FUME GENERATION AND CHEMICAL ANALYSIS OF FUME FOR A SELECTED RANGE OF FLUX-CORED STRUCTURAL STEEL WIRES — AWRA DOCUMENT P9-44-85 (REVISED 15/9/86)

By I.D. Henderson*, U.E. Senff and A.J. Wilson*****

ABSTRACT

This report sets down the collected fume results from a range of nine classified wires supplied by five welding companies. The intention was to look at commonly used flux-cored wires in the structural welding field and investigate the fume characteristics by operating the wires at the manufacturers' recommended conditions.

In part, the results have been compared with similar work completed by AWS and they show reasonable correlation. The report also describes the methods employed in collecting the fume by an electrostatically assisted filter and the technique of elemental chemical analysis using x-ray fluorescence spectrometry.

INTRODUCTION

This investigation which is an extension of the AWS data on flux-cored welding wires was intended to give an overview of the consumables used in this segment of the industry to see:

(a) what level and type of particulate fume was generated, and

(b) how this would show up in the classified divisions of the consumables.

The following classified electrodes were employed in the exercise.

AWS	SAA	TYPE
E70T	ETD-Cp-W502H	Gas shielded
E71T-*	ETP-Cp-W502H & Mp	Gas shielded
E70T	ETP-Cp-W502H & Mp	Gas shielded
E70T	* —	Gas shielded
E70T--	ETD-Np-W500	No gas shield
E70T-5	ETD & P-Cp & Mp-W503	Gas shielded
E70T-7	ETD-Nn-W500	No gas shield
E110T5-K3	Not classified	Gas shielded
E71T-11	ETP-Nn-W500	No gas shield

* Not nominated by the supplier.

These classifications are defined in the AWS Codes A5.20[1] and A5.29[2] and the Australian Standard AS2203[3].

The programme was divided into sections. The CSIRO Division of Manufacturing Technology in Adelaide carried the operation of running the wire at the recommended welding parameters and measuring the fume rate (g/hr) and the fume produced per kg of consumable (g/kge).

Samples of fume, electro-deposited on hard filter paper and then collected by scraping, were then sent to BHP Steel International Port Kembla for chemical analysis.

In order to facilitate the testing operation the following information was requested from the electrode supplier for each consumable: current; arc voltage; wire feed rate; travel speed; contact tip to work distance; gas shielding; chemical elements in the wire; and electrode angle to work.

1 FUME MEASUREMENT EQUIPMENT

CSIRO Division of Manufacturing Technology developed an electrostatically assisted felt filter system to cope with the high fume generated by the flux-cored range of wires. The AWS experiments on flux-cored wires of the E70T-1 type showed that deposits were of the order of 12 g per square metre of filter and this was collected in 30 seconds.

Since some wires would produce fume at a rate of 10 times this figure, the limit of 12 g/m^2 would be reached in 3 seconds, which is too short for testing these wires.

The AWS report also mentioned clogging and overloading being a problem possibly occurring at the high generation rate of 200 g/hr, and if a reasonable filter load before clogging is taken to be 15 g/m^2 the maximum arc time would be of the order of 13.5 seconds.

When a tubular open arc hardfacing electrode was tested locally in a device similar to a Swedish Fume Box and using a membrane of 200 mm diameter (area 0.03 m^2), the system was hopelessly clogged very shortly after the test began. From the visual evidence of fume production as compared to a flux-cored, gas shielded electrode, it was apparent that a system less susceptible to clogging would have to be designed.

The immediate search for a filter medium of greater flow, perhaps compensated by a larger effective area and thicker cross-section (ie. longer trapping path), was centred on the materials used in bag-houses such as exist at lead

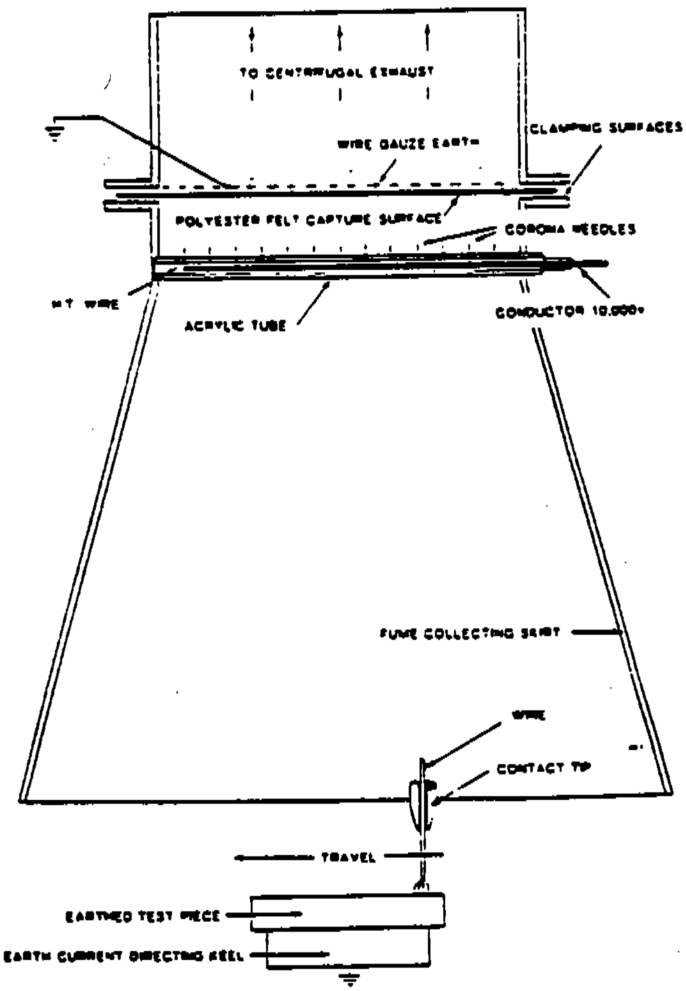


FIG 1. HIGH INTENSITY FUME COLLECTOR.

