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CHAPTER 11

OXYFUEL GAS WELDING

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Photograph courtesy of Victor Equipment Company

CHAPTER 11

OXYFUEL GAS WELDING

INTRODUCTION

The term *oxyfuel gas welding* (OFW) refers to the group of welding processes that achieve the coalescence of metals by heating the workpieces with an oxyfuel gas flame. These processes are implemented with or without the application of pressure and with or without a filler metal.[1,2] Of this group, oxyacetylene welding (OAW) has the widest range of applications.

Oxyacetylene welding is one of the oldest welding processes. Experiments by the French chemist LeChatelier demonstrated that the combustion of acetylene combined with oxygen produced a flame with a far higher temperature than any previously known. He described the characteristics of the oxyacetylene flame in a paper delivered in 1895. Others had been independently investigating similar aspects of acetylene, including its commercial possibilities. In 1892, a method of producing calcium carbide, from which acetylene is made, was invented in North Carolina, and in 1895, a machine for producing liquid oxygen was placed in operation in Indiana. In 1897, a method of stabilizing acetylene with acetone was developed in France, and in 1904, a pressurized container for stabilized acetylene was introduced. This made possible the safe transportation and handling of this volatile gas. Development of oxyacetylene welding apparatus and techniques rapidly followed, and in fewer than ten years the process had become very valuable to the metal fabricating industry. It was especially well known for its effectiveness in repair welding. The usefulness and reliability of this new process were solidly established and confirmed many times over during the war years of 1914 through 1918.[3,4]

Although the use of oxyfuel gas welding has been surpassed by the arc welding processes for most applications, oxyfuel gas welding remains popular because it is versatile, portable, and inexpensive. The process is capable of making quality welds in many materials, and when used with modified basic equipment, is also important for its cutting and heating capabilities.

This chapter presents an overview of oxyacetylene welding and the other processes in the oxyfuel welding group, including air acetylene welding and oxyhydrogen welding. Also described in this chapter are oxyfuel gas welding equipment, materials, procedures, process variables, weld quality and economics. The safe practices required for the welding processes and the handling of compressed gas cylinders and accessories are presented.

FUNDAMENTALS OF OXYFUEL GAS WELDING

The oxyfuel gas welding processes involve melting the base metal and applying a filler metal (if one is used) by means of a flame produced at the tip of a welding torch. Fuel gas and oxygen are combined in specific proportions inside a mixing chamber, which is usually a part of the welding torch assembly. Molten metal from the plate edges and the filler metal, if used, intermix in a common weld pool and coalesce on cooling.

The metals normally welded with the oxyfuel gas welding process include carbon steels, low-alloy steels, and most nonferrous metals, but generally not refrac-

1. American Welding Society, (AWS) Committee on Definitions and Symbols, 2001, *Standard Welding Terms and Definitions*, A3.0:2001, Miami: American Welding Society.
2. At the time of the preparation of this chapter, the referenced codes and other standards were valid. If a code or other standard is cited without a date of publication, it is understood that the latest edition of the document referred to applies. If a code or other standard is cited with the date of publication, the citation refers to that edition only, and it is understood that any future revisions or amendments to the code or standard are not included; however, as codes and standards undergo frequent revision, the reader is advised to consult the most recent edition.
3. ESAB Welding and Cutting Products, 1995, *The Oxy-Acetylene Handbook*, Florence, South Carolina: ESAB Welding and Cutting Products.
4. American Welding Society, 1997, O'Brien, R. L., ed., *Jefferson's Welding Encyclopedia*, Miami: American Welding Society.

tory or reactive metals. The process is used to weld thin sheet, tubes, and small-diameter pipe, and is ideally suited for repair welding. Thick-section welds, except those associated with repair work, are not cost effective when compared to many of those produced with the available arc welding processes.

Oxyfuel gas welding is also used for many surfacing operations, some of which are not possible with arc welding processes. For example, the application of surfacing materials high in zinc content, such as admiralty metal, can be accomplished with oxyfuel gas welding. Automated operations are often used to apply surfacing to products such as tube sheets or heat exchangers.

ADVANTAGES AND LIMITATIONS

An important advantage offered by oxyfuel gas welding is the control the welder can exercise over the heat input and temperature, independent of the addition of filler metal. The welder can also control weld bead size, shape, and weld pool viscosity. The equipment used in oxyfuel gas welding is low in cost, usually portable, and versatile enough to be used for a variety of related operations, including bending and straightening, preheating, postheating, surfacing, brazing, braze welding, and soldering. Cutting attachments, multiflame heating nozzles, and a variety of special application accessories add greatly to the overall versatility of the basic oxyfuel gas welding equipment. This versatility makes the oxyacetylene process particularly attractive from the viewpoint of initial investment.

