

WELDING TECHNOLOGY

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WELDING AND WELDING TECHNOLOGY

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WELDING AND WELDING TECHNOLOGY

IN MEMORY OF MY FATHER JOHN EVANS "BUCK" LITTLE WHO FIRST INTRODUCED ME TO THE FIELD OF WELDING

PREFACE

The basic purpose of this text is to present welding and welding technology in such a manner that the beginning college student can understand the underlying theories of welding, apply these theories to the process, and then apply the process to the fabrication of goods. The theories and principles of welding technology, while based on mathematics and science, are presented so that a scientific background is not mandatory although the student will learn to apply an amount of mathematics and science in welding technology.

The text follows the same basic format in all its five major sections. Each section is divided into specific technical units. The first unit for most of the sections is an introduction which presents the operating theories and principles, and the remaining units explain how to apply the theory to the fabrication of goods.

A set of questions to reinforce the information within the unit and

suggested further readings are also included at the end of each unit. Where applicable, each unit has sample projects or exercises that emphasize the manipulative aspects of welding technology. Many of the suggested activities are ideas to instructors for possible demonstrations.

The text provides the basic information to explain the "how as well as the why" of the welding processes. The material contained in the introductory unit of Sections I, II, and III is technical in nature and could be omitted if the educational program is not technically oriented. Thus the text will appeal to the more general educational approach to the welding processes as well as to the technical.

The last two sections are more general in nature than the first three. Section IV on special welding processes is an overview of many welding processes which are either too expensive, too new, or too hazardous to be included in a welding curriculum but with which welding students should be familiar. The last section is a basic study of metals; it presents the basis for a better understanding of how welding affects metal, how to relieve entrapped stresses, and how to test the effectiveness of the weld joint.

The text is not machine oriented; that is, step-by-step directions for operating particular machines are not emphasized. Instead, concepts of welding processes are explained so that a student will be able to operate any machine, whether he has ever operated it before or not, and will know not only how to operate it but also why it does what it does.

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Preface

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GAS WELDING

INTRODUCTION

Oxyacetylene welding is a fusion-welding process; the coalescence of metals is produced by an oxygen-acetylene flame. Extreme heat is concentrated on the edges or on the edge and surface of the pieces of metal being joined until the molten metal flows together. The type of joint design determines whether a filler metal should be used to complete the weldment. Filler metal is added by inserting it into the molten puddle of the base metals. The puddle then solidifies making the weld bead (Figure 1-1).

The extremely high heat depends on the mixture of two types of gaseous substances: oxygen and acetylene. The oxygen supports higher combustion; the acetylene is the fuel for the combustion.

Oxygen is a nonmetallic chemical element, designated by the symbol O, which can be found in a free state or in

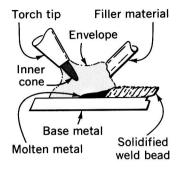


Fig. 1-1 Oxygen-acetylene welding.

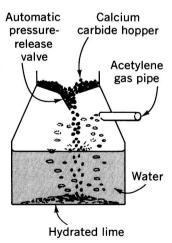


Fig. 1-2 Carbide-to-water acetylene generator.

combination with the other elements in nature. The atmosphere is composed of about one-fifth (20.95 percent) oxygen by volume. The element was first isolated in 1774 by Joseph Priestley when red mercury oxide was heated in a confined heated chamber in an experiment. Oxygen is now produced commercially in the almost pure state by two methods: electrolysis and the liquid-air process. In the electrolytic method water is broken down into hydrogen and oxygen by sending an electrical current through a solution of caustic soda and water. Oxygen is released at one terminal and hydrogen at the other one. Because of the high cost, this method of generating pure oxygen is not used to any great extent.

The liquid-air process is the prime method used in the production of commercial-quality oxygen. By this method, the air is first washed with caustic soda; then the temperature is lowered to -317° F. This low temperature liquifies or vaporizes all of the material within the chamber. The basic principle behind this method is that all gases vaporize at different temperatures. Oxygen, being one of the chief constituents of air and having a higher vaporization point than nitrogen and argon, vaporizes last. When the liquid air is allowed to evaporate slowly, the nitrogen and the argon boil off more rapidly than the oxygen until finally almost pure oxygen remains. The gas from the boiling liquid is compressed into steel cylinders specially designed to withstand pressure of 2200 psi (pounds per square inch) at a room temperature of 70°F. The oxygen is then ready to be transported for use with oxyacetylene welding and cutting equipment.

