ENGINEERING WORKSHOP PRACTICE III
(ENG 201 WORKSHOP MANUAL)

CENTRE FOR INDUSTRIAL STUDIES

BY
OAKAFOR B.E., ASOEGWU S.N AND EHUJUO S.

By

Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International
ENGINEERING WORKSHOP PRACTICE III
(ENG 201 WORKSHOP MANUAL)

CENTRE FOR INDUSTRIAL STUDIES

Prepared by
Okafor B.E., Asoegwu S.N. and Ehujuo S.
ENG 201 WORKSHOP MANUAL
This manual cannot be used if there is no Technologist to guide the students because the equipment, drawings and the diagrams need explanations and the machines need the technologists to explain how to operate them. The manual is intended to ameliorate the problems of using pictures and drawing boards since the students already have it on their hands.
SAFETY IN THE WORKSHOP

GENERAL SAFETY

1. **Mode of Dressing:** It is recommended that a person working inside the engineering workshop should put on the appropriate clothes with appropriate shoes having hard soles. Ties, long sleeve shirts, necklace and dripping long hairs are not safe and are therefore not allowed.

2. Fighting or unnecessary horse plays are not allowed.

3. Over-crowding and inadequate ventilation should be avoided.

4. Avoid any liquid spillage of any type on the workshop floor to reduce the risk of slipping (falling down).

5. Ensure that the Technologist is with you anytime you are in the workshop.

6. Appropriate goggles or shields including gloves and aprons should be worn during welding, turning, grinding and chiseling.

7. Avoid fiddling with the machines to avoid damage to the machines accidental switching on that could cause severe injury or death.

8. Ensure that there is a technologist to start the machines in the first instance and to remain there till the work is completed.

9. Tool safety should be maintained to avoid mishandling.

10. The workshop floor is often littered with sharp protruding objects and scrap metals. It is very important for one to wear safety boots or safety shoes.

11. Metals during transfer from one place to the other always attract dirt, oil or grease and bacteria of all kinds. During soldering and brazing, those materials used are toxic and corrosive, because of that, always wash your hands thoroughly before eating or drinking.
WORKSHOP HAZARDS
Hazards within the workshop environment can only be eliminated when one is safety-conscious by adhering strictly to safety measures attached to each work. For example, the grinding processes are extensively used for preparation of the edges of the plate for welding and the residues of the process consists of flying particles and dust. It is thus mandatory to wear eye protection goggles during such operations.

Welding process emit flying hot particles of metal, intense heat and light infra-red and ultra violet radiation. These are extremely dangerous hazards which in severe cases can cause serious eye irritation and permanent eye damage. It is therefore necessary to wear filter lens when welding, as well as other protective wears such as leg aprons, hand gloves, flame proof wears.

The feet are always vulnerable to damage from falling objects, scrap metal on the floor or protruding objects which appear to be part and parcel of the workshop. It is very important to wear safety boots or safety shoes.

Metal sheets are somewhat dirty. Oil and grease and other anti-rust coatings can cause stomach disorder if absorbed whilst eating and drinking. Fluxes used in welding, brazing and soldering are toxic. Always wash your hands properly especially before eating and drinking.

MEASUREMENT

Use of measuring tools and gauges have to be repeated by the instructors, eg. vernier callipers, micrometer screw gauge, workshop compass and measuring tapes.

WELDING Manual metal-arc welding (MMAW)

Arc Welding

Manual metal-arc welding is a metal fusion process that uses electrical energy to provide heat required to melt the metal work piece and the electrode. This is achieved as a result of arc initiated by the electrode.

Two forms of electrical energy are used. These are alternating current (a.c) and direct current (d.c). Fig. 1 shows the MMAW arrangement with the tools used.
Welding Positions
Welding positions are classified into five (5) basic positions

1. Flat (F) 2. Horizontal (H) 3. Vertical (V) 4. Vertical down (D)
5. Overhead (O)

Types of Weld Joints
Various types of weld joints are shown in figure 2.