Oxyacetylene welding is usually not recommended for high-strength heat-treatable steels, especially when they are being fabricated in the heat-treated condition. When welding quenched and tempered steels, the slow rate of heat input of oxyacetylene welding may cause metallurgical changes in the heat-affected zone and so may destroy the heat-treated base metal properties. One of the arc welding processes should be selected for these metals.

OXYFUEL GAS WELDING PROCESS VARIATIONS

Variations of the oxyfuel gas welding processes are air acetylene welding, oxyacetylene welding, oxyhydrogen welding and pressure gas welding. These techniques are described briefly in this section.

Air Acetylene Welding

Air acetylene welding (AAW) is an oxyfuel gas welding process that uses an air-acetylene flame to achieve the coalescence of materials. This obsolete or seldom-used process is performed (without the application of pressure) only on metals with very low melting points that are not affected by the flame chemistry. However, the process is frequently adapted to various soldering and brazing applications in which only the filler metal is melted.

Oxyacetylene Welding

Oxyacetylene welding (OAW), which uses acetylene as the fuel gas, is the most widely used of the oxyfuel gas welding processes. Acetylene is the fuel gas of choice because of its high combustion intensity. The acetylene flame, enhanced with the addition of varying amounts of oxygen, provides the "tool" for welding and can be adjusted according to the needs of the application.

Oxyacetylene welding equipment consists of a welding torch, regulators, an oxygen cylinder, and an acetylene cylinder, typically on a two-wheeled cart. With the addition of a cutting attachment, the unit is a complete and relatively inexpensive welding and cutting outfit. This self-contained unit can be readily moved about in a shop or plant. It can be moved easily into the field on a small truck to repair a breakdown wherever it may have occurred. This equipment is illustrated in Figure 11.1, shown with welding rods and flux, which are used in some applications.

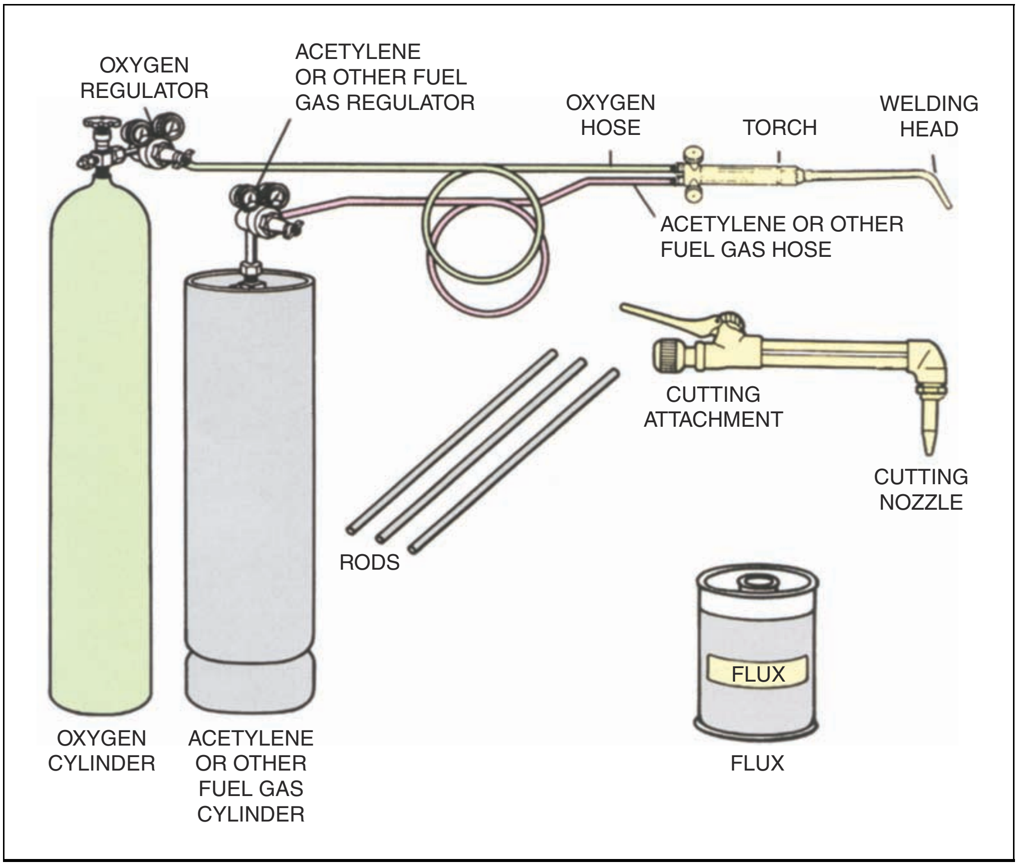
Oxyacetylene welding is almost universally used for maintenance and repair, where its flexibility and mobility result in significant savings of time and labor. The process is also well suited for use in machine and automobile repair shops, and is equally useful in shops devoted entirely to welding, where the repair of industrial, agricultural, and household equipment may be the main business.