* CSIRO Adelaide Laboratory
** BHP Steel International
*** AWRA

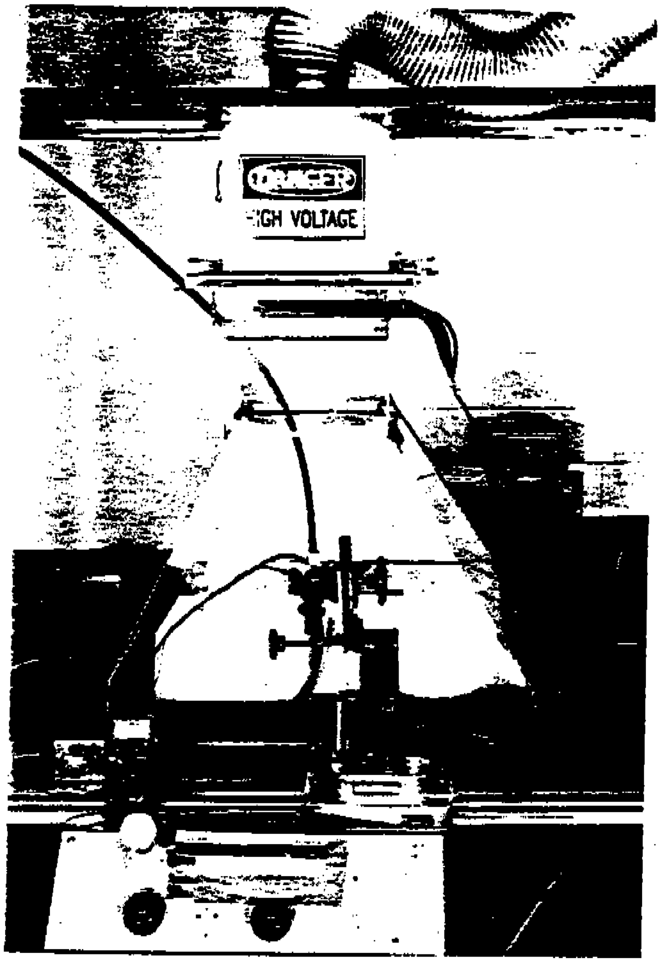


FIG 2. FUME BOX ASSEMBLY (WITH FRONT PERSPEX PANEL REMOVED).

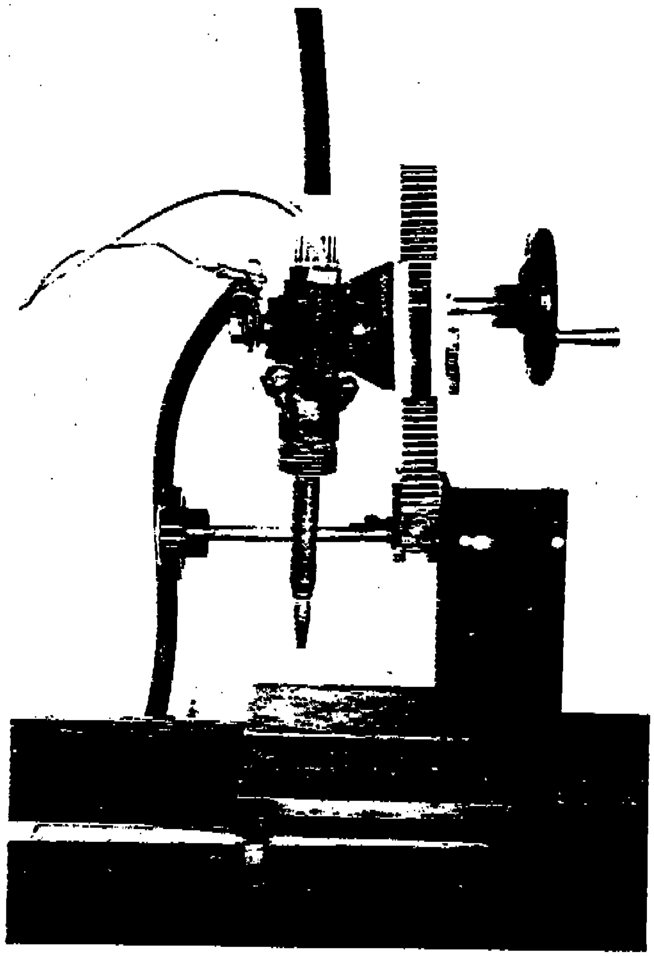


FIG 3. CLOSE-UP OF TORCH SHOWING THE MECHANISM FOR GUN ADJUSTMENT.

smelting works (ie. CSIRO considered filters used at the Port Pirie Smelters). All possible sources of filters, felt cloths and the like were contacted for samples and information. In order to reduce the tendency of fine particles to pass through the intersticies between filter fibres or the like, it was decided that a corona beam should supply gaseous current in the direction of flow of the particles in the air stream, to constrain the particles to a path perpendicular to the equipotential planes and hence to a site on a solid surface, ie. the filter fibre. The thoughts behind the electrostatic aid to filtration follow naturally from the behaviour relationships between charged substances, ie. thick film insulators discharge mechanisms of absorbed gas layers and other electrostatic phenomena.

