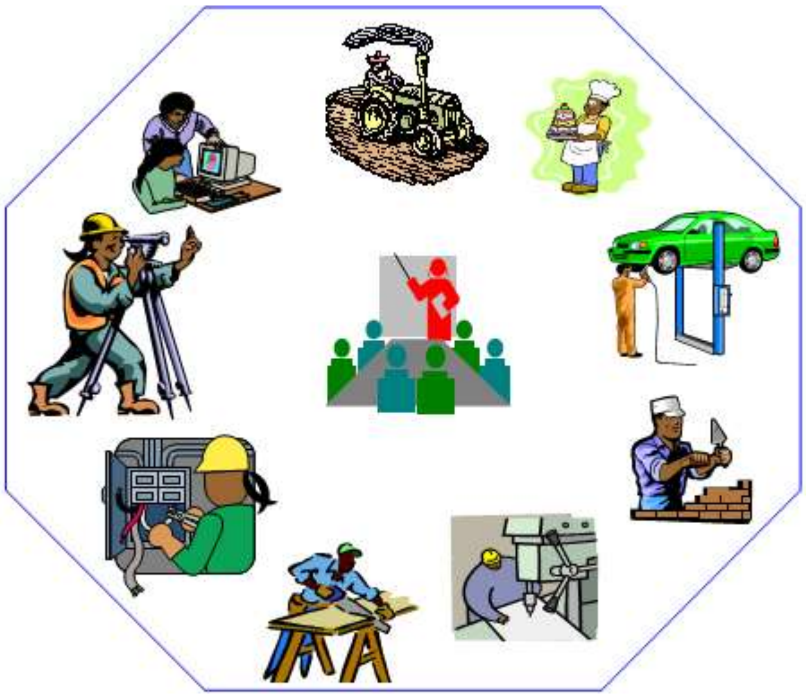
WElDING

LEVEL IV

Based on May 2017, Version 1 Occupational standard



Module Title: Applying and Supervising Welding Codes and Principles

LG Code: IND WED4 M012 LO (1-3) LG (53-55)

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February, 2021

Adama, Ethiopia

Table of content

LG #53	LO 1 Apply all statutory and regulatory requirements

Instruction sheet

This learning guide is developed to provide you the necessary information regarding the following content coverage and topics:

- Applying statutory and safety requirements.
- Interpreting and applying welding terms and symbols

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

- Apply statutory and safety requirements.
- Interpret and apply welding terms and symbols

Learning Instructions

1. Read the specific objectives of this Learning Guide.
2. Follow the instructions described below.
3. Read the information written in the "Information Sheets". Try to understand what are being discussed. Ask your trainer for assistance if you have hard time understanding them.
4. Accomplish the "Self-checks" which are placed following all information sheets.
5. Ask from your trainer the key to correction (key answers) or you can request your trainer to correct your work. (You are to get the key answer only after you finished answering the Self-checks).
6. If you earned a satisfactory evaluation proceed to "Operation sheets
7. Perform "the Learning activity performance test" which is placed following "Operation sheets" ,
8. If your performance is satisfactory proceed to the next learning guide,
9. If your performance is unsatisfactory, see your trainer for further instructions or go back to "Operation sheets".

Information Sheet-1	Statutory and safety requirements are applied according to industry required welding codes

1. Introduction to welding safety requirement

Welding is the process of joining together two pieces of metal so that bonding takes place at their original boundary surfaces". When two parts to be joined are melted together, heat or pressure or both is applied and with or without added metal for formation of metallic bond. The arc is struck between the electrode and the metal. It then heats the metal to a melting point. The electrode is then removed, breaking the arc between the electrode and the metal. This allows the molten metal to "freeze" or solidify. The arc is like a flame of intense heat that is generated as the electrical current passes through a highly resistant air gap. There are various welding processes but commonly used types include the following:

- SMAW (Shielded Metal Arc Welding)
- GMAW (Gas Metal Arc Welding)
- GTAW (Gas Tungsten Arc Welding)
-

1.2. Application of Manual metal welding

This also referred to as "Stick Welding" is the most commonly used type of welding and used for everything from pipeline welding, farm repair and complex fabrication. It uses a "stick" shaped electrode and thus its name indicates. Materials that can be welded by this process include: steel, cast iron, stainless steel, **Electricity and welding**

All welding processes depend on three main requirements for their operation. These are

- A heat or energy source – needed for fusion.
- Atmospheric shielding – to prevent oxygen and nitrogen in the atmosphere from contaminating the weld.
- Filler metal – to provide the required weld build-up.

1.3. General working principle of MMAW

The electrode is placed in an electrode holder, which is connected to one lug of a constant current welding power supply. This power supply can be operated on alternating current (AC),direct current electrode positive (DCEP), or direct current electrode negative (DCEN) depending on the type of electrode being used.

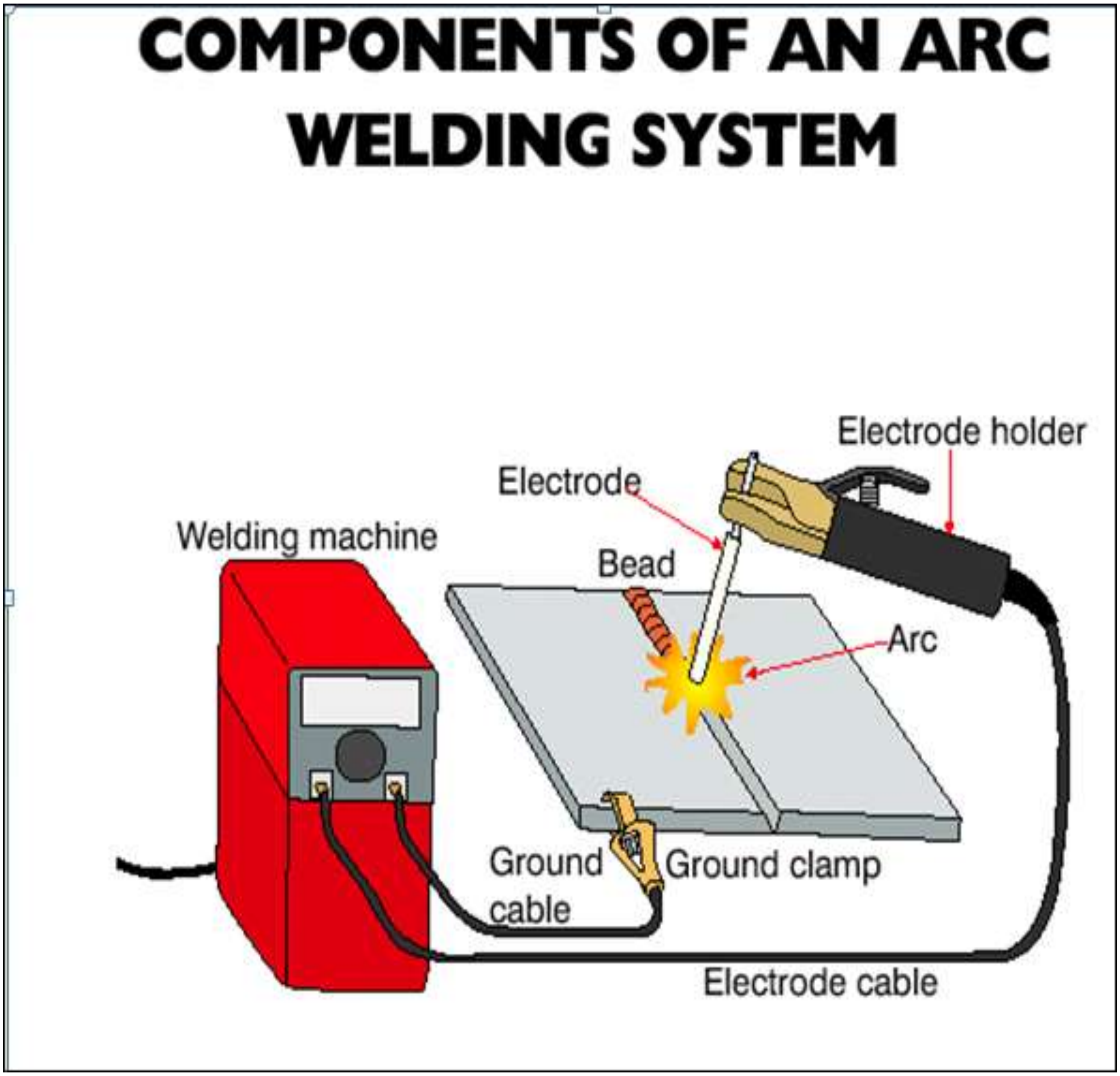


Figure 1. Manual arc welding diagram

Table 1 PERSONAL PROTECTIVE EQUIPMENT

	Safety glasses must be worn at all times in work area!
	Respirator with HEPA filters must be worn when working with asbestos containing materials. Workers must be fit tested prior to performing any asbestos work.
	Work Boots must be worn at all times when working in an area where there is risk of serious foot injury due materials falling onto the foot.
	Welding work gloves should be worn when there is a risk of hand injury during the course of work tasks.
	Hard hats must be worn when working in an environment where there is a risk of objects falling from above or where there is a high risk of striking your head on objects.
	Welding helmets must be kept in good shape and have protective lenses meeting shade selection requirements for the task.
	Protective clothing must be worn whenever cutting, welding and grinding is done. This includes welding jacket, welding gloves, and respirator is required.

1.4. Safety requirement

Taking precautions in welding shops will keep our selves, working area, tools, equipments and material free of accidents. It is important to know about some of these and precautions in relation to working area, tools and equipment's used in welding shop.

1.5 Safe welding practices

• Radiation from the arc is dangerous to the eyes. The arc gives off infrared and ultraviolet rays which may burn the eyes and the skin. An arc welder's helmet, with a suitable colored lens, must be worn to keep the rays from the skin and eyes.
• Flying sparks and small globules of molten metal are present most of the time when arc welding. Protective clothing which is not highly flammable, gloves, and high shoes help to protect the welder from burns.
• Avoid striking an arc when other persons are close. Warn others that an arc is to be struck so they may protect their eyes from the arc.
• Fumes given off from the arc and the material being welded may be injurious. Adequate ventilation is required at all times when welding is in process.
• Electric shock is always a possibility. Be sure the floor is dry and wear dry gloves. Use an insulated electrode holder.
• The danger of burns is always present. Do not handle hot metal with the hands. Use tongs or pliers.

1.6. Use and application of personal protective equipment for MMAW

A. Other related hazards

These are hazards specific to an individual manual electric arc welding operation. These include, but not limited to,

- Hazards related to the access to and working at high levels such as falling from height and the loss of stability of structures used to access high levels;

- Tripping hazards due to tangling welding cables;
- Hazards due to the exhaust fumes from engine-driven electric generator and the storage of fuel;
- Hazards from changes in weather conditions when welding in the open ground;
- Noise hazards from high pitch screaming or hissing from power source or associated equipment, and banging noise from grinding and chipping, etc.; and
- Musculoskeletal problems resulting lifting heavy objects, repetitive motions and long periods of customary postures.

Table 2.   Potential health & safety hazards signs

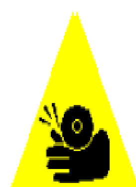
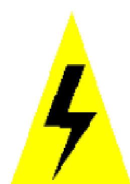
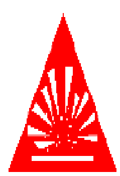
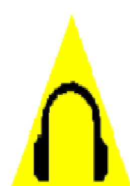
HAZARD		TO PROTECT YOURSELF
PINCH POINTS **There are gears and exposed moving parts on machinery.**		Use LOCK-OUT procedures when performing maintenance or conducting any work within 12" of an exposed pinch point. NEVER put your hands or feet near an exposed pinch point or gears!
ELECTRICAL HAZARD		Ensure all electrical equipment and machines have plugs and wires that are in good condition.
EXPLOSIVE		Make sure cylinders are stored and handled correctly. Proper grounding must be used.
HIGH SOUND LEVELS **Sound levels exceed 85 dB**		**HEARING PROTECTION** is required when working in designated areas.

*Table.3.preparingmaterials*totherequiredweldspecification**.**

Wire Size	Amperage Range	Recommended Wire Feed Speed	Wire Feed Speed*
0.023 in. (0.58 mm)	30-90 A	3.5 in. (89 mm) per amp	3.5 x 62.5 A = 219 ipm (5.56 mpm)
0.030 in. (0.76 mm)	40-145 A	2 in. (51 mm) per amp	2 x 62.5 A = 125 ipm (3.19 mpm)
0.035 in. (0.89 mm)	50-180 A	1.6 in. (41 mm) per amp	1.6 x 62.5 A = 100 ipm (2.56 mpm)
*62.5 A based on 1/16 in. (1.6 mm) material thickness.		ipm = inches per minute; mpm = meters per minute	

1.7. SMAW Joint Preparation

SMAW can be used to create nearly any type of joint. However, SMAW requires proper joint preparation. Just as with any arc welding process, the surfaces of the base metals must be free of dirt or other substances. You may have to use a wire brush to scrape off excess debris. Other preparations required for SMAW depend on the type of joint and the type of metal. Some joints, like the **square groove** joint, require that the welder square off the edges of the base metals.

1.8. Welding Equipment

The arc welding process uses special equipment. The welding student must set up and operate this equipment according to established industrial standards of safe and economical Operation.

1.9. Arc Welding Machine

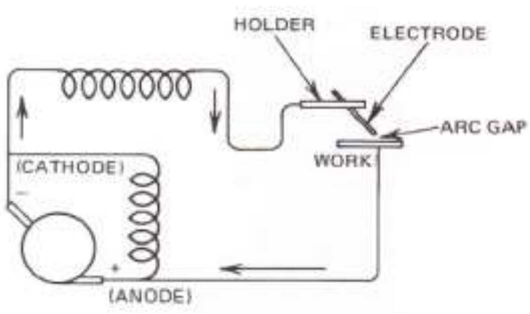
Arc welding machines are classified as either AC or DC. DC welding machines may be motor driven generators, or *rectifier* welders, figure b. A rectifier is a device which converts AC to DC. Since the DC rectifier welder is most commonly used in shops and in school laboratories, the welding student should concentrate on that type..

1.10. Direct Current, Straight Polarity (DCSP)

When the parent metal is connected to the positive side of the welder, and the electrode (rod) holder is connected to the negative side of the welder; the circuit is in *straight polarity.* With the electrode negative the current travels from the electrode to the base metals Two-thirds of the total heat produced is released at the base metal and one-third is released at the electrode.

1.11. Direct Current, Reverse Polarity

When the parent metal is connected to the negative side of the welder, and the electrode holder is connected to the positive (+) side of the welder, the circuit is called *reverse polarity.* With the electrode positive the current travels from the base metal to the electrode, figure d. Two-thirds of the total heat is released at the electrode and one-third is released at the base metal.



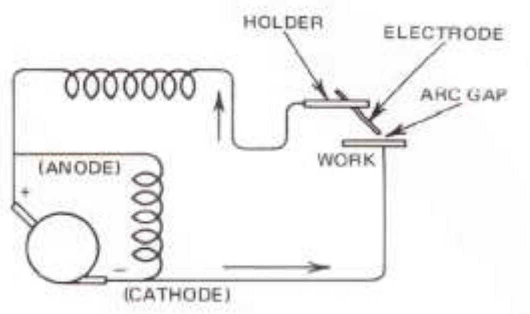


Fig 1(a) wiring diagram, DCSP

Fig 1(b) wiring diagram, DCRP

1.12 Alternating current

Most AC welders, figure e, have transformers which step down the voltage and increase the welding current. Electric current furnished by most electric utilities is 60-cycle, alternating current. (The current reverses its direction of flow 120 times per second.) Approximately 50 percent of the heat is released at the parent metal and 50 percent at the electrode.

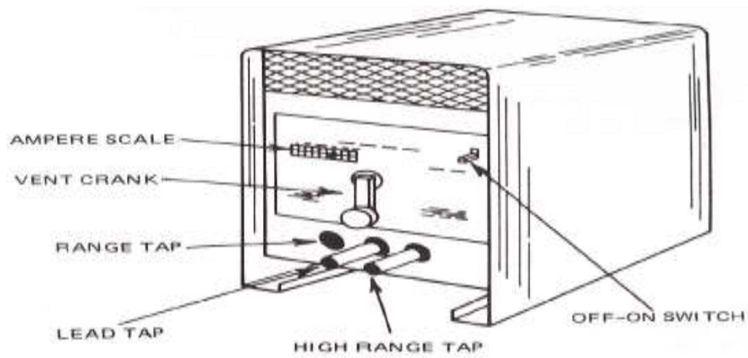


Fig 2. Welding Machine

1.13 Leads

The cables used to carry the electric current to the work and back to the welding machine are called *leads;* figure f. Well-built leads of adequate size to carry the current used are essential. Leads which are used a considerable distance from the welding machine must be larger than leads used for jobs close to the machine.