Oxyacetylene welding is not recommended for the repair of high-strength heat-treatable steels. These should be welded with an arc welding process.

Oxyacetylene welding is used in the fabrication of sheet metal, tubing, pipe, and other metal shapes. Pipelines up to 51 millimeters (mm) (2 inches [in.]) in diameter are welded with this process. Applications include projects such as the installation of industrial piping systems and the fabrication of many products used in automotive manufacturing. The process is widely used by artists and metal sculptors. Figure 11.2 shows an oxyfuel gas welding application, in which a neutral flame is used as the heat source and the forehand technique is used.

Oxyhydrogen Welding

Oxyhydrogen welding (OHW) is an oxyfuel gas welding process that uses hydrogen as the fuel gas. This process is almost exclusively used for the melting and welding of low-melting metals, such as aluminum, magnesium, lead, and their alloys. The low-temperature, nearly invisible oxyhydrogen flame is capable of



Courtesy of ESAB Welding and Cutting Products

Figure 11.1—Oxyfuel Gas Equipment

Photograph courtesy of Victor Equipment Company

Figure 11.2—Oxyacetylene Welding on Mild Steel Using a Neutral Flame and the Forehand Technique

maintaining its very small size without producing carbon soot, thus allowing the process to be used for very fine, precise work, such as joining the intricate components of jewelry and electronic assemblies.

Oxyhydrogen welding is an especially convenient process for intricate applications when hydrogen and oxygen can be generated from a water electrolysis process.

Pressure Gas Welding

Pressure gas welding (PGW) is an oxyfuel gas welding process in which the abutting surfaces of the workpieces are heated to the welding temperature, and with the application of pressure, a weld is produced simultaneously over the entire faying surfaces of the workpieces. A filler metal is not used.

Pressure gas welding is used to make upset welds in butt joints. The joints are heated with the oxyfuel flame and forced together to obtain the forging action needed to produce sound welds in plain carbon steel, low-carbon and high-carbon steels, low-alloy and high-alloy steels and some nonferrous metals. The process is useful in joining dissimilar metals. Pressure gas welding adapts well to mechanized operations such as pipe welding, although the process has largely been replaced by gas metal arc welding.[5]

MATERIALS

The materials used in oxyfuel gas welding are gases; filler metal in the form of welding rods, and flux, although rods and fluxes are not used in all applications. The principal gases are oxygen, which supports the combustion of the fuel gas, and acetylene, which provides the heat and the atmosphere required for welding. Hydrogen, methane (natural gas), and various proprietary fuel gases are less commonly used.

OXYGEN

Oxygen in the gaseous state is colorless, odorless, and tasteless. A chief source of oxygen is the earth's atmosphere, which contains approximately 21% oxygen by volume. Although air contains sufficient oxygen to support fuel gas combustion, the use of pure oxygen speeds up burning reactions and increases flame temperatures. The use of the term *oxygen* throughout this chapter refers to pure oxygen.

5. See Reference 4, p. 401.

Most oxygen used in the welding industry is extracted from the atmosphere by liquefaction techniques employed by gas manufacturing companies. In the extraction process, air may be compressed to approximately 20 megapascals (MPa) (3000 pounds per square inch gauge [psig]), although some types of equipment operate at much lower pressures. Carbon dioxide and any impurities in the air are removed. The air passes through coils, where it is allowed to expand to a rather low pressure. During the expansion, the air becomes substantially cooled. It is then conveyed back over the coils, inducing further cooling until liquefaction occurs.

The liquid air is sprayed on a series of evaporating trays or plates in a rectifying tower. The nitrogen and other gases that boil at lower temperatures than the oxygen escape from the top of the tower, and high-purity liquid oxygen collects in a receiving chamber at the base. Some plants are designed to produce liquid oxygen for bulk delivery; in other plants, gaseous oxygen is withdrawn for compression into cylinders.

FUEL GASES

Commercial fuel gases have one common property—they all require oxygen to support combustion. To be suitable for welding operations, a fuel gas, when burned with oxygen, must have the following characteristics:

1. High flame temperature,
2. High rate of flame propagation,
3. Adequate heat value, and
4. Minimum chemical reaction of the flame with base and filler metals.

Among the commercially available fuel gases, acetylene most closely meets all of these requirements. Other fuel gases such as methylacetylene-propadiene (stabilized) (MPS), propylene, propane, methane (natural gas), and proprietary gases based on these gases, provide sufficiently high flame temperatures but exhibit lower flame propagation rates.

The gas flames produced by these gases (other than acetylene) are excessively oxidizing at oxygen-to-fuel gas ratios that are high enough to produce usable heat transfer rates required for welding. To ensure stable operation and optimal heat transfer, flame-holding devices such as counter bores on the tips are usually necessary. However, these commercial fuel gases are frequently used for oxygen cutting. They are also used for torch heating, brazing, soldering, and other operations in which the demands on the flame characteristics and heat transfer rates are not as stringent as those for welding.

