

Part V. Fumes and Gases from Oxygen Cutting

Introduction

Oxygen cutting encompasses several processes that are used to cut, groove, scarf, and otherwise shape ferrous metals by means of the chemical reaction between iron and a confined stream of high-purity oxygen. Carbon and many alloy steels can be cut readily in this manner; highly alloyed and heat-resistant steels require flux or iron powder additions in the oxygen stream to facilitate the chemical reaction. Oxygen cutting processes are differentiated by the gas used as a fuel for the preheating flames. Among the fuel gases used by industry are acetylene, natural gas, propane, stabilized methylacetylene, and others. Acetylene is the most commonly used fuel gas because of its ready availability, high flame temperature, and familiar flame characteristics. However, other fuel gases (e.g., natural gas or propane) may be used, depending on availability and the economics of the cutting applications.

The fumes associated with oxygen cutting operations occur as the result of the chemical reaction between iron and high-purity oxygen and the process through which molten oxides and unoxidized metal are removed from the kerf by the cutting jet. Fume quantities are dependent upon the cutting process parameters, base metal thickness, base metal composition, surface contaminants, and other factors. Fume compositions are governed by the composition of the metals being cut and any coating that may be on the surface of the metal.

Although the potential problems presented by oxygen cutting fumes have been noted by the American Welding Society (see ANSI Z49.1-1973, Safety in Welding and Cutting), there are few references to this subject in the technical literature on safety and health. Fume samples have been collected in various industrial environments

and analyzed to determine concentrations of specific elements and compounds in cutting areas (Refs. 5.1 and 5.2). However, little has been done to determine the rate at which fumes are produced during oxygen cutting operations. Such information is of interest to the welding engineer, the industrial hygienist, and the ventilation specialist. The data obtained in the course of this investigation partially fill this void in the technical knowledge and provide the impetus for further research.

Scope

Research was directed toward a study of the fumes produced during oxyacetylene and oxynatural gas (methane) cutting of low carbon steel plate in thicknesses of 1/2, 1, and 2 in. (12.7, 25.4, and 50.8 mm).

Cutting was done under the normal conditions recommended by the cutting torch manufacturer, using various gas pressures and various travel speeds. Total fume samples were collected to accumulate data for use in determining fume generation rates and quantities relating fume generation rates to important process variables.

Limitations

Fume compositions were analyzed only by optical emission spectroscopy (except for iron, which was confirmed by wet chemical analysis). Concentrations of major elements cannot be determined accurately by optical emission spectroscopy because of difficulty in interpreting the spectrographic record and because of the lack of suitable standards. As a result, concentrations of such

elements are expressed in a range of weight percentages instead of discrete weight percentages. If more accurate compositional data are needed, optical emission spectroscopy should be supplemented by other analytical techniques such as atomic absorption analyses or wet chemistry methods.

Particle sizes of fume deposits were examined briefly with the light microscope. Additional research would be needed to more fully characterize cutting fumes. Such research should include studies to determine the distribution of fume particles by size and examination of fume deposits with the scanning electron microscope.

Acetylene and methane were the gases chosen for this study. Methane was chosen as a cutting fuel gas instead of natural gas because it was readily available in cylinders.

No study of arc cutting or plasma arc cutting was made, for lack of readily accessible equipment.

Program

Cutting experiments were conducted within the Battelle fume collection chamber. Fume samples for gravimetric analyses were collected on glass fiber absolute filters. Cellulose membrane filters were used to collect fumes for chemical analysis and were weighed before and immediately after each run. Fume generation data were computed as both the rate of generation in grams per minute and the weight generated per unit length of cut. The composition of the fume during cutting of carbon steel plate was determined by optical emission spectroscopy and wet chemistry (iron only). The fume particles were studied with the light microscope.

Equipment, Materials, and Procedures

Equipment and Facilities

Cutting Equipment: The equipment used during this investigation is described below:

(1) An Oxyweld W-22 torch was used for oxyacetylene cutting. As indicated below, it was equipped with tips appropriate to the thickness of plate being cut.

Plate thickness		Tip number	Cutting orifice diameter	
in.	mm		in.	mm
1/2	12.7	4	0.04	1.0
1	25.4	6	0.06	1.5
2	50.8	8	0.08	2.0

(2) A Harris 63-2 torch equipped with the following tips was used for oxy methane cutting.

Plate thickness		Tip number	Cutting orifice diameter	
in.	mm		in.	mm
1/2	12.7	OOVVC	0.036	0.9
1	25.4	0-1/2VVC	0.40	1.0
2	50.8	1VVC	0.046	1.2

Fume Collection Chamber. Samples of oxygen cutting fumes were collected in the Battelle fume collection chamber. The features of this chamber and the manner in which its performance was evaluated are discussed fully in Part II. Briefly, the chamber was a sheet metal structure with a volume of about 33 ft³ (0.93 m³). The upper third of the chamber tapered inward to form an area in which the filters and holder were located; fumes were removed from the chamber by an exhaust blower attached to the exit side of the filter holder. The front of the chamber had a hinged opening to provide access for equipment installation and adjustment; the opening could be sealed for fume collection experiments. In this study, the access opening was not closed during sampling because of the size of the cutting torch and the need to ignite it and adjust the flame before cutting ensued. The suction rate of the blower was sufficiently high to prevent any significant loss in fumes during the sampling.

The chamber was equipped with a turntable and a variable speed motor to permit cutting to be done at selected rates. A steady-rest was provided for supporting the cutting torch.

Materials

The cutting studies were conducted using hot-rolled low carbon steel plate with thicknesses of 1/2, 1, and 2 in. (12.7, 25.4, and 50.8 mm); the plate was grit-blasted to remove rust and other surface contaminants. The oxygen was welding grade, supplied from cylinders; the acetylene and methane were commercial grade, in cylinders.

Fume Sampling Procedures

The plate to be cut was positioned on the turntable. Then the speed of the turntable was adjusted to produce the selected cutting speed, and fume samples were collected in accordance with the following procedures:

(1) The glass fiber absolute filter was weighed to 0.1 mg on an analytical balance.

(2) The filter was placed in the holder located in the apex of the fume collection chamber, the sealing gaskets were installed, and the holder was clamped in place.

(3) The oxygen and fuel gas gages were set to produce the desired cutting conditions. To avoid introducing soot into the fume chamber, the cutting torch was ignited, and the flame was adjusted before the torch was placed in the chamber.¹¹

11. To ignite the cutting torch, the fuel gas valve was opened slightly and the torch was lit with a sparklighter. Then the oxygen valve was opened gradually until a neutral flame was obtained. Successive adjustments of the oxygen and fuel gas flow rates were made to produce a flame with the desired intensity. While the fuel gas flow rate was increased during these adjustments, the valve was not opened completely.

(4) The blower that exhausted the chamber was started. Immediately thereafter, cutting began and continued for a period of one-half minute.

(5) With the blower functioning, fumes were collected during the cutting period and afterwards until the chamber atmosphere cleared (about 5 minutes).

(6) The filter was weighed immediately after its removal from the filter holder to determine the weight of fumes collected.

While some fumes were generated below the workpiece, the workpiece did not appear to interfere with their collection since there was little evidence of settling of the fumes.

Samples of fumes produced under specific cutting conditions were collected in triplicate and the following data were recorded: (a) filter weight before and after sampling, (b) plate thickness, and (c) cutting conditions (oxygen and fuel gas pressures, cutting speed, etc.).

Gravimetric analyses of fume samples were conducted to determine the rate at which fumes were produced during the cutting of various thicknesses of carbon steel plate with the oxyacetylene and oxymethane cutting processes. Ideally, plates with thicknesses of 1/2, 1, and 2 in. (12.7, 25.4, and 50.8 mm) were cut using conditions recommended by the manufacturer of the cutting equipment to produce a drop cut. Cutting was also done at other oxygen and fuel gas pressures and other cutting speeds to determine the effect of these variables on the rate at which fumes were produced. For each cutting condition, the fume generation rate and the amount of fumes per unit length of plate cut were determined.

