LIBRARY REFERENCE ONLY

THE LIBRARY
FIRE RESEARCH STATION
BOREHAMWOOD
HERTS.
NO AC/FR. N 1040

Fire Research Note No 1040

THE ACUTE INHALATION TOXICITY OF CARBON MONOXIDE FROM BURNING WOOD

by

J A G Edginton and R D Lynch

August 1975

FIRE
RESEARCH
STATION

52998

© BRE Trust (UK) Permission is granted for personal noncommercial research use. Citation of the work is allowed and encouraged.

Fire Research Station
BOREHAMWOOD
Hertfordshire WD6 2BL

Tel: 01 953 6177

FR Note No.1040
August 1975

THE ACUTE INHALATION TOXICITY OF CARBON MONOXIDE FROM BURNING WOOD

by

J A G Edginton* and R D Lynch*

SUMMARY

The acute inhalation toxicity to rats and guinea pigs of carbon monoxide as a pure gas, or as evolved during the controlled burning of two different plywoods has been measured. There were significant, though very slight, differences. The slightly greater toxicity with the plywood exposures was probably due to changes in the respiratory minute volume produced by the irritants in the wood pyrolysis products, although this is unproven.

*Chemical Defence Establishment
Porton Down
Salisbury
Wiltshire

© Crown copyright 1975

Department of the Environment and Fire Offices' Committee
Joint Fire Research Organization

FOREWORD

This note reports part of a study of the toxicity of the combustion products of wood and plastics carried out at the Chemical Defence Establishment, Porton Down, under contract to the Fire Research Station.

A complete account of the work under the contract and discussion of its implications, is to be published elsewhere. All enquiries concerning the work described in this note should be directed to the Fire Research Station.

The principal objective of the study has been to determine whether or not the inhalation toxicity of the combustion products from wood and from a selection of plastics materials commonly present in buildings, can be accounted for entirely by the carbon monoxide present. The inhalation toxicity has been measured in terms of the LCt_{50}* with respect to the carbon monoxide present for half-hour exposures of rats and guinea pigs.

The work reported in this note compares the toxicity of carbon monoxide in the combustion products from birch plywood, and from flame retardant grade birch plywood (Class 1) treated with mono-ammonium phosphate, with the toxicity of pure carbon monoxide gas.

P.C.B.

*Product of concentration and exposure time giving a mortality of 50 per cent.

THE ACUTE INHALATION OF TOXICITY OF CARBON MONOXIDE FROM BURNING WOOD

by

J A G Edginton and R D Lynch

INTRODUCTION

The acute inhalation toxicity of carbon monoxide (CO) to rats and guinea pigs, as a pure gas or as evolved during the controlled burning of two different types of plywood, was investigated under contract to the Joint Fire Research Organisation of the Department of the Environment and Fire Offices' Committee [1].

METHODS

All the experiments were carried out in a 10 m^3 chamber (Plate 1).

For the 'pure gas' experiments cylinder-CO was metered into the chamber until the required concentration was reached. For the generation of 'pyrolysis' CO, standard plywood or 'flame proofed' plywood, in slabs 228 mm x 228 mm x 12 mm was burnt in the BSI Fire Propagation Test Box [2]. (Plate 2).

CO and CO_2 concentrations within the chamber were measured with non-dispersive infra-red gas analysers, O_2 by means of its paramagnetism, and smoke by weight after sampling onto filters. Thermocouples measured the furnace and chamber temperatures, and their outputs were recorded along with those from the gas analysers.

Originally it was hoped that rigorous compliance with BSS 476/6 (Appendix 1) in the operation of the test box would be possible, and to this end the calibration required in the standard was carried out. However, although the thermal characteristics of the box were satisfactory, the CO concentrations produced were far too low and permission was obtained from the contractees to vary the standard running conditions. The major changes were:

1. The air inlet at the base of the box was closed down to restrict ventilation.
2. The electrical energy input was increased, both by using electrical heating from the beginning of each run and by not reducing power during the run.
3. The 'burn' phase was continued for 60 minutes.