Safety precautions recommended throughout this chapter and in the "Safe Practices" section should be

Table 11.1
Characteristics of Common Fuel Gases

Fuel Gas	Chemical Formula	Specific Gravity*	Volume-to-Weight Ratio*		Oxygen-to-Fuel Combustion Ratio[a]	Flame Temperature with Oxygen[b]		Heat of Combustion					
								Primary		Secondary		Total	
		Air = 1	m^3/kg	ft^3/lb		°C	°F	MJ/m^3	Btu/ft^3	MJ/m^3	Btu/ft^3	MJ/m^3	Btu/ft^3
Acetylene	C_2H_2	0.906	0.91	14.6	2.5	3087	5589	19	507	36	963	55	1470
Propane	C_2H_8	1.52	0.54	8.7	5.0	2526	4579	10	255	94	2243	104	2498
Methylacetylene-propadiene (stabilized) (MPS)[c]	C_3H_8	1.48	0.55	8.9	4.0	2927	5301	21	571	70	1889	91	2460
Propylene	C_3H_4	1.48	0.55	8.9	4.5	2900	5250	16	438	73	1962	89	2400
Methane (natural gas)	CH_4	0.62	1.44	23.6	2.0	2538	4600	0.4	11	37	989	37	1000
Hydrogen	H_2	0.07	11.77	188.7	0.5	2660	4820						325

*At 15.6°C (60°F)

a. The volume units of oxygen required to completely burn a unit volume of fuel gas according to the formulas shown in Table 11.2. A portion of the oxygen is obtained from the atmosphere.
b. The temperature of the neutral flame.
c. May contain significant amounts of saturated hydrocarbons.

observed when using fuel gases. Storage and distribution systems should be installed according to applicable national, state, or local codes. Recommendations listed in Material Safety Data Sheets (MSDS) from gas suppliers should be observed and the manufacturers' instructions for the safe installation and use of oxyfuel gas apparatus should be followed. Additional safety resources are listed in Appendix B, "Safety and Health Codes and Other Standards."

Gas-Related Terminology

Table 11.1 summarizes some of the pertinent characteristics of common fuel gases. In order to appreciate the significance of the information in this table, it is necessary to understand the following terms and concepts used to describe fuel gases.

Specific Gravity. Specific gravity is the density of a gas compared to the density of air (as a ratio). The value indicates how the gas may accumulate in the event of a leak. For example, gases with a specific gravity less than that of air tend to rise. They may collect in the corners of rooms, in lofts, and in ceiling spaces. Gases with a specific gravity greater than that of air tend to accumulate in low, still areas.

Volume-to-Weight Ratio. A quantity of gas at a standard temperature and pressure can be described by a known volume or weight. The values shown in Table 11.1 provide the volume per unit weight of gases at 15.6°C (60°F) under atmospheric pressure. Multiplying these figures by the known weight yields the volume. If the volume is known, multiplying the volume by the reciprocal of the figures shown by the volume yields the weight.

Combustion Ratio. The oxygen-to-fuel combustion ratio indicates the volume of oxygen theoretically required for complete combustion of a fuel gas as a multiple of the fuel gas volume. These oxygen-to-fuel gas ratios, termed *stoichiometric mixtures*, are obtained from the balanced chemical equations given in Table 11.2. The values shown for complete combustion are useful in calculations. They do not represent the oxygen-to-fuel gas ratios actually delivered by an operating torch because, as explained with the next term, complete combustion is partly supported by oxygen in the surrounding air.

Table 11.2
Chemical Equations for the Complete Combustion of the Common Fuel Gases

Fuel Gas	Reaction with Oxygen
Acetylene	$C_2H_2 + 2.5O_2 \rightarrow 2CO_2 + H_2O$
Methylacetylene-propadiene (stabilized) (MPS)	$C_3H_4 + 4O_2 \rightarrow 3CO_2 + 2H_2O$
Propylene	$C_3H_6 + 4.5O_2 \rightarrow 3CO_2 + 3H_2O$
Propane	$C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$
Methane (natural gas)	$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$
Hydrogen	$H_2 + 0.5O_2 \rightarrow H_2O$

Heat of Combustion. The total heat of combustion (heat value) of a hydrocarbon fuel gas is the sum of the heat generated in the primary and secondary reactions that take place in the overall flame. The combustion of hydrogen takes place in a single reaction. The theoretical basis for these chemical reactions and their heat effects are discussed in *Welding Science and Technology*, Volume 1 of the *Welding Handbook*, 9th edition, Chapter 2.[6]

Typically, the heat content of the primary reaction is generated in an inner, or primary, flame, where combustion is supported by the oxygen supplied by the torch. The secondary reaction takes place in an outer, or secondary, flame envelope in which the combustion of the primary reaction products is supported by oxygen from the air.