Fig. 1: MMAW arrangement

Fig. 2: types of weld joints
Methods of Establishing Arc

There are two methods of establishing arc in welding.

1. Scratching method
2. Touching and withdrawal

Ancillary Equipment uses in MMAW Welding
There are two types of ancillary equipment used in manual metal arc welding. They are:

Electrode Holders
a. Twist grip type
b. Spring type

Fig.3: Protective equipment for arc welding

Face Shield and Helmet
The protective equipment used in arc welding include (figure 3):

a. Hand shield
b. Slip-front helmet

The chipping hammer is used for removing slag and spatter from a weld. And the wire brush is used to remove small particles remaining after welding.

Welding Positions for Arc Welding
There are several positions of placing the weld. These are as shown in figure 4.
Fig. 4: Welding positions

Size of Electrode
There are current sizes of electrodes for which welding transformers have inbuilt settings. These are:

- 2.5mm
- 3.2mm
- 4.0mm
- 5.0mm
- 6.0mm

Current (amps) 70-95/90-120 130-190 180-230 220-300

Arc Welding Equipment
Fig. 5 shows a shielded metal arc welding equipment consisting of the work piece, electrode holder, work clamp, electrode, work cables, and the welding machine powered from the main power supply cable.
Fig. 5: Shielded metal arc welding equipment

Gas Tungsten Arc Welding Equipment
The equipment is shown in Fig. 6. It combines gas and electric to weld. The welding machine therefore consists of gas and electric power supplies, also with water supply to cool the equipment.
Fig. 6b: Gas metal arc welding equipment

The fundamental resistance welding machine circuit is shown in Fig. 6c.

Fig. 6c: Fundamental resistance welding machine circuit

Arc Length: This is the distance between the electrode and the work piece. It is normally about 3mm or 1/8 inch.

Note that any change in the arc length causes a change in arc voltage as the arc length increases the voltage with a small drop in amperage and also if the arc length is short the electrode will make contact with the work piece and cause short circuit. It is a normal practice to maintain a consistent arc length and this can be achieved by constant practice.
OXY-ACTYLENE WELDING OR GAS WELDING Identification by colour of gas cylinder

Oxygen cylinders are normally black or orange in colour. Acetylene cylinders are normally maroon in colour.

**Oxygen Cylinders:** These are compressed up to gauge pressure of 175 Bars. The valve outlet has a right hand thread and any oxygen regulators can be fitted on it. Two sizes of oxygen cylinders are available for welding. Cylinder sizes: D 3.4m\(^3\) and E 5.8m\(^3\).

**Acetylene:** This is a hydrocarbon gas produced by the chemical action between calcium carbide and water. Acetylene is not compressed in a free state into cylinder at high pressure use. At oxygen pressure above 0.6 Bar, acetylene will decompose and revert to its base elements, carbon and hydrogen. Much heat will be liberated and this may cause explosion. This is why the cylinder is packed with porous mass such as charcoal or lime. Silica held in this mass is liquid acetone which will absorb or dissolve 25 times its own volume of acetylene. Acetylene cylinders are charged to a pressure of 15 bars and acetylene stored in this way is referred to as dissolved acetylene.

A typical gas cylinder is shown in Figure 7.

![Figure 7: Typical gas cylinder (oxygen or acetylene)](image-url)
Flame
There are three types of flames (Figure 8) used in arc welding. They are used for different types of welds. These are neutral, oxidizing and carburizing flames.

![Neutral flame, Oxidizing flame, Carburizing flame]

Fig: 8: Types of Flames

**Neutral flame:** This is used for fusion welding of mild steel, copper, aluminum, stainless steel and cast iron.

**Oxidizing Flame:** This can be used for fusion welding of copper-zinc alloy and cutting. It is also used for fusion welding of copper-zinc alloy and galvanized steel.

**Carburizing flame:** This is used when depositing hard facing and wear resistance material onto the surface of steel and cast iron. It can be used for flame brazing of aluminum.