The exact power inputs are listed for a typical experiment in Appendix 2.

Animals

Male rats and guinea pigs, supplied by Allington Farm, were used for all exposures. Body weights are given in Appendix 3. Fifteen animals of each species were used for measuring the equivalent L Ct_{50}, and an additional five of each species were exposed and then sacrificed at the end of the exposure for blood carboxyhaemoglobin (COHb) estimations. In all cases where animals were used for COHb estimations they were randomly allocated for this purpose before the experiment.

It was planned to observe animals for 14 days following an exposure, but experience indicated that results were always stable within 24 hours.

Carboxyhaemoglobin Estimations

At the end of an exposure animals allocated for COHb estimations were sacrificed with CO_2 unless dead already. Blood was taken by heart puncture and the COHb content estimated spectrophotometrically[3]. Calibration standards were prepared by bubbling CO through whole blood.

Procedure

The general protocol for an experiment using wood was as follows:

1. One hour for pyrolysis of plywood, followed by the ventilation of the chamber and injection of O_2 to obtain the required CO levels and 21% oxygen.
2. Emplacement of animals for 30 minutes exposure.
3. Ventilation of chamber and withdrawal of animals.

It was thought better to burn the wood to standard time and CO levels and then to reduce the CO concentration by ventilation, since this method kept the ratios of other pyrolysis products to CO more consistent.

Although power to the furnace was turned off before the animals were emplaced, there was always a slight but continuous evolution of smoke and gases during the exposure. When the furnace was cool the residue of unburnt wood was weighed.

The wood samples were specified and/or supplied by the Fire Research Station. They were:

12 mm Finnish Birch Exterior WPB plywood, and the equivalent to this but treated commercially to be flame retardant (Class 1)*.

---

*Pressure impregnated with aqueous solution of mono-ammonium phosphate.

RESULTS

There were five groups of experiments:

Two separate series of exposures to carbon monoxide gas alone, and one each to:

a) a mixture of CO and CO_2,

b) the effluent from burning plywood,

c) the effluent from burning flame retardant treated plywood.

Under the conditions of the experiments only rats died; no guinea pig was visibly affected. In all cases, any rat that died did so either during the exposure or within a very few minutes of the exposure ending.

Death was preceded by slight excitation, uncoordinated rearing and then unconsciousness. Unconscious animals that did not die recovered within one hour, and appeared normal at 24 hours or one week. Excitation appeared to be greater during the wood burns than in the 'pure gas' experiments, but due to the large quantities of smoke evolved, visibility was bad and examination difficult.

Analysis of Mortality Results for Rats

The results (Appendix 3) were subjected to Probit Analysis[4] . to determine L Ct_{50}'s and 95% confidence limits, together with the slopes (b) of the regression lines relating mortality to CO dosage.

L Ct_{50}'s and associated statistics are summarized in the following table for the 5 series of experiments.

	Experiment	L Ct_{50} (mg min/m^3)	95% Limits	Slope (b)	S.E. (b)
1.	CO alone (Series 1)	178,900	149,800-215,600	12.4	3.9
2.	CO alone (Series 2)	157,700	122,500-179,600	5.4	1.6
3.	CO/CO_2 mixture	173,000	156,600-191,000	9.4	2.2
4.	Standard Plywood	145,100	128,500-158,800	11.1	3.1
5.	Flame retardant treated plywood	141,500	125,700-161,400	7.4	1.9

The full details of the above results are given in Appendix 3.

There was little difference between the L Ct_{50} values but, in order to examine any significance of small differences, potency ratios (L Ct_{50} A/L Ct_{50}B) were determined for all pairs of experiments.