Although the heat of the secondary flame is important in most applications, the more concentrated heat of the primary flame is the major contributor to the welding capability of an oxyfuel gas system. The primary flame is said to be *neutral* when the chemical equation for the primary reaction is exactly balanced, yielding only carbon monoxide and hydrogen. Under these conditions, the primary flame atmosphere is neither carburizing nor oxidizing. Since the secondary reaction is necessarily dependent on the products of the primary reaction, the term *neutral* serves as a convenient reference point for describing combustion ratios and comparing the various heat characteristics of different fuel gases.

Flame Temperature. The flame temperature of a fuel gas varies according to the oxygen-to-fuel ratio. Although the flame temperature provides an indication of the heating ability of the fuel gas, it is only one of the many physical properties to be considered in an overall evaluation. Flame temperatures are usually calculated mathematically, as no practical method of accurately measuring these values is available.

The flame temperatures listed in Table 11.1 are for the neutral flame, that is, the primary flame that is neither oxidizing nor carburizing in character. Flame temperatures higher than those listed may be achieved, but these flames are oxidizing in nature, an undesirable condition in the welding of most metals.

Combustion Velocity. One characteristic property of a fuel gas, the combustion velocity (flame propagation rate), is an important factor in the heat output of the oxyfuel gas flame. This is the velocity at which a flame front travels through the adjacent unburned gas. It influences the size and temperature of the primary flame.

The combustion velocity also affects the velocity at which gases may flow from the torch tip without causing a flame standoff or backfire. A flame standoff occurs when combustion takes place some distance away from the torch tip rather than right at the torch tip. A backfire is the momentary recession of the flame into the welding tip or mixer, followed by the reappearance or complete extinction of the flame.

As shown in Figure 11.3, the combustion velocity of a fuel gas varies in a characteristic manner according to the proportions of oxygen and fuel gas in the mixture.

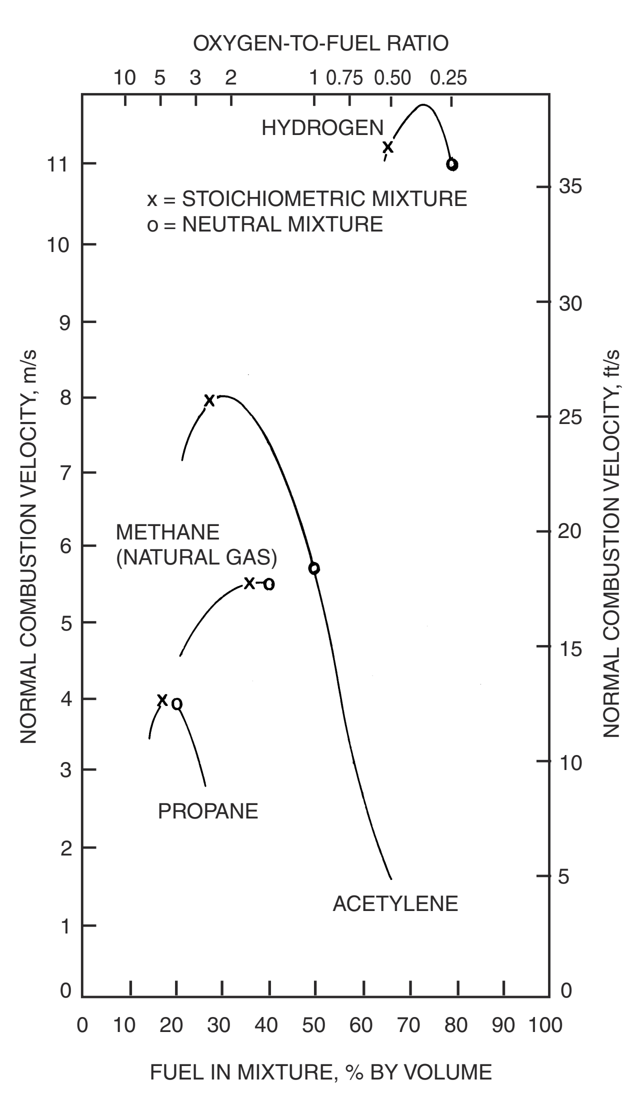


Figure 11.3—Normal Combustion Velocity (Flame Propagation Rate) of Various Fuel Gas-Oxygen Mixtures

6. American Welding Society (AWS) Welding Handbook Committee, Jenney, C. L. and A. O'Brien, eds., 2001, *Welding Science and Technology*, Vol. 1 of Welding Handbook, 9th ed., Vol. 1, Miami: American Welding Society, pp. 60–61.