The final choice was a felt made from polyester fibres, and an array of needle points at 12,000 volts producing point to plane electrical corona discharges to this felt (see Figure 1).

Fume monitoring requires that the rate of collection versus time be constant, ie. at the first indication of a diminished rate of capture, which is defined as the onset of clogging, the fume collection must be ceased.

Typical CSIRO collection times for fume rates of 200 g/hr (which is quite a high rate) was 30 seconds and for very high rates of 600 g/hr the times were reduced to 10 seconds.

Onset of clogging was found to occur at a filter loading of 15 g/m^2 of filter area or higher.

Figures 2 and 3 show the Fume Box arrangement and the gun adjustment mechanism for adjusting electrical stickout.

2 METHOD OF CHEMICALLY ANALYSING THE FUME

Known weights of the welding fume samples ranging from 0.1 to 0.5 grams, depending on sample availability were mixed with 6.0 grams of a lithium borate flux (12 parts lithium tetraborate to 22 parts lithium metaborate) in Pt-Rh-Au alloy crucibles. This mixture was fused in a muffle furnace for 15 minutes at 1000°C swirling the metal at five minute intervals to ensure complete sample dissolution and homogeneity. The metal was then cast into Pt-Rh-Au alloy moulds also heated to 1000°C. On cooling, this produced glass beads 40 mm in diameter suitable for analysis on x-ray fluorescence (XRF) spectrometers.

The concentration of all elements in Table 2 except fluorine were determined on a PW1400 wavelength dispersive XRF spectrometer. The spectrometer was equipped with a chromium tube powered at 50 kV and 50 mA. Measurements were made on the Lα line of barium and Kα lines of the remaining elements. All measured lines were corrected for background and line overlaps if present. Matrix effects were accounted for using matrix coefficients obtained from a fundamental parameters programme written by one of us (UES) which is based on the method of de Jongh[4].

The concentration of fluorine was not determined in the PW1400 due to the low excitation efficiency of the chromium tube for this element.

Fluorine concentrations were therefore determined on a PW1600 wavelength dispersive XRF spectrometer using a rhodium tube at 40 kV and 50 mA. The concentra-

TABLE 1 RESULTS OF FUME TESTING BY CSIRO ADELAIDE FUME GENERATION DATA

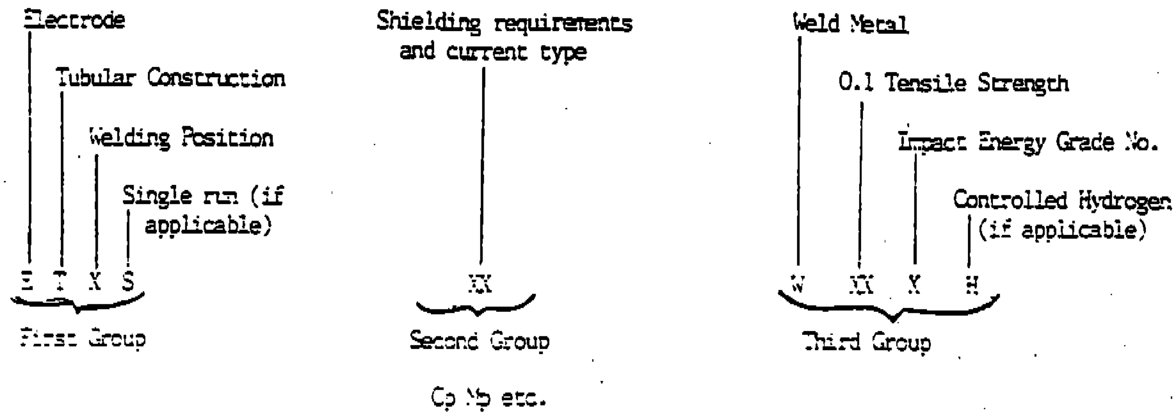
Flux Cored Welding Wires (Gasless and Gas Shielded)