Section VA. Oxyacetylene Cutting

The results of the oxyacetylene cutting studies are summarized in Table 5.1; the data upon which this table is based are included in Appendix E (Tables E1, E2, and E3). The following comments are based on an examination of the experimental data.

Cutting under Normal Conditions

The fume generation rate increased as a function of plate thickness when plates with thicknesses of 1/2 to 2 in. (12.7 to 50 mm) were cut using recommended gas pressures and cutting speeds (Fig. 5.1). This trend is reasonable, since the rate at which fumes are produced is dependent upon the volume of metal that is oxidized and removed by the cutting jet to form the kerf, and this volume increases with increasing plate thickness. However, the fume generation rate did not increase in direct proportion to the plate thickness. Extrapolation down to zero plate thickness would indicate fume generation at 0.35 g/min. with no material being cut. The fume generation curve is presumed to drop off as sketched in Fig. 5.1.

The generation rate for 2 in. (50 mm) plate seems low, since the wider kerf of those cuts removed more than twice as much metal as that removed from the 1 in. (25.4 mm) plate; the oxygen orifice diameters were 0.08 in. (2.0 mm) and 0.06 in. (1.5 mm) respectively (Tables E3, Appendix E). Although actual kerf widths were not recorded, the kerfs were observed to be wider in the thicker plate.

Figure 5.1 also shows the variation in the ratio of fume weight to the length of cut as a function of plate thickness (dashed curve). This factor appears to be closely proportional to plate thickness.

Cutting at Various Gas Pressures

Deviations from recommended oxygen and acetylene pressures have a generally adverse effect on the quality of cut produced during oxygen cutting because the oxygen-acetylene ratio is unbalanced. As indicated in Table 5.1, such deviations also affected fume generation rates and ratios of fume weight to length of cut. For any given plate thickness, the experimental data showed a consistent trend toward higher fume generation rates with increased oxygen and acetylene pressures and lower rates with decreased gas pressures (Fig. 5.1A). Weights of fumes per unit length of plate cut varied in the same manner (Fig. 5.1B). The data plotted are for cutting done at recommended speeds; other results would be obtained by using other cutting speeds. For example, half-inch plate cut at 9.5 in./min (4 mm/s) produced 50% more fumes per minute than the 13 in./min (5.5 mm/s) cut.

Extrapolation of the curves for 2 in. and 1 in. plates to lower oxygen pressure would suggest no fume generation below 20 to 25 psi (138 to 172 kPa). The data for 1/2 in. plate extrapolate to zero pressure. The same relationship is true for the ratios of fume weights to lengths of cut.

These results should not be interpreted to mean that potential hazards presented by cutting fumes could be minimized by the use of lower-than-recommended pressures, because the quality of the cut deteriorated when reduced gas pressure was used.

Cutting at Various Speeds

Variations in cutting speed appeared to have less effect on the fume generation rates than variations in gas pressures. For example, when 1/2 and 1 in. thick plates were cut at speeds higher and lower than those recommended with normal gas pressures, fume generation rates trended upward slightly with increasing cutting rates (Fig. 5.1C). The upward trend was more pronounced when 2 in. thick plate was cut. Since more metal is being melted and oxidized at high cutting speeds, fume generation rates tend to increase.

A stronger trend was evident in ratios of fume weight to unit length of cut (Fig. 5.1D). This ratio appears to decrease hyperbolically as the speed of cutting increases. The high fume ratio at low cutting speeds correlates with the poor quality of cut obtained at low speed.

Table 5.1
Effect of variations in oxyacetylene cutting conditions on average fume generation characteristics

Operating conditions ¹	Oxygen pressure		Acetylene pressure		Plate thickness		Cutting speed		Fume generation rate, g/min		Weight of fumes/length of plate cut	
	kPa	psi	kPa	psi	mm	in.	mm/s	in./min			g/m	g/in.
Normal	241.3	35	34.5	5	12.7	0.50	5.50	13	0.42		1.26	0.032
High gas pressures	275.8	40	48.3	7	12.7	0.50	5.50	13	0.46		1.39	0.035
Low gas pressures	206.8	30	20.7	3	12.7	0.50	5.50	13	0.34		1.01	0.026
High cutting speed	241.3	35	34.5	5	12.7	0.50	6.77	16	0.49		1.21	0.031
Low cutting speed	241.3	35	34.5	5	12.7	0.50	4.23	10	0.45		1.77	0.045
Normal	275.8	40	34.5	5	25.4	1.00	4.66	11	0.54		1.93	0.049
High gas pressures	310.3	45	48.3	7	25.4	1.00	4.66	11	0.64		2.27	0.058
Low gas pressures	241.3	35	20.7	3	25.4	1.00	4.66	11	0.35		1.25	0.032
High cutting speed	275.8	40	34.5	5	25.4	1.00	5.93	14	0.57		1.60	0.041
Low cutting speed	275.8	40	34.5	5	25.4	1.00	3.39	8	0.54		2.68	0.068
Normal	275.8	40	41.4	6	50.8	2.00	2.75	6.5	0.67		4.05	0.103
High gas pressures	310.3	45	55.2	8	50.8	2.00	2.75	6.5	0.81		4.89	0.124
Low gas pressures	241.3	35	27.6	4	50.8	2.00	2.75	6.5	0.48		2.86	0.073
High cutting speed	275.8	40	41.4	6	50.8	2.00	4.02	9.5	0.72		2.98	0.076
Low cutting speed	275.8	40	41.4	6	50.8	2.00	1.48	3.5	0.53		5.96	0.151

1. Tip number (cutting orifice diameter): 1/2 in. (12.7 mm) thick plate: No. 4 (0.04 in. [1.02 mm]); 1 in. (25.4 mm) thick plate: No. 6 (0.06 in. [1.5 mm]); 2 in. (50.8 mm) thick plate: No. 8 (0.08 in. [2.0 mm]).