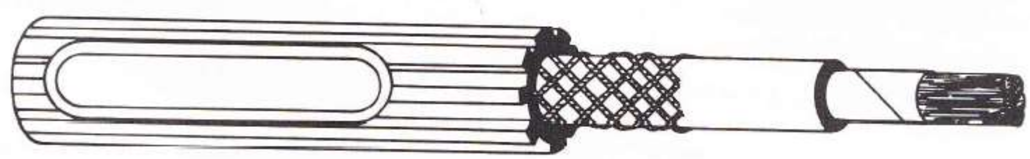


Fig a. Welding Cable

1.14 Electrode Holder

The electrode holder is the part of the arc welding equipment held by the welder, figure g. It is attached to the electrode lead on the welding machine. The “stinger,” as it is sometimes called, is a well-insulated handle which is made to withstand the heat from welding.

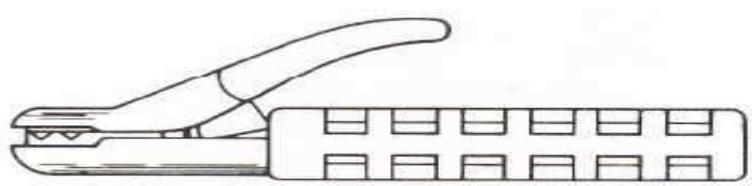


Fig b. Electrode Holder

1.15 Ground Clamp

The ground cable from the machine to the work is generally connected to a spring- loaded clamp which can be easily attached to the work. This is the ground clamp, figure h. In order to do a good job of welding, the ground must be solidly connected to the work.

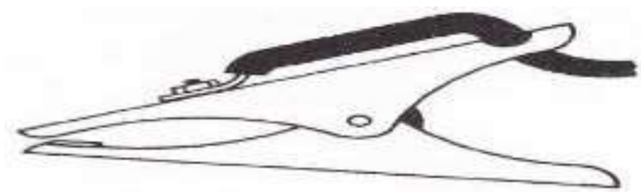


Fig c. Ground Clamp

Helmet

The helmet is generally made of fiber, and formed to cover the front half of the welder's head, figure I. An opening is provided in front of the eyes, and a clear-glass cover lens is installed in the opening. Behind the cover lens is a colored glass which filters the infrared and ultraviolet rays from the arc. The clear-glass lens is provided to catch the spatter from the welding process which would otherwise adhere to the

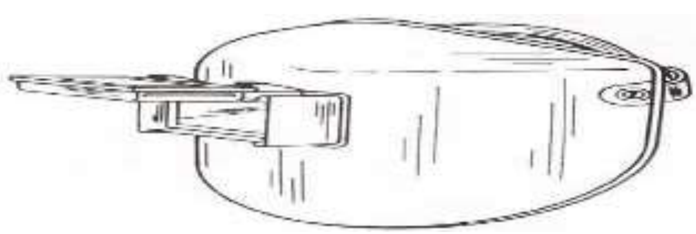


Fig d. Helmet

1.16 Welding Electrodes

Most welding electrodes are covered with a coating of *flux.* This flux forms a gaseous shield which prevents oxygen from contacting the molten metal. The chemical content of the coating varies with the manufacturer's specifications. Welding rods are manufactured and coated to fulfill specific welding functions. The welder must learn to identify electrodes and choose the type most suited for the job at hand.

Electrode, or one which can be used in any position; a 2 indicates that it is for flat or horizontal – welding; and a 3 indicates that it is intended for flat position welding only. The last digit refers to the operating characteristics, such as coating and polarity.

1.17 Weld **joints to code requirements using MMAW**

Striking the Arc

When a ground and a wire carrying an electrical charge contact each other, an *arc* (continuous spark) occurs, causing intense heat and bright light. This is the principle on which arc welding operates, except that after the arc is started, the welding electrode is moved a short distance away from the parent metal. This keeps a constant arc and continuous heat. An arc length of 1/8 inch is maintained most of the time. Lengthening the arc by moving the electrode farther away from the parent metal increases the heat and the size of the puddle.

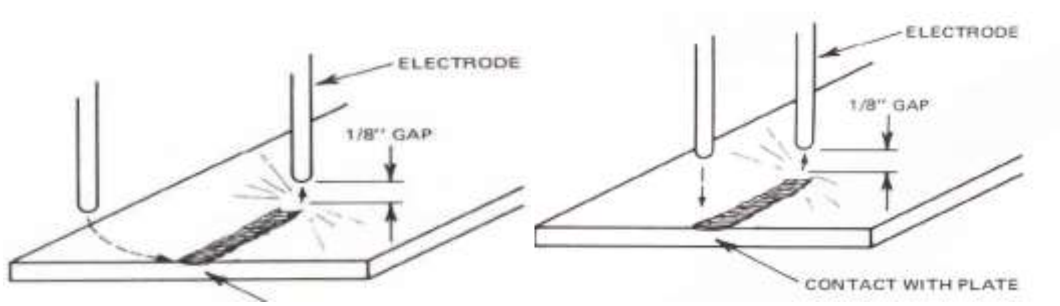


Fig 3 Striking an Arc

Fig 8. Electrode Angle for Fifing Puddle and Welding

After the arc is established, movement across the plate must be made in a steady forward motion, and the arc must be kept a uniform length. Too rapid progress will result in poor penetration. Right-handed welders generally progress from left to right, so that the weld puddle can be seen and the filling (or buildup) of the rod can be controlled. Left-handed welders should work from right to left.

1.18 Electrode

After the arc has been started, the electrode should be held away from the plate to begin the weld. A good rule to follow is to keep the arc at a distance equal to the diameter of the rod being used. The rod must be held perpendicular to the plate being welded, and tipped slightly (about 1 0 degrees) in the direction of travel, figure m. The bead width should be approximately twice the diameter of the rod.

- Making straight beads
- Cleaning of joints to specification.
- Welding variables (electrode selection, current setting, voltage, travel speed, electrode angle)

1.19 Electrode Selection

Welding electrodes are classified according to whether they are to be used with DC reversed polarity (DCRP), DC straight polarity (DCSP), or alternating current (AC). The electrodes used most commonly for mild steel welding are discussed here. **E-6010** indicates an all-position welding rod (flat, vertical, horizontal, and overhead). It performs best when used with DCRP. Deep penetration can be achieved with this electrode which has a thin coating, and which lends itself particularly well to out-of-position welding.

1.20 Welding Currents

Generally, the amperage at which the rod runs most readily is indicated by the manufacturer. Differences in rod diameter and in material used for the Flux coating require differences in the current settings used. Figure 4-1 indicates current settings which generally give satisfactory results.

Table 4.current setting for common electrode

Diameter of Electrode	Amperage Used					
	E-6010	E-601 1	E-6012	E-6013	l E-6020	E-6030
1/8”	80-120	80-120	80-130	70-120	100-140	100-140
5/32”	120-160	120-160	120-180	120-170	120-180	120-180
36”	140-220	140-220	140-250	140-240	*175-250*	*175-250*

- **STRINGER BEADS IN THE FLAT POSITION, DCRP**

Equipment and Material:

Standard AC or DC welding machine

Helmet

Gloves

Chipping hammer

Safety glasses

Wire brush

Necessary protective clothing

1/4” mild steel plate

1/8”, E-601 I and E-6013 electrodes

STRINGER BEADS IN THE FLAT POSITION, DCSP

Equipment and Material:

Standard arc welding equipment

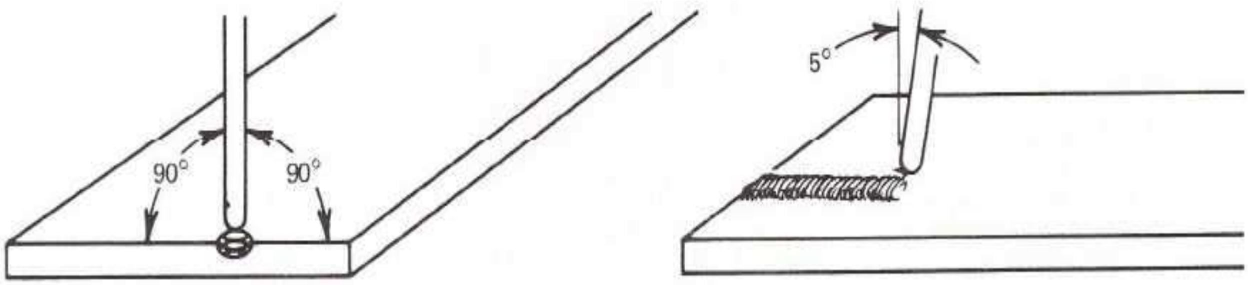


Fig.4. Electrode Angle for Stringer Beads in the Flat Position

1.21 Weave Bead

Weaving a bead increases the width of the deposit. It also increases the overlap. Weaving is used to widen a bead, to fill undercut at the sides and to assist in slag formation. Weaving is generally recommended for filling poor fitting joints. A weave bead is deposited by moving the rod back and forth across the surface to be welded. Stringer beads may be run at the edges first. Several different electrode movements may be used, but weaving is generally done in the flat position using a semicircular motion to the left and the right figure..

fig. a “>” fig .b.” 8 “ fig.” u “

Fig.5 Weave Bead Techniques

1.22 Flat Position

A weld made on the topside of the parent metal and within 30 degrees of horizontal is called a *flat weld.* The flat position is the most desirable position for welding, since the operator can see the work easily. In many welding shops a device called a *positioned* is used to hold the work, so that it can easily be turned into the flat position. Flat welds can be made successfully with AC, DCRP, or DCSP.

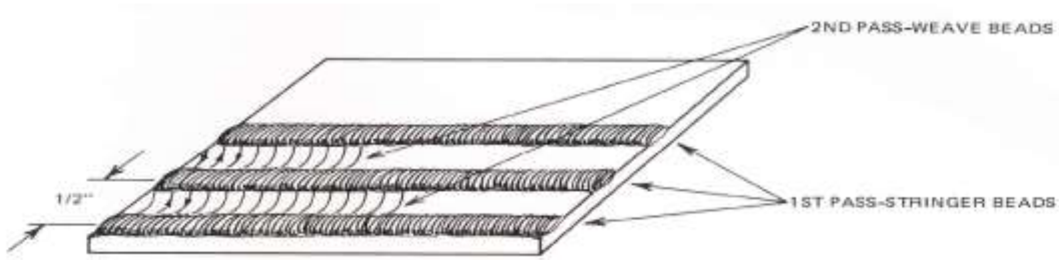


Fig.6 Perform welding joints & Edge preparation for groove welding.

- Butt (groove) welding.

A butt weld joins the edges of two pieces of metal which are in line with one another. When welded, the two pieces of metal form a flat surface. For a butt weld to have full strength it must have 100 percent penetration into the parent metal. When 1 00 percent penetration is achieved, the bottom edges of the plates will be completely fused together.

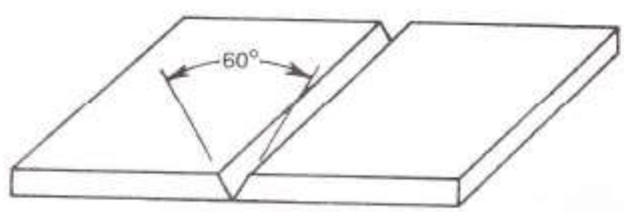


Fig.7 Beveling Plate for a Butt Weld

thick, the edges will melt rapidly and *may* fill the gap without completely fusing the bottom edges of the joint. If the parts can be welded from both sides this will improve fusion, but often butt welds must be made where the metal is welded from one side only. Such welds can be prepared by beveling the edges of the two plates with a grinder. Usually the edges are beveled about 30 degrees so that when they are fitted together their edges form a V of about 60 degrees.

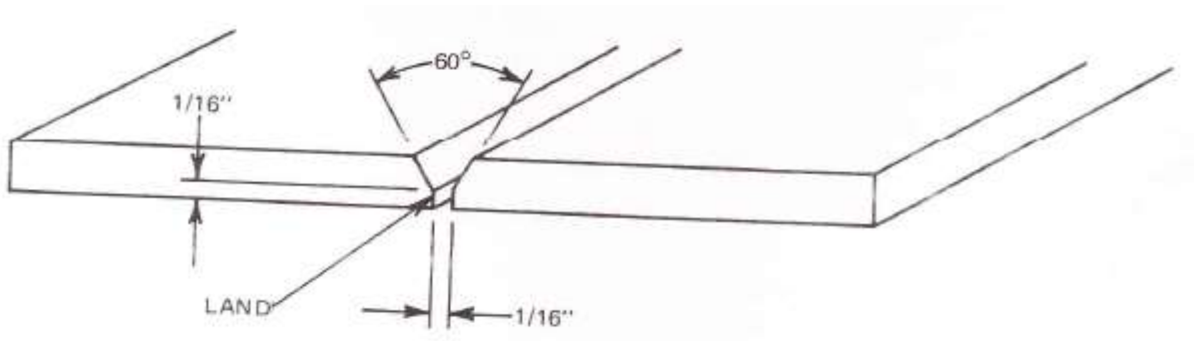


Fig. 8 Plates Prepared for a Butt Weld

When the plates are tack welded, a narrow gap is left between them. This helps insure 100 percent penetration of the root pass. After each pass, the weld must be chipped and cleaned, to prevent slag from being trapped in the following passes.

1.23 Fillet Weld

The fillet weld, figure 7-1, is the type of weld used most often in industry. A fillet weld is a weld made on two pieces of metal which are joined in any way other than in a flat plane. A *fillet* is a reinforcement, and a weld made in an inside corner is called a *fillet weld.* Fillet welds are sometimes called *T welds,* when the pieces form a 90-degree angle..

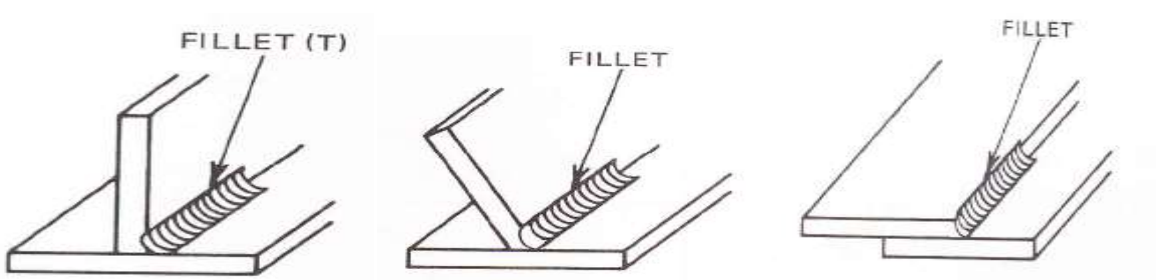


Fig. 9 Fillet Welds

1.24 Preparation for a Fillet Weld

When the pieces to be welded are less than 3/1 6 inch thick, welding on both sides of the joint should produce a strong joint. When thicker metal is welded the joint must be prepared in such a way that the weld penetration is 100 percent. The pieces may be gapped, as in figure 7-2. Another method is to bevel the edge, figure 7-3 so the weld can penetrate the joint.

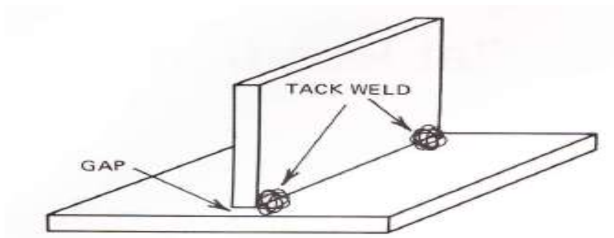


Fig. 10{a} Gapping the Pieces for a Fillet Weld

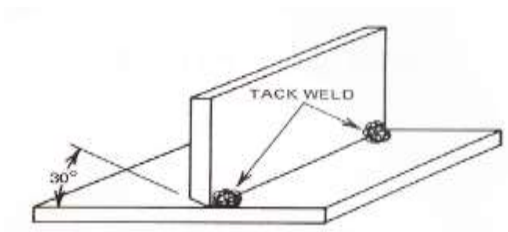


Fig. 10{b} Beveled Edge for a Fillet Weld

1.25 Welding in different position

An *out position* weld is a weld made in any position other than flat. A horizontal weld is a weld made in a horizontal line and against a surface which is approximately vertical. Horizontal welding presents a problem because gravity works against the welder. The molten metal deposited by the arc has a tendency to sag downwards. This g must be controlled by rod angle and rod manipulation.