M_1 = 25% CO_2 in argon
M_2 = 16% CO_2, 2.5% O_2 in argon

	SAA Classification	AWS Classification	Wire dia mm	Current	Voltage	Travel Speed mm/min	Fume Generation Rate g/hr	Fume Generation per kg of electrode g/kge
1	ETD Cp-W502H	E70 T-1-CO_2	1.6	275	28	360	50	12.0
2	ETD Cp-W502H	E70 T-1-CO_2	1.6	350	28.5	510	58	7.3
3	ETD Mp-W502	E70 T-1-M_1	1.6	400	30	610	100	15.4
4	*	E70 T-1-CO_2	2.4	450	28	465	75	9.4
5	*	E70 T-1-CO_2	2.4	550	33	675	90	9.0
6	ETP Mp-W502	E71 T-1-M_2	1.2	240	26	310	45	9.0
7	ETP Cp-W502H	E71 T-1-CO_2	1.2	240	28	345	45	9.0
8	ETP Cp-W502	E71 T-1-CO_2	1.2	250	31	410	40	7.3
9	ETP Mp-W502H	E71 T-1-M_1	1.6	275	25	310	40	7.5
10	ETP Cp-W502H	E71 T-1-CO_2	1.6	275	27	310	50	9.7
11	ETD Mp-W504H	E71 T-1-M_1	1.6	300	28	360	58	13.4
12	ETP Cp-W502	E71 T-1-CO_2	1.6	350	32	510	68	10.1
13	ETD Mp-W502H	E70 T-G-M_2	1.6	340	30	470	48	7.5
14	ETD Cp-W502H	E70 T-G-CO_2	1.6	340	32	465	52	8.3
15	ETD Mp-W502H	E70 T-G-M_2	1.6	350	32.5	490	30-60	4.7-9.4
16	ETD Cp-W502H	E70 T-G-CO_2	1.6	380	33	560	63	8.4
17	ETD Cp-W502H	E70 T-G-CO_2	2.4	450	32	550	70	9.3
18	*	E70 T-2-CO_2	1.6	300	27	350	60	11.9
19	*	E70 T-2-CO_2	1.6	375	30	480	72	9.8
20	ETD Np-W500	E70 T-4	2.4	325	28.5	360	95	17
21	ETD Np-W500	E70 T-4	2.4	350	30	400	112	14.6
22	ETD Np-W500	E70 T-4	3.0	400	28	360	115	21.8
23	ETD Np-W500	E70 T-4	3.0	420	28	340	180	19
24	ETD Np-W500	E70 T-4	3.0	470	28-29	385	240	23
25	ETD Np-W500	E70 T-4	3.0	550	31-32	530	350	26
26	ETD Mp-W503H	E70 T-5-M_1	1.6	300	26	340	48	8.8
27	ETD Cp-W503H	E70 T-5-CO_2	1.6	300	28	370	65	11.3
28	ETP Cp-W503H	E70 T-5-CO_2	1.6	360	32	510	105	14.7
29	ETD Mp-W503H	E70 T-5-M_1	1.6	400	30	500	85	12.2
30	*	E70 T-5-CO_2	2.4	300	26	290	95	18.8
31	ETD Cp-W503H	E70 T-5-CO_2	2.4	400	28	470	100	17.3
32	ETP Cp-W503H	E70 T-5-CO_2	2.4	400	32	480	110	18.4
33	*	E70 T-5-CO_2	2.4	500	32	609	196	22.3
34	ETD Nn-W500	E70 T-7	2.4	200	21	160	70	23
35	ETD Nn-W500	E70 T-7	2.4	340	25	310	180	29
36	ETD Nn-W500	E70 T-7	2.4	490	30	550	430	41
37	**	E110 T5-K3 CO_2	2.4	370	32	360	120	20.8
38	ETP Nn-W500	E71 T-11	1.7	120	19	110	25	19
39	ETP Nn-W500	E71 T-11	1.7	140	19	120	40	21
40	ETP Nn-W500	E71 T-11	1.7	200	19	160	50	17

* *Supplier has not provided Australian Classification.*
** *There is no Australian Classification.*

ORDER OF EXPRESSION FOR AUSTRALIAN SAA CLASSIFICATION SYSTEM (AS 2203)



tions of the remaining elements of Table 2 with the exception of V, Ni, Cu and Ba were also determined on this instrument for use in correcting for matrix effects on the fluorine Kα radiation and to provide a check on the PW1400 results.

Concentrations of V, Ni, Cu and Ba were not determined on the PW1600 because existing calibrations on this instrument did not include these elements.

Since a glass bead technique was used to prepare the samples, particle size and mineralogical effects on the intensities of the analyte lines are eliminated and matrix effects are greatly reduced. The effect of omitting the fluorine matrix correction to the determined concentrations of the remaining elements measured on the PW1400 was thus expected to be small due to the small matrix coefficient of fluorine on the remaining elements. The effect of excluding V, Ni Cu and B matrix corrections in the PW1600 results were also expected to be small due to the low concentrations of these elements in the fume samples. These expectations were confirmed by the close agreement between results obtained on both instruments.

3 RESULTS

The wires have been classified according to AWS and SAA. The essential parameters listed for each are shown in the Tables.

Table 1 shows the fume generation data (intrinsic or total particulate matter generated over a specific arcing time). The generation rate is measured in gms/hour. There is also a figure showing generation in gms/kg of electrode wire to show the effect of welding productivity, which is a feature of these wires.

Table 2 shows the elemental analysis of fume deposits as a percentage by weight.

Table 3 shows the weld parameters nominated by manufacturers for their particular flux-cored wires.

Table 4 shows the comparison between CSIRO and AWS fume results for 3 wire types E70-T1, E70-T4 and E70-T5. (AWS had a limited range of F/C wires.)

Figure 4 shows fume generation graphs in g/hr related to the welding current for various types of wire. The graphs are shown for each wire classification and freehand curves have been drawn between the points.

Figure 5 shows the weight of fume per kg of electrode consumed, related to welding current for various types of wire.

4 DISCUSSION

The method of fume collection established by CSIRO Adelaide is an important one for coping with the high fume generation processes associated with flux-cored wires. The ability to operate the welding for long periods before the onset of clogging means that the results can be more accurate due to longer averaging times.

Comparing the results with some similar work completed by AWS in 1979 shows by and large agreements in the major fume measuring parameters for three types of wire. Table 4 is a comparison that has been made on results for the type wires E70-T1, E70-T4 and E70-T5. The comparison is limited because the other wire types were not tested by AWS. There were also limitations in the wire sizes available for comparison as the more recent trend is to use thinner wires particularly for out of position welding. Given the changes in welding conditions between the two sets of test figures there is reasonable correlation between the results.

The work completed in this study extends previous data[5] on fume generation and analysis to electrodes covered by the AWS classifications E71T1, E70T6, E70T2, E70T7, E110T5-K3 and E71T11.

