1. Terms and definitions
   a. **Base metal**—Metal to be welded, brazed, or cut.
   b. **Fusion welding**—A welding process that joins metals by heating them to be a melting point and allowing them to fuse or flow together.
   c. **Gap wire**—A wire used for correct spacing of butt joints.
   d. **Interpass heating**—Application of heat to a base metal during a welding process.
   e. **Penetration**—Distance from the original surface of the base metal to that depth at which fusion stops.
   f. **Post-heating**—Heating after a welding operation to provide uniform cooling and stress relief.
   g. **Preheating**—Heating prior to a welding or cutting operation.
   h. **Stress relief**—A process whereby base metals are heated to even temperature below the critical range, held at that temperature for a given time, and uniformly cooled to avoid distortion, cracking, or other stress-related problems.
   i. **Tack weld**—A short weld used to temporarily hold workpieces in place.
   j. **Welding positions**—A numbered reference to the physical positioning of a workpiece with 1 as flat, 2 as horizontal, 3 as vertical, and 4 as overhead.

2. Benefits of learning oxyacetylene welding and cutting
   a. Teaches methods used in forming, recognizing, and controlling a weld puddle.
   b. Teaches methods of properly holding and manipulating welding equipment and develops techniques that are useful in other welding processes.
   c. Provides practice leading to good eye-hand coordination required in the welding trade.
   d. Teaches the basics of metallurgy and the characteristics of metals being welded or cut.
   e. Provides a familiarity with the welding workplace and its activities.
f. Teaches a welding skill that will increase employability when facing job demands that require both arc and oxyacetylene skills.

3. **Equipment required for oxyacetylene welding**

   a. Oxygen cylinder
   b. Acetylene cylinder
   c. Pressure regulator for oxygen
   d. Pressure regulator for acetylene
   e. Two hoses encased together
   f. Welding torch with assorted tips
   g. Welding goggles and safety glasses
   h. Spark-lighter
   i. Check valves to prevent flashback

   **Caution: Never use a welding or cutting torch that does not have check valves.**

   j. Cylinder wrench
   k. Chipping hammer and wire brush

4. **Safety rules for the oxyacetylene workplace**

   a. Keep work area free of grease, oil, and flammable materials because flying sparks can fly for several feet and cause a fire.

   b. Cool or quench not metal and extinguish all sparks before leaving the work area, but do not quench during a welding process.

   c. Do not leave torches, tips or hot metal where they can be accidentally touched by a co-worker or a visitor.

   d. Never carry matches or lighters filled with butane or propane into any work area where any kind of welding or cutting is taking place.
e. Do not withdraw too much volume at one time from an acetylene tank because a high demand of acetylene could withdraw acetone from the cylinder and create a hazardous condition.

Note: Two or more acetylene cylinders can be manifolded together to provide high flow rates.

5. Personal safety requirements

a. Shirts—Keep collar and sleeves buttoned to keep out sparks and remove pockets from front of shirt or tape them shut if they don’t have pocket flaps.

b. Pants—These should have no cuffs and be long enough to come down over shoe tops.

Caution: Clothes made of polyesters and other synthetics catch fire easily so it’s better to wear wool or heavily-starched cottons, and frayed clothing of any kind is dangerous.

c. Welding cap—These should be worn to protect hair from sparks and spatter.

Caution: Some hair sprays are highly flammable and can be ignited by sparks, and any kind of plastic hair cap or covering is dangerous in the welding area.

d. Shoes—These should have high tops of tough leather, and steel toes are recommended.

Caution: Never wear sneakers, tennis shoes, or loafer-type shoes when welding.

e. Gloves—These should be leather with gauntlets.

Caution: Use pliers or another suitable tool for handling hot metal because good welding gloves are expensive and it’s foolish to burn them up because of bad work habits.

f. Safety glasses—These should be worn under helmets and goggles.

6. Eye protection required for oxyacetylene welding
a. Wear safety glasses when cleaning or chipping base metals.
b. Wear safety glasses and a face when grinding joints or bevels.
c. Wear welding goggles to protect eyes from spatter, and choose goggles with a lens shade dark enough to protect eyes from radiation burns.

d. Play it safe and start with a lens shade too dark on a single manifold; one gauge indicates the cylinder pressure, the other indicates the working pressure for the torch.

7. Pressure regulating valves
   a. Each regulator has two gauges mounted on a single manifold; one gauge indicates the cylinder pressure, the other indicates the working pressure for the torch.