The results indicate that

A. No significant difference (P 0.05) existed between:

1. The two pure CO experiments.
2. The two pure CO experiments either separately or pooled, and the CO/CO_2 experiment.

B. Significant (P 0.05) but trivial differences existed between:

1. Either pure CO or the pooled CO experiments, and flame retardant treated plywood.
2. Some of the pure CO experiments and standard plywood.

Thus it appears that the toxicity with respect to CO generated by pyrolysis of plywood is slightly greater than that for pure CO, though the maximum increase is only 13%.

Carboxyhaemoglobin (COHb) results

The individual results for the COHb measurements on animals exposed to the two series of wood burns are contained in Appendix 3. In summary:

The lowest COHb % for any death was 86%

The highest COHb % for any survivor was 69%

Since there was no overlap in COHb values between animals that died and those that survived it is not possible to calculate a COHb value for a 50% chance of death. A COHb content of 75% is the mean of the two figures and appears to be a reasonable estimate of the concentration of COHb in heart blood to cause 50% mortality in rats.

DISCUSSION

All the results indicate that death in every case was due to carbon monoxide intoxication. In the case of the 'pure gas' exposures no other toxic principle was present. With respect to the 'wood' exposures the COHb measurements are quite unequivocal. Stewart and Stolman[5] list COHb figures for man, Hofman and Oettel[6] for rats, and Kishitani[7] for men and mice, for man and rats the

concentration of COHb measured after death has a mean of between 70-80%. The slightly greater toxicity of the effluent from burning wood,then, does not need to be ascribed to some other toxic product. At first it was thought that the very slight differences were due to high levels of CO_2 causing a larger respiratory minute volume, resulting in higher doses of CO, and to examine this possibility the CO, CO_2 mixture exposures were carried out. No differences were found, however it is still possible that irritant products of pyrolysis cause over breathing in particular as the smoke is an aldehyde rich complex[8,9] .

CONCLUSION

The work reported here suggest that the sole toxic principle released in hazardous amounts by burning plywood or flame retardant treated plywood* is carbon monoxide.

REFERENCES

1. F.R.O. 2805 Measurement of Toxic Hazards from Combustion Products.(Contract).
2. British Standard 476 : 1968
   Fire Tests on Building Materials and Structures
   Part 6. Fire Propagation Test for Materials.
3. KAMPEN Van & KLOWEN. Recherches Travailles Cliniques 73 (119) 1954.
4. FINNEY D J, Probit Analysis. Cambridge University Press 1947
5. Stewart and Stolman. 'Toxicology' Vol. 1, 1960.
6. HOFMAN and OETTEL 'Relative Toxicity of Thermal Decomposition Products of Expanded Polystyrene' from the 'Institute of Industrial Hygiene and Pharmacology'. Badisches Anilin - und - Soda - Fabrick A.G.
7. KISHITANI. 'Study on Injurious Properties of Combustion Products' Journal of the Faculty of Engineering, University of Tokyo (B) Vol XXXI No.1 (1971).
8. DUFOUR. 'Survey of Available Information on the Toxicity of Thermal Decomposition Products. Underwriters Laboratories Inc. U.S.A.
9. BAMBURG. 'The Destructive Distillation of Wood'. New York 1926.

*This conclusion applies to fire retardant grade plywood only when treated with mono-ammonium phosphate.

P.C.B.

APPENDIX I

Reprinted by permission of the British Standards Institute.

This appendix outlines the test and calibration procedures in B.S. 476 : Part 6 : 1968.

TEST PROCEDURE

7.1. Before commencement of a test the operator shall ascertain that the apparatus is clean and dry, that the joints are adequately sealed and that it is located in a draught-free atmosphere.

The specimen shall be placed in the holder having a recess suitable for the thickness of the specimen, and the holder shall then be mounted to form one vertical face of the combustion chamber, making sure that the joint between the holder and the sides of the chamber is gas-tight. The apparatus shall be set level and the chimney and cowl truly vertical.