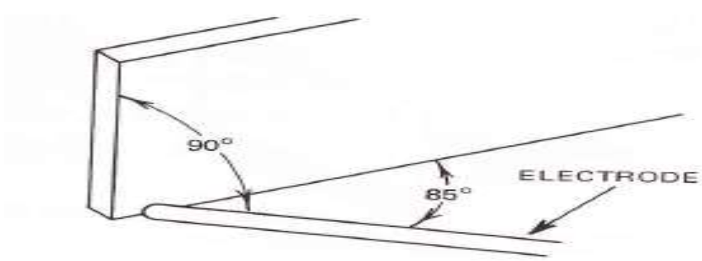


Fig.11 Electrode Angle

Tabel.5 Procedure or welding joints

<table>
<tr><td>PROCEDURE</td><td>KEY POINTS</td></tr>
<tr><td>1. Place a sample plate in position for horizontal welding.
2. Set the welding machine for reverse polarity.
3. Beginning at the bottom left corner of the plate, weld a stringer bead across the plate.

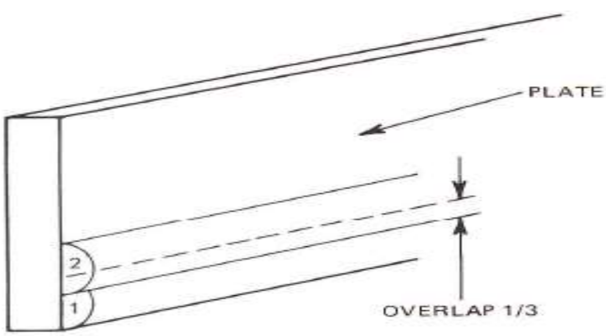
4. Chip and brush the weld.
5. Weld another bead across the plate, just above and slightly overlapping the first bead. The first head welded will help support the second bead.
6. Continue welding horizontal beads until the plate has been completely filled with weld. Figure 9-3.
7. Save this plate for use in unit 15.


Fig Overlap for stringer beads</td><td>3. Hold the welding rod at an angle of 90 degrees with the plate and pointed slightly toward the completed weld. Move at a steady, uniform rate of speed.

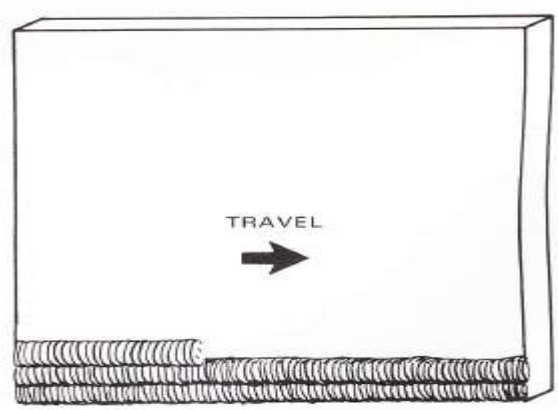
5. The second bead should overlap about one-third of the first head, figure 9-2.
6. Be sure to chip and brush each bead before welding the next one.


Fig Cover the Entire plate with striger beads</td></tr>
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1.26 Vertical position welding

A vertical weld is any weld made in an approximately vertical line. Vertical welding may be difficult for the beginner, but with practice attractive welds with excellent strength can be made. The electrode should be held at an angle of 90 degrees with the plate, and then pointed slightly upward, Keep the electrode pointed directly at the plate. Allowing it to point slightly left or right will allow the arc to wash the molten metal out of the puddle..

1.27 Overhead Weld

An overhead weld is one which is made on the underside of the joint and runs in a horizontal line, figure 17-1. Welds which are inclined *45* degrees or less are considered to be in the overhead position.

1.27 Welding Polarity

Out-of-position welds (welds made in positions other than the flat position) are generally made with DCRP. However, out-of-position welds can be made with DCSP or AC. When the plate is the negative terminal and the electrode is the positive terminal, two-thirds of the welding heat is in the electrode. This means that the coupon does not become as hot and does not have as great a tendency to drip down. AC welding machines release about half of the heat at each terminal, so they are also useful for out-of-position welding.

1.29 Difficulties of Overhead Welding

Overhead welding may seem more difficult than other positions because of four factors:

• Welding overhead places the arms and neck in an awkward position and tends to cause muscle cramp.

• Molten metal tends to drip down from the weld because of the force of gravity. If the electrode is not handled correctly and if the welder does not flash off from the weld when the heat becomes too intense, a poor weld results.

• In order to prevent an excessive concentration of heat in one area, the weld must be made with more passes, depositing a smaller bead in each pass. This means that overhead welding takes more time than other welding positions.

• Because of the hazard created by the molten metal dropping from the weld, bulky fireproof clothing must be worn for overhead welding. This bulky clothing slows down the welder and creates an uncomfortable working condition.

1.30 Positioned

A fixture which is used to hold material while it is being worked on is called a fig. A *positioned* is a special jig for holding material in the desired position for welding. For overhead welding the coupon must be clamped above the welder's head in the positioned.

Manual metal arc welding Aluminum

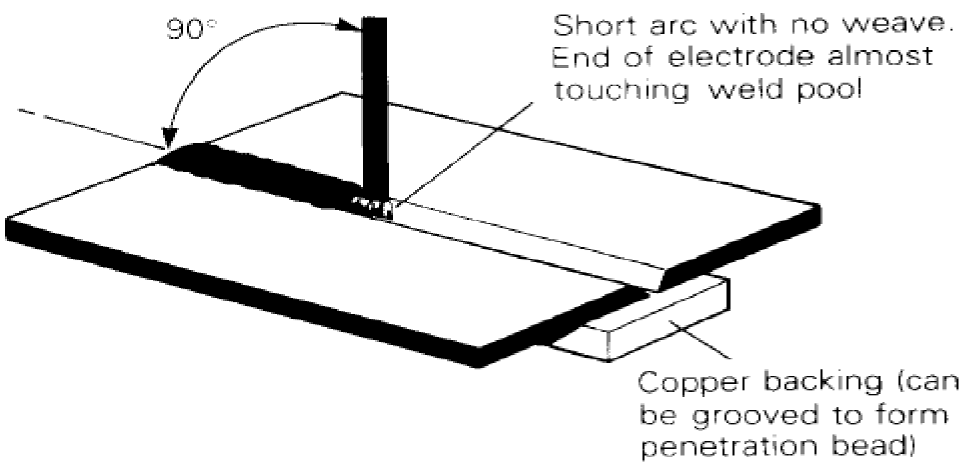


Fig.12 Manual metal arc welding of aluminum.

1.31 Manual metal arc welding copper

Electrodes for manual metal arc welding are usually of the silicon-bronze Of tin-bronze type, as copper electrodes tend to give a porous weld with this process. Therefore, if the

weld has to have characteristics that match the parent material. For electrical conductivity or other reasons, you should use the TAGS or MAGS processes.
If you are using the manual metal arc process, connect the electrode to the positive terminal of a d.c. Power source. After preheat, make the weld with a short arc and. holding the electrode almost vertical. Perform a crescent-shaped weave, pausing slightly at each fusion face.

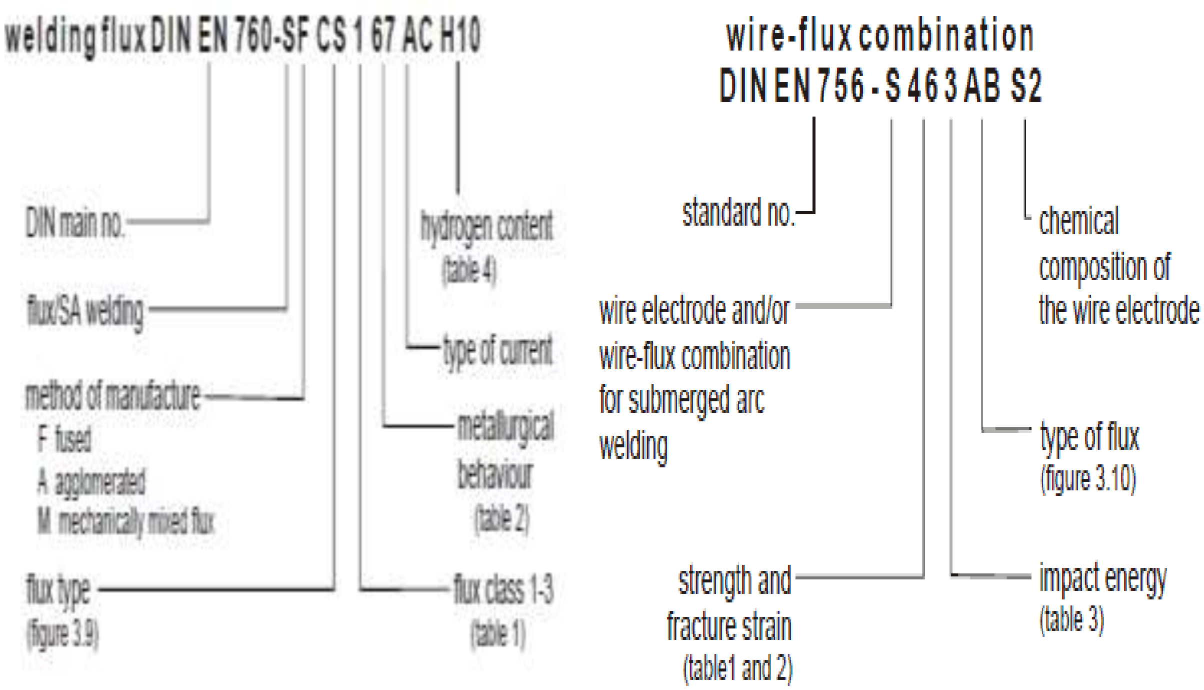


Fig 13. Identification of a welding flux according to DIN EN 76

The chart below sets out general recommendations for choosing operating conditions.

Electrode diameter	Gas cup size	AC(hf)	DC(–)
0.5 mm	6 mm	5–15	5–20
1.0 mm	6 mm	15–40	15–70
1.2 mm	6 mm	20–60	40–90
1.6 mm	6 mm or 10 mm	20–90	65–120
2.4 mm	10 mm	60–160	140–250
3 mm	12 mm	120–220	250–380
5 mm	15 mm	160–340	300–550
6 mm	15 mm	280–470	500–700

3.32 Personal safety:

- **The basic dress rules that you should always follow are:**

Before you set up your welding and strike an arc, you'll first prepare your safety tools and equipment for welding.

- **Proper clothing.**

You must not wear loose clothes that can be caught in moving machinery. You must wear tight fitting overalls as shown in Figure.1.2.

- **Proper shoes.**

You must not wear sandals or soft shoe inside the workshop as they will not protect your feet from falling objects. A safety shoes (steel-toe shoes) will protect your feet if you accidentally drop something. A safety shoe is shown inFigure.1.3.

The way you dress in the workshop is very important for your safety, always be sure to wear properly and encourage your friends to do the same.

Figure. 1.3: Shows a safety shoe

- **Proper eye protection.**

You must always wear goggles to protect your eyes while you are working in the workshop. A safety goggles is shown in Figure.1.4

Figure. 1.4: Safety shield/ Helmet

- **Welding Hand gloves**

Gloves must always be worn when arc welding. Special welding gloves with long gauntlets are necessary. These must be of leather. Long lined welding gloves are recommended for welding with coated electrodes show figure 1.5

Figure. 1.5 hand Gloves

1.33. Welding Safety Precaution and equipments

A. Do not simultaneously touch the ground clamp and the electrode.

B. Do not weld around combustibles.

C. Locate the nearest fire extinguisher before welding.

D. Do not operate in wet areas, wear wet or damp clothing, or have wet hands.

E. Use the correct size welding cables.

F. Check to be sure that cables, holder, and connections are properly insulated.

G. Do not change welding current setting while making a weld; cut off power to welder before making internal adjustments or cleaning.

H. Do not operate the polarity switch while welding (DC welders only

Self-Check- 1	Choose the best answer

PART I: Choose brief answer for the following question.

1. ------------- hold the voltage constant and vary the current, and as a result,
   A. Constant Current C. Power supply
   B. Constant voltage power supplies D. All
2. Which one are the points careful considering for selection of welding current.
   A. Thickness of plate/sheet
   B. Length of cable required
   C. Arc blow D. All
3. Select the amperage used for1/8” electrode diameter of E-601 3 type electrode.
   A.120-170 B. 140-240 C. 70-120 d All

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

Answer Sheet

Score = ____________

Rating: _____________

Name: ___________________________ Date: ________________

Short Answer Questions

Information Sheet-2	Welding terms and symbols are correctly interpreted and applied to welding due to slandered

2.1 Welding terminology

- **Electrode** – a rod that is used in arc welding to carry a current through a work piece to fuse two pieces together. In some welding processes, the electrode may also act as the filler metal.
- **Filler metal** – metal deposited into the weld to add strength and the welded joint.
- **Flux** – a chemical cleaning agent that is applied to a joint just prior to the welding process to
  clean and protect the metal surface from surface oxides that form as a result of heating.
- **Porosity** – the appearance of tiny bubbles on a weld bead as a result of gas entrapment; excessive porosity can weaken a weld.
- **Root opening** – the separation at the joint root between the base metals.
  Shielding Gas – inert or semi-inert gas that is used to protect the weld puddle reacting negatively with the atmosphere.
- **Slag** – cooled flux that forms over the top of the weld; slag protects the cooling metal and is then chipped off.
- **Spatter** – liquid metal droplets expelled from the welding process.
- **Weld ability**– the ability of a material to be welded under prescribed conditions and to perform intended.
- **Bead-** the weld/deposited melted metal
- **Ripple -** Shape of the bead
- **Pass** – Each layer of the weld bead deposited
- **Crater-** Depression in the base metal
- **Penetration –** Depth of fusion with metal
- **Arc Length –** Distance from electrode to metal
- **Weld Face** - Exposed surface of weld
- **Root** - Base of weld
- **Toe -** Where the face meets metal

- **Leg** - Distance between toe and root
- **Porosity** – Voids of gas pockets in the weld
- **Post-Heating** – Heating after welding
- **Pre-Heating** – Heating before welding
- **Spatter** – Metal particles expelled during welding
- **Weaving** – Back and forth movement
- **Undercut** – Toe below metal surface
- **Overlap** – Toe above metal surface

2.2 Manual metal arc welding (MMAW)

MMAW is a welding process that creates an electric arc between a hand held, flux-coated, consumable filler wire and the work piece. Welding commences when an electric arc is struck by making contact between the tip of the electrode and the work.

2.3 Application of Manual metal arc welding (MMAW)

This also referred to as "Stick Welding" is the most commonly used type of welding and used for everything from pipeline welding, farm repair and complex fabrication. It uses a "stick" shaped electrode and thus its name indicates. Materials that can be welded by this process include: steel, cast iron, stainless steel, **Electricity and welding**

All welding processes depend on three main requirements for their operation. These are

- A heat or energy source – needed for fusion.
- Atmospheric shielding – to prevent oxygen and nitrogen in the atmosphere from contaminating the weld.
- Filler metal – to provide the required weld build-up.

2.4 General working principle of MMAW

The electrode is placed in an electrode holder, which is connected to one lug of a constant current welding power supply. This power supply can be operated on alternating current (AC),direct current electrode positive (DCEP), or direct current electrode negative (DCEN) depending on the type of electrode being used.

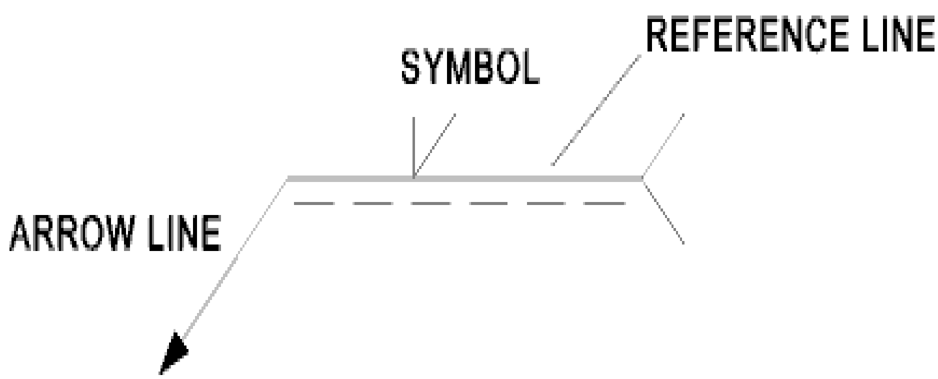
standards

The British Standard for weld symbols is BS EN 22553. When identification of the weld process is required as part of the weld symbol the relevant weld process code is listed in BS EN ISO 4063.