Combustion Intensity. The flame temperatures and heating values of fuels have been used almost exclusively as the criteria for evaluating fuel gases. However, these two factors alone do not provide sufficient information for a complete appraisal of fuel gases for heating purposes. A concept known as *combustion intensity*, or *specific flame output*, is used to evaluate different oxygen-fuel gas combinations. The combustion intensity takes into account the burning velocity of the flame, the heating value of the mixture of oxygen and fuel gas, and the area of the flame cone issuing from the tip. The combustion intensity, C_i, is expressed as follows:

$$C_i = C_v \times C_h \quad (11.1)$$

where

C_i = Combustion intensity, joules per square meter (J/m^2) × seconds (s) (British thermal units per square foot [Btu/ft^2] × s);
C_v = Normal combustion velocity of flame, meters per second (m/s) (feet per second [ft/s]; and
C_h = Heating value of the gas mixture under consideration, joules per cubic meter (J/m^3) (British thermal units per cubic foot [Btu/ft^3]).

Therefore, the combustion intensity, C_i, is maximum when the product of the normal burning velocity of the flame, C_v, and the heating value of the gas mixture C_h, is maximum.

Like the heat of combustion, the combustion intensity of a gas can be expressed as the sum of the combustion intensities of the primary and secondary reactions. However, the combustion intensity of the primary flame, located near the torch tip where it can be concentrated on the workpiece, is of major importance in welding. The secondary combustion intensity influences the thermal gradient in the vicinity of the weld.

Figures 11.4 and 11.5 show the typical rise and fall of the primary and secondary combustion intensities of several fuels with varying proportions of oxygen and fuel gas. Figure 11.6 provides the total combustion intensities for the same gases. These curves illustrate that acetylene produces the highest combustion intensities of the gases plotted.

Acetylene (C_2H_2) is a hydrocarbon compound that contains a larger percentage of carbon by weight than any of the other hydrocarbon fuel gases. Colorless and lighter than air, it has a distinctive odor resembling garlic. Because the acetylene contained in cylinders is dissolved in acetone, it has a slightly different odor from that of pure acetylene.