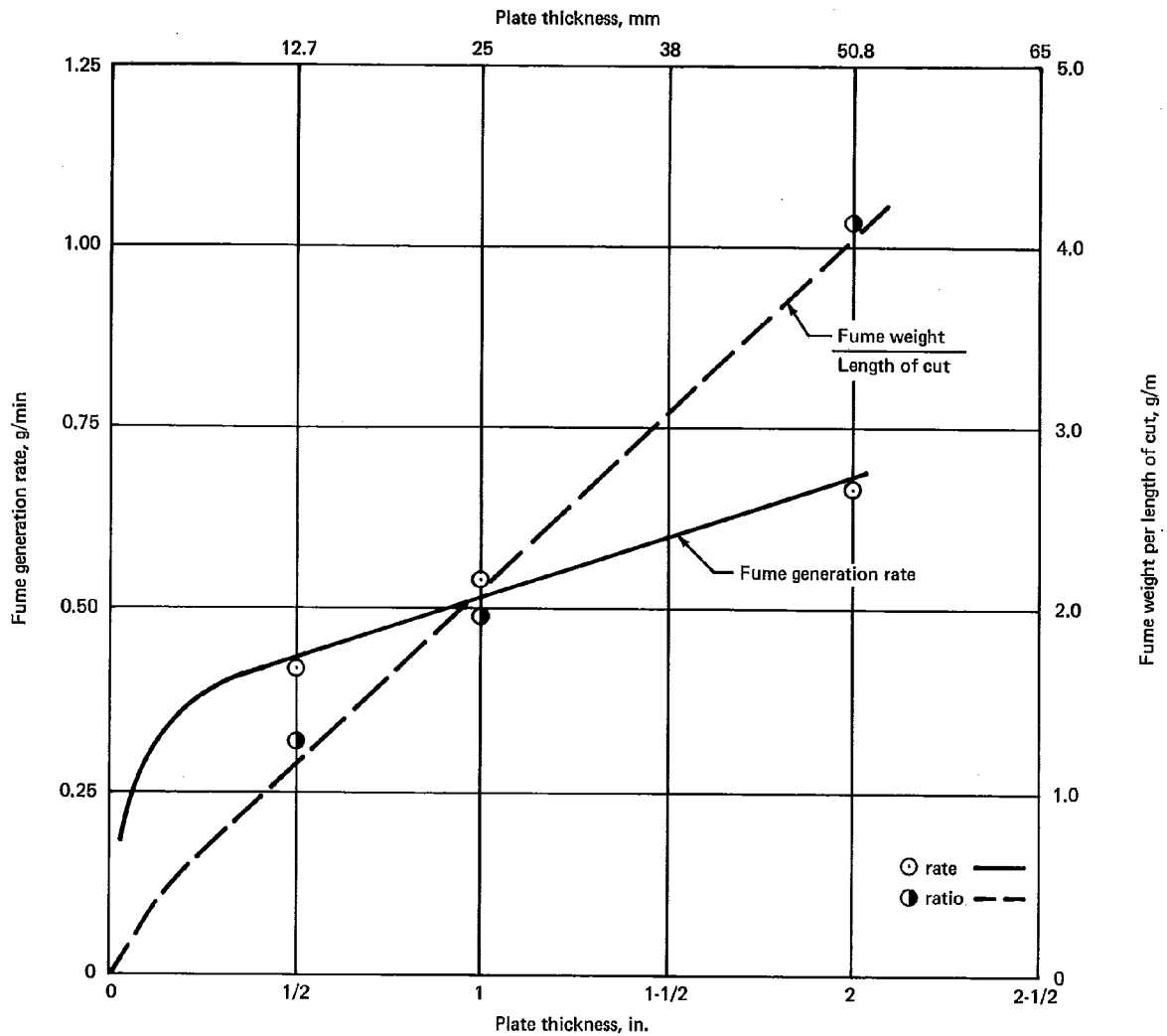


Fig. 5.1—Fume generation rate and weight of fumes per length of plate cut as a function of plate thickness during oxyacetylene cutting at recommended oxygen and acetylene pressures

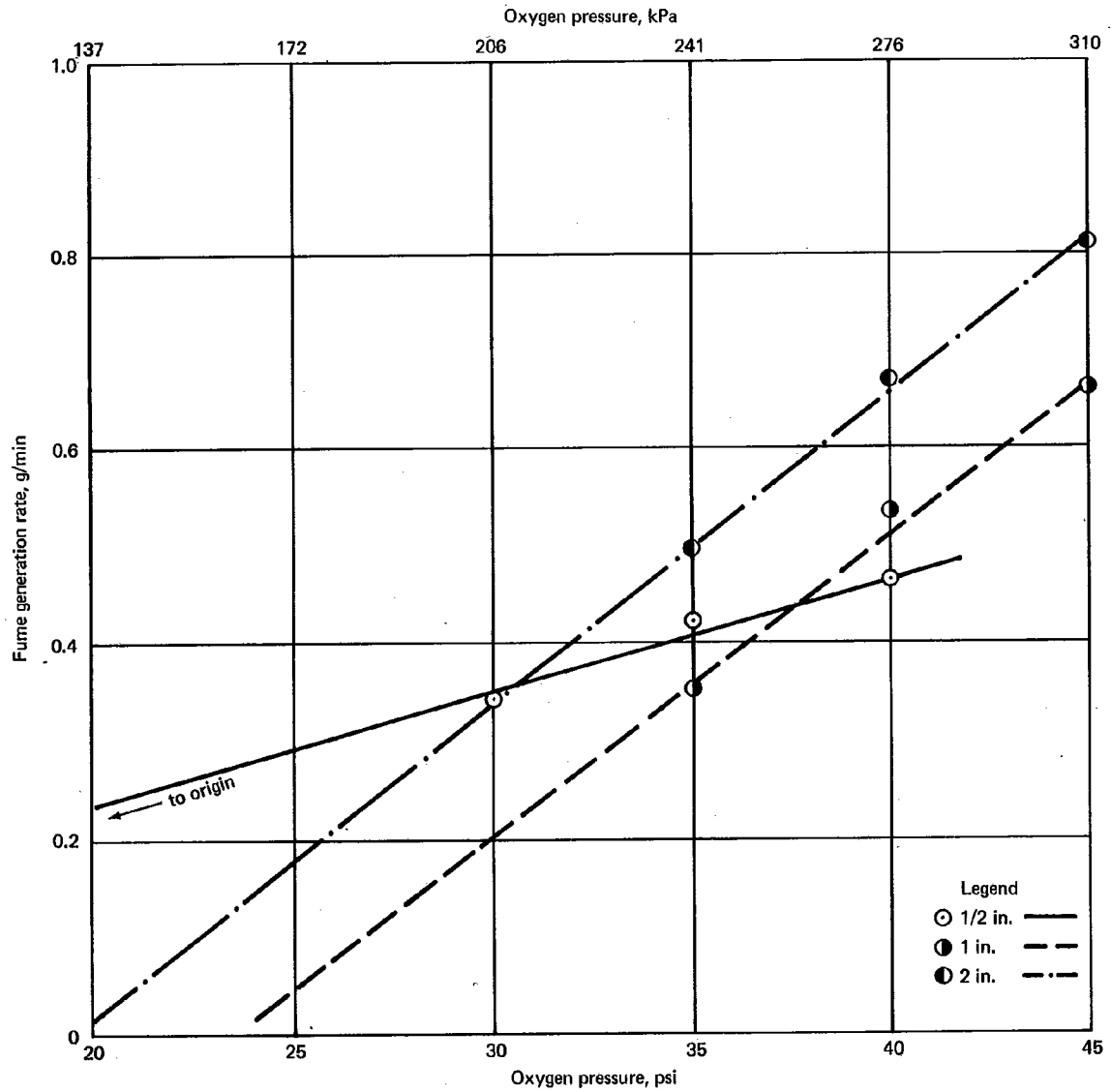


Fig. 5.1A—Fume generation rate as a function of gas pressure during oxyacetylene cutting at recommended speeds