By using XRF to analyse the fume, the presence of elements of atomic number greater than eight could be detected and quantitatively determined. However, the method precluded a study on the lithium content of the fume, a component known to be a minor constituent in some electrodes.

Small quantities of strontium were found in the E71T11 electrode fume. This is not considered significant in terms of health risk.

The various wire classifications conformed in a general way chemically, despite the variety of wires being tested from five different companies, ie. the gasless wires contain levels of aluminium, magnesium, calcium and fluoride, the basic wires are high in fluoride and calcium whilst the rutile electrodes are higher in titanium, etc.

The significance of these results is that they can be used for estimating the requirements of ventilation. The limitation of respirable air for dust loading at 5 mg/cubic metre will be rapidly exceeded by many of these wires in a confined location. The individual element limitation for iron oxide and fluorides is also likely to be exceeded in confined areas.

Overall, the results show that gasless wires type E70T4, E70T7 and E71T11 have higher fume generation than gas-shielded wires although the figures are modified when the deposition rate is considered.

Small amounts of barium were measured in the gasless wires E70T7 and E71T11 but only negligible amounts in the E70T4 type.

The gasless wires have the ability to withstand wind

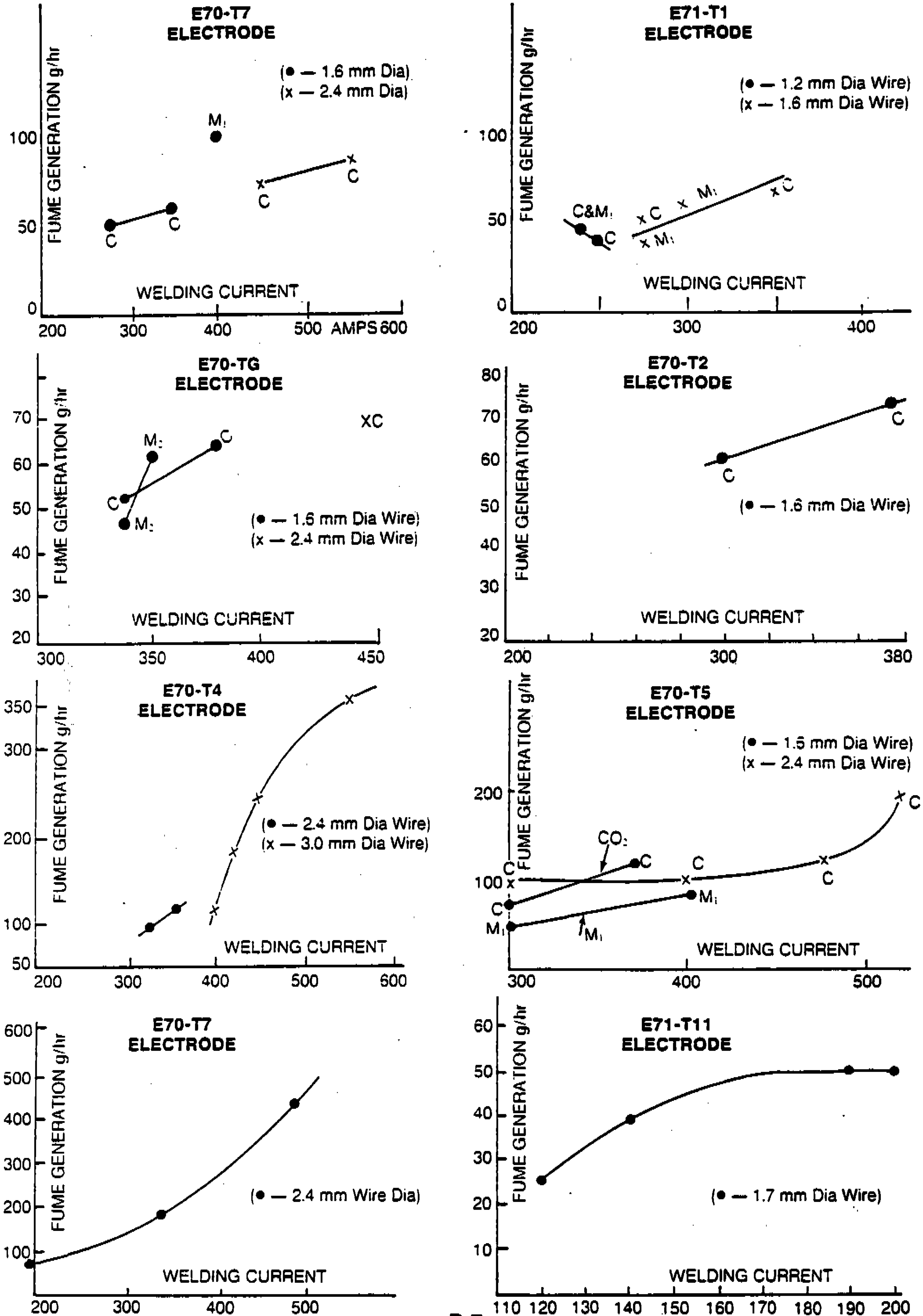


FIG. 4. FUME GENERATION RATE.