<table>
<thead>
<tr>
<th>Type of Welding</th>
<th>Metal Thickness</th>
<th>Shade #</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brazing</td>
<td>---</td>
<td>3</td>
</tr>
<tr>
<td>Light</td>
<td>up to 1/8&quot;</td>
<td>4 or 5</td>
</tr>
<tr>
<td>Medium</td>
<td>1/8 – 1/2&quot;</td>
<td>5 or 6</td>
</tr>
<tr>
<td>Heavy</td>
<td>1/2&quot; +</td>
<td>6 or 8</td>
</tr>
</tbody>
</table>

b. Each regulator has an adjusting screw so pressure to the torch can be quickly controlled by turning the screw clockwise to increase pressure or counterclockwise to decrease or completely shut off pressure.
8. **Welding hoses and their characteristics**

   a. Transport—Special nonporous hoses are used to transfer the gases from the cylinders to the torch.

   b. Color—Acetylene hose are always red; oxygen hoses are usually green, but sometimes black.

   c. Connector threads—Acetylene connectors have a V-groove and left-handed threads, and oxygen connectors have plain surfaces and right-handed threads.

   **Note: The left-handed threads are to assure that the hoses can never be connected to the wrong cylinder.**

   d. New hoses—New hoses are coated inside with a powder to provide storage protection; before use, the powder should be blown out by attaching each hose to the proper cylinder regulators, and opening the regulator to about five (5) pounds of pressure.

9. **Parts of a welding torch**

   a. The torch body is that part of a torch designed to be held; it contains two needle valves to control the flow of acetylene and oxygen.
b. The welding head is the torch component that contains a mixer or injector, the mixing throat, and the welding tip to control the flame.

10. **Types of mixers and their purposes**

   a. Equal-pressure type—Supplies oxygen and acetylene at approximately equal pressures through a mixer; these systems are usually more fuel efficient than injector types.

   b. Injector type—Supplies oxygen at a relatively high pressure and acetylene at a relatively low pressure, and can maintain normal pressure even when there are oxygen fluctuations.

**Note: Oxygen fluctuations sometimes occur in plant piping systems.**

11. **Welding tips and their uses**

   a. Welding tips should be selected according to the metal thickness of the workpiece.

   b. Tip sizes vary from 000 for use on 1/32" metal, up to a number 12, which can be used on metal from 3" to 4".

   c. Replaceable elbow tips are one-piece tips that fit onto the torch body and provide long cone flame characteristics for general purpose welding and brazing.

   d. Other welding tips use replaceable welding tip ends that can be easily switched for working with oxy-propane or ox-natural gas applications.
12. Basic safety rules for oxyacetylene cylinders and gases

Note: These basic rules and illustrations are courtesy of Smith’s Welding Equipment.

a. Secure cylinder in a vertical position, make sure the area is clear, and blow out cylinder valves before attaching regulators.

b. Release adjusting screw on regulators before opening cylinder valves.

c. Stand on the side opposite the regulator when opening a cylinder valve.
d. Open cylinder valve **SLOWLY**.

e. Do not use or compress acetylene at pressures higher than 15 psi.

f. Light acetylene before opening oxygen valve on torch.

g. Do not use oxygen as a substitute for compressed air.
h. **NEVER** use oil on regulators, torches, fittings, or other equipment in contact with oxygen.

i. Do not use oxygen as a substitute for compressed air.

j. Keep heat, flames, and sparks away from combustibles.
13. **Types of oxyacetylene flames**

<table>
<thead>
<tr>
<th>Name</th>
<th>Characteristics</th>
<th>Uses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oxidizing</td>
<td>Excess oxygen to acetylene burning ratio with an acetylene feather, and makes a harsh, hissing sound</td>
<td>Least used because it oxidizes metal, but is used for braze welding with a bronze rod</td>
</tr>
<tr>
<td>Neutral X</td>
<td>Burns equal amounts of oxygen and acetylene, and has a clean, clean-edged inner cone</td>
<td>The most used flame for oxyacetylene applications</td>
</tr>
<tr>
<td>Reducing X to 2X (Lightly carburizing)</td>
<td>Burns slightly more acetylene than oxygen, acetylene feather appears just beyond the point of the neutral flame, and is also a carburizing flame</td>
<td>Used for backhand welding and for welding mild steel with low-alloy rods</td>
</tr>
<tr>
<td>Carburizing</td>
<td>Excess acetylene to oxygen burning ratio with an acetylene feather two to three times the length of the inner cone</td>
<td>Used for some hardfacing, but must be used selectively because it adds carbon to base metals</td>
</tr>
</tbody>
</table>

14. **Guidelines for flame adjustment**

a. To secure a neutral flame, always start with an excess of acetylene, then increase the flow of oxygen or decrease the flow of acetylene until the acetylene feather disappears from the center cone.

b. An excess of acetylene is easy to spot, but an excess of oxygen is difficult to spot except that it will cause molten metal to spark excessively.

c. Make sure regulator working pressures are those recommended for the tip size you are using.

d. Beginning welds should not use the harshest flame the welding torch can produce.