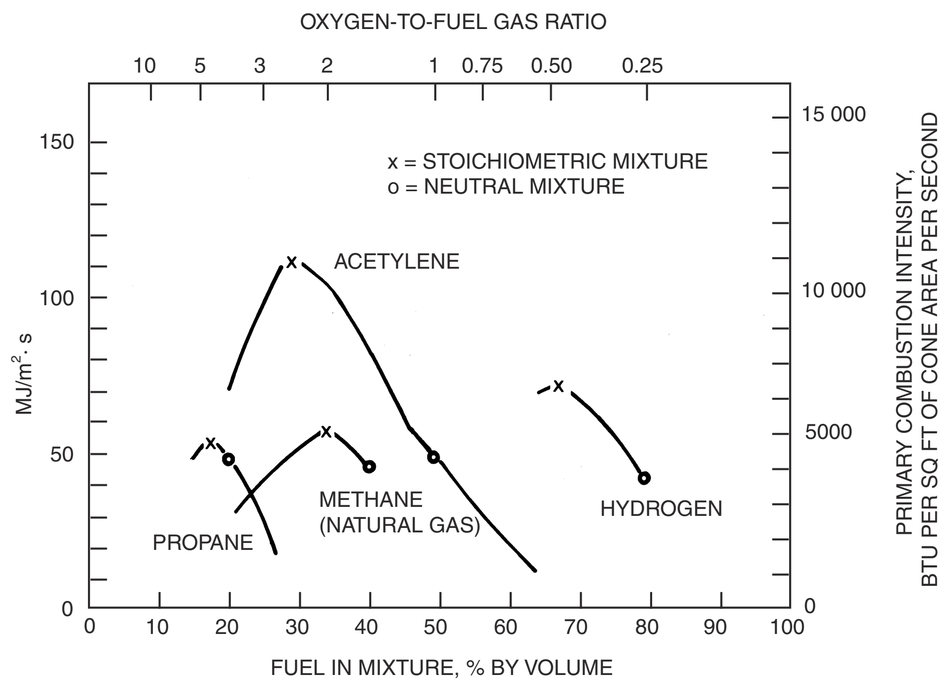


Figure 11.4—Primary Combustion Intensities of Various Fuel Gas-Oxygen Mixtures

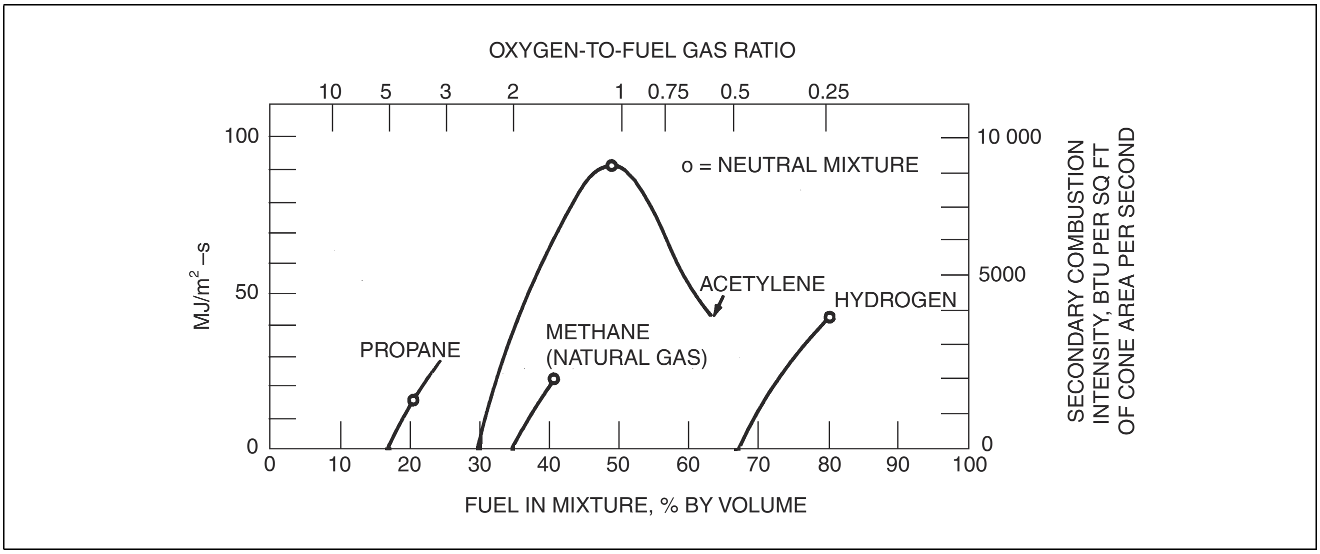


Figure 11.5—Secondary Combustion Intensities of Various Fuel Gas-Oxygen Mixtures

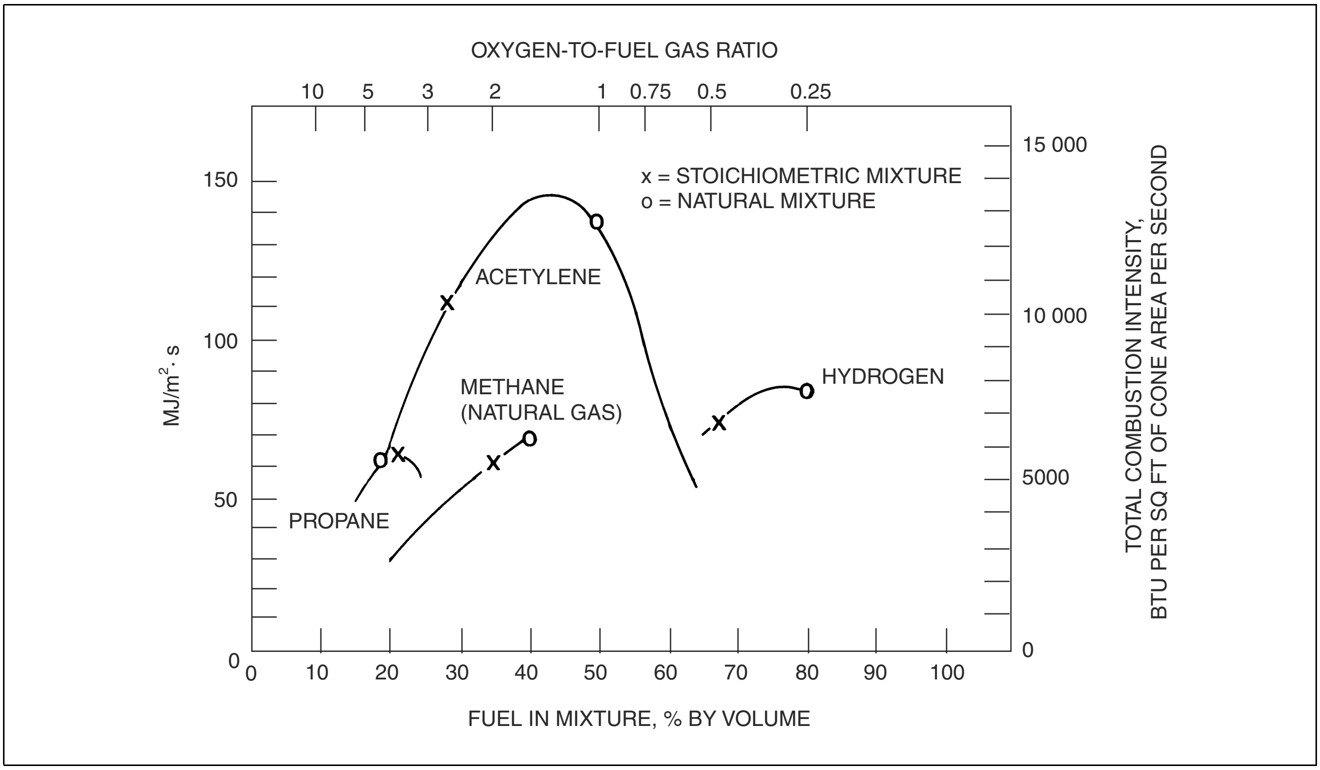


Figure 11.6—Total Combustion Intensities of Various Fuel Gas-Oxygen Mixtures

The complete combustion of acetylene is theoretically represented by the following chemical equation:

$$C_2H_2 + 2.5O_2 \rightarrow 2CO_2 + H_2O \quad (11.2)$$

This equation indicates that one volume of acetylene (C_2H_2) and 2.5 volumes of oxygen (O_2) react to produce two volumes of carbon dioxide (CO_2) and one volume of water vapor (H_2O). The volumetric ratio of oxygen to acetylene is 2.5 to 1.