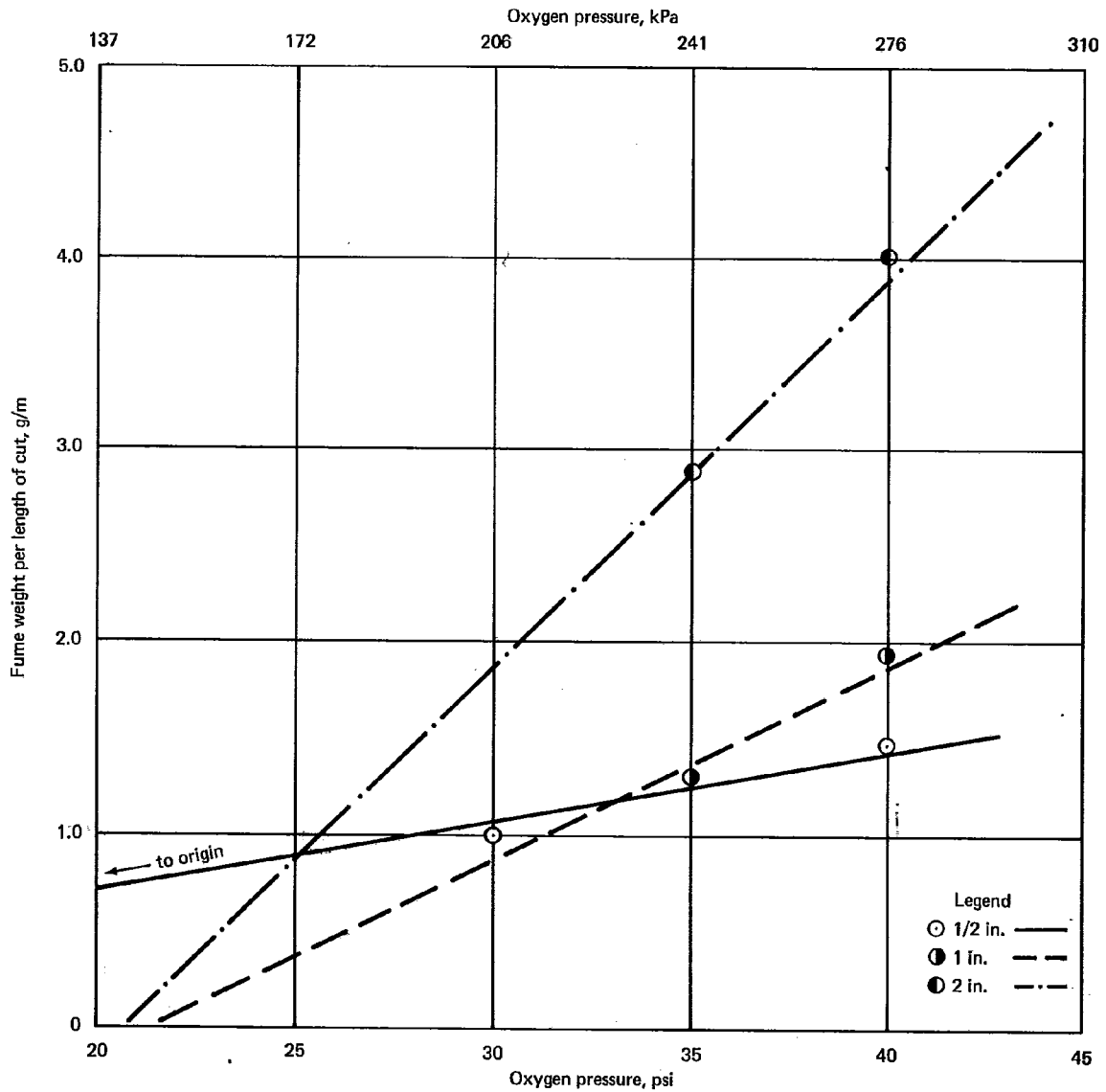


Fig. 5.1B—Weight of fumes per length of plate cut as a function of oxygen pressure during oxyacetylene cutting at recommended speeds.

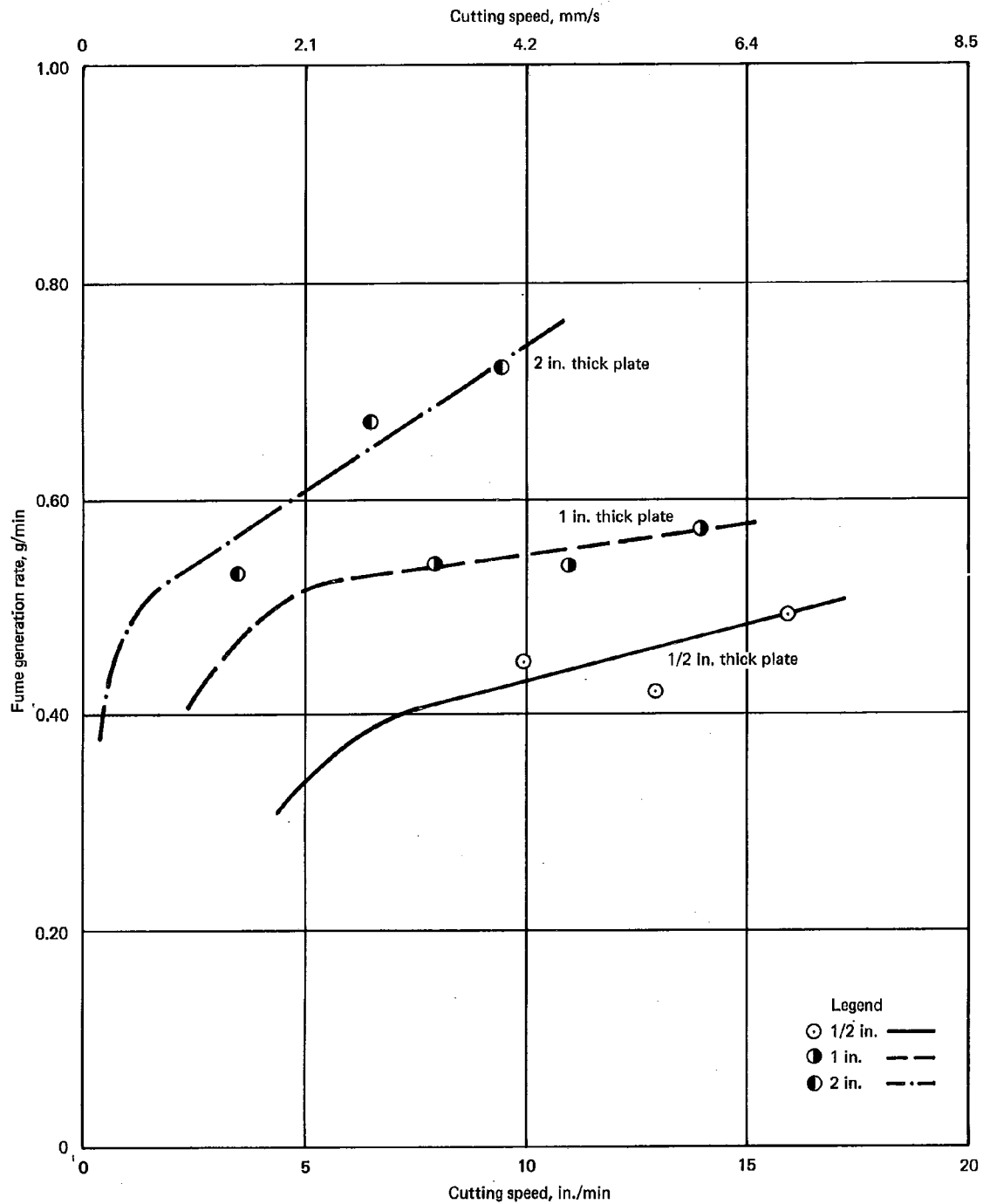


Fig. 5.1C—Fume generation as a function of cutting speed during oxyacetylene cutting of carbon steel plate at recommended oxygen and acetylene pressures