**Required Tools for Gas Welding**
1. Welding blowpipe
2. Spark lighter
3. Welding goggles with filtered lens

**Gas fuel Welding Equipment**

Figure 9 shows a gas fuel welding equipment consisting of two cylinders (one for oxygen, and the other for acetylene gas). The equipment has a touch body to which the welding/brazing tip or cutting head is attached depending on whether one wants to weld or cut. Each has safety release valve as shown in figure 10.
Fig. 9: Oxyfuel welding and cutting equipment

Fig. 10: Safety release valve on an oxygen regulator
The torch body is fed by two gas valves, one for each gas. Opening and adjusting the valves give the flames shown in figures 1 la and 1 lb.

**Fig. 11a: Adjust the gas valve until the flame stops smoking**

**Fig. 11b: Achieving the neutral setting of the flame**

Adjusting the screw against the flexible diaphragm (figures 12a and b) regulates the pressure of the gas coming from the cylinders to the welding tip or cutting head to work.
Fig. 12a: Force applied to the flexible diagram by the adjusting screw through the spring opens the high-pressure valve.

Fig. 12b: A drop in the working pressure occurs when the torch valve is opened and gas flows through the regulator at a constant pressure.

Standard Welding Symbols
Types and location of welds are shown in figure 13. Note the following.
1. The side of the joint to which the arrow points is the arrow side.
2. Side welds of same types are of same size unless otherwise shown.
3. Symbols apply between abrupt changes in direction of joint or as dimensioned (except where all around symbol is used).
4. All welds are continuous and of user's standard proportions unless otherwise stated.
5. Tail of arrow used for specification reference. (Tail may be omitted when reference is not used.)

6. Dimensions of weld size, increment lengths and spacing are in inches.

**Fig. 13: Types and Location of welds**

**Types of Welds**
There are several types of welds used in the workshop

**Fillet Welds**

Dimensions of fillet welds are shown on the same side of the reference line as the weld symbol and are shown to the left of the symbol when both sides of a joint have the same size. Fillet weld is indicated by placing the weld symbol above the reference line as shown in figures 14 and 15.
Plug Welds

Holes in the narrow side member of a joint for plug welding are indicated by placing the weld symbol below the reference line. Holes in the other side member of a joint for plug welding are indicated by placing the weld symbol above the reference line as shown in figure 16.
Fig. 16: Dimensioning of plug weld symbol

Spot Welds
Dimensions of spot welds are indicated on the same side of the reference line as the weld symbol (figure 17). Such welds are dimensioned either by size or strength. The size is designated as the diameter of the weld expressed in fractions or in decimal hundredth of an inch (figure 18). The size is shown with or without inch marks to the left of the weld symbol. The center-to-center spacing (pitch) is shown to the right of the symbol as in figure 19.

The strength of spot weld is shown as the minimum shear strength in pounds (Newtons) per spot and is shown to the left of the symbol. When a definite number of spot welds are desired in a certain joint, the quantity is placed above or below the weld symbol in parentheses.

Fig. 17: Spot Weld Symbol
Fig. 18: Arc Spot Weld

REQUIRED

SYMBOL
Seam Welds

Dimensions of seam welds are shown on the same side of the reference line as the weld symbol. Dimensions relate to either size or strength. The size of seam welds is designated as the width of the weld expressed in fractions or decimal hundredths of an inch. The size is shown with or without the inch marks to the left of the weld symbol. When seam welding extends for the full distance between abrupt changes in the direction of welding, a length dimension is not required on the welding symbol as in figure 20.

The strength of seam welds is designated as the minimum acceptable shear strength in pounds per linear inch. The strength value is placed to the left of the weld symbol (figures 21a, b and c).
Fig. 20: Wide resistance seam weld

Fig. 21a: Strength of seam weld
Groove Welds

The various types of groove welds are classified as follows:

**Single-groove and symmetrical double-groove welds:** These extend completely through the members being joined. No size is included on the weld symbol as in figure 22.