Note: The harshest flame is one which would separate slightly from the tip of the torch if each gas pressure were increased slightly.

e. Cut back flame length slightly when a flame is too harsh.

Note: Cutting back the flame will produce a softer flame, which is best for beginning welders because it makes welding a bit slower but affords better control.
15. **Characteristics and causes of backfire and flashback.**
   a. Backfire is a momentary backing of the flame into the welding tip; it is usually accompanied by a loud pop.

   **Caution:** Repeated backfire indicates the potential for greater problems and the equipment should be shut down and serviced.

   b. Flashback is a continued burning back of the flame into the tip, mixer, or torch body; it is accompanied by a loud hiss or squeal.

   **Caution:** When flashback occurs, IMMEDIATELY shut off the oxygen torch valve, then the acetylene torch valve, and then SHUT THE SYSTEM DOWN COMPLETELY and check for damage. Always remember that a loud hiss or squealing sound indicates IMMEDIATE DANGER and a need for IMMEDIATE SHUTDOWN.

   c. Overheating a tip, using a tip too close to the work, or touching the tip to the work can all cause backfire and flashback.

   d. An insufficient volume of oxygen or acetylene or incorrect gas pressures can also cause backfire and flashback.

   e. Dirty seating surfaces, leaks from loose tips, and failure to purge the equipment can also cause backfire and flashback.

16. **Welding tip selection**
   a. Welding tip sizes should be selected according to the thickness of the metal to be welded and type of fuel gas to be used.

   b. Drill size listed with a tip indicates the size of the orifice when new so the correct size tip cleaner can be selected and the orifice can be properly checked for wear.

   **Caution:** When using a tip cleaner on an orifice, select a cleaning probe slightly smaller than the orifice, and work your way up to the proper size, but never force an oversize probe into an orifice. The small diameter probe is easy to break off in the orifice, and that renders the tip useless.

   c. Tip manufacturer’s recommended regulator pressures for fuel gases should not exceed the minimum or maximum recommended for a specific size tip.
d. Tip size and regulator pressures recommended by the manufacturer should be carefully followed.

e. Gas consumption data on tip selection charts are for estimating purposes, and the actual consumption will vary with the material being welded and operator’s skill.

f. Gas pressure recommendations on tip data charts are usually based on a hose length of 25 feet, and longer lengths of hose should have about 3 psi added per each additional 25 feet.

<table>
<thead>
<tr>
<th>Metal Thickness</th>
<th>Tip Size</th>
<th>Drill Size</th>
<th>Oxygen Pressure PSIG</th>
<th>Acetylene Pressure PSIG</th>
<th>Acetylene Consumption SCFH*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Up to 3/6&quot;</td>
<td>000</td>
<td>75</td>
<td>3</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>3/6&quot; - 1/6&quot;</td>
<td>00</td>
<td>70</td>
<td>3</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>1/6&quot; - 3/32&quot;</td>
<td>0</td>
<td>65</td>
<td>3</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>3/32&quot; - 1/32&quot;</td>
<td>1</td>
<td>60</td>
<td>3</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>1/32&quot; - 1/16&quot;</td>
<td>2</td>
<td>56</td>
<td>3</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>1/16&quot; - 5/32&quot;</td>
<td>3</td>
<td>53</td>
<td>4</td>
<td>7</td>
<td>3</td>
</tr>
<tr>
<td>5/32&quot; - 1/8&quot;</td>
<td>4</td>
<td>49</td>
<td>5</td>
<td>10</td>
<td>4</td>
</tr>
<tr>
<td>1/8&quot; - 3/32&quot;</td>
<td>5</td>
<td>43</td>
<td>6</td>
<td>12</td>
<td>5</td>
</tr>
<tr>
<td>3/32&quot; - 1/16&quot;</td>
<td>6</td>
<td>36</td>
<td>7</td>
<td>14</td>
<td>6</td>
</tr>
<tr>
<td>1/16&quot; - 1/8&quot;</td>
<td>7</td>
<td>30</td>
<td>8</td>
<td>16</td>
<td>7</td>
</tr>
<tr>
<td>1/8&quot; - 1/4&quot;</td>
<td>8</td>
<td>29</td>
<td>10</td>
<td>19</td>
<td>8</td>
</tr>
<tr>
<td>1/4&quot; - 3/16&quot;</td>
<td>9</td>
<td>28</td>
<td>12</td>
<td>22</td>
<td>9</td>
</tr>
<tr>
<td>3/16&quot; - 1/8&quot;</td>
<td>10</td>
<td>27</td>
<td>14</td>
<td>24</td>
<td>10</td>
</tr>
<tr>
<td>1/8&quot; - 5/32&quot;</td>
<td>11</td>
<td>26</td>
<td>16</td>
<td>26</td>
<td>11</td>
</tr>
<tr>
<td>5/32&quot; - 1/16&quot;</td>
<td>12</td>
<td>25</td>
<td>18</td>
<td>28</td>
<td>12</td>
</tr>
</tbody>
</table>