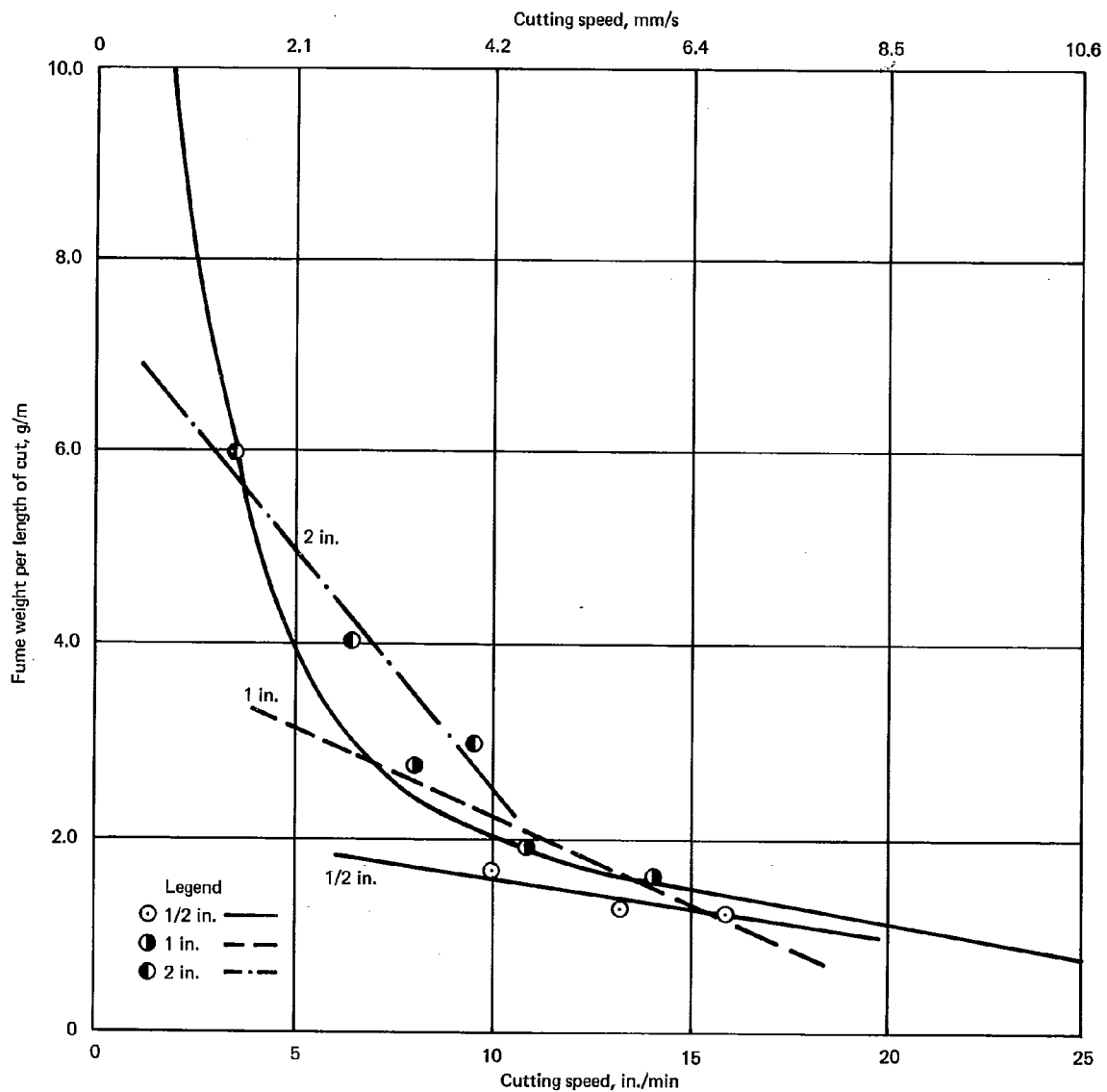


Fig. 5.1D -Weight of fumes per length of plate cut as a function of speed during oxyacetylene cutting at recommended oxygen and acetylene pressures

Table 5.2
Effect of variation in oxymethane cutting conditions on average fume generation characteristics

Operating conditions ¹	Oxygen pressure		Methane pressure		Plate thickness		Cutting speed		Fume generation rate, g/min	Weight of fumes/length of plate cut	
	kPa	psi	kPa	psi	mm	in.	mm/s	in./min		g/m	g/in.
Normal	517.1	75	6.9	1	12.7	0.50	7.79	18.4	0.60	1.28	0.033
High gas pressures	689.4	100	6.9	1	12.7	0.50	7.86	18.6	0.68	1.47	0.037
Low gas pressures	344.7	50	6.9	1	12.7	0.50	6.95	16.4	0.30	0.71	0.018
High cutting speed	689.4	100	6.9	1	12.7	0.50	8.93	21.1	0.27	0.50	0.013
Low cutting speed	689.4	100	6.9	1	12.7	0.50	6.90	16.3	0.59	1.42	0.037
Normal	689.7	100	6.9	1	25.4	1.00	6.01	14.2	0.53	1.47	0.037
Low gas pressures	517.1	75	20.7	3	25.4	1.00	4.23	10.0	0.61	2.38	0.061
High cutting speed	689.4	100	6.9	1	25.4	1.00	8.66	20.5	0.35	0.67	0.017
Low cutting speed	689.4	100	6.9	1	25.4	1.00	2.89	6.8	0.36	2.08	0.056
Normal	723.9	105	6.9	1	50.8	2.00	5.28	12.5	0.54	1.70	0.043
Low gas pressures	517.1	35	27.6	4	50.8	2.00	1.48	3.5	0.14	1.57	0.040
Low cutting speed	723.9	105	6.9	1	50.8	2.00	4.78	11.3	0.41	1.43	0.036

1. Tip number (cutting orifice diameter): 1/2 in. (12.7 mm) thick plate: No. 00VVC (0.036 in. [0.9 mm]); 1 in. (25.4 mm) thick plate: No. 0-1/2 VVC (0.040 in. [1.0 mm]); 2 in. (50.8 mm) thick plate: No. 1 VVC (0.046 in. [1.2 mm]).

Section VB. Oxymethane Cutting

The results of studies to investigate the fumes produced during oxymethane cutting are summarized in Table 5.2; the data upon which this table is based are shown in Tables E4, E5, and E6, Appendix E. This process was examined in somewhat less detail than the oxyacetylene process. For example, the cutting of 1 and 2 in. thick plate at high oxygen pressures was not done, because it was decided that use of oxygen at substantially higher-than-recommended levels (100 psi for 1 in. thick plate and 105 psi for 2 in. thick plate) would not be relevant to the research objectives.

The following comments are based on an examination of the data presented in Table 5.2.

Cutting Under Normal Conditions

The rates at which fumes were produced during the oxymethane cutting of carbon steel with thicknesses of 1/2 to 2 in. ranged from 0.53 to 0.60 g/min. (Fig. 5.2). These rates are similar in magnitude to those observed during the oxyacetylene cutting studies. However, in oxyacetylene cutting the fume generation rates tended to increase with increasing plate thickness; in oxymethane cutting, these rates were almost constant. Extrapolation to zero plate thickness would again show fume production with no metal being cut. Additional research would be needed to substantiate these results.

When the thicker plates were being cut, fume weights as a function of unit length of cut (dashed curve) were considerably less than those determined for oxyacetylene cutting (Fig. 5.1).

Cutting at Various Pressures

Limited testing was done. All results have been plotted in Figs. 5.2A and 5.2B. When 1/2 in. thick plate was cut at the recommended speed using higher-than-recommended oxygen pressure, the fume generation rate increased. At that higher pressure, slightly higher speed dramatically reduced the fume rate, while slightly lower speed reproduced the rate obtained at the recommended speed and pressure. At lower oxygen pressure, the lower speed also reduced the fume rate. The curves suggested in Fig. 5.2A are drawn in the manner of the oxyacetylene curves of Fig. 5.1A.

The data for 1 in. thick plate show greater dependency on speed than on oxygen pressure. Judging from the effect of pressure on cuts in 1/2 in. plate, the one low pressure reading for 1 in. plate seems questionably high.

The three data points for 2 in. plate seem to fit a line drawn through the origin (see Fig. 5.2A).

The ratio of fume weight to length of cut for oxymethane cutting (Fig. 5.2B) presents a picture similar to the rate data. Low oxygen pressure again produced a lower ratio of fumes to length except for 1 in. thick plate.

Cutting at Various Speeds

Contrary to the case of oxyacetylene cutting, half of the fume generation rates obtained for oxymethane cutting at various speeds (Fig. 5.2C) fell in a scatter-band directly proportional to speed. The exceptions were two experiments at high speed (21 in./min), two experiments at low oxygen pressure (50 psi in 1/2 in. thick plate and 75 psi in 1 in. plate), and the "normal" data point for 1/2 in. plate. If the accuracy of those points is not questioned, curves must be drawn showing a maximum rate of fume generation at intermediate speeds to explain the variations found at the same oxygen pressures.

The ratio graph (Fig. 5.2D) showing fume weight per length of cut as a function of speed shows an overriding benefit of high speed cutting. In two of the three pairs of experiments comparing low and high oxygen pressures at the same cutting speed, the use of low pressure was beneficial in reducing the fume ratio. Nevertheless, these results should be confirmed by further studies before recommendations are made.

Discussion

Fume Composition

To determine the composition of the fumes produced during oxyacetylene and oxymethane cutting operations, fume samples were collected on cellulose membrane filters and analyzed by optical spectroscopy. This semiquantitative analytical technique provides a means for obtaining a quick overview of a wide spectrum of the elements in fume samples; however, it is more accurate in detecting the presence of elements in small amounts than in large amounts. If more accurate compositional data are needed, optical emission spectroscopy should be supplemented by other analytical techniques such as atomic absorption analyses or wet chemistry methods.