**Groove welds** extend only partway through the parts being joined. The size is included to the left of the welding symbol.

The size of groove welds with a specific effective throat is indicated by showing the depth of groove preparation with the effective throat appearing in parentheses and placed to the left of the weld symbol. The size of square groove welds is indicated by showing the root penetration (figure 23). The depth of chamfering and the root penetration is read in that order from left to right along the reference line.

The size of flare groove weld is considered to extend only to the tangent points of the members (figure 24).
The root opening of groove welds is the user’s standard unless otherwise indicated. The root opening of groove welds, when not the user’s standard is shown inside the weld symbols.

Fig. 22: Single and Double Groove welds with complete penetration

Fig. 23: Size and root penetration of grooved welds
Flanged Weld

The following welding symbols are used for light-gauge metal joint where the edges to be joined are flanged or flared.

- Edge flange welds are shown by the edge flange weld symbol.
- Corner flange welds are indicated by the corner flange weld symbol.
- Dimensions of flanged welds are shown on the same side of the reference line as the weld symbol and are placed to the left of the symbol. The radius and height above the point of tangency are indicated by showing both the radius and the height separated by a plus sign.
- The size of the flange weld is shown by a dimension placed outward of the flanged dimensions (see figure 25).
Fig. 25: Applying dimensions to flange weld

**Process Designation in Welding**

Table 1 shows the different welding processes and how they are designated in letters.

<table>
<thead>
<tr>
<th>Welding Process</th>
<th>Letter Designation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brazing</td>
<td></td>
</tr>
<tr>
<td>Torch brazing</td>
<td>TB</td>
</tr>
<tr>
<td>Induction brazing</td>
<td>IB</td>
</tr>
<tr>
<td>Resistance Brazing</td>
<td>RB</td>
</tr>
<tr>
<td>Flow Welding</td>
<td>FLOW</td>
</tr>
<tr>
<td>Induction Welding</td>
<td>IW</td>
</tr>
<tr>
<td>Arc Welding</td>
<td></td>
</tr>
<tr>
<td>Bare metal arc welding</td>
<td>BMAW</td>
</tr>
<tr>
<td>Submerged arc welding</td>
<td>SAW</td>
</tr>
<tr>
<td>Shielded metal arc welding</td>
<td>SMAW</td>
</tr>
<tr>
<td>Carbon arc welding</td>
<td>CAW</td>
</tr>
<tr>
<td>Gas Welding</td>
<td></td>
</tr>
<tr>
<td>Oxyhydrogen welding</td>
<td>OHHW</td>
</tr>
<tr>
<td>Oxyacetylene welding</td>
<td>OAH</td>
</tr>
</tbody>
</table>
The following suffixes may be applying the above process:

- Automatic welding .AU
- Machine welding .ME
- Manual welding .MA
- Semiautomatic welding .SA

LIGHTING UP PROCEDURE
1. Open the cylinders valve slowly.

2. As cylinders open, adjust the regulator to the required working pressure.

3. Open the fuel gas valve on the blow pipe and shut.

4. Open the oxygen valve on the blow pipe and shut.

5. Purge each hose with its own gas by opening the valve in the blow pipe in turn and shut.

6. Open the fuel gas valve on the blowpipe and light up. Adjust the valve to reduce smoking and soot.

7. Gradually open the oxygen valve and adjust to the required flame.

8. The blowpipe may be adjusted to give the following flames (as shown in figure 8 above).

   (a) Neutral flame
   (b) Oxidizing flame
   (c) Carburising flame

WELDING AND JOINING OF MATERIALS

Small Hoe
1. From a half inch pipe, cut out 230mm.
2. From the half inch round bar cut out 160mm length, cut and arrange as shown in figures 28, 29 and 30.