Basic Weld Symbol

The weld symbol always includes

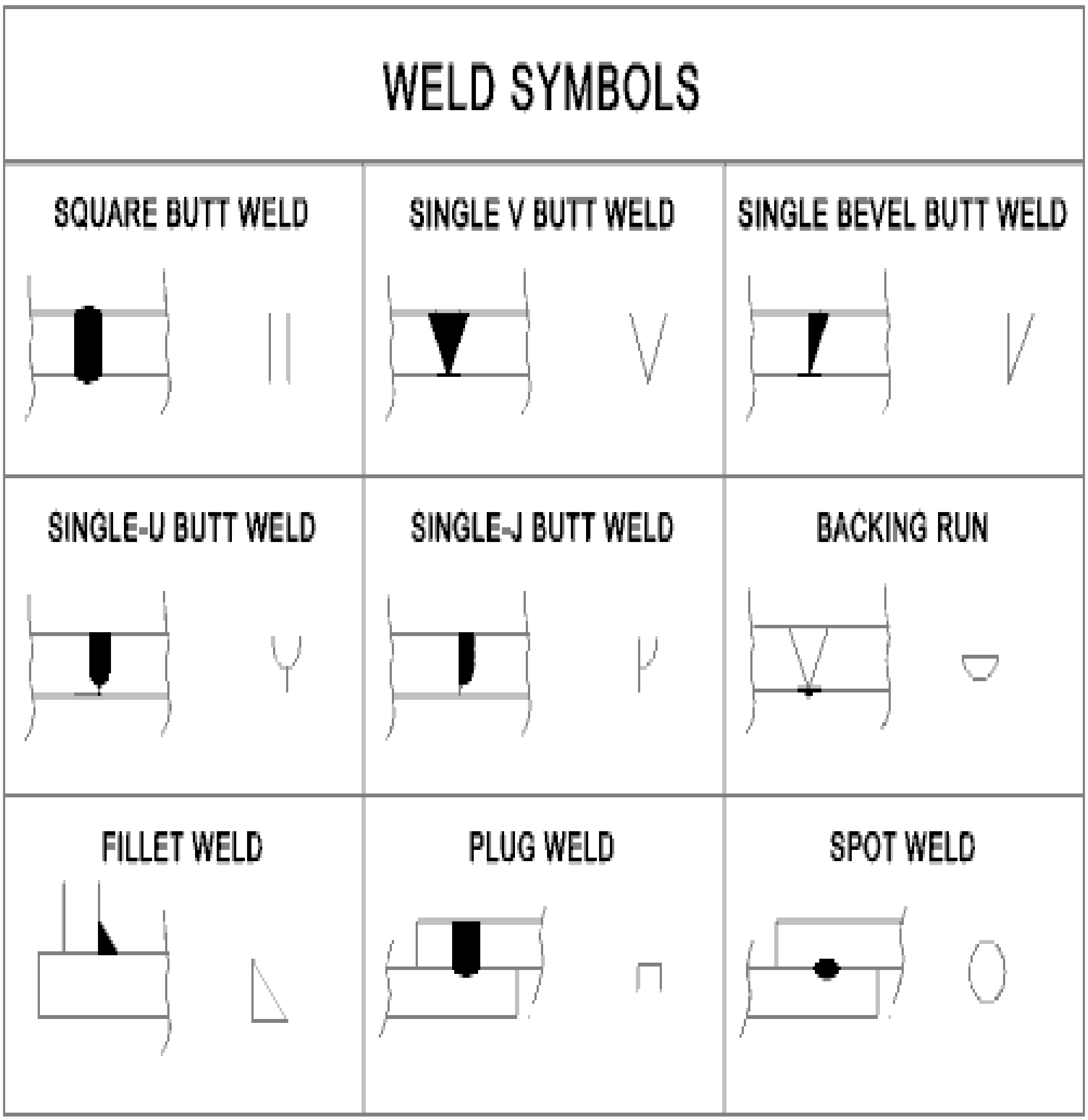
1. An arrow line
2. A reference line
3. A symbol



Note: Weld symbols on the full reference line relates to welds on the near side of the plate being welded. Weld symbols on the dashed line relates to weld on the far side of the plate. If the welds are symmetrical on both sides of the plate the dashed line is omitted. If the dashed line is above the full line then the symbol for the nearside weld is drawn below the reference line and the symbol for the far side weld is above the dashed line

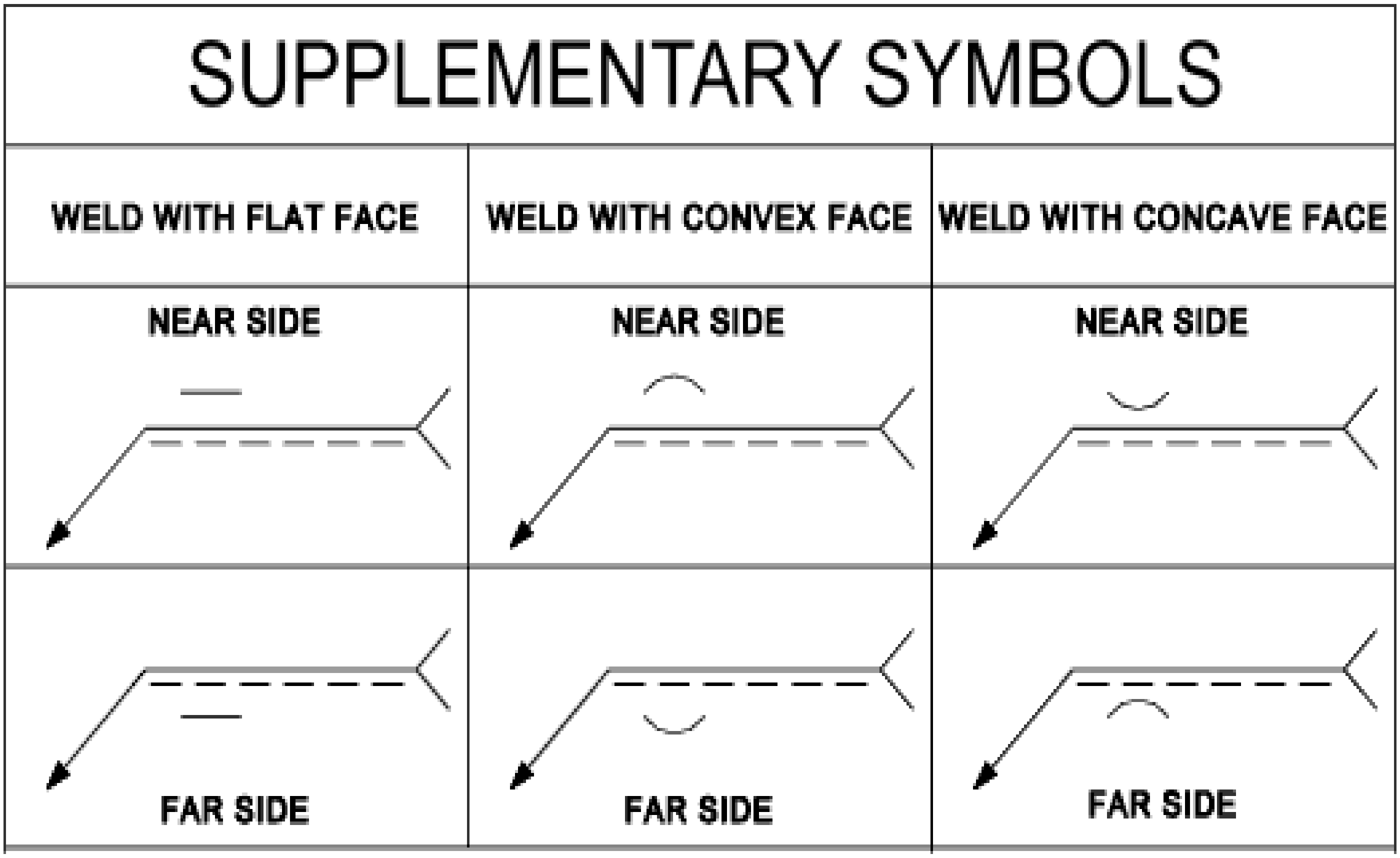
More Detailed Symbolic Representation of Weld

Table of Weld Symbols

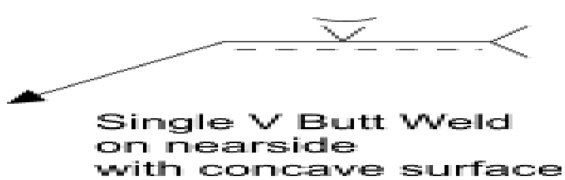


Supplementary Symbols

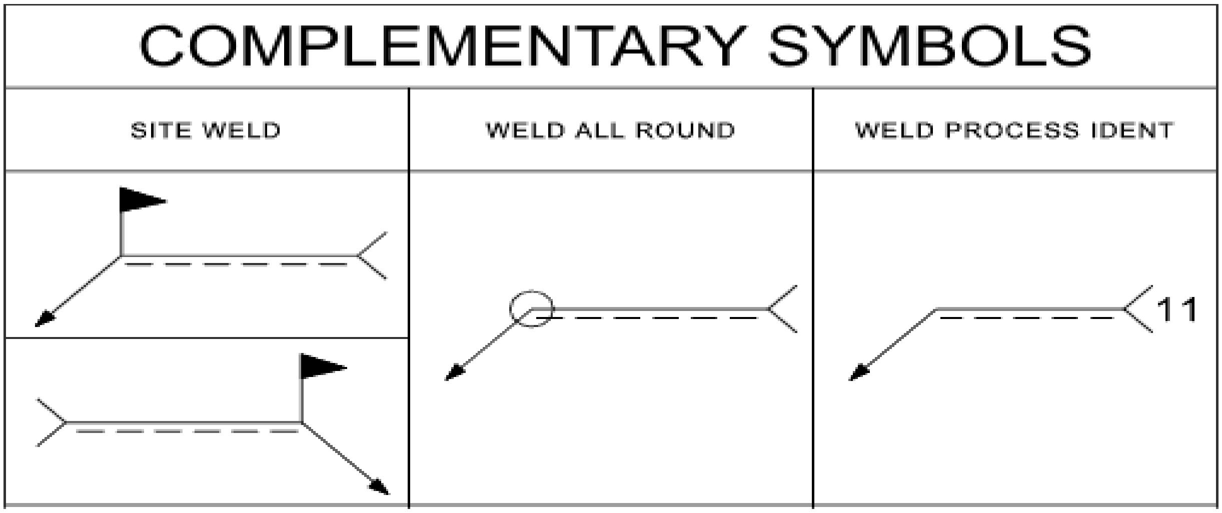
The weld symbols below are used in addition to the primary weld symbols as shown above. They are not used on their own.



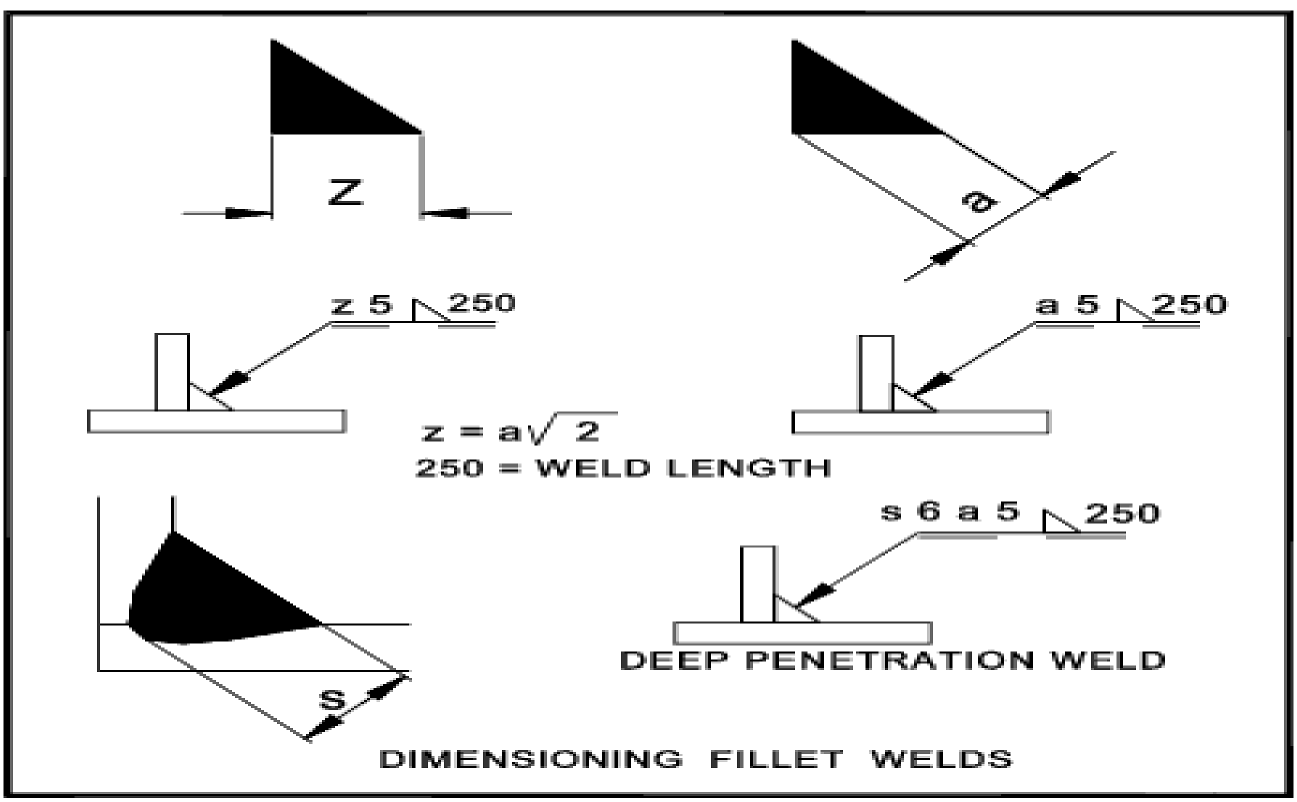
Below is an example of the application of this symbl.