7.2. The gas supply to the jets shall be turned on, the jets ignited and the test timed from this point. After 2 minutes 45 seconds the electrical supply shall be switched on to give an input of 1800 watts (430 cal/s) $\pm$ 2% and reduced to 1500 watts (358 cal/s) $\pm$ 2% at 5 minutes. The electric input shall be maintained constant at this rate for the remainder of the test. The duration of the test shall be 20 minutes.

7.3. After a test, the apparatus shall be allowed to cool to ambient temperature before another specimen is tested. The chimney and the cowl shall be cleaned of all soot and scale and the hot junctions of the thermocouples cleaned before each test.

7.4. Observations during test. The temperature difference between the ambient conditions in the laboratory and the thermocouples inside the cowl shall be recorded continuously by a suitable instrument having an accuracy of not less than $\pm$ 0.5%.

CALIBRATION OF APPARATUS

The apparatus shall be calibrated by carrying out the test with an asbestos board 228 mm x 228 mm x 12.5 mm having the properties specified for the apparatus and conditioned as in 5. A calibration curve shall be obtained immediately before the commencement of the test on a group of three specimens but when the apparatus is in continuous daily use up to nine specimens may be tested between calibrations.

The ideal calibration curve for the apparatus is shown in Fig.3 together with the permissible tolerance. The values of the curve at four time intervals shall be within the tolerances given in the following table.

Time for start of test	Calibration curve	Tolerance
min	deg C	deg C
3	33	± 5
5	115	± 10
10	200	± 12
20	245	± 15

APPENDIX 2

Complete exptl protocol for run dated 31 7 72, pieces of flame-retardant plywood (Wt 895 grams) burnt in the Fire Propagation Test apparatus. Air vent NIL. Town gas supply 1.6 l/m. Electric power 2 k watts.

To = Furnace on

Time min	CO%	CO_2%	O_2%	Furnace °C	Chamber °C	Smoke mgms/l
0	-	-	20.93	44	20.2	
5	-	-	20.80	234	21.2	
10	0.045	0.05	20.50	305	21.7	
15	0.110	0.18	20.30	340	22.2	
20	0.180	0.30	20.10	339	22.2	
25	0.230	0.38	20.00	333	22.7	
30	0.290	0.46	19.90	332	22.7	1.14
35	0.380	0.54	19.75	318	22.9	
40	0.440	0.63	19.60	314	22.9	
45	0.488	0.70	19.40	310	22.9	2.17
50	0.520	0.80	19.20	305	23.4	
55	0.560	0.90	19.00	303	23.2	
60	0.572	0.98	18.90	304	23.2	1.30
	Power and gas turned off. O_2 level adjusted.			20 guinea pigs and 20 rats placed in chamber.		
To = beginning of animal exposure						
0	0.552	1.00	21.45	N/A	22.9	1.20
5	0.552	1.00	21.40	"	22.7	
10	0.548	1.00	21.40	"	22.4	1.20
15	0.528	0.96	21.30	"	22.7	
20	0.528	0.94	21.30	"	22.7	1.30
25	0.524	0.92	21.30	"	22.7	1.01
30	0.520	0.90	21.25	"	22.7	
	Weight of unburnt residue 371 grams					
Mortality		On withdrawal		24 hrs	7 days	
Rats		12/15		12/15	12/15	
Guinea Pigs		0/15		0/15	0/15	

APPENDIX 3

INDIVIDUAL EXPOSURE RESULTS

Results using pure CO only

Series 1

Run 1.	Rat body wts		190 ± 14 grams	
	Average conc CO		0.616%	for 30 min
		or	7.18 mgm/l	
			215,400 Ct units	
	Mortality		20/20	
Run 2.	Rat body wts		180 ± 23.5 grams	
	Average conc CO		0.488%	for 35 min
		or	5.69 mgm/l	
			198,980 Ct units	
	Mortality		14/19	
Run 3.	Rat body wts		177.5 ± 22 grams	
	Average conc CO		0.43%	for 35 min
		or	5.10 mgm/l	
			178,500	
	Mortality		5/20	
Run 4.	Rat body wts		173 ± 24 grams	
	Average conc CO		0.415%	
		or	4.83 mgm/l	
			169,050	
	Mortality		7/20	
Run 5.	Rat body wts		167.5 ± 15.5 grams	
	Average conc CO		0.375%	for 37 min
		or	4.37 mgm/l	
			161,640 Ct units	
	Mortality		5/20	