In this instance, the content of iron in oxygen cutting fumes was lower than expected when the fume samples were analyzed by optical emission spectroscopy. Subsequent analysis for total iron by wet chemistry produced iron concentrations in the expected range.¹²

In Table 5.3, the sum of the major constituents (iron, manganese, and silicon) approaches 100 percent, if it is assumed that these elements are converted to oxides.

An examination of the data presented in Table 5.3 indicates that there was little or no difference in the elemental composition of the fumes associated with oxyacetylene and oxymethane. These results were anticipated since both cutting studies were conducted with the same type of steel plates.

12. Wet chemistry analyses for total iron were performed by a program sponsor.

Table 5.3
Composition of fumes produced during
oxygen cutting of carbon steel plate with
acetylene and methane fuel gases by
optical emission spectroscopy

Element	Concentration according to cutting method, weight percent	
	Oxyacetylene cutting	Oxymethane cutting
Ba	0.01	0.01
Si	0.1	0.05
Mn	0.3	0.3
Fe	69.28*	67.22*
Mg	<0.01	<0.01
Cr	0.02	0.02
Sn	0.01	0.01
Ga	0.01	0.01
Ni	0.05	0.05
Al	0.02	0.02
Mo	0.03	0.04
Ca	0.02	0.02
V	<0.01	<0.01
Cu	0.1	0.1
Zn	<0.1	<0.1
Co	0.02	0.02
Zr	0.02	0.02
K	<0.1	<0.1

*Total iron was determined by wet chemical analysis.

Fume Particles

Limited examinations of fume deposits were made with the light microscope to determine if cutting fume particles were significantly larger than those produced during arc welding operations. A few spherical particles of metal that had solidified from the molten state were observed; particles with diameters up to 0.00063 in. (16 μm) were noted. However, the bulk of the deposit was in the form of agglomerated particles, as in the case of welding fumes.

Importance of Fume Generation Rates

Fume generation rates are important because they provide a measure of the amount of fumes that will be produced when plate is cut under specified conditions. They also provide an indication of the fume concentrations that will exist in an area after an interval of cutting. For example, assume that iron oxide fumes are produced at the

rate of 0.60 g/min during oxygen cutting of carbon steel plate in an unventilated room with a volume of 10,000 ft³ (283 m³). Assuming further that the fumes diffuse uniformly throughout the room, the fume concentration in the room will exceed the threshold limit value (TLV) for iron oxide of 5 mg/m³¹³ (as defined by the American Conference of Governmental Industrial Hygienists) in about 2.5 minutes. Ventilation provided at the rate of about 120 m³/min should alleviate this problem.

As in the case of arc welding, there are many available methods for minimizing the potential hazards of oxygen cutting. Hoods and down-draft tables provide effective means to remove cutting fumes from the atmosphere. Water tables are particularly useful with automatic cutting equipment that incorporates a multiplicity of torches.

13. Note that the value accepted by OSHA for iron oxide is 10 mg/m³. See General Industry Safety and Health Regulations, Title 29 CFR, Part 1910.1000.

Summary of Part V

Limited research was conducted to investigate the fumes associated with oxygen cutting operations. In this work, fumes were sampled during the oxyacetylene and oxymethane cutting of carbon steel plates with thicknesses of 1/2, 1, and 2 in. (12.7, 25.4, and 50.8 mm). Cutting was done at recommended conditions to obtain data that were used to calculate base-line fume generation rates and amounts of fume as a function of the length of the cut. Cutting was also done using other-than-recommended oxygen and fuel gas pressures and cutting speeds to study the effect of these process variables on fume generation characteristics.

Depending on the thickness of metal being cut, the fume generation rates for oxyacetylene and oxymethane

cutting were similar in magnitude when recommended cutting conditions were used; they ranged from 0.42 to 0.67 g/min for oxyacetylene cutting and 0.53 to 0.60 g/min for oxymethane cutting. Such rates are comparable to those encountered in many arc welding operations studied in the laboratory investigation of welding fumes.

Fume generation rates increased somewhat over base-line levels when cutting was done at higher-than-recommended gas pressures or speeds. However, this may not constitute an additional problem, since cutting conditions that deviate substantially from recommended levels frequently result in unacceptable cuts.

Ratios of fume weight to unit length of cut were determined for various cutting applications during this program. If the amount of cutting to be done is known, this factor can be used to estimate the quantity of fumes that will be produced in completing specific tasks.

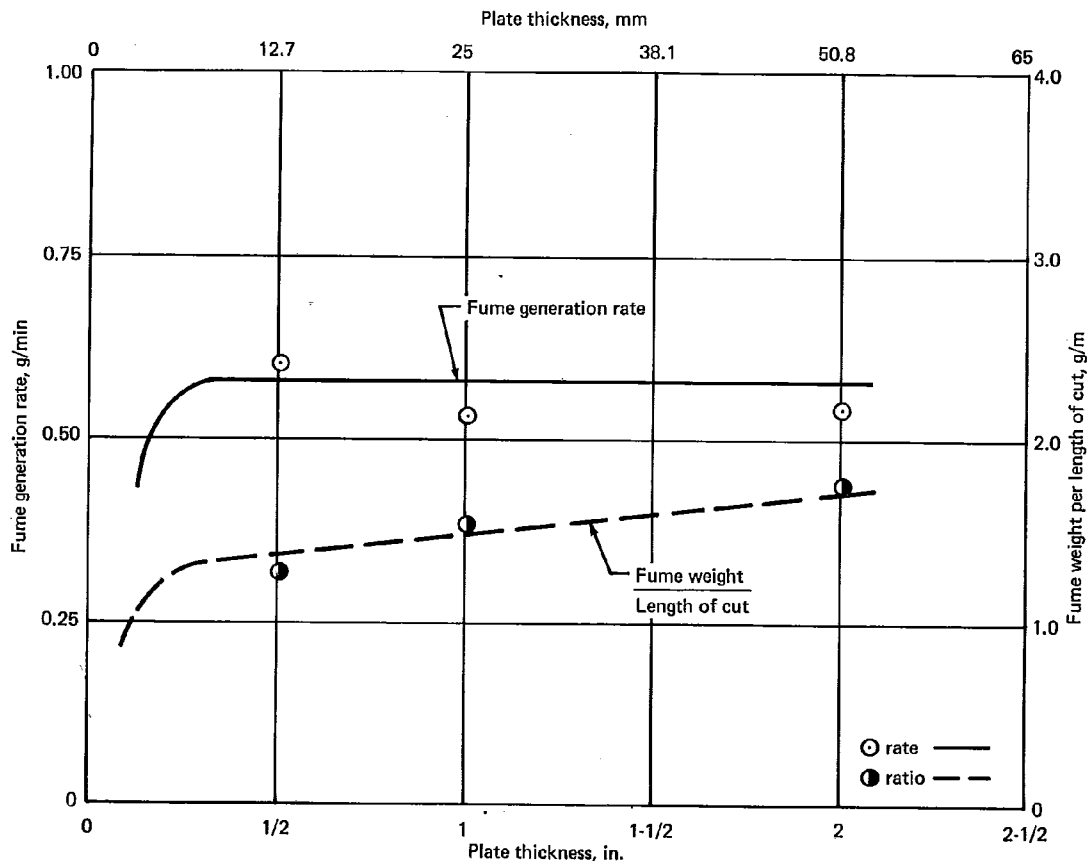


Fig. 5.2—Fume generation rate and weight of fumes per length of plate cut as a function of plate thickness during oxymethane cutting