Gas consumption data is merely for rough estimating purposes. It will vary greatly with the material being welded and the particular skill of the operator.

Pressures are approximate for hose length up to 25 ft. Increase for longer hose lengths about 3 psi per 25 feet.

"Oxygen consumption is 1.1 times the acetylene under neutral flame conditions.

17. **Filler rod selection, handling, and safety**

a. Select a rod that has the same or similar properties of the base metal.

b. Select a rod that is the correct size for the thickness of the metal being welded.

**Note:** The general rule is that the rod should have a diameter equal to the metal being welded, but since standard diameters go to only 1/4", adjustments in weld design are required for certain applications.
c. Keep rods properly labeled and stored in a clean, dry place.

d. Keep hot filler rods away from combustible materials.

e. Bend the end of the filler rod to prevent eye injuries.

Note: This is especially a good rule for beginners in a school shop, and sometimes instructors have students cut the filler rods in half to minimize problems.

<table>
<thead>
<tr>
<th>Metal</th>
<th>Flame Adjustment</th>
<th>Flux</th>
<th>Welding Rod</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steel, Cast</td>
<td>Neutral</td>
<td>No</td>
<td>Steel</td>
</tr>
<tr>
<td>Steel pipe</td>
<td>Neutral</td>
<td>No</td>
<td>Steel</td>
</tr>
<tr>
<td>Steel plate</td>
<td>Neutral</td>
<td>No</td>
<td>Steel</td>
</tr>
<tr>
<td>Steel sheet</td>
<td>Neutral</td>
<td>No</td>
<td>Steel</td>
</tr>
<tr>
<td>Steel Sheet</td>
<td>Slightly oxidizing</td>
<td>Yes</td>
<td>Bronze</td>
</tr>
<tr>
<td>High Carbon Steel</td>
<td>Reducing</td>
<td>No</td>
<td>Steel</td>
</tr>
<tr>
<td>Wrought iron</td>
<td>Neutral</td>
<td>No</td>
<td>Steel</td>
</tr>
<tr>
<td>Galvanized iron</td>
<td>Neutral Slightly oxidizing</td>
<td>No</td>
<td>Yes Steel Bronze</td>
</tr>
<tr>
<td>Cast iron, gray</td>
<td>Slightly oxidizing</td>
<td>Yes</td>
<td>Cast Iron Bronze</td>
</tr>
<tr>
<td>Cash iron, malleable</td>
<td>Slightly oxidizing</td>
<td>Yes</td>
<td>Bronze</td>
</tr>
<tr>
<td>Cast iron pipe, gray</td>
<td>Neutral Slightly oxidizing</td>
<td>Yes</td>
<td>Cast iron Bronze</td>
</tr>
<tr>
<td>Cast iron pipe</td>
<td>Neutral</td>
<td>Yes</td>
<td>Cast iron or base metal Composition</td>
</tr>
<tr>
<td>Chromium-nickel steel castings</td>
<td>Neutral</td>
<td>Yes</td>
<td>Base metal composition or 15-12 Chromium-nickel steel</td>
</tr>
<tr>
<td>Chromium-nickel steel (18-8 and 25-12)</td>
<td>Neutral</td>
<td>Yes</td>
<td>Columbium stainless steel or base metal composition</td>
</tr>
<tr>
<td>Chromium steel</td>
<td>Neutral</td>
<td>Yes</td>
<td>Columbium stainless steel or base metal composition</td>
</tr>
<tr>
<td>Chromium iron</td>
<td>Neutral</td>
<td>Yes</td>
<td>Columbium stainless steel or base metal composition</td>
</tr>
</tbody>
</table>