Run 6.	Rat body wts	220 ± 26.5 grams	
	Average conc CO	0.287%	for 37 min
	or	3.34	
		169,050 Ct units	
	Mortality	7/20	
Run 7.	Rat body wts	182.5 ± 14.5 grams	
	Average conc CO	0.175%	for 39 min
	or	2.04 mgm/l	
		79,510 Ct units	
	Mortality	0/20	

Results using pure CO only

Series 2

Run 1.	Rat weights	197.5 ± 8 grams	
	Average conc CO	0.70%	for 30 min
	or	8.16 mgm/l	
		244,650 Ct units	
	Mortality	14/15	
Run 2.	Rat weights	197 ± 7 grams	
	Average conc CO	0.62%	for 30 min
	or	7.22	
		216,690	
	Mortality	9/15	
Run 3.	Rat weights	202.5 ± 9 grams	
	Average conc CO	0.56%	for 30 min
	or	6.52 mgm/l	
		195,720 Ct units	
	Mortality	11/15	

Run 4.	Rat weights		201.5 ± 12.5 grams	
	Average conc CO		0.46%	for 30 min
		or	5.36 mgm/l	
			160,770 Ct units	
	Mortality		9/15	
Run 5.	Rat weights		194.5 ± 8 grams	
	Average conc CO		0.36%	for 30 min
		or	4.19 mgm/l	
			125,820 Ct units	
	Mortality		4/15	

Results using a mixture of CO and CO_2

Run 1.	Rat weights		206 ± 6.5 grams	
	Average conc CO		0.68%	for 30 min
		or	7.92 mgm/l	
	Average conc CO_2		1.2%	for 30 min
		or	22.0 mgm/l	
	Ct w.r. to CO		237,600 Ct units	
	" " " CO_2		660,000 Ct units	
	Mortality	14/15		
Run 2.	Rat weights		185 ± 14 grams	
	Average conc CO		0.56%	for 30 min
		or	6.49 mgm/l	
	Average conc CO_2		0.89%	for 30 min
		or	16.1 mgm/l	
	Ct w.r. to CO		194,700 Ct units	
	" " " CO_2		483,000	
	Mortality		9/15	

Results from standard plywood

Run 1.	Guinea pig wts	339 ± 18.5 grams	
	Rat wts	213 ± 10.5 "	
	Average CO conc	0.502)	for 30 mins
	or	5.85 mgm/l)	
	Average smoke conc	0.76 mgm/l	
	Original wt of plywood	838 grams	
	" " residue	43 "	
	CO Ct	175,450	
	Mortality Guinea pigs	0/15	
	Rats	13/15	

% carboxyhaemoglobin in each of sacrificed animals

Rats	100%	all dead on withdrawal
	100%	" " "
	100%	" " "
	100%	" " "
	100%	" " "
G.Ps	52%	all survivors
	59%	" "
	49%	" "
	54%	" "
	52%	" "

Run 2.	Guinea pig wts	310.5 ± 21 grams	
	Rats wts	224 ± 11 grams	
	Average CO conc	455%)	for 30 min
	or	5.30 mgm/l)	
	Average smoke conc	0.536 mgm/l	
	Original wt of plywood	836 grams	
	" " residue	32 grams	
	CO Ct	159,000 Ct units	
	Mortality Rats	9/15	
	Guinea Pigs	0/15	

Carboxyhaemoglobin results

	% CO Hb	
Rats	100%	dead on withdrawal
	92%	" " "
	100%	" " "
	100%	" " "
	21%	survivor
G.Ps	57%	survivor
	47%	"
	44%	"
	37%	"
	41%	"

Run 3.