150/FUMES AND GASES

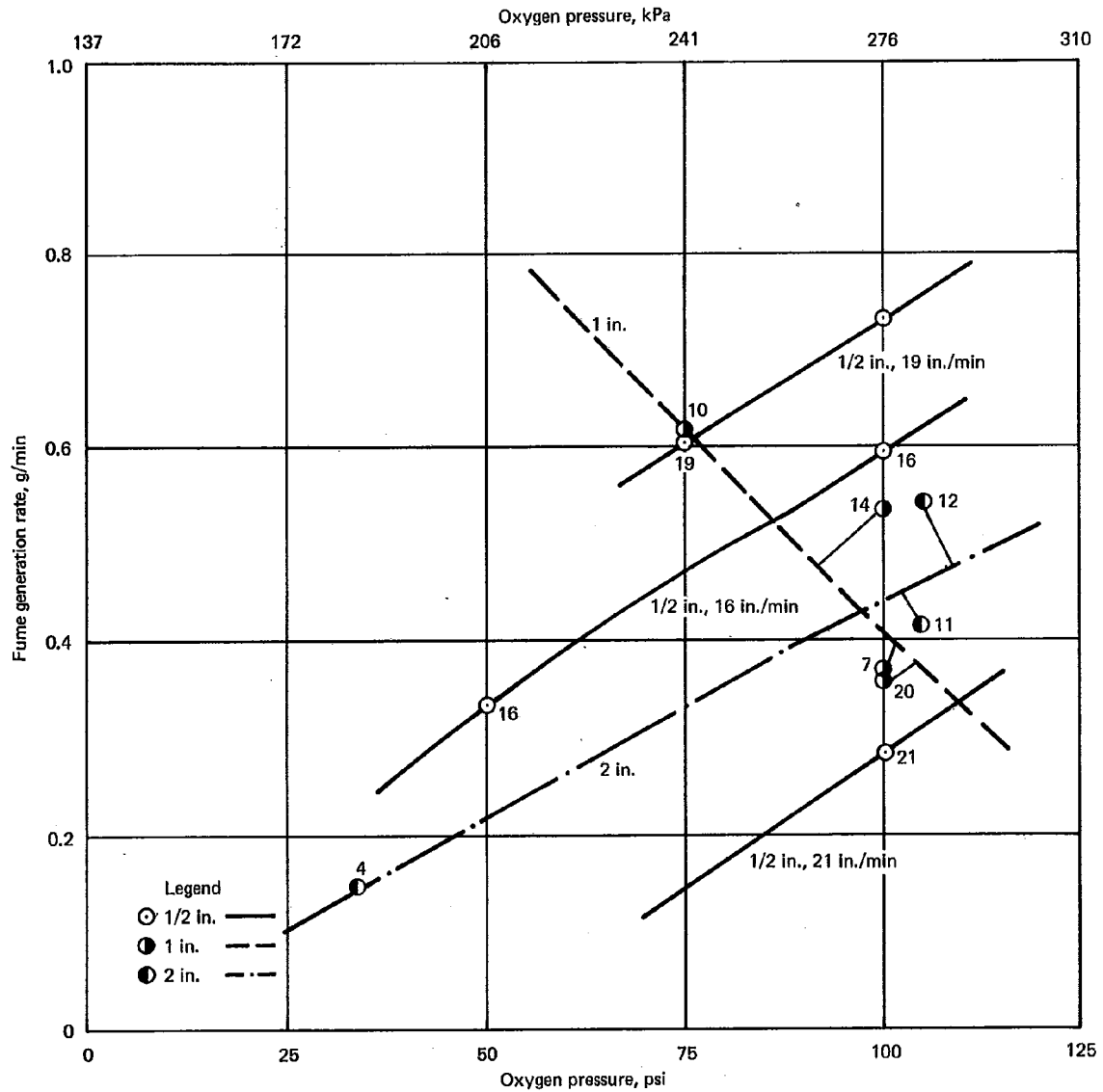


Fig. 5.2A—Fume generation rate as a function of gas pressure during oxymethane cutting at various speeds (in./min, beside data points)

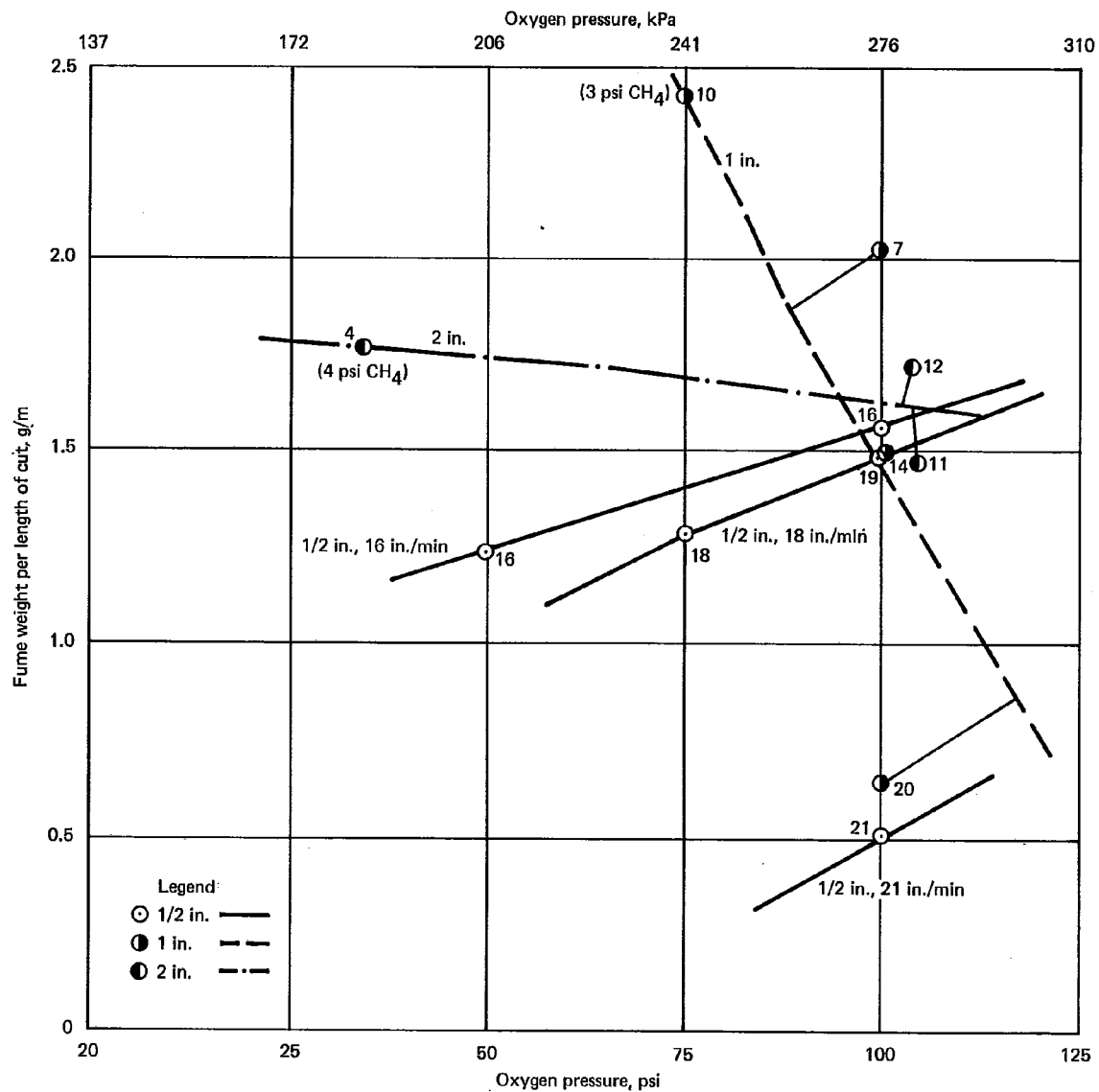


Fig. 5.2B—Weight of fumes per length of plate cut as a function of oxygen pressure during oxymethane cutting at various speeds (methane pressure 1 psi [6.9 kPa] except as noted; in./min, beside data points)