TABLE 2 WELDING FUME ANALYSIS

	Classification	Sample No.	Ti	Si	Fe	Al	Mn	Ca	Mg	S	K	Na	Cr	F	Zn	Ni	Cu	Ba	V	Sr
			Elemental Composition in %																	
1	E70T-1CO2	4	2.5	5.5	45.5	.03	10.8	.11	<.01	.05	.06	3.0	.02	<.1	.10	.03	.18	.01	.03	ND
2	E70T-1CO2	18	2.8	5.5	37.8	.48	9.5	.29	.48	.09	2.1	5.3	.02	9.4	15	.03	.15	<.01	04	ND
3	E70T-1M1	3	.11	5.4	52.5	.27	7.2	.36	.30	.05	.03	.96	<.01	<.1	02	04	.17	<.01	.009	ND
4	E70T-1CO2	40	2.2	7.5	43.1	.03	13.5	.07	.05	.04	.29	.10	.04	<.1	04	.08	.32	<.01	.03	ND
5	E70T-1CO2	41	2.2	7.5	43.1	.03	13.5	.07	.05	.04	.29	.10	.04	<.1	.04	.08	.32	<.01	.03	ND
6	E71T-1-M1	1	3.7	5.5	39.7	.11	13.5	.25	.09	.04	.12	3.9	.03	<.1	.08	.04	.17	<.01	05	ND
7	E71T-1-CO2	2																		
8	E71T-1-CO2	11	5.5	3.4	39.9	.79	10.0	.14	.72	.10	1.1	4.5	.01	1.5	15	03	12	<.01	.09	ND
9	E71T-1-M1	9	3.5	7.7	34.1	.03	14.3	.29	12	.10	.08	3.8	.02	<.1	.06	.05	.19	<.01	.06	ND
10	E71T-1-CO2	8	3.5	7.7	34.1	.03	14.3	29	.12	.10	.08	3.8	.02	<.1	.08	.05	19	<.01	06	ND
11	E71T-1-M1	6	2.7	2.9	48.3	.11	7.8	14	.45	.05	.12	4.5	.03	1.4	.06	.04	11	<.01	04	ND
12	E71T-1-CO2	12	5.0	3.6	43.0	.64	10.5	14	.60	.07	.83	3.6	.02	1.0	.12	.06	.20	<.01	08	ND
13	E70T-G-M2	25	3.1	4.6	43.1	.32	14.3	.07	.05	.05	1.7	.31	.01	<.1	40	29	.29	<.01	.04	ND
14	E70T-G-CO2	22	6.9	4.1	39.0	74	14.0	.50	.12	.04	1.3	.16	.03	<.1	44	65	.21	<.01	10	ND
15	E70T-G-M2	10	.13	6.6	46.5	.11	13.3	.14	.42	07	.02	.05	01	<.1	.14	03	.13	<.01	.009	ND
16	E70T-G-CO2	26	6.9	4.1	39.0	.74	14.0	.50	.12	.04	1.3	.16	.03	<.1	44	.65	21	<.01	10	ND
17	E70T-G-CO2	23	4.9	4.6	40.5	.58	15.6	.26	.07	.05	1.3	.13	.03	<.1	.1	41	.25	.02	.08	ND
18	E70T-2-CO2	42	1.7	4.3	47.4	.05	10.5	.07	.05	08	.15	4.1	.01	<.1	02	02	.08	<.01	02	ND
19	E70T-2-CO2	43	1.7	4.3	47.4	.05	10.5	.07	.05	.08	.15	4.1	.01	<.1	.02	.02	.08	<.01	02	ND
20	E70T-4	16	.01	.28	21.3	8.2	.7	19.8	8.0	.05	.15	1.1	<.01	18.5	03	.05	.05	<.01	<.005	ND
21	E70T-4	7	.02	.61	20.1	8.2	1.4	13.9	12.1	.09	3.1	.10	<.01	15.6	04	.02	.08	<.01	<.005	ND
22	E70T-4	15	.01	.28	28.1	9.2	1.0	14.5	7.5	.28	12	.9	<.01	13.5	<.01	06	.06	01	<.005	ND
23	E70T-4	32	.01	19	25.0	7.1	1.8	14.7	10.1	.05	1.9	.07	.01	15.4	.09	.03	.05	04	<.005	ND
24	E70T-4	31	.01	19	23.9	6.4	1.6	13.9	9.7	07	2.0	.08	<.01	15.4	.1	02	.05	04	<.005	ND
25	E70T-4	30	.01	19	24.3	6.4	1.9	15.1	10.0	06	2.1	.13	<.01	16.5	1	02	06	04	<.005	ND
26	E70T-5-M1	24	.15	2.2	32.7	1.4	7.7	12.9	1.2	04	4.4	13	<.01	19.1	14	04	.45	<.01	.005	ND
27	E70T-5-CO2	20	.12	2.8	30.2	1.6	7.8	13.9	1.1	.03	4.9	.14	01	21.1	16	03	.39	<.01	.005	ND
28	E70T-5-CO2	14	04	3.8	41.1	.11	7.7	10.0	3.1	04	.06	.19	.02	6.6	.04	02	14	<.01	.01	ND
29	E70T-5-M1	5	19	2.9	36.7	27	8.4	12.4	<.01	.05	.21	2.0	<.01	15.6	.06	03	20	.03	.008	ND
30	E70T-5-CO2	44	.29	3.3	34.3	.53	12.0	10.7	.14	<.01	2.7	.17	.02	15.5	04	01	.09	01	.01	ND
31	E70T-5-CO2	21	24	3.4	25.9	1.4	9.8	15.6	1.7	10	5.2	11	.02	22.5	07	02	14	<.01	005	ND
32	E70T-5-CO2	13	05	3.5	38.8	.11	8.0	12.0	3.0	.05	.06	15	.03	9.3	.07	.03	18	<.01	02	ND
33	E70T-5-CO2	46	.29	3.3	34.3	.53	12.0	10.7	.14	<.01	2.7	17	.02	15.5	04	.01	.09	01	.01	ND
34	E70T-7	38	.01	15	21.5	7.8	.74	10.1	17.4	24	1.7	.10	15	9.8	.02	.04	.04	.6	<.005	ND
35	E70T-7	37	.01	12	20.8	7.7	74	11.0	16.8	4	1.7	.05	.01	11.7	02	.04	.05	.7	<.005	ND
36	E70T-7	36	.01	.08	26.2	7.9	.76	6.2	13.9	16	1.4	.10	01	10.4	.02	03	.04	.6	<.005	1.2
37	E110T5-K3CO2	19	1.0	4.9	37.6	.32	9.7	3.7	<.01	05	03	4.5	01	13.0	04	54	.18	<.01	02	ND
38	E71T-11	35	.01	<.01	38.1	5.9	1.2	<.05	8.0	.03	<.01	.33	.01	4.4	.02	03	06	4	<.005	12.0
39	E71T-11	34	<.01	<.01	31.1	6.6	1.2	<.05	11.3	07	<.01	.45	.01	5.1	.03	03	.04	5	<.005	14.2
40	E71T-11	33	<.01	<.01	28.7	7.1	1.2	<.05	11.1	05	<.01	.42	<.01	5.9	03	03	04	5	<.005	15.8
	TLV TWA (mg m³ (Air))		—	—	5	5	[illegible]	2	10	5	—	—	Cr 2: 5, Cr 3: .5, Cr 6: .05	2	5	[illegible]	2	.5	.05	x
	TLV STEL (mg m³ (Air))		—	20	10	—	3	—	—	10	—	—	— — —	4	10	3	—	—	—	—