As previously noted, the reaction of Equation 11.2 does not proceed directly to the products shown. Combustion takes place in two stages. The primary reaction takes place in the inner zone of the flame (referred to as the *inner cone*) and is represented by the following chemical equation:

$$C_2H_2 + O_2 \rightarrow 2CO + H_2 \quad (11.3)$$

In this case, one volume of acetylene and one volume of oxygen react to form two volumes of carbon monoxide and one volume of hydrogen. The heat content and high temperature of this reaction (see Table 11.1) result from the decomposition of the acetylene and the partial oxidation of the carbon resulting from that decomposition.

When the gases issuing from the torch tip are in the one-to-one ratio indicated in Equation 11.3, the reaction produces the typical brilliant blue inner cone. This relatively small flame creates the combustion intensity needed for welding steel. The flame is considered neutral because no excess carbon or oxygen exists to carburize or oxidize the metal. The products are actually in a reducing status, a benefit when welding steel.

In the outer envelope of the flame, the carbon monoxide and hydrogen produced by the primary reaction burn with oxygen from the surrounding air. This forms carbon dioxide and water vapor, respectively, as shown in the following chemical equation for the secondary reaction:

$$2CO + H_2 + 1.5O_2 \rightarrow 2CO_2 + H_2O \quad (11.4)$$

Although the heat of combustion of this outer flame is greater than that of the inner flame, its combustion intensity and temperature are lower because of its large cross-sectional area. The final products are produced in the outer flame because they cannot exist in the high temperature of the inner cone.

The oxyacetylene flame is easily controlled by valves on the welding torch. By a slight change in the proportions of oxygen and acetylene flowing through the torch, the chemical characteristics in the inner zone of the flame and the resulting action of the inner cone on the molten metal can be varied over a wide range. Thus, by adjusting the torch valves, it is possible to produce an oxidizing, neutral, or carburizing flame.

Acetylene Production. Acetylene is the product of a chemical reaction between calcium carbide (CaC_2) and water. In that reaction, the carbon in the calcium carbide combines with the hydrogen in the water, forming gaseous acetylene. At the same time, the calcium combines with oxygen and hydrogen to form a calcium hydroxide residue. Following is the chemical expression:

$$2CaC_2 + 2H_2O \rightarrow C_2H_2 + Ca(OH)_2 \quad (11.5)$$

The calcium carbide used in this process is produced by smelting lime and coke in an electric furnace. When removed from the furnace and cooled, the carbide is crushed, screened, and packed in airtight containers. The most common of these holds 45 kg (100 lb) of the hard, grayish solid. Approximately 0.28 m^3 (10 ft^3) of acetylene can be generated from 1 kg (2.2 lb) of calcium carbide.

Acetylene is also produced in petrochemical plants and is used for a variety of purposes other than oxyfuel gas welding and cutting.

Safe Handling of Acetylene. Free acetylene under certain pressure and temperature conditions may dissociate explosively into its hydrogen and carbon constituents; therefore, cylinders to be filled with acetylene are initially packed with a porous filler. Acetone, a solvent capable of absorbing 25 times its own volume of acetylene per atmosphere of pressure, is then added to the filler to stabilize the acetylene. By dissolving the acetylene and dividing the interior of the cylinder into small, partly separated cells within the porous filler in this manner, a safe acetylene-filled container is produced.

Gaseous acetylene is unstable at temperatures above 1435°F (780°C) or at pressures above 207 kPa (30 psig), and decomposition may result even in the absence of oxygen. This characteristic has been taken into consideration in the preparation of a code of safe practices for the generation, distribution, and use of acetylene gas.[7] It is a requirement of safe practice that acetylene must never be used in generators, pipelines, or hoses at pressures exceeding 103 kPa (15 psig).

Cylinders of acetylene are available in sizes containing from 0.28 m^3 to 12 m^3 (10 ft^3 to 420 ft^3) of the gas. The cylinders are equipped with fusible safety plugs made of a metal with an approximate melting point of 100°C (212°F). This allows the gas to escape if the

7. See, for example, Compressed Gas Association (CGA) *Acetylene*, CGA-G1, Arlington, Virginia: Compressed Gas Association.