Guinea pig wts		314.5 ± 15 grams
Rat wts		218.5 ± 10.5 grams
Average CO conc	0.344%	for 30 min
or	4.01 mgm/l	for 30 min
Original wt of plywood		855 grams
wt of residue		41 grams
CO Ct		120,230 Ct units
Mortality Rats		3/15
Guinea Pigs		0/15

Carboxyhaemoglobin results

	% CO Hb	
Rats	45%	all survivors
	52%	" "
	69%	" "
	48%	" "
	57%	" "
G.Ps	39%	" "
	37%	" "
	40%	" "
	40%	" "
	43%	" "

Results from flame retardant treated plywood

Run 1.	Guinea pig wts	274 ± 25.5 grams	
	Rat wts	197 ± 15 grams	
	Average CO conc	0.536%	for 30 min
	or	6.24 mgm/l	
	Average smoke conc	1.17 mgm/l	
	Wt of wood	895 grams	
	" " residue	371 grams	
	CO Ct	187,200 Ct units	
	Mortality Rats	12/15	
	Guinea Pigs	0/15	

Carboxyhaemoglobin results

	% CO Hb	
Rats	97%	all dead
	88%	" "
	88%	" "
	100%	" "
	88%	" "
G.Ps	38%	all survivors
	46%	" "
	48%	" "
	40%	" "
	54%	" "

Run 2.	Guinea pig wts	290.5 ± 17.5 grams	
	Rat wts	197 ± 18 grams	
	Average CO conc	0.42%	for 30 min
	or	4.96 mgm/l	
	Average smoke conc	0.817 mgm/l	
	Wt of wood	912 grams	
	" " residue	391 grams	
	CO Ct	148,800 Ct units	
	Mortality Rats	8/15	
	Guinea Pigs	0/15	

Carboxyhaemoglobin results

% CO Hb

Rats	93%	all dead
	93%	" "
	90%	" "
	45%	survivors
	44%	"
G.Ps	28%	all survivors
	39%	" "
	37%	" "
	43%	" "
	34%	" "

Run 3.

Guinea pig wts	213.5 ± 12.5 grams
Rat wts	365 ± 32.5 grams
Average CO conc	0.369%) for 30 min
or	4.29 mgm/l)
Average smoke conc	1.0 mgm/l
Wt of wood	925 grams
" " residue	377 grams
CO Ct	128,700 Ct units
Mortality Rats	7/15
Guinea Pigs	0/15

Carboxyhaemoglobin results

% CO Hb

Rats	86%	all dead
	93%	" "
	90%	" "
	48%	survived
	53%	"
G.Ps	57%	survived
	44%	"
	35%	"
	32%	"
	34%	"

Run 4.

Guinea Pig wts		373.5 ± 33.5 grams
Rat wts		194 ± 10.5 grams
Average smoke conc		0.27%) for 30 min
	or	3.15 mgm/l)
Average smoke conc		0.76 mgm/l
Wt of wood		912 grams
" " residue		320 grams
CO Ct		94,500 Ct units
Mortality Rats		1/15
Guinea Pigs		0/15

Carboxyhaemoglobin results

	% CO Hb	
Rats	48%	all survivors
	57%	" "
	47%	" "
	41%	" "
	44%	" "
G.Ps	34%	all survivors
	66%	" "
	37%	" "
	35%	" "
	40%	" "

CARBON MONOXIDE SERIES 1

PROBIT ANALYSIS MAXIMUM LIKELIHOOD

IDE	ID	DOSE	NET RESPONSE	CHECK	OBSERVED	RESPONDED
1	1	215400.000000	100.000000	0.000000	20.	20.
1	2	198980.000000	73.684211	0.000000	19.	14.
1	3	178500.000000	25.000000	0.000000	20.	5.
1	4	169050.000000	35.000000	0.000000	20.	7.
1	5	161640.000000	25.000000	0.000000	20.	5.
1	6	123710.000000	10.000000	0.000000	20.	2.
1	7	79510.000000	0.000000	0.000000	20.	0.