TLV levels for Time Weighted Average (TWA) and Short-Term Exposure Limits (STEL) are taken from the National Health and Medical Research Council (Threshold Limit Values 1983-84).

ND = Not Detected
TWA = Time Weighted Average
STEL = Short-Term Exposure Limit
TLV = Threshold Limit Value
Cr.2. 3. 6 = Are different forms of Chromium with specific TLV levels.
X = Considered to be very similar to Ca.

effects to a resonable degree and hence these wires are commonly used in field applications, thus minimising the problems of ventilation.

REFERENCES

1 ANSI/AWS A5.20-80 — Specification for carbon steel electrodes for flux-cored arc welding.

2 AWS A5.29-80 — Specification for low alloy steel electrodes for flux cored arc welding.

3 AS2203-1981 — Carbon steel electrodes, cored (for arc welding).

4 X-ray Spectrom by W.K. de Jongh, 2(1973) 151.

5 Fumes and Gases in the Welding Environment. American Welding Society (1979).

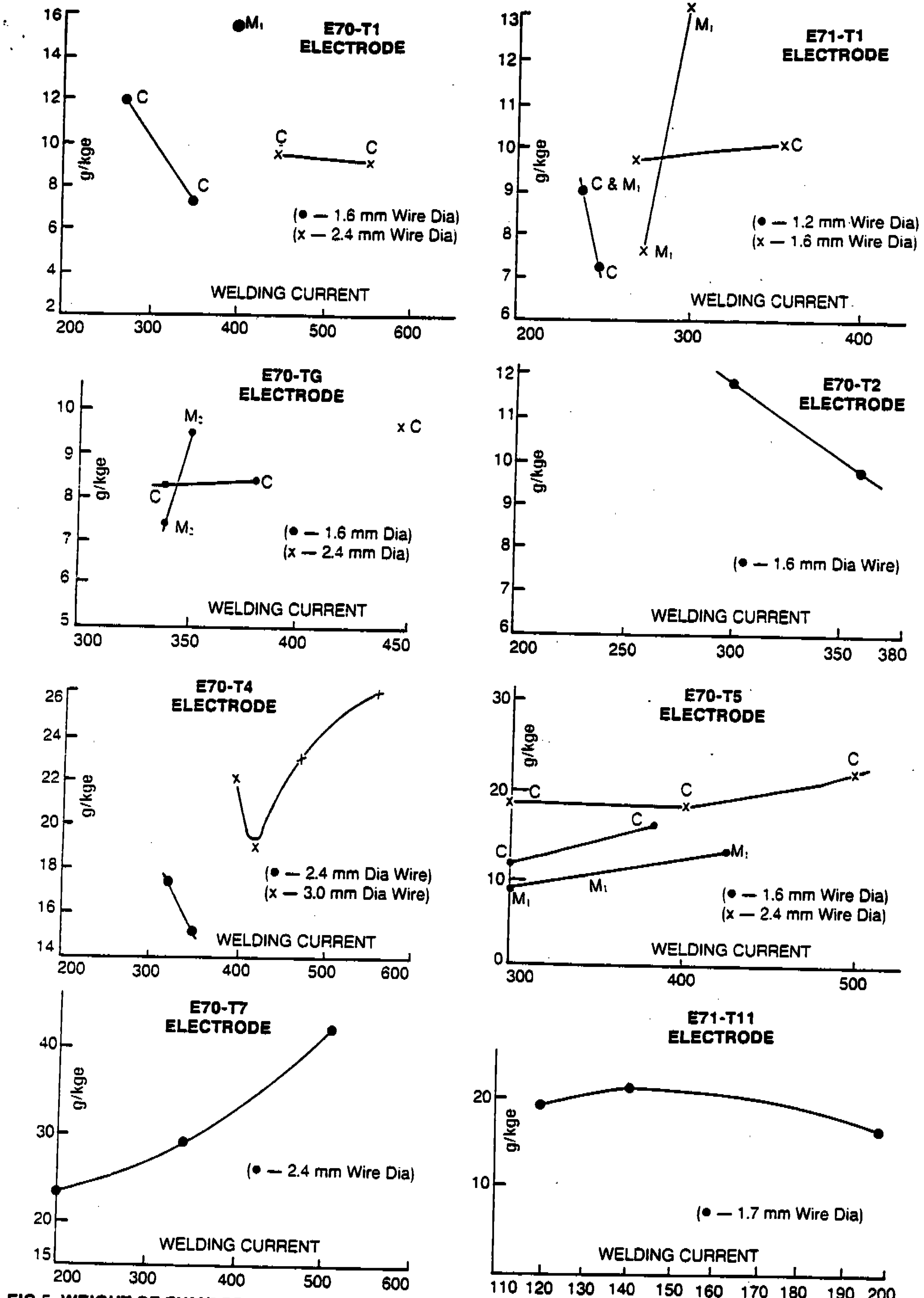


FIG 5. WEIGHT OF FUME PER kg OF ELECTRODE g/kge.

TABLE 3 WELDING PARAMETER DETAILS

	Classification	Gas Flow litres/min	Torch Angle degrees	Stick-out mm	Wire Feed metres/min
1	E70T-1CO2	15	80	20	5.0
2	E70T-1CO2	20	90	25	10.8
3	E70T-1M1	15	80	20	7.4
4	E70T-1CO2	20	75	25	4.4
5	E70T-1CO2	20	75	25	5.4
6	E71T-1-M1	15	80	20	12.6
7	E71T-1-CO2	—	—	—	—
8	E71T-1-CO2	20	90	25	12.8
9	E71T-1-M1	15	80	20	5.7
10	E71T-1-CO2	15	80	20	5.6
11	E71T-1-M1	15	80	20	5.2
12	E71T-1-CO2	20	90	25	10.4
13	E70T-G-M2	10	75	25	8.4
14	E70T-G-CO2	20	75	25	8.2
15	E70T-G-M2	20	90	25	7.9
16	E70T-G-CO2	20	75	25	9.8
17	E70T-G-CO2	20	75	25	4.2