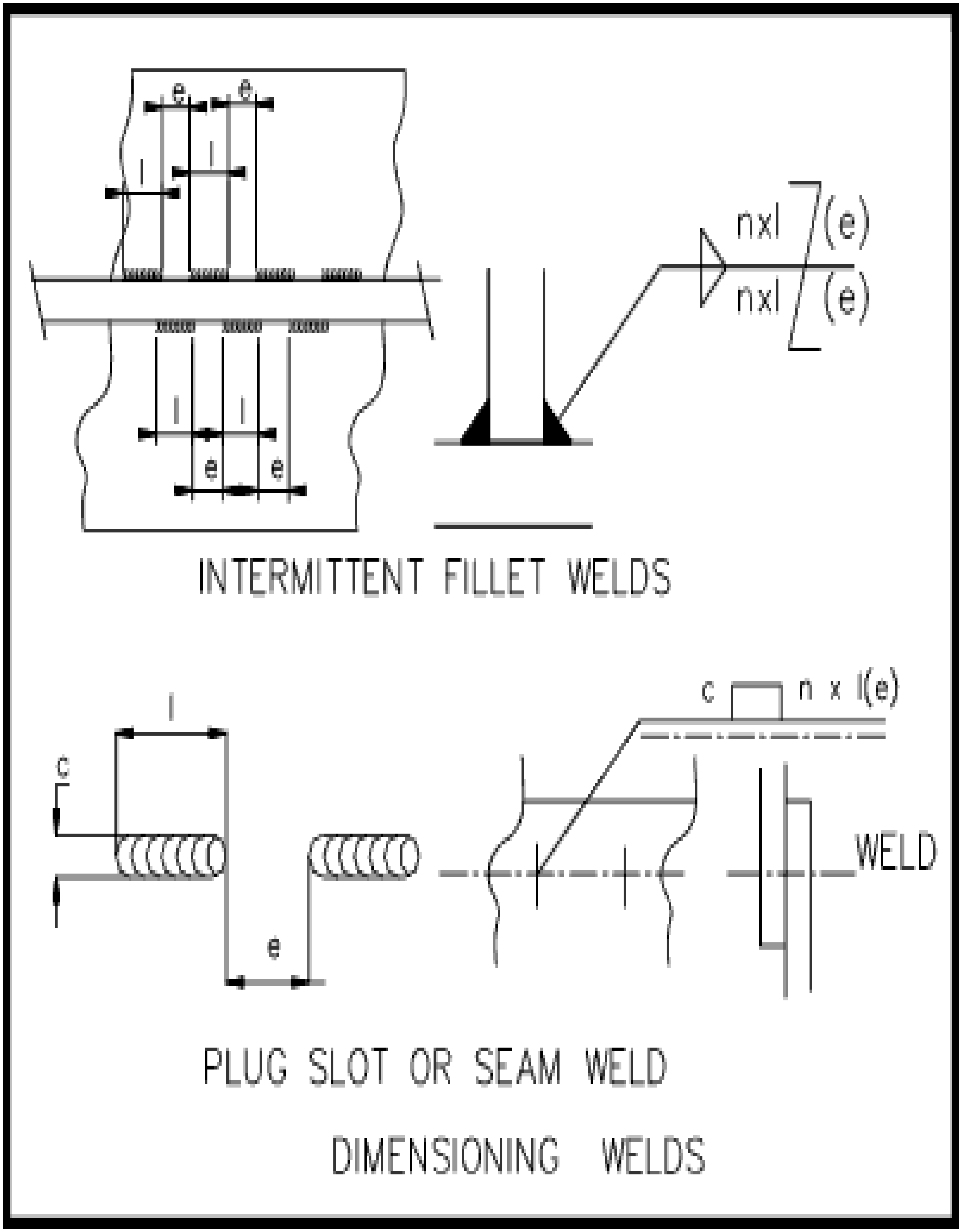


Complementary Indication

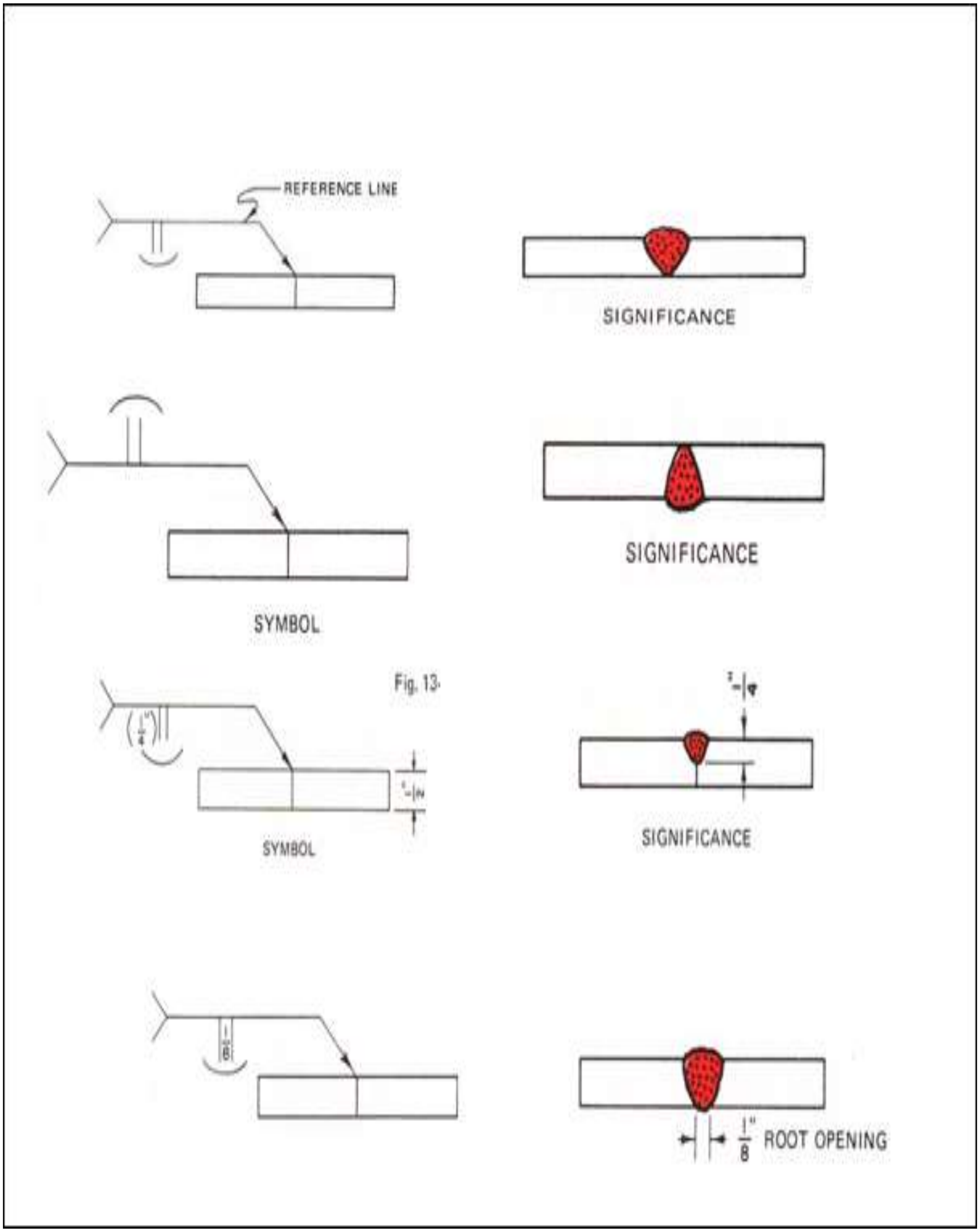


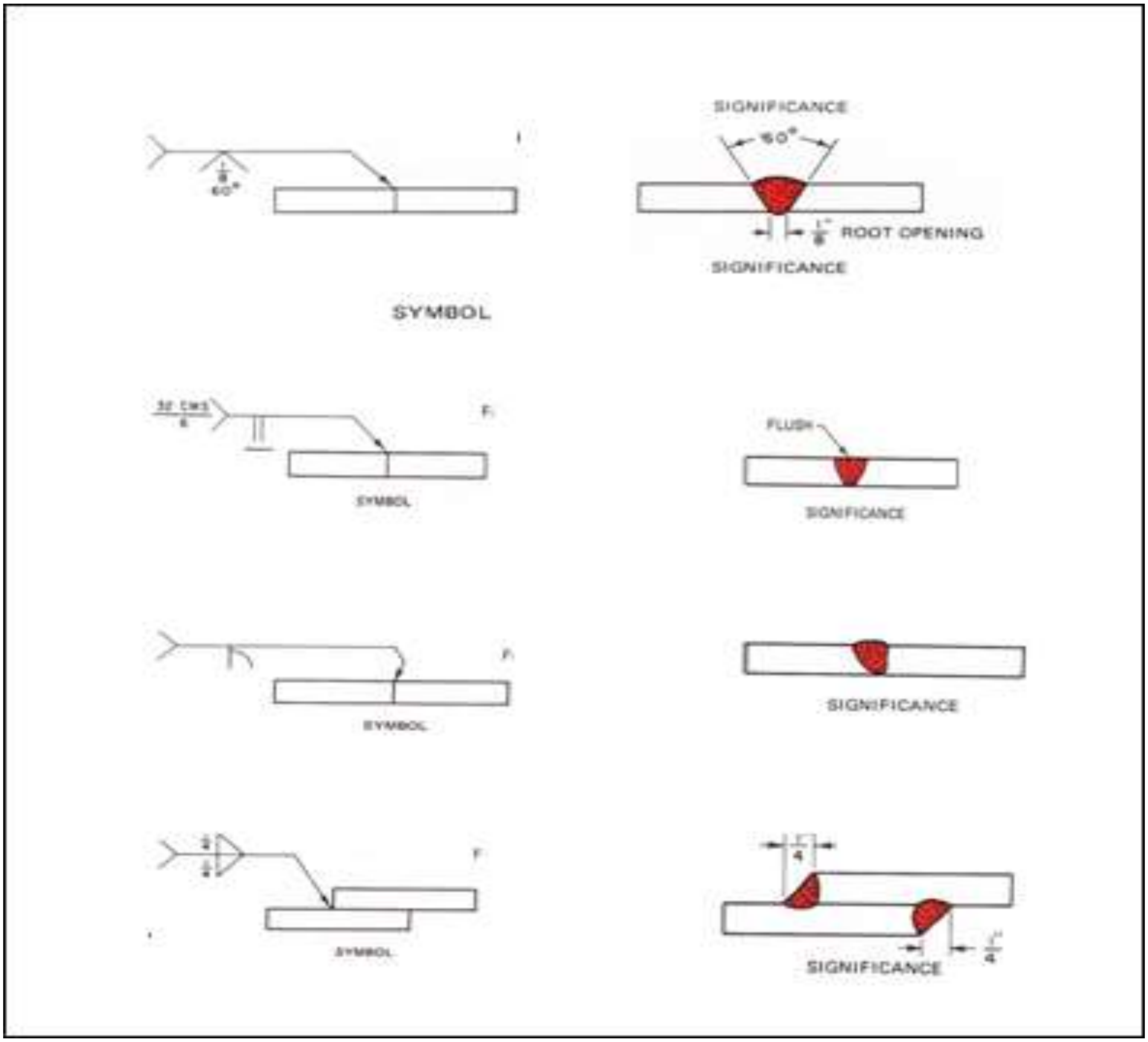
Dimensioning Welds





e
l
nxl
(e)
INTERMITTENT FILLET WELDS
c
n x l(e)
WELD
PLUG SLOT OR SEAM WELD
DIMENSIONING WELDS


REFERENCE LINE
SIGNIFICANCE
SIGNIFICANCE
SYMBOL
Fig. 13
SYMBOL
SIGNIFICANCE
ROOT OPENING


SIGNIFICANCE
60°
ROOT OPENING
SIGNIFICANCE
SYMBOL
FLUSH
SYMBOL
SIGNIFICANCE
SYMBOL
SIGNIFICANCE
SYMBOL
SIGNIFICANCE

Self-check-2	Written-Questions

Direction-Choose the best answer

1. In the bond electrons are shared between atoms outermost shells.

   A Ionic bond — C Metallic bond
   B Covalent bond — D none

2 The smallest unit of which matter was composed and the indivisible.

   A proton — C atom
   B electron — D None

3 the same itself points out this type of crystal structure has

   A BCC — C HCP
   B FCC — D None

4 This types of crystal structure has one single atom in every cubic atom

   A BCC — C FCC
   B HCP — D .None

Note: **Satisfactory rating –7points** **Unsatisfactory - below 7 points**

You can ask you teacher for the copy of the correct answers.

Answer Sheet

Score = ____________

Rating:_____________

Name: ___________________________ Date: ________________

Short Answer Questions

LG #54	**LO.2** Apply heat treatment in relation to welds

Instruction sheet

This learning guide is developed to provide you the necessary information regarding the following content coverage and topics:

- Reasons for performing heat treatment are identified in compliance with regulations
- Processes such as pre-heat/post-heat treatment, stress relieving, normalizing and annealing are applied according to operational standards

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

- Principles of planning and setting up welding process are supervised and applied based on operational specifications
- Where specified, welds are prepared for external testing based on applicable welding code , and safety and reliability regulations

Learning Instructions:

10. Read the specific objectives of this Learning Guide.
11. Follow the instructions described below.
12. Read the information written in the “Information Sheets”. Try to understand what are being discussed. Ask your trainer for assistance if you have hard time understanding them.
13. Accomplish the “Self-checks” which are placed following all information sheets.
14. Ask from your trainer the key to correction (key answers) or you can request your trainer to correct your work. (You are to get the key answer only after you finished answering the Self-checks).
15. If you earned a satisfactory evaluation proceed to “Operation sheets
16. Perform “the Learning activity performance test” which is placed following “Operation sheets” ,
17. If your performance is satisfactory proceed to the next learning guide,
18. If your performance is unsatisfactory, see your trainer for further instructions or go back to “Operation sheets”.

Information Sheet-1	Reasons for performing heat treatment are identified in compliance with regulations

2.1 Purpose of heat treatment

The purpose of heat treating is to make a metal more useful by changing or restoring its mechanical properties. There are innumerable purposes, which are achieved by heat treatment yet the following are important:-

- To relieving internal stresses, which are set up in metal due to cold or hot working
- To soften the metal.
- To improve hardness of metal surface.
- To improve mach inability.
- To refine grain size structure
- To improve mechanical properties like, tensile strength, ductility and shock resistance, etc.
- To improve electrical and magnetic properties.
- To increase the resistance to wear, tear, heat and corrosion, etc.

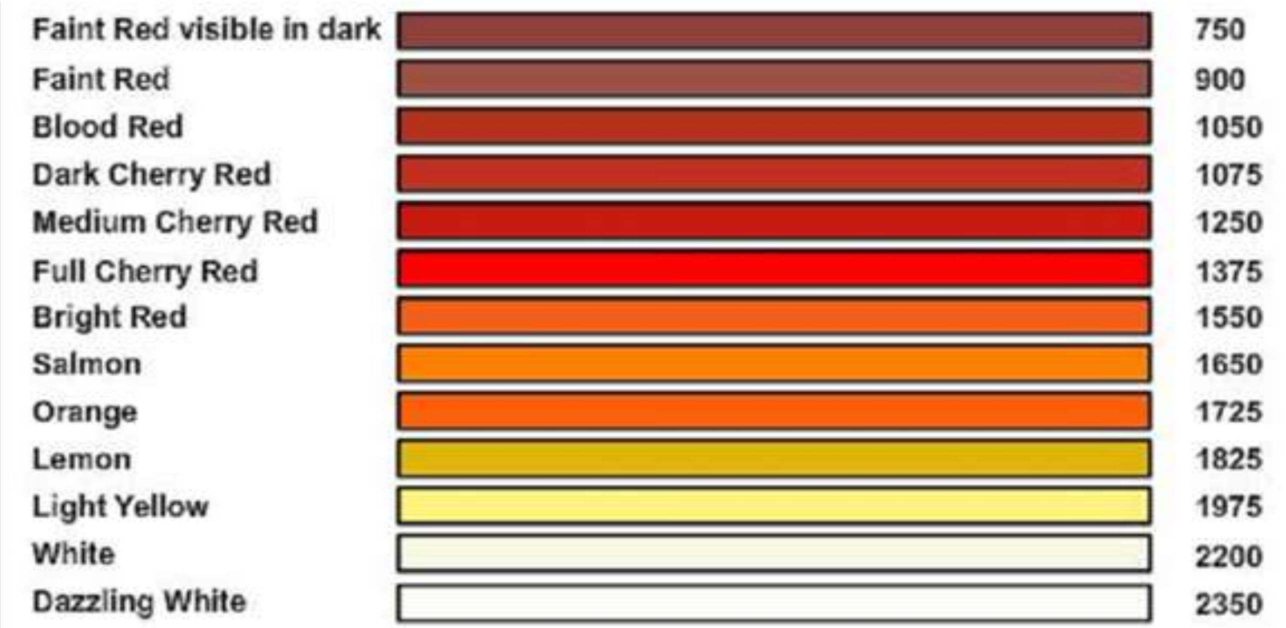
2.2 The Influence of Loading

Of all the variables affecting heating, loading is the one most often taken for granted. Non-uniformity of results, even from the same heat of steel, can be introduced if different parts of the workload are unequally exposed to heat (or cooling). Hence, it is not merely time and temperature but a time-temperature-mass-surface relationship that must be factored into the heating time.

Component parts come in all shapes and sizes. To meet this demand, standard and custom furnaces have been designed to accommodate the many workload confi-gurations. Loading arrangements fall into two general classes: weight-limited and volume-limited. In either case, when loading parts in furnace baskets or onto racks, the goal is often to maximize loading efficiency. As heat treaters, however, we must also be concerned with proper part spacing (i.e. how parts are situated within the load for optimal heat transfer, atmosphere circulation, temperature uniformity and heat extraction during quenching so as to minimize dimensional variation).

2.3 Recognizing heat colors for steel

“Red-hot” is a term you are probably familiar with as applies to steel, but steel actually takes on several colors and shades from the it turns a dull red unit it reaches a white heat. Figure shows approximate colors and their corresponding temperatures.



Color	Perceived colors depend on lighting.	Temperature	
		F°	C°
Faint Red visible in dark		750	399
Faint Red		900	482
Blood Red		1050	565
Dark Cherry Red		1075	579
Medium Cherry Red		1250	677
Full Cherry Red		1375	746
Bright Red		1550	843
Salmon		1650	899
Orange		1725	940
Lemon		1825	996
Light Yellow		1975	1079
White		2200	1204
Dazzling White		2350	1288

Figure 2-1 — Example of approximate heat colors for steel.

3.1. Types of Heat Treatment processes

Basic types of heat treatment are used today. They are annealing, normalizing, hardening, tempering and surface hardening, and others (austempering, martempering, etc). More of them can be shown below figures 2.