ANALYSIS OF LINEAR REGRESSION

SOURCE OF VARIATION	DF	SUM OF SQUARES	MEAN SQUARE		
TOTAL	6	41.344266		6.610000	F05
REGRESSION	1	27.422105	27.422105	9.848365	FCAL
DEV REGRESSION	5	13.922161	2.784432	11.070000	CHI SQUARE

ITERATIONS	SLOPE	SUM OF NW	MEAN DOSE	MEAN RESPONSE
7	12.368855	58.689520	5.251858	4.988498

IDE	T05	G	SSXX	SSXY
1	2.571000	0.671182	0.179243	2.217029

IDE	STANDARD ERROR	STD ERROR SLOPE
1	1.668662	3.941372

	UPPER LIMIT	LD	LOWER LIMIT
LD-10	161183.677340	140985.079840	46970.487672
LD-30	180210.689119	162327.250875	99019.027304
LD-50	215613.505974	178973.299662	149863.863453
LD-70	329128.668655	197326.338062	177779.161995
LD-90	694990.927444	227197.388710	198436.019581

CARBON MONOXIDE SERIES 2

PROBIT ANALYSIS MAXIMUM LIKELIHOOD

IDE	ID	DOSE	NET RESPONSE	CHECK	OBSERVED	RESPONDED
2	1	244650.000000	93.333333	0.000000	15.	14.
2	2	216690.000000	60.000000	0.000000	15.	9.
2	3	195720.000000	73.333333	0.000000	15.	11.
2	4	160770.000000	60.000000	0.000000	15.	9.
2	5	125820.000000	26.666667	0.000000	15.	4.

ANALYSIS OF LINEAR REGRESSION

SOURCE OF VARIATION	DF	SUM OF SQUARES	MEAN SQUARE		
TOTAL	4	15.973773		10.130000	F05
REGRESSION	1	12.012811	12.012811	9.098404	FCAL
DEV REGRESSION	3	3.960962	1.320321	7.810000	CHI SQUARE

ITERATIONS	SLOPE	SUM OF NW	MEAN DOSE	MEAN RESPONSE
4	5.435657	40.991819	5.254972	5.309938

IDE	T05	G	SSXX	SSXY
2	1.960000	0.319792	0.406575	2.210001

IDE	STANDARD ERROR	STD ERROR SLOPE
2	1.000000	1.568302

	UPPER LIMIT	LD	LOWER LIMIT
LD-10	119492.027468	91659.266386	37299.647033
LD-30	149295.538944	126321.930908	76662.746921
LD-50	179586.329853	157743.992094	122466.811424
LD-70	244755.258511	196982.161884	172671.289484
LD-90	480087.264641	271474.647671	226057.819138

CARBON MONOXIDE/DIOXIDE TOXICITY

PROBIT ANALYSIS MAXIMUM LIKELIHOOD

IDE	ID	DOSE	NET RESPONSE	CHECK	OBSERVED	RESPONDED
3	1	237600.000000	93.333333	0.000000	15.	14.
3	2	194700.000000	60.000000	0.000000	15.	9.
3	3	153900.000000	40.000000	0.000000	15.	6.
3	4	136200.000000	13.333333	0.000000	15.	2.