18	E70T-2-CO2	15	75	20	6.4
19	E70T-2-CO2	15	75	20	9.1
20	E70T-4	—	90	40	3.8
21	E70T-4	—	80	60	4.8
22	E70T-4	—	90	40	2.2
23	E70T-4	—	60	70	3.8
24	E70T-4	—	60	70	4.45
25	E70T-4	—	60	70	5.7
26	E70T-5-M1	10	75	25	7.6
27	E70T-5-CO2	10	75	25	8.0
28	E70T-5-CO2	20	90	25	9.0
29	E70T-5-M1	15	80	20	8.5
30	E70T-5-CO2	20	75	25	2.7
31	E70T-5-CO2	10	75	25	3.4
32	E70T-5-CO2	20	90	25	3.5
33	E70T-5-CO2	20	75	25	5.1
34	E70T-7	—	60	40	1.9
35	E70T-7	—	60	40	3.8
36	E70T-7	—	60	40	6.85
37	E110T5-K3CO2	20	90	25	3.3
38	E71T-11	—	75	20	1.5
39	E71T-11	—	75	20	1.9
40	E71T-11	—	75	20	2.8

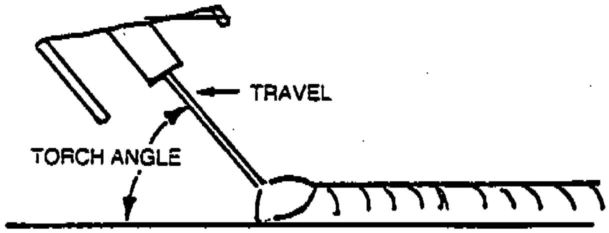


TABLE 4 COMPARISON OF FUME GENERATION RESULTS (AWS[a] AND CSIRO)

Reference and Classification	Wire Size (mm)	Current — amps / Melt Rate (kg/hr)		Voltage (volts dc)		Fume Gen' g/hr		Fume Weight to Weight El' g/kge		Stick Out (mm)	
		AWS	CSIRO	AWS	CSIRO	AWS	CSIRO	AWS	CSIRO	AWS	CSIRO
E70-T1 (AWS 44[c], Tables B12 and B43)[b]	2.4	445/(8.17)	450 (7.9)	29	28	61	75	7.5	9.4	25.4	25
(CSIRO Nos. 4 & 5)		515/(8.9)	550/(9.9)	28	33	79.2	90	7.9	9.0	25.4	25
E70-T4 (AWS 48[c], Table B12)[b]	2.4	385/(9.2)	350/(7.6)	32	30	178	112	19.2	14.6	70	60
(CSIRO Nos. 20 & 21)		390/(9.2)	325(5.5)	31	28.5	177.6	95	19.1	17	70	40
E70-T5 (AWS 44[c], Table B13)[b]	2.4	425/(8.7)	400/(5.7)	30	28	136.2	100	15.5	17.3	38	25
(CSIRO Nos. 31 & 32)		445/(8.8)	400(5.9)	31	32	135.6	110	15.4	18.4	38	25

a = American Welding Society Data taken from, "Fumes and Gases in the Welding Environment", 1979.
b = Appendix B of AWS publication (see a).
c = Electrode Code No. in AWS Publication (see a).