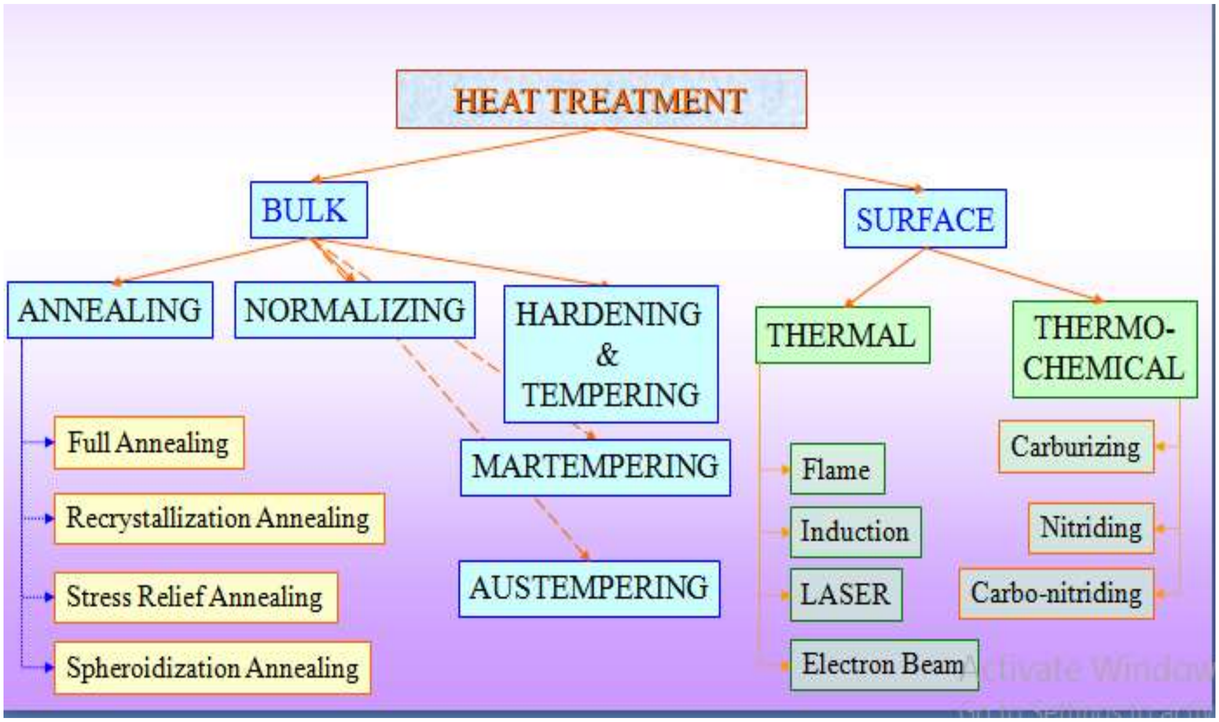


Fig. 2 Types of heat treatment processes

2.4 ANNEALING

- In general, annealing is the opposite of hardening, you anneal metals to relieve internal stresses, soften them, make them more ductile, and improve their grain structures.
- Annealing consists of heating a metal to a specific temperature, holding it at that temperature for a set length of time, and then cooling the metal to room temperature.
- The cooling method depends on the metal and the properties desired. Some metals are furnace-cooled, and others are cooled by burying them in ashes, lime, or other insulating materials.

2.5 Purpose

- Reduce hardness and brittleness
- Alter the microstructure for a special property
- Soften the metal for better machinability
- Recrystallize cold worked (strain hardened) metals
- Relieve induced residual stresses

2.6 ANNEALING Types

- ✓ Full Annealing
- ✓ Recrystallization Annealing
- ✓ Stress Relief Annealing
- ✓ Spheroidization Annealing

2.7 Full Annealing

- ✓ The purpose of this heat treatment is to obtain a material with high ductility. A microstructure with coarse pearlite (i.e. pearlite having high interlamellar spacing) is endowed with such properties.
- ✓ The range of temperatures used is given in the figure 3 bellows.
- ✓ The steel is heated above A_3 (for hypo-eutectoid steels) & A_1 (for hyper-eutectoid steels) → (hold) → then the steel is furnace cooled to obtain Coarse Pearlite.
- ✓ Coarse Pearlite has low (↓) Hardness but high (↑) Ductility.
- ✓ For hyper-eutectoid steels the heating is not done above A_{cm} to avoid a continuous network of proeutectoid cementite along prior Austenite grain boundaries (presence of cementite along grain boundaries provides easy path for crack propagation).

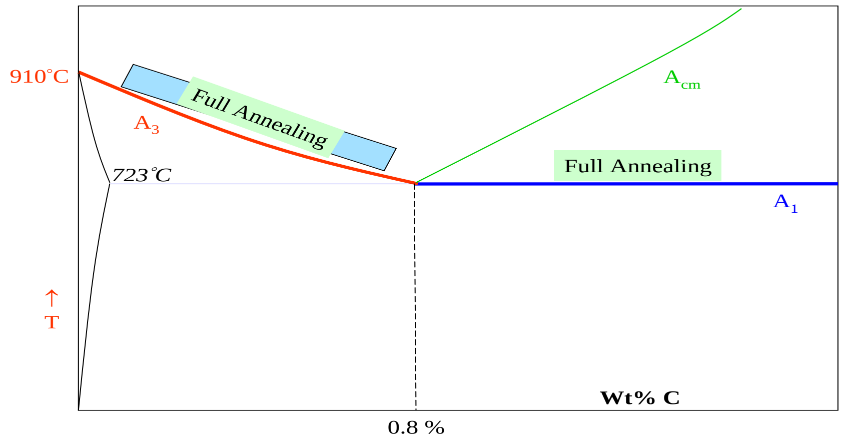


Fig. 3. Shows full annealing

2.8 Recrystallization Annealing

- ✓ During any cold working operation (say cold rolling), the material becomes harder (due to work hardening), but loses its ductility. This implies that to continue deformation the material needs to be recrystallized (wherein strain free grains replace the 'cold worked grains').
- ✓ Hence, recrystallization annealing is used as an intermediate step in (cold) deformation processing. Show in the below figure 4.
- ✓ To achieve this sample is heated below A_1 and held there for sufficient time for recrystallization to be completed.

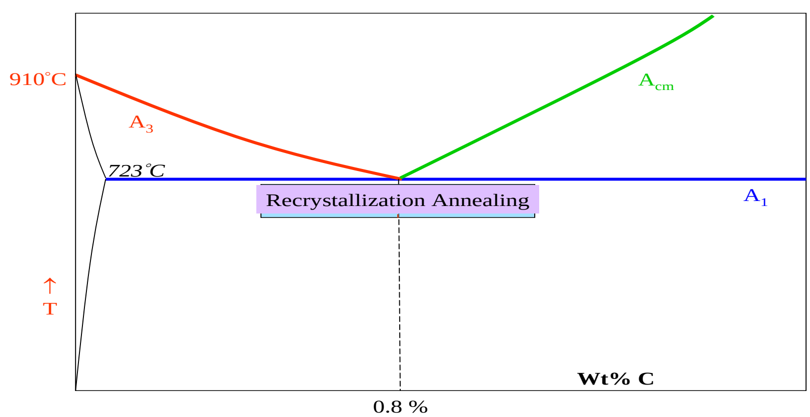


Fig.4. Shows Recrystallization annealing

2.9 Stress Relief Annealing

- ✓ Due to various processes like quenching (differential cooling of surface and interior), machining, phase transformations (like martensitic transformation), welding, etc. The residual stresses develop in the sample. Residual stress can lead to undesirable effects like warpage of the component. Shown bellow fig.5.
- ✓ The annealing is carried out just below A_1, wherein 'recovery*' processes are active (Annihilation of dislocations, polygonization).

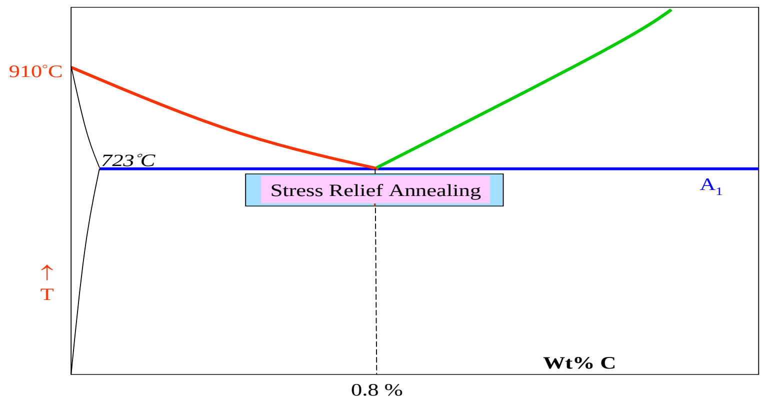


Fig.5. show at which stress relief annealing will be occurs

2.10 Spheroidization Annealing

- ✓ This is a very specific heat treatment given to high carbon steel requiring extensive machining prior to final hardening & tempering. The main purpose of the treatment is to increase the ductility of the sample.
- ✓ Like stress relief annealing the treatment is done just below A_1. See fig.6.
- ✓ Long time heating leads cementite plates to form cementite spheroids. The driving force for this (microstructure) transformation is the reduction in interfacial energy.

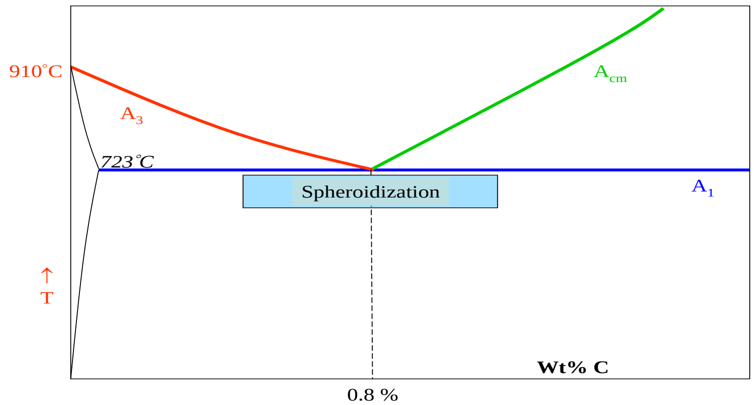


Fig.6. shows the spheroidization annealing

2.11 NORMALIZING

- Normalizing is a type of heat treatment applicable to ferrous metals only. It differs from annealing in that the metal is heated to a higher temperature and then removed from the furnace for air cooling.
- The purpose of normalizing is to remove the internal stresses induced by heat treating, welding, casting, forging, forming, or machining. Stress, if not controlled, leads to metal failure; therefore, before hardening steel, you should normalize it first to ensure the maximum desired results.
- The sample is heat above A_3 | A_{cm} to complete Austenization. The sample is then air cooled to obtain Fine pearlite. Fine pearlite has a reasonably good hardness and ductility. See below fig.7.
- In hypo-eutectoid steels normalizing is done 50°C above the annealing temperature.
- In hyper-eutectoid steels normalizing done above A_{cm} → due to faster cooling cementite does not form a continuous film along GB.

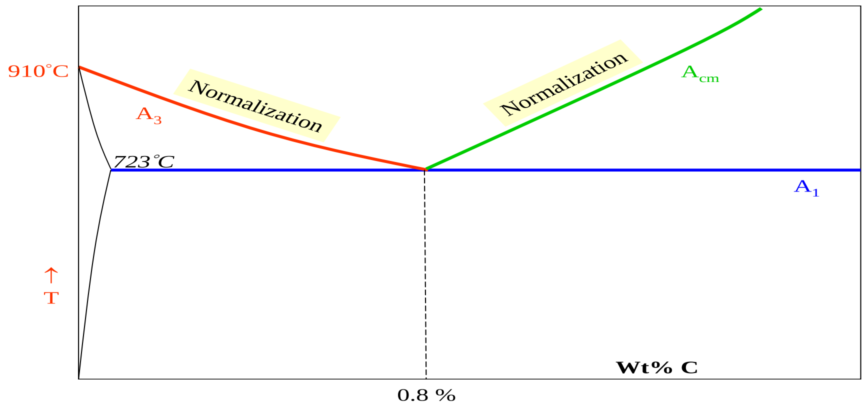


Fig.7. shows the normalization place

2.12 HARDENING

- The hardening treatment for most steels consists of heating the steel to a set temperature and then cooling it rapidly by plunging it into oil, water, or brine. Most steels require rapid cooling (quenching) for hardening but a few can be air-cooled with the same results. Hardening increases the hardness and strength of the steel, but makes it less ductile. Generally, the harder the steel, the more brittle it becomes. To remove some of the brittleness, you should temper the steel after hardening.
- The sample is heated above A_3 | A_{cm} to cause Austenization. The sample is then quenched at a cooling rate higher than the critical cooling rate (i.e. to avoid the nose of the CCT diagram).
- The quenching process produces residual strains (thermal, phase transformation).
- The transformation to Martensite is usually not complete and the sample will have some retained Austenite. See below fig.8.
- The Martensite produced is hard and brittle and tempering operation usually follows hardening. This gives a good combination of strength and toughness.
- Some purpose of hardening ; to harden the steel slightly, refine grain structure to hardening, to reduce segregation in casting or forgings, etc.

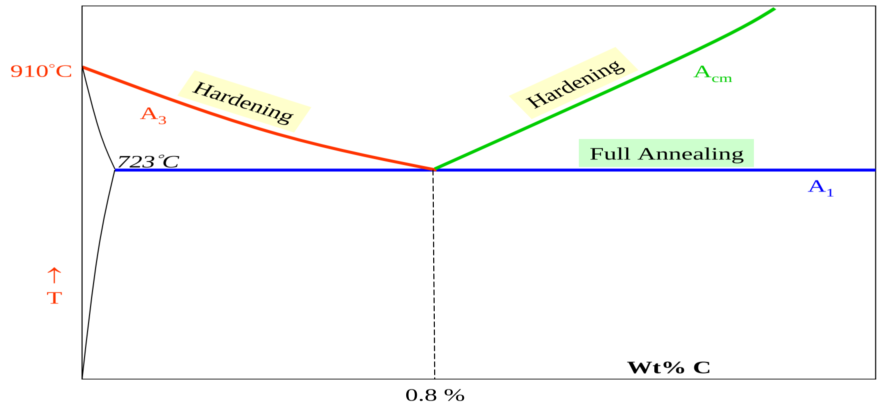


Fig.8. shows hardening takes place

2.13 TEMPERING

- After the hardening treatment is applied, steel is often harder than needed and is too brittle for most practical uses. Internal stresses are set up during the rapid cooling from the hardening temperature. To relieve the internal stresses and reduce brittle-ness, you should temper the steel after it is hardened. Tempering consists of heating the steel to a specific temperature (below its hardening temperature), holding it at that temperature for the required length of time, and then cooling it, usually instill air. The resultant strength, hardness, and ductility depend on the temperature to which the steel is heated during the tempering process.
- Heat below Eutectoid temperature → wait→ slow cooling
- The microstructure changes which take place during tempering are very complex
- Time temperature cycle chosen to optimize strength and toughness
- Tool steel: As quenched (R_c 65) → Tempered (R_c 45-55)
- The purpose of tempering is to reduce the brittleness imparted by hardening and to produce definite physical properties within the steel.

Self-Check -1	Written Test

Direction-Choose the best answer

2. In the bond electrons are shared between atoms outermost shells.

A Ionic bond C Metallic bond
B Covalent bond D none

2 The smallest unit of which matter was composed and the indivisible.

A proton C atom
B electron D None

3 the same itself points out this type of crystal structure has

A BCC C HCP
B FCC D None

3 This types of crystal structure has one single atom in every cubic atom

A BCC C FCC
B HCP D .None

Note: **Satisfactory rating –7points** **Unsatisfactory - below 7 points**

Answer Sheet

Score = ____________

Rating:

Name: ___________________________ Date: ________________

Information sheet#2	Processes such as pre-heat/post-heat treatment, stress relieving, normalizing and annealing are applied according to operational standards

2.1 Surface Hardening

Sometimes called case hardening, Case hardening produces a hard, wear-resistant surface or a "thermo chemical" treatment whereby the surface is altered by the addition of carbon, nitrogen, or other elements. Materials of surface hardening only ferrous metals are case-hardened. Commonly applied to low carbon steels for get a hard ware resistant shell, and tough inner core.

- The common techniques; Carburizing, cyaniding, Nitriding, Carbonnitriding, Chromizing, flame hardening, boronizing, induction hardening, etc.