Acetylene gas—a hydrocarbon with the chemical formula C₂H₂—is not found in a free state in nature. This gas was first discovered in 1815 by Sir Humphry Davy, but it was of little commercial use until 1892 when it was produced by means of calcium carbide. Acetylene gas is produced in this country by the carbide-to-water method, which allows water to react upon calcium carbide in a carbide-to-water generator (Figure 1–2). The reaction between water and carbide is instantaneous; the carbon in the carbide combines with the hydrogen in the water, forming acetylene gas. This chemical reaction is

$$CaC_2 + 2H_2O = C_2H_2 + Ca(OH)_2$$

Calcium Water Acetylene Hydrated lime

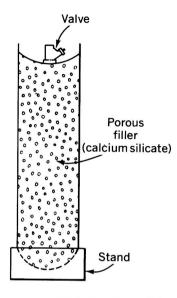


Fig. 1-3 Acetylene cylinder.

A carbide-to-water generator operates on a ratio of 1 gal (gallon) of water to 1 lb (pound) of carbide. The rate at which these parts are mixed, in some generators, is 1 lb carbide hopper capacity/hr to produce 1 ft³ (cubic foot) acetylene gas.

Acetylene gas under pressure becomes very unstable and in the free state will explode before reaching a pressure of 30 psi. This instability places special requirements on the storage of acetylene. A storage cylinder is filled with a mixture of calcium silicate, a material that is 92 percent porous. The cylinder is then filled with acetone, which is the solvent agent of acetylene gas and which has an absorptive capacity of up to 35 volumes of acetylene per volume of acetone per atmosphere of pressure. This enables about 420 volumes of acetylene to be compressed at 250 psi. Under these conditions, the gas is present in the form in which it is to be used. Acetylene comes out of the acetone solution at a slow constant rate as the pressure in the cylinder is released. The rate, however, depends on the temperature of the gas (Figure 1–3).

The burning of oxygen and acetylene is accomplished in five steps. First, the cylinder pressure is released to a working-line pressure by means of special regulators. The gases are transported, by hoses usually, to the torch body. These gases are mixed in the mixing chamber, and then this mixture is ejected into the atmosphere (Figure 1-4). All that is needed now to supply combustion is for this mixture to be ignited. When the spark of ignition is supplied, the triangle of combustion is then complete.

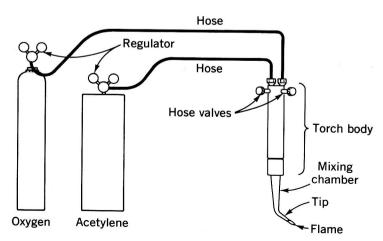


Fig. 1-4 Gas welding system.

The three requirements for oxygen-acetylene flame are those for any combustion: an oxygen source, a fuel source, and a kindling (or ignition) temperature. To control combustion, one need only to adjust or remove one of these three elements (Figure 1-5).

THE OXYACETYLENE FLAME

The combination of oxygen (O) and acetylene (C₂H₂) to support maximum combustion has been found to be

$$2C_{2}H_{2} + 5O_{2}$$

That is, 2 volumes of acetylene combine with 5 volumes of oxygen for the complete burning of the two gases. Upon the complete burning or combustion the residue is

$$4CO_2 + 2H_2O$$

or 4 volumes of carbon dioxide and 2 volumes of water vapor. However, this burn does not all happen at one time. Normally, it occurs in two stages. First, equal volumes of oxygen and acetylene are ejected from the torch tip to burn in the atmosphere $(2C_2H_2 + 2O_2-2)$ volumes of acetylene and 2 volumes of oxygen). When these equal amounts of the gases go through combustion, the inner cone is created and is readily visible at the end of the torch tip (Figure 1-6). The inner cone is referred to as the primary combustion zone or the primary stage of combustion. This first combustion has a residue of 4 volumes of carbon monoxide and 2 volumes of hydrogen. Since both these residual gases are capable of supporting combustion, when they are liberated, they ignite and burn at a lower temperature than the primary burn of acetylene and oxygen are consumed. The 4 volumes of carbon monoxide combine with 2 volumes of oxygen from the atmosphere and burn in the secondary combustion zone (Figure 1-7) or outer envelope, which is also called the second stage of combustion. This combustion can be expressed chemically as 4CO + 2O₂ and liberates 4 volumes of carbon dioxide $(4CO_2)$.

The last volume of oxygen combines in the secondary combustion zone with the remaining 2 hydrogen volumes that resulted from the original combustion release. These

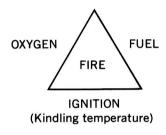


Fig. 1-5 Combustion triangle.