3. Cut out from gauge 16 flat sheet the dimension 120mm by 110mm.

4. Mark out the flat sheet as shown in figures 26 and 27 with a scribe. "Note" Draw the curve first (else your work will not be good) before the straight edges.
   (a) Divide the longest side into two, place the workshop compass at the middle with the radius of 210mm from center 'O'.
   (b) At the upper side, mark out 15mm as shown in figure 26 and cut out the shaded portion and make the figure 27 as shown.
   (c) Remove the sharp edges by using the radius of 10mm to mark out as shown with the center 'O' draw the arc and cut off the shaded portion as shown.

5. Sharpen the blade of the plate along the curve on one side only.

6. Bend or fold the curve with the sharpened side outwards to reduce the length AB by 0.5cm uniformly, in a gentle curve.

7. Attach the plate and weld as shown in figures 30, 31 and 32.

8. Draw an Engineering Drawing of the work you have produced in an oblique view, indicating the type of weld with symbols of welding.
Big Hoe

1. Cut out 260 X 200mm of gauge 14 plate.

2. Mark out as shown in figure 33 with scriber and workshop compass.

3. Mark and cut the curve as was demonstrated with the small hoe.

4. Remove the sharp edges as was demonstrated with the small hoe with 10mm (see Fig.34)

5. Sharpen only one side as was demonstrated with the small hoe.

6. Fold A-B uniformly to reduce the length AB by 10mm, sharpen only one side.

7. Cut out half inch bar of length 270 into 2 places and mark out as shown in Figures 35 and 36. Cut out 70mm and 80mm to be inserted. The 80mm will be inserted as a pair into 2 as in figure 37.

8. Cut out three quarter inch pipe as shown in Fig.38 and insert the pair of half inch rod with length of 80mm inside the pipe.

9. Draw an oblique view of what you have produced individually.
FOUNDARY

This involves all operations that take place in a Workshop for the production of engineering components according to their predetermined shapes or dimensions or cavities.

We may consider the following foundry operations:

a) Pattern: making of patterns and production
b) Moulding: provision of the cavity;
c) Melting: a function of temperature;
d) Casting: pouring into predetermined cavity
e) Cleaning: involving machining.

Objective of Foundry Practice

To determine how molten materials solidify in predetermined dimensions or cavities in the production of components.

Equipment Required

a) Flask: two piece retaining form in which the mould is made;
b) Cope: upper half of the mould made in the top part of the flask;
c) Drag: bottom half of the mould made in the lower part of the flask;
d) Sprue: vertical passage cut into the cope to admit metal to the mould cavity;
e) Gate: a passage connecting the sprue opening to the mould cavity;
f) **Pattern:** replica of the actual casting. Removable pattern is made of steel or wood. Disposable pattern is made of polystyrene or wax that forms the cavity into which the molten metal is poured.

g) **Bottom Board:** a flat surface upon which (moulding board) is placed as part of all the pattern so that sand can be around it to form both cope and drag impressions;

h) **Pouring Basin:** a cavity provided at the top of the sprue into which metal is poured;

i) **Green Sand:** mixture of sand, silica blended with bentonite + 3 - 8% and water used as a moulding mixture with coal dust, called “green” because of the moisture present;

j) **Riddle:** circular coarse screen through which is passed the first sand to contact the pattern when moulding;

k) **Rammer:** a wooden block used to compact sand around a mould;

l) **Spike:** metal rod used to perforate the mould to allow for the escape of entrapped air.

**FOUNDARY PROCESSES:**

(A) **Moulding:** Moulding provides the cavity into which the molton material is poured.

**The Moulding Procedure:**

The following steps are used in the moulding procedure (Fig.39).

STEP i) Pattern laid on a moulding board along with the drag.

Fig 39 (i).
STEP ii) Moulding sand is riddled over the pattern and rammed sufficiently to adhere together - Fig. 39 (ii).

STEP iii) The assemble is turned over - Fig. 39 (iii).

STEP iv) A layer of parting powder is spread on the surface and cope is put in place with the runner and riser pins - (held by sand) Fig. 39 (iv).

NOTE: The runner is to admit the molten metal while the riser serves as an indicator to determine when the molten metal has filled the cavity.