2.2 Carburizing

- Heating a low carbon steel in the presence of carbon rich environment at temperature ~ 900°C
- This results in carburized steel that has a high-carbon surface and a low-carbon interior.
- When the carburized steel is heat-treated, the case be-comes hardened and the core remains soft and tough. Two methods are used for carburizing steel.
- One method consists of heating the steel in a furnace con-training a carbon monoxide atmosphere.
- The other method has the steel placed in a container packed with charcoal or some other carbon-rich material and then heated in a furnace. therefore
  - ✓ Carbon diffuses into the surface
  - ✓ End up with a high carbon steel surface.
  - ✓ Pack parts in a compartment with coke or charcoal
  - ✓ Gas carburizing

- Uses propane (C_3H_8) in a sealed furnace: Liquid carburizing, Used NaCN, $BaCl_2$, Thickness 0.005 in. to 0.030 in

2.3 CYANIDING

- This process is a type of case hardening that is fast and efficient. Preheated steel is dipped into a heated cyanide bath and allowed to soak.
- This process produces a thin, hard shell that is harder than the one produced by carburizing and can be completed in 20 to 30 minutes vice several hours. The major drawback is that cyanide salts are a toxic.

2.4 NITRIDING

- Nitrogen is diffused in the surface of special alloy steels at temperatures around ~510°C.Steel must contain elements that will form nitride compounds. Aluminum, Chromium
- It differs from the other methods in that the individual parts have been heat-treated and tempered before nitriding. The parts are then heated in a furnace that has an ammonia gas atmosphere. No quenching is required so there is no worry about warping or other types of distortion. This process is used to case harden items, such as gears, cylinder sleeves, camshafts and other engine parts, that need to be wear resistant and operate in high-heat areas.Forms a thin hard case without quenching, Thicknesses 0.001 in – 0.020 in.

2.5 Chromizing

- Diffuse chromium into the surface 0.001 – 0.002 in.
- Pack the parts in Cr rich powders or dip in a molten salt bath containing Cr salts.

2.6 Bronzing

- Performed on tool steels, nickel and cobalt based alloy steels.
- When used on low carbon steels, corrosion resistance is improved.

2.7 Flame Hardening

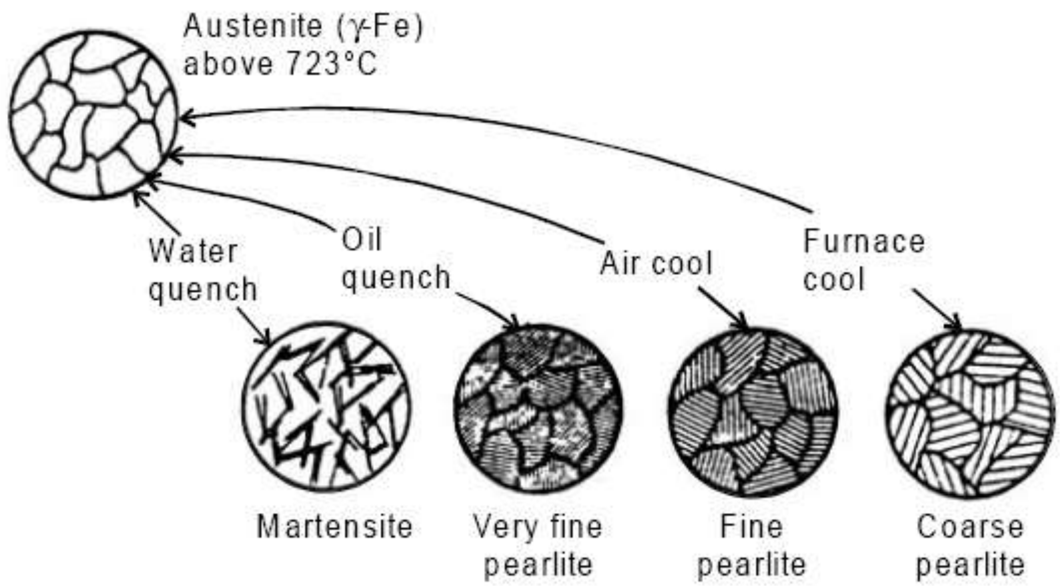
Flame hardening is another procedure that is used to harden the surface of metal parts. When you use an oxyacetylene flame, a thin layer at the surface of the part is rapidly heated to its critical temperature and then immediately quenched by a combination of a water spray and the cold base metal. This process produces a thin, hardened surface, and at the same time, the internal parts retain their original properties. Whether the process is manual or mechanical,

2.8 QUENCHING

Steel parts are rapidly cooled from the austenitizing or solution treating temperature. Stainless and high-alloy steels may be quenched to minimize the presence of grain boundary carbides or to improve the ferrite distribution, but most steels, including carbon, low-alloy, and tool steels, are quenched to produce controlled amounts of martensite in the microstructure. The ability of a quenchant to harden steel depends upon the cooling characteristics of the quenching medium. Quenching effectiveness is dependent on steel composition, type of quenchant, or quenchant use conditions, as well as the design and maintenance of a quenching system.

2.9 QUENCHING MEDIA

Selection of a qunchant depends on the hardenability of the steel, section thickness and shape involved, and the cooling rates needed to achieve the desired microstructure. Typically, quenchants are liquids (water, oil that could contain a variety of additives, aqueous polymer solutions, and water that could contain salt or caustic additives), and gases (inert gases including helium, argon, and nitrogen).



Figure; Effects of cooling of austenite transformation

2.10 Defects and distortion of heat treating

Defects and Distortion in Heat-Treated Parts most of the problems in heat treated parts are attributed to faulty heat treatment practices such as overheating and burning, and non uniform heating and quenching, deficiency in the grade of steels used, part defect, improper grinding, and/or poor part design

Self-Check -2	Written Test

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

Multiple choose

1 TIG welders assemble and weld metal parts, usually for manufacturing or construction projects.

(**3 points)**

A. TIG welder's C. SMAW welders

C. MIG welders D. PAW welders

2. TIG welders regularly perform a variety of tasks depending on their employer.(5points)

A. SMAW welder's C. TIG welders

C. MIG welders D. PAW welders

Note: **Satisfactory rating - 8points** **Unsatisfactory - below 8 points**

You can ask you teacher for the copy of the correct answers.

Answer Sheet

Score = ____________

Rating:

Name: ___________________________ Date: ________________

Short Answer Questions

LG #55	LO 3. Plan the logical sequence of welding operations

Instruction sheet

This learning guide is developed to provide you the necessary information regarding the following content coverage and topics:

- Principles of planning and setting up welding process are supervised and applied based on operational specifications
- Where specified, welds are prepared for external testing based on applicable welding code , and safety and reliability regulations

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

- Principles of planning and setting up welding process are supervised and applied based on operational specifications
- Where specified, welds are prepared for external testing based on applicable welding code , and safety and reliability regulations

Learnistructions:

19. Read the specific objectives of this Learning Guide.
20. Follow the instructions described below.
21. Read the information written in the “Information Sheets”. Try to understand what are being discussed. Ask your trainer for assistance if you have hard time understanding them.

Information Sheet 1	Principles of planning and setting up welding process are supervised and applied based on operational specifications

3 1 Introduction to heat treatment

The process of altering the physical, chemical, and mechanical properties of a metal by applying controlled heating and cooling is known as heat treatment. It is a procedure that is applied to improve or restore a product's manufacturability. Heat treatments are most commonly applied in metallurgy, manufacturing, hot forming, and welding.

3 Three reasons for heat treatment

- ✓ To soften before shaping
- ✓ To relieve the effects of strain hardening
- ✓ *To acquire the desired strength and toughness in the finished* product.

4 Principal heat treatments

- ✓ Annealing
- ✓ Martensite formation in steel
- ✓ Precipitation hardening
- ✓ Surface hardening

5 Process

- ✓ Heat the metal to a temperature
- ✓ Hold at that temperature
- ✓ Slowly cool

6 Purpose

- ✓ Reduce hardness and brittleness
- ✓ Alter the microstructure for a special property
- ✓ Soften the metal for better machinability
- ✓ Recrystallize cold worked (strain hardened) metals
- ✓ Relieve induced residual stresses

7 The Iron Carbon System

- ✓ Steels, ferrous alloys, cast irons, cast steels
- ✓ Versatile and ductile
- ✓ Cheap
- ✓ Irons (< 0.008% C)
- ✓ Steels (< 2.11% C)
- ✓ Cast irons (<6.67% [mostly <4.5%]C)

The material properties are more than composition – they are dependent on how the material has been treated. The Fe-C equilibrium diagram in which various structure (obtained during heating and cooling), phases and microscopic constituents of various kinds of steel and cast iron are depicted. The main structures, significance of various lines and critical points are discussed as under.

3.3 Structures in Fe-C-diagram

The main microscopic constituents of iron and steel are as follows:

1. Austenite
2. Ferrite
3. Cementite

3.4 Austenite

Austenite is a solid solution of free carbon and (ferrite) iron in gamma iron. On heating the steel, after upper critical temperature, the formation of structure completes into austenite which is hard, ductile and non-magnetic. It is able to dissolve large amount of carbon. It is in between the critical or transfer ranges during heating and cooling of steel. It is formed when steel contains carbon up to 1.77% at 1147°C. On cooling below 727°C, it starts transforming into pearlite and ferrite. Austenitic steels cannot be hardened by usual heat treatment methods and are non-magnetic.

3.5 Ferrite

Ferrite contains very little or no carbon in iron. It is the name given to pure iron crystals which are soft and ductile. The slow cooling of low carbon steel below the critical temperature produces ferrite structure. Ferrite does not harden when cooled rapidly. It is very soft and highly magnetic.

3.6. Cementite

Cementite is a chemical compound of carbon with iron and is known as iron carbide (Fe3C). Cast iron having 6.67% carbon is possessing complete structure of cementite. Free cementite is found in all steel containing more than 0.83% carbon. It increases with increase in carbon % as reflected in Fe-C Equilibrium diagram. It is extremely hard. The hardness and brittleness of cast iron is believed to be due to the presence of the cementite. It decreases tensile strength. This is formed when the carbon forms definite combinations with iron in form of iron carbides which are extremely hard in nature. The brittleness and hardness of cast iron is mainly controlled by the presence of cementite in it. It is magnetic below 200°C.

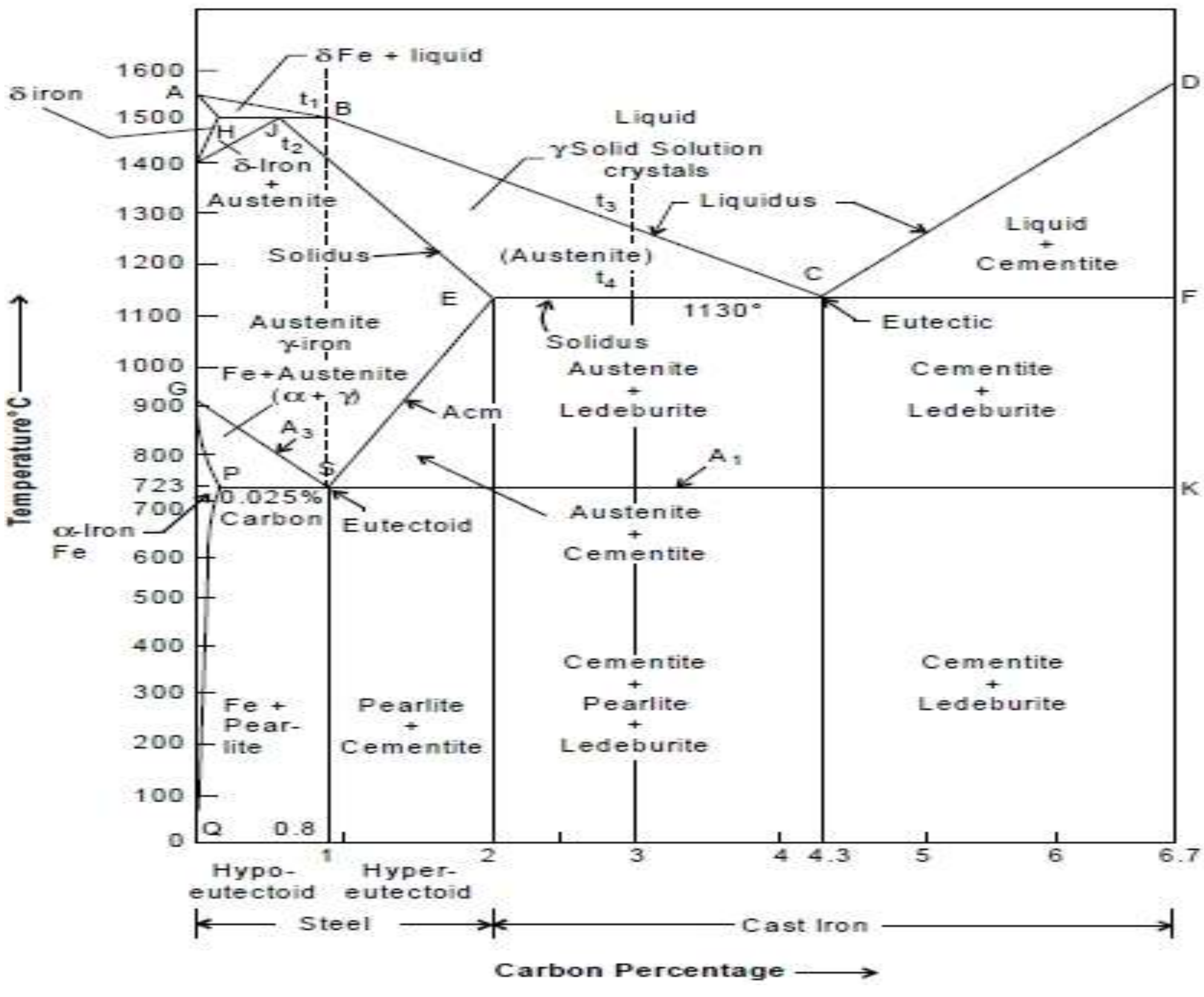


Figure 1 Fe-C equilibrium diagram

3.7. Pearlite

Pearlite is a eutectoid alloy of ferrite and cementite. It occurs particularly in medium and low carbon steels in the form of mechanical mixture of ferrite and cementite in the ratio of 87:13. Its hardness increases with the proportional of pearlite in ferrous material. Pearlite is relatively strong, hard and ductile, whilst ferrite is weak, soft and ductile. It is built up of alternate light and dark plates. These layers are alternately ferrite and cementite. When seen with the help of a microscope, the surface has

3.8. Significance of Transformations Lines

The line ABCD tells that above this line melting has been completed during heating the iron. The molten metal is purely in the liquidus form. Below this line and above line AHJECF the metal is partially solid and partially liquid. The solid metal is known as austenite. Thus the line ABCD represents temperatures at which melting is considered as completed. Beyond this line metal is totally in molten state. It is not a horizontal line the melting temperature will vary with carbon content.

Phase	*Term*	*Structure*	*Temperature Conditions*	*Notes*
α-Fe	Ferrite	BCC	T<911.5 °C	Solubility is very low
δ-Fe	δ-Ferrite	BCC	1396 °C<T<1538 °C	Only seen in transient when melting
γ-Fe	Austenite	FCC	911.5 °C<T<1396 °C	C is an "Austenite stabilizer": add C, γ field widens
C	Graphite	Hexagonal		Rarely observed, competes with Fe_3C, hard to nucleate except in the presence of Si
Fe_3C	Cementite	Orthorhombic		Hard ceramic, lower nucleation barrier than for graphite
Fe-C solid solution	Martensite	BCT		Metastable, formed by quenching

3.9. Critical Temperatures

The temperatures at which changes in structure takes place is known as critical temperatures, these are as follows:

1. The temperature along **GSE is known as upper critical temperature.** The temperature along GS during heating as (upper critical temperature) where austenite + alpha iron changes into austenite and vice versa.
2. The temperature along GS during cooling as $\mathbf{A_3}$ where austenite changes into austenite + alpha iron and vice versa during heating.
3. The temperature along line SE during heating as **Acm** changes into austenite from austenite + cementite and vice versa.
4. The temperature along PSK is known as lower critical temperature (Eutectoid temperature which is average 727 ^{o}C) when pearlite changes into austenite on heating as denoted, by A1.
5. Paratactic Temperature which is average about 1495 ^{o}C

3.10. CONSTITUENTS OF IRON AND STEEL

White constituent in the following figure A is very pure iron or having very low free carbon in iron in form of ferrite and dark patches contain carbon in iron is chemically combined form known as carbide (Cementite). Cementite is very hard and brittle. Now if the dark patches of the above figure are further observed, a substance built up of alternate layer of light and dark patches **is reflected in the**

Therefore, the temperature points at which such changing takes place into allotropic forms are called critical points. The critical points obtained during cooling are slightly lower than those obtained in heating. The most marked of these range commonly called the point of re-calescence and point of decalescence.