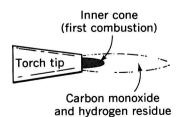


Fig. 1-6 The inner cone (primary combustion).

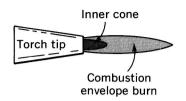


Fig. 1-7 The combustion envelope (secondary combustion).

two gases react and liberate 2 volumes of water vapor $(2H_2O)$.

The complete combustion of oxyacetylene could be represented by the following formula:

$$2C_2H_2 + 5O_2 = 4CO_2 + 2H_2O$$

where
$$4CO_2 = 4CO + 2O_2$$

 $2H_2O = 2H_2 + O_2$

The approximate temperature range that can be attained by the oxyacetylene flame is from 5000 to 6300°F at the inner cone, around 3800°F in the middle of the envelope, and approximately 2300°F at the extreme end of the secondary combustion envelope (Figure 1–8). These temperatures can be varied to some extent by changing the mixture of gases or by causing an improper balance in the volumes of oxygen and acetylene ejected from the tip of the torch. This imbalance is usually accomplished by adjusting the needle valves on the blowpipe or torch body.

Flame adjustment Oxygen and acetylene can be ejected from the torch tip in three possible gas mixtures: an excess of acetylene, an equal mixture, or an excess of oxygen. These mixtures can be identified by the appearance of the flame at the tip of the torch. The heat liberated by the combustion also is dependent upon the type of mixture. The lower inner-cone temperature is associated with carbon-rich mixtures (excess of acetylene in mixture), and the highest cone temperature is associated with the oxygen-rich mixture (excess oxygen in the mixture).

The first step in igniting the flame is to open the acetylene valve on the torch and ignite the acetylene gas coming out of the tip. Enough oxygen will be drawn in from the atmosphere to burn the fuel gas partially. The needle valve should be opened until the flame separates from the tip and then closed just enough for the flame to join the tip. This is a method of estimating proper acetylene flow. The main characteristic of this flame is the abundance of free carbon released into the air. In fact, this flame is sometimes used to apply carbon to mold faces in the foundry, for the carbon acts as an insulator between the molten metal and the mold face.

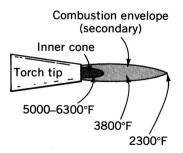
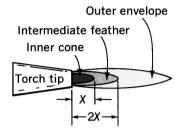


Fig. 1-8 Burn temperatures.



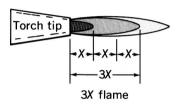


Fig. 1-9 Carburizing-reducing flame.

There are three types of flames: the carburizing or reducing, the balanced or neutral, and the oxidizing. The carburizing or reducing flame has an excess of acetylene (Figure 1-9) and is characterized by three stages of combustion instead of two as in the other two types of flames. The extra combustion stage, called the intermediate feather, can be adjusted by the amount of acetylene imbalance induced at the torch body needle valve. The length of the intermediate feather is usually measured, by eye, in terms of the inner-cone length. A 2× carburizing flame, then, would be a feather approximately 2 times as long as the inner cone (Figure 1-9). The carburizing flame does not completely consume the available carbon; therefore, its burning temperature is lower and the leftover carbon is forced into the metal. This action is characterized by the molten weld puddle appearing to boil. After this carbon-rich weld bead solidifies, the weld will have a pitted surface; these pits can extend through the entire weld bead. The bead will also be hardened and extremely brittle because of the excessive amount of carbon that was injected into the molten base metal. This excess of carbon. however, is an ideal condition when welding high-carbon steel.

Upon further adjustment of the torch needle valves, the intermediate feather can be drawn into the inner cone. The oxygen is usually increased in order to maintain the minimal amount of acetylene flow. Increase of the oxygen flow causes the intermediate feather to recede into the inner cone.

The instant that the feather disappears into the cone, the oxygen-acetylene mixture produces a balanced or neutral flame. This two-stage neutral flame, which should have a symmetrical inner cone and should make a hissing sound (Figure 1-8), is the most-used flame in both the welding and the flame cutting of metals. It has little effect upon the base metal or the weld bead and usually produces a clean-appearing, sound weld bead with properties equal to the base-metal properties. The inner cone of the neutral flame is not hot enough to melt most of the commercial metals, and the secondary combustion envelope is an excellent cleanser and protector of ferrous metals.

Further opening of the oxygen needle valve on the torch body shortens the inner cone approximately twotenths of its original length. The inner cone then loses