with safety helmet instead of headband.

Safety helmet w/face shield

Figure 187: Safety Helmet

- **Face Shield with handle** the face shield with handle is also supplied with shade 11 dark glass and clear protection glass as standard. It is designed to also protect the hand holding it from radiation.

Face shield w/handle

Figure 188: Face Shield

- **Glasses for Arc Welding** the glasses have dimension 60 x 110 mm and are manufactured in accordance with DIN standard and are CE approved. When ordering face shields, filter shade glass of correct shade should be ordered in addition to the filter shade 11 glasses which is included. The filter glasses are supplied in sets consisting of 5 safety glasses, 5 protection glasses and 5 filter shade glasses.
    - Items to be mounted into Unit or face shield in the following manner

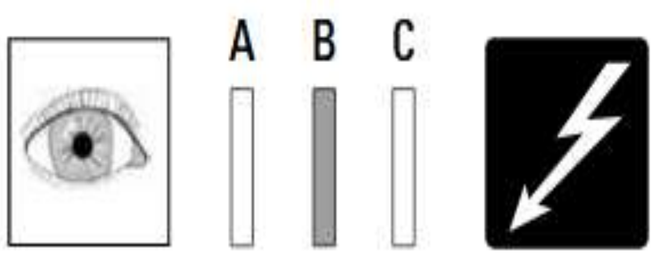

Figure 189: Description of ABC

- ✓ A. Safety glass (Polycarbonate) the glass should be placed nearest to the eyes to protect against slag or other particles while chip-ping/grinding. When using a shield with a flip-up front frame, the safety glass shall be placed in the fixed frame.

- ✓ B. Filter shade glass filters out harmful infra-red and ultra-violet rays from the welding arc, and reduces visible light to a level which is sufficient to see the welding process without straining the welder’s eyes. Filter Shade Glass should be selected after consulting the welding process and amperage (see table). The glasses are marked Protane Shade SO 1 DIN 0196 CE

- ✓ C. Protection glass is placed in front of the filter shade glass to protect against spatter. The protection glass should be replaced at regular intervals.

- **SAFETY IN WELDING**

- ✓ https://video.search.yahoo.com/yhs/search?fr=yhs-aztec-default&hsimp=yhsdefault&hspart=aztec&p=observing+ohs+procedures+on+simple+welding%2F+smaw+video#id=0&vid=80876aac56f577dd9c4aff43132cad40&action=click

- ✓ https://video.search.yahoo.com/yhs/search?fr=yhs-aztec-default&hsimp=yhsdefault&hspart=aztec&p=observing+ohs+procedures+on+simple+welding%2F+smaw+video#id=0&vid=a232c693841eeb11ee6b9e32d3f63079&action=click

Self-Check-4	Written test

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

Say true or false for the following questions below

1. Proper safety precautions are required to avoid accidents related to the gas and power supplies, to the sparks, heat and fumes.
2. Protection against burns may be caused by hot work pieces, sparks, molten metal and red-hot electrodes.
3. Protection glass is placed in front of the filter shade glass to protect against Spatter.
4. Burns and eye injuries are the most common types of injuries for welders.
5. Safety supplies and protective equipment keep work sites secure.

Note: **Satisfactory rating 4 and above points Unsatisfactory - below 3points**

Answer sheet

Score = ____________

Rating: _____________

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