3.11 Objectives of Heat Treatment

The major objectives of heat treatment are given as under

1. It relieves internal stresses induced during hot or cold working.
2. It changes or refines grain size.

3. It increases resistance to heat and corrosion.
4. It improves mechanical properties such as ductility, strength, hardness, toughness, etc.
5. It helps to improve machine-ability.
6. It increases wear resistance
7. It removes gases.
8. It improves electrical and magnetic properties.
9. It changes the chemical composition.
10. It helps to improve shock resistance.
11. It improves weld-ability.

The above objectives of heat treatment may be served by one or more of the following heat treatment processes:

1. Normalizing
2. Annealing.
3. Hardening.
4. Tempering
5. Case hardening
    (a) Carburizing
    (b) Cyaniding
    (c) Nitriding

3.12. NORMALIZING

Normalizing is a defined as softening process in which iron base alloys are heated 40 to 50°C above the upper-critical limit for both hypo and hyper eutectoid steels and held there for a specified period and followed by cooling in still air up to room temperature.

3.13. Objectives

1. To soften metals
2. Refine grain structure
3. Improve machine-ability after forging and rolling
4. improve grain size
5. Improve structure of weld

6. Prepare steel for sub heat treatment

3.14. ANNEALING

It is a softening process in which iron base alloys are heated above the transformation range held there for proper time and then cool slowly (at the of rate of 30 to 150°C per hour) below the transformation range in the furnace itself. Heating is carried out 20°C above upper critical temperature point of steel in case of hypo eutectoid steel and the same degree above the lower critical temperature point in case of type eutectoid steel. The above figure shows the heating temperature ranges for annealing or softening process of both hypo and hyper carbon steel. The structure of steel on slow cooling changes into ferrite and pearlite for hypo eutectoid steel, pearlite for eutectoid steel and pearlite and cementite for hyper eutectoid steel. The time for holding the article in furnace is **½ to 1 hour**. As ferrous metals are heated above the transformation range, austenite structure will be attained at this temperature.

3.15. Objectives of Annealing

The purpose of annealing is to achieve the following

1. Soften the steel.
2. Relieve internal stresses
3. Reduce or eliminate structural in-homogeneity.
4. Refine grain size.
5. Improve machine-ability.
6. Increase or restore ductility and toughness.

3.14. In process annealing, ductility is increased with somewhat decrease in internal stresses. In this, metal is heated to temperature some below or close to the lower critical temperature generally it is heated 550°C to 650°C holding at this temperature and it is slowly cooled. This causes completely re-crystallization in steel.

Self-check 1	Written-Questions

1. Why are the Time-Temperature-Transformation (TTT) diagrams constructed?
2. How do you classify the different heat treatment processes?
3. What are the objectives of annealing?
4. Explain the various methods of annealing?
5. Explain various hardening methods?

***Note:* Satisfactory rating –7points** **Unsatisfactory - below 7 points**

Answer Sheet

Score = __

Rating: ______________

Name: ________________ Date: ________________

Short Answer Questions

Information sheet #2	Where specified, welds are prepared for external testing based on applicable welding code , and safety and reliability regulations

3.1 Introduction. Setting up welding process

Composites consist of combinations of two or more different materials, whereas semiconductors are utilized because of their unusual electrical characteristics; biomaterials are implanted into the human body. A brief explanation of the material types and representative characteristics is offered n

3.2 Classifications between ferrous and non-ferrous metals

Common engineering materials are normally classified as metals and non-metals. Metals and non-metals differ in their properties. The choice of materials for a given job depends very much on its properties, cost, availability and such other factors. Metals may conveniently be divided into ferrous and non-ferrous metals.

3.3 Ferrous metals

Ferrous metals may be defined as those metals whose main constituent is iron such as pig iron, wrought iron, cast iron, steel and their alloys. They are usually stronger and harder and are used in daily life products. They possess a special property that their characteristics can be altered by heat treatment processes or by addition of small quantity of alloying elements.

3.4. The most Ferrous metals are:

8 Cast iron

It is primarily an alloy of iron and carbon. The carbon content in cast iron varies from 1.5 to 4 per cent. Small amounts of silicon, manganese, sulphur and phosphorus are also present in it. Carbon in cast iron is present either in Free State like graphite or in combined state as cemented. Cast iron contains so much carbon or its equivalent that it is not malleable. One characteristic (except white cast iron) is that much of carbon content is present in free form as graphite. Largely the properties of cast iron are determined by this fact. Melting point of cast iron is much lower than that of steel. The characteristics of cast iron which make it a valuable material for engineering applications are:

- Very good casting characteristics.
- Low cost
- High compressive strength
- Good wear resistance
- Excellent mach inability

3.5 Inspection and weld quality

The term **inspection** usually implies a formal inspection, prescribed by a code or by the requirements of a purchaser that is given to welds and welded structures. The minimum requirements of welding codes are inflexible, and must be met. The appearance of a weld does not necessarily indicate its quality, If discontinuities exist in a weld, they can be grouped into two broad classifications: those that are apparent to visual inspection and those that are not. Visual examination of the underside of a weld will determine whether there is complete penetration and whether there are excessive globules of metal. Inadequate joint penetration may be due to insufficient beveling of the edges, too thick a root face,-too high a welding speed, or poor torch and welding rod manipulation. Heating of the base metal, too rapid travel, or gas or dirt inclusions.

3.6. Nondestructive Testing

Nondestructive testing is a method of testing that does not destroy or impair the usefulness of a welded item. These tests disclose all of the common internal and surface defects that can occur when improper welding procedures are used. A large choice of testing devices is available and most of them are easier to use than the destructive methods, especially when working on large and expensive items.

3.7 .Visual Inspection

Visual inspection is usually done automatically by the welder as he completes his welds. This is strictly a subjective type of inspection and usually there are no definite or rigid limits of acceptability. The welder may use templates for weld bead contour checks.

Visual inspections are basically a comparison of finished welds with an accepted standard. This test is effective only when the visual qualities of a weld are the most important.

3.8. Magnetic Particle Inspection

Magnetic particle inspection is most effective for the detection of surface or near surface flaws in welds. It is used in metals or alloys in which you can induce magnetism. While the test piece is magnetized, a liquid containing finely ground iron powder is applied. As long as the magnetic field is not disturbed, the iron particles will form a regular pattern on the surface of the test piece. When the magnetic field is interrupted by a crack or some other defect in the metal, the pattern of the suspended ground metal also is interrupted.

3.9 Liquid Penetrate Inspection

Liquid penetrate methods are used to inspect metals for surface defects that are similar to those revealed by magnetic particle inspection. Unlike magnetic particle inspection, which can reveal subsurface defects, liquid penetrate inspection reveals only those defects that are open to the surface. Four groups of liquid penetrates are presently in use. Group I is a dye penetrate that is non water washable. Group II is water washable dye penetrates. Group III and Group IV are fluorescent penetrates.

3.10. Radiographic Inspection

Radiographic inspection is a method of inspecting weldments by the use of rays that penetrate through the welds. X rays or gamma rays are the two types of waves used for this process. The rays pass through the weld and onto a sensitized film that is in direct contact with the back of the weld. When the film is developed, gas pockets, slag inclusions, cracks, or poor penetration will be visible on the film.

3.11. Ultrasonic Inspection

Ultrasonic inspection of testing uses high-frequency vibrations or waves to locate and measure defects in welds. It can be used in both ferrous and nonferrous materials. This is an extremely sensitive system and can locate very fine surface and subsurface cracks as well as other types of defects. All types of joints can be tested.

3.12. Eddy Current Testing

Eddy current is another type of testing that uses electromagnetic energy to detect faults in weld deposits and is effective for both ferrous and nonferrous materials. Eddy current testing operates on the principle that whenever a coil carrying a high-frequency alternating current is placed next to a metal, an electrical current is produced in the metal by induction. This induced current is called an *eddy current.*

3.13. Destructive Testing

In destructive testing, sample portions of the welded structures are required. These samples are subjected to loads until they actually fail. The failed pieces are then studied and compared to known standards to determine the quality of the weld. The most common types of destructive testing are known as free bend, guided bend, nick-break, impact, fillet welded joint, etching, and tensile testing.

3.12. Free-Bend Test

The free-bend test is designed to measure the ductility of the weld deposit and the heat-affected area adjacent to the weld. Also it is used to determine the percentage of elongation of the weld metal. Ductility, you should recall, is that property of a metal that allows it to be drawn out or hammered thin. The first step in preparing a welded specimen for the free-bend test is to machine the welded reinforcement crown flush with the surface of the test plate. on the outside and the piece placed so all the bending occurs in the weld, bend the test piece by using a hydraulic press or similar machine.

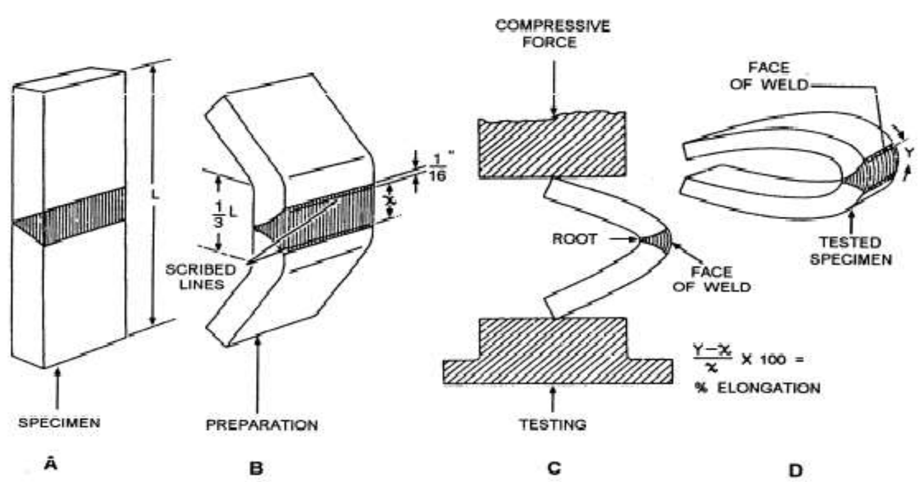


Fig.2. free bend test

3.13. Guided-Bend Test

you use the guided-bend test to determine the quality of weld metal at the face and root of a welded joint. this test is made in a specially designed jig. an example of one type of jig

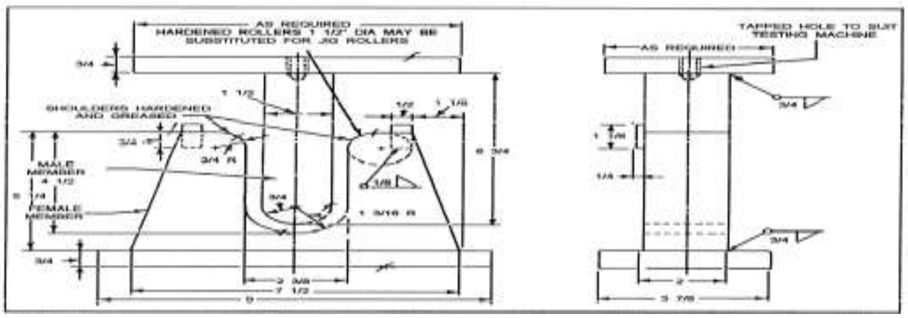


Fig. 3.Guided bend test

3.14. Nick-Break Test

the nick-break test is useful for determining the internal quality of the weld metal. this test reveals various internal defects (if present), such as slag inclusions, gas pockets, lack of fusion, and oxidized or burned metal. to accomplish the nick-break test for checking a butt weld, you must first flame-cut the test specimens from a sample weld (fig. 7-65). make a saw cut at each edge through the center of the weld. the depth of cut should be about ¼ inch.

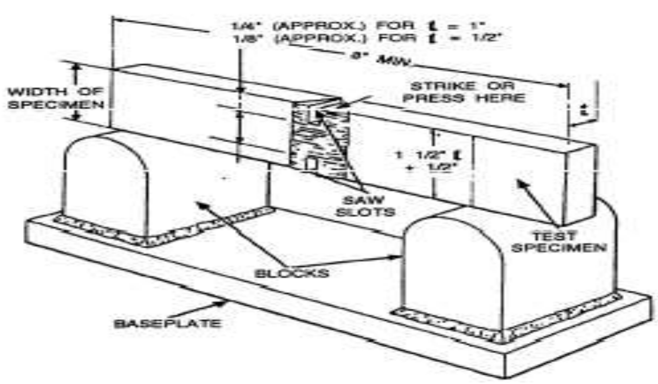


Fig4. Nick-break test

3.15. Impact Test

you use the impact test to check the ability of a weld to absorb energy under impact without fracturing. this is a dynamic test in which a test specimen is broken by a single blow, and the energy used in breaking the piece is measured in foot-pounds. this test compares the toughness of the weld metal with the base metal. it is useful in finding if any of the mechanical properties of the base metal were destroyed by the welding process. the two kinds of specimens used for impact testing are known as *chirpy* and *izod* (fig. 7-66). both test pieces are broken in an impact testing machine. the only difference is in the manner that they are anchored.

Self-Check-2	Multiple choice

Directions: Select one of the appropriate alternatives for the given questions.

1. Non-destructive method of testing that does not destroy the usefulness of a welded item:

A. magnetic particle inspection B. visual inspection
C. radiographic inspection D. all

2. A method of testing in which the samples are subjected to loads until they actually fail:

A. non-destructive test B. visual inspection
C. destructive test D. quality assurance

3. One of the following testing methods is classified under destructive test

A. impact test B. free-bend test
C. magnetic particle inspection
D. A and C

Note: **Satisfactory rating –7points** **Unsatisfactory - below 7 points**

Answer Sheet

Name: ________________ Date: ________________

Score = __
Rating:

Short Answer Questions

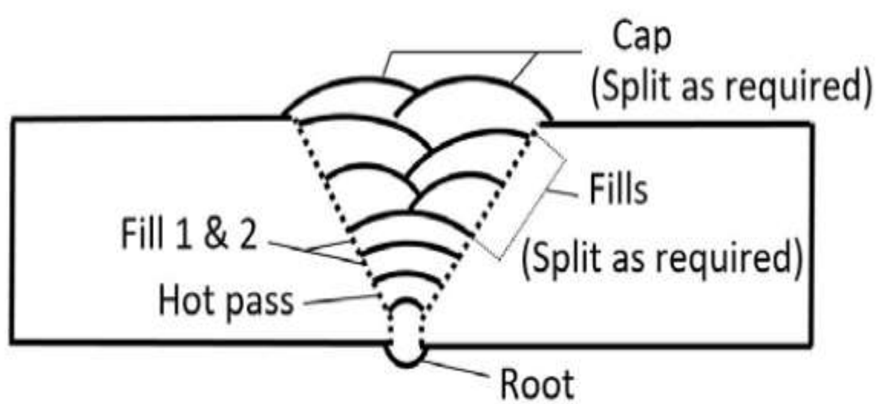
Operation Sheet 1	Performing Capping with WPS

JOINT GEOMETRY

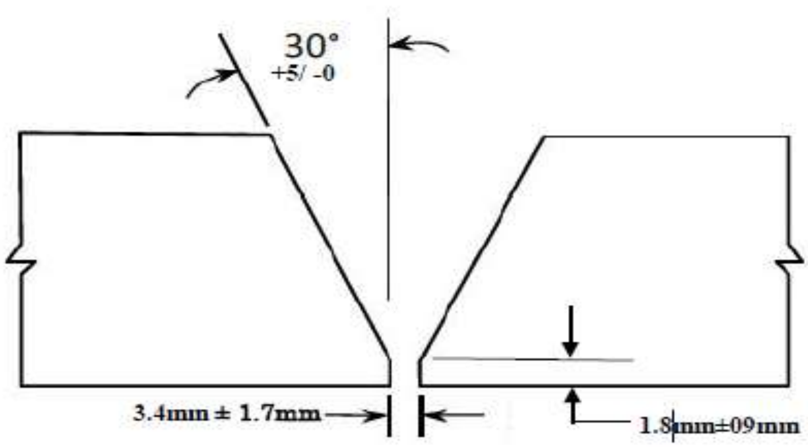
Note #1 - If cap pass is more than 2 beads wide the outer edges of the bevel shall be capped first and the final cap pass shall be in the center of the bevel.

Note # 2 - Maximum cap height above adjacent parent material: 2.5mm for W.T.≤ 10.0mm. 3.5mm for W.T. >10.0 mm. (+1mm permitted in localized areas).

Pass Sequence



Schematic of Joint Design



LAP Test	Practical Demonstration

Name: ______________________________ Date: ________________

Time started: _________________________ Time finished: ________________

Instructions: Given necessary templates, tools and materials you are required to perform the following tasks within 2 hours.

Task 1. Layout from the prepped metal.

Task 2. Cut to the required dimension.

Task 3. Complete the welding process.

Task4. Clean the joint correctly with the wrights cleaning equipments

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