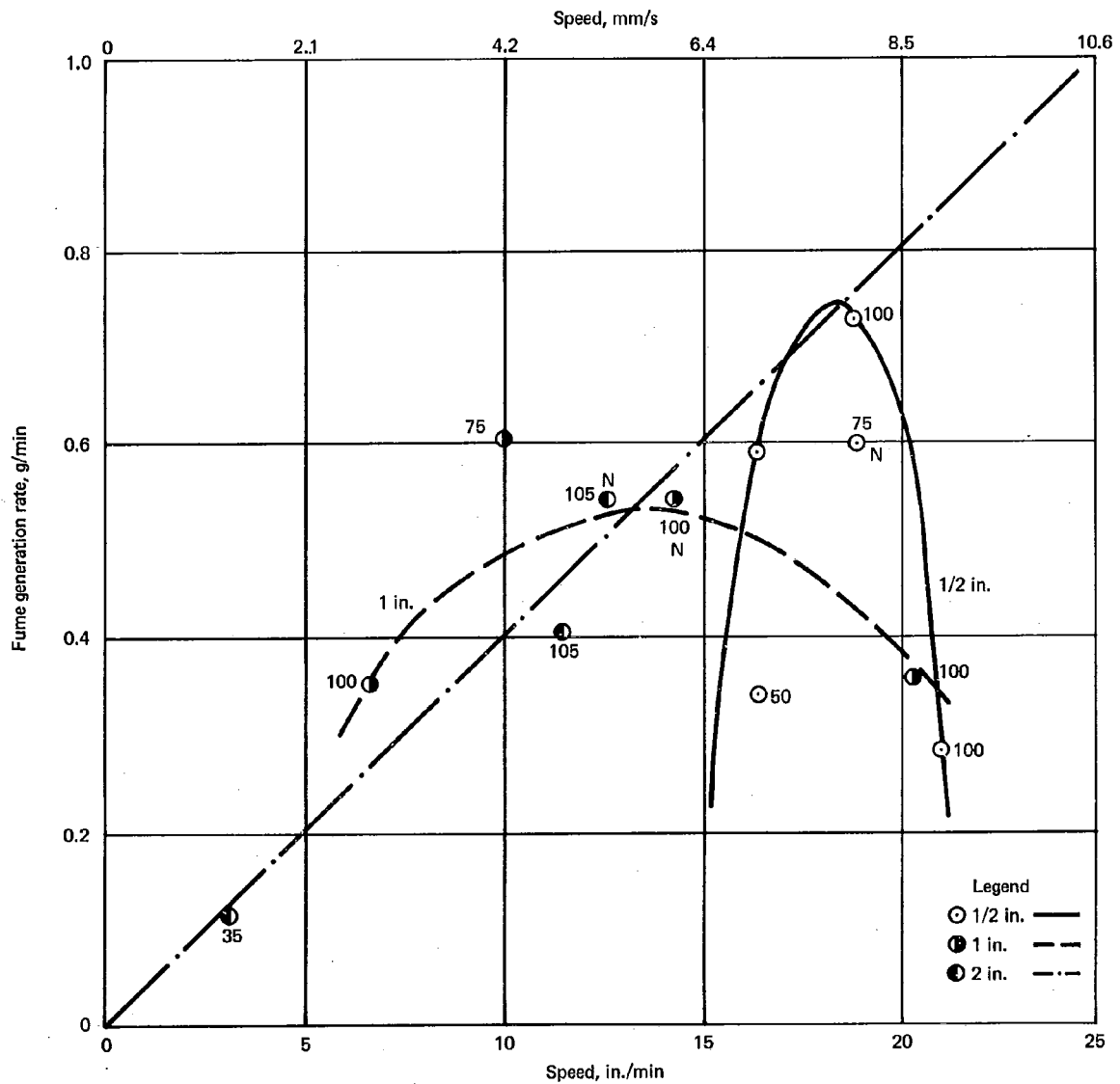


Fig. 5.2C—Fume generation rate as a function of speed during oxy-methane cutting at various oxygen pressures (psi, beside data points)

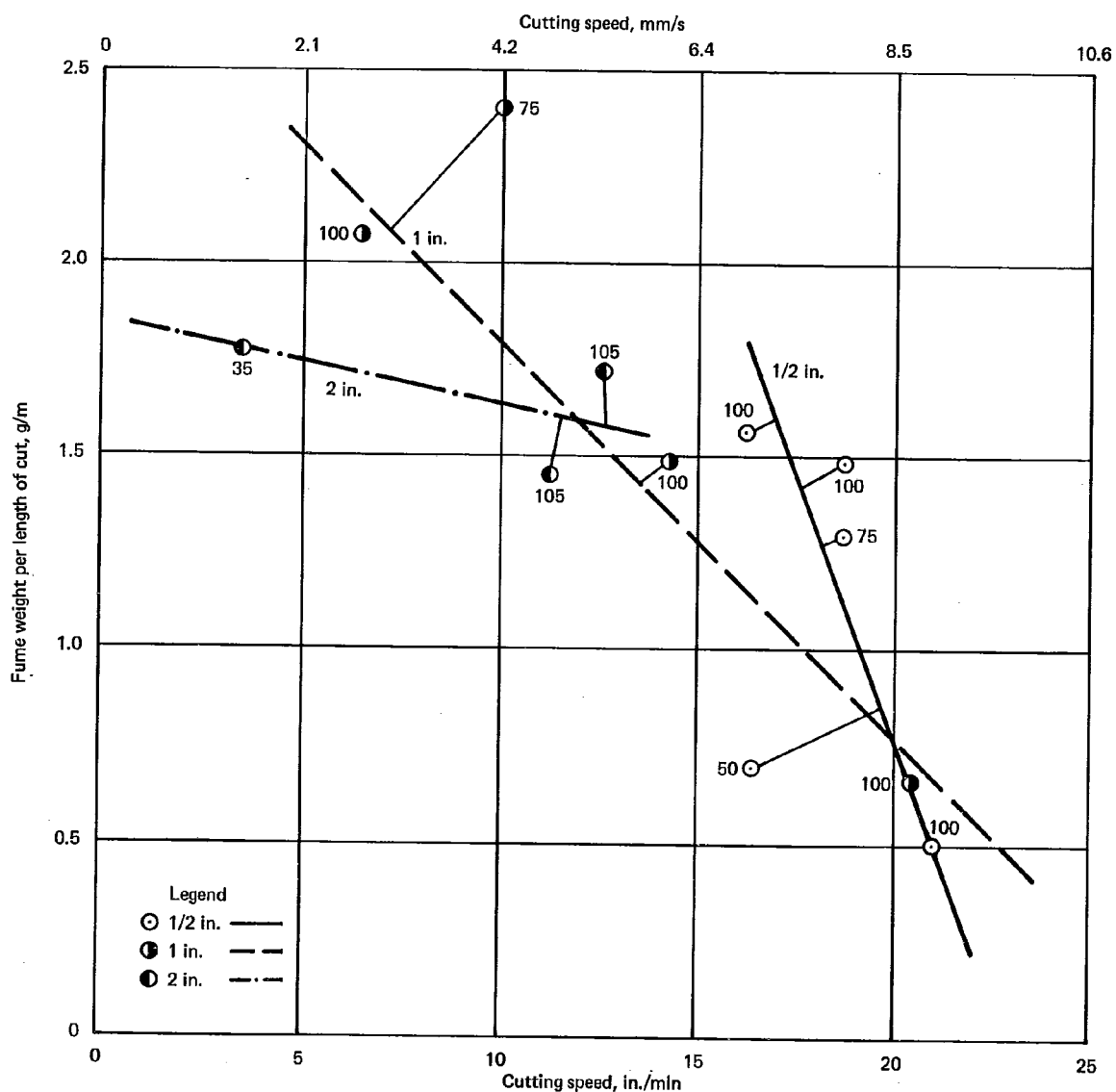


Fig. 5.2D—Weight of fumes per length of plate cut as a function of cutting speed during oxy-methane cutting at various oxygen pressures (psi, beside data points)