STEP v) Moulding sand is riddled into the cope and rammed around the pattern, runner and riser (Fig. 39 (v)). The cope is lifted off, pattern is removed and the cope replaced in its former position (Fig. 39 (vi)).

NOTE: At this point the finished mould is ready to receive the molten metal.
Fig 39: Six steps in moulding process

Definitions

1. **Parting sand** - This is dry clay free material used to separate two surfaces from sticking together along the parting line.

2. **Gating system** - This is a channel way for bringing the molten materials into the mould cavity. It consists of:
   
   a) Runner for distribution of molten material around the cavity from the sprue base.
   b) Riser - i) which indicates when molten metal fills the cavity.
      ii) it also helps to remove dross;
   c) Venting - Provided to allow the escape of gases during casting.

3. **Dowels** are provided to serve as location pins to the mould and to prevent mismatch in casting.

4. **Melting**: This is a function of temperature in which a metal or solid is caused to become liquid (molten). There are many types of furnaces that can be considered to generate enough heat to melt metals.
Open hearth, electric arc, induction, rotary, crucible etc.
Different metals have different melting temperatures at which they can melt. The choice of furnace would depend largely on the temperature at which the materials would melt e.g.

- Aluminum (Al) scraps - 660°C
- Steel (Fe) scraps - 1536°C
- Zinc (Zn) scraps - 419°C
- Copper (Cu) scraps - 1080°C, etc.

The crucible pot to hold the material must have a higher melting temperature than the material to be melted.

- (a) Scraps are charged into the crucible pot (improvised steel pot)
- (b) Charcoal is used as fuel to generate the required temperature.
- (c) The furnace is also an improvised one called blacksmith hearth's furnace.

Once the arrangement is set, heating/firing continues until the solid scraps become liquid and is ready for casting to fill the cavity.

5. **Casting:** This involves the pouring of the molten material into the mould cavity through the runner to fill it.

Different casting methods may be applied - Ingot casting, die casting centrifugal casting, and sand casting, etc.

Hand ladles may be used to carry the molten metal to be cast or poured into the mould to fill the cavity.

After solidification, the casting is shaken from the mould and allowed to cool.

6. **Cleaning:** The casting is thereafter ready for cleaning. Each successful operation or production of the item will now be subjected to machining, milling, and shaping for dimensional accuracy of the casting.
DETECTION OF DEFECTS IN CASTING

There are different methods of finding out defects in casting process. These are:

1. Visual inspection is used to detect common defects like surface roughness, obvious shifts/mismatch, omission of cores, and cracks and cold slits.

2. Hydrostatic pressure test is carried out to locate leak points on a casting. The casting is used as a pressure vessel by:
   - Blocking all flanges and ports.
   - Filling casting with water, oil or compressed air.
   - Thereafter, the casting is submerged in soap solution and notice where the solution will leak out as soap bubbles.

3. Magnetic particle inspection is used to detect very small voids and cracks using powdered ferromagnetic material. The steps are as follows:
   - Spread the ferromagnetic material on the surface of the casting.
   - Induce a magnetic field through the surface.
   - Presence of cracks results in abrupt change in permeability of the surface, thereby causing a leak in the magnetic field.
   - Powdered ferromagnetic materials accumulate along the boundary of discontinuity.

4. Radiographic examination is very expensive. It is used for subsurface exploration with x-rays and γ-rays.

5. Ultra-sonic inspection uses an oscillator to send ultra-sonic signal through the casting. If the signal encounters a discontinuity it is Reflected back and detected by the ultra-sonic detector. Ultra-sonic inspection is found not very suitable for cast iron with high damping capacity.
6. Dye penetrant inspection (DPI) is used to detect invisible surface defects in non-magnetic castings. The steps are as follows:
   - The casting is brushed with, sprayed with, or dipped into a dye containing a fluorescent material.
   - Wipe and dry the surface of the casting.
   - View the casting in darkness and any discontinuity on the surface will be easily discernible.

7. Coin testing is done by hitting the casting with coin and listening to the sound. The presence of defect can be estimated.