ANALYSIS OF LINEAR REGRESSION

SOURCE OF VARIATION	DF	SUM OF SQUARES	MEAN SQUARE		
TOTAL	3	20.175731		18.510000	F05
REGRESSION	1	18.917935	18.917935	30.081080	FCAL
DEV REGRESSION	2	1.257796	0.628898	5.990000	CHI SQUARE

ITERATIONS	SLOPE	SUM OF NW	MEAN DOSE	MEAN RESPONSE
4	9.398885	29.317351	5.238199	5.002244

IDE	T05	G	SSXX	SSXY
3	1.960000	0.203067	0.214151	2.012785

IDE	STANDARD ERROR	STD ERROR SLOPE
3	1.000000	2.160924

	UPPER LIMIT	LD	LOWER LIMIT
LD-10	142977.839788	126358.361536	95132.205143
LD-30	166500.737852	152113.139772	130125.376245
LD-50	191004.047703	172965.935823	156587.447708
LD-70	229761.984962	196677.387692	179697.773998
LD-90	314221.846775	236764.821869	209298.618023

STANDARD PLYWOOD TOXICITY

PROBIT ANALYSIS MAXIMUM LIKELIHOOD

IDE	ID	DOSE	NET RESPONSE	CHECK	OBSERVED	RESPONDED
4	1	175450.000000	86.666667	0.000000	15.	13.
4	2	159000.000000	60.000000	0.000000	15.	9.
4	3	120230.000000	20.000000	0.000000	15.	3.

ANALYSIS OF LINEAR REGRESSION

SOURCE OF VARIATION	DF	SUM OF SQUARES	MEAN SQUARE		
TOTAL	2	13.219984		161.400000	F05
REGRESSION	1	12.633080	12.633080	21.524957	FCAL
DEV REGRESSION	1	0.586904	0.586904	3.840000	CHI SQUARE

ITERATIONS	SLOPE	SUM OF NW	MEAN DOSE	MEAN RESPONSE
3	11.058703	22.969626	5.177163	5.171189

IDE	T05	G	SSXX	SSXY
4	1.960000	0.304091	0.103300	1.142365

IDE	STANDARD ERROR	STD ERROR SLOPE
4	1.000000	3.111355

	UPPER LIMIT	LD	LOWER LIMIT
LD-10	126337.585947	111120.056606	75031.334485
LD-30	142390.842617	130095.841442	104730.798538
LD-50	158823.479361	145105.235115	128505.852226
LD-70	187977.369011	161846.289812	148598.074717
LD-90	258542.521988	189484.508060	169968.326622

FLAME PROOF PLYWOOD TOXICITY

PROBIT ANALYSIS MAXIMUM LIKELIHOOD

IDE	ID	DOSE	NET RESPONSE	CHECK	OBSERVED	RESPONDED
5	1	187200.000000	80.000000	0.000000	15.	12.
5	2	148800.000000	53.333333	0.000000	15.	8.
5	3	128700.000000	46.666667	0.000000	15.	7.
5	4	94500.000000	6.666667	0.000000	15.	1.

ANALYSIS OF LINEAR REGRESSION

SOURCE OF VARIATION	DF	SUM OF SQUARES	MEAN SQUARE		
TOTAL	3	16.016681		18.510000	F05
REGRESSION	1	15.298652	15.298652	42.612945	FCAL
DEV REGRESSION	2	0.718028	0.359014	5.990000	CHI SQUARE

ITERATIONS	SLOPE	SUM OF NW	MEAN DOSE	MEAN RESPONSE
4	7.415497	30.793297	5.144268	4.953051

IDE	T05	G	SSXX	SSXY
5	1.960000	0.251107	0.278210	2.063065

IDE	STANDARD ERROR	STD ERROR SLOPE
5	1.000000	1.895892

	UPPER LIMIT	LD	LOWER LIMIT
LD-10	111226.103607	95010.548830	62760.039792
LD-30	134335.164465	120193.868778	97363.771297
LD-50	161407.863514	141448.741011	125175.473217
LD-70	210167.067059	166462.287443	148503.298332
LD-90	327650.183151	210584.472794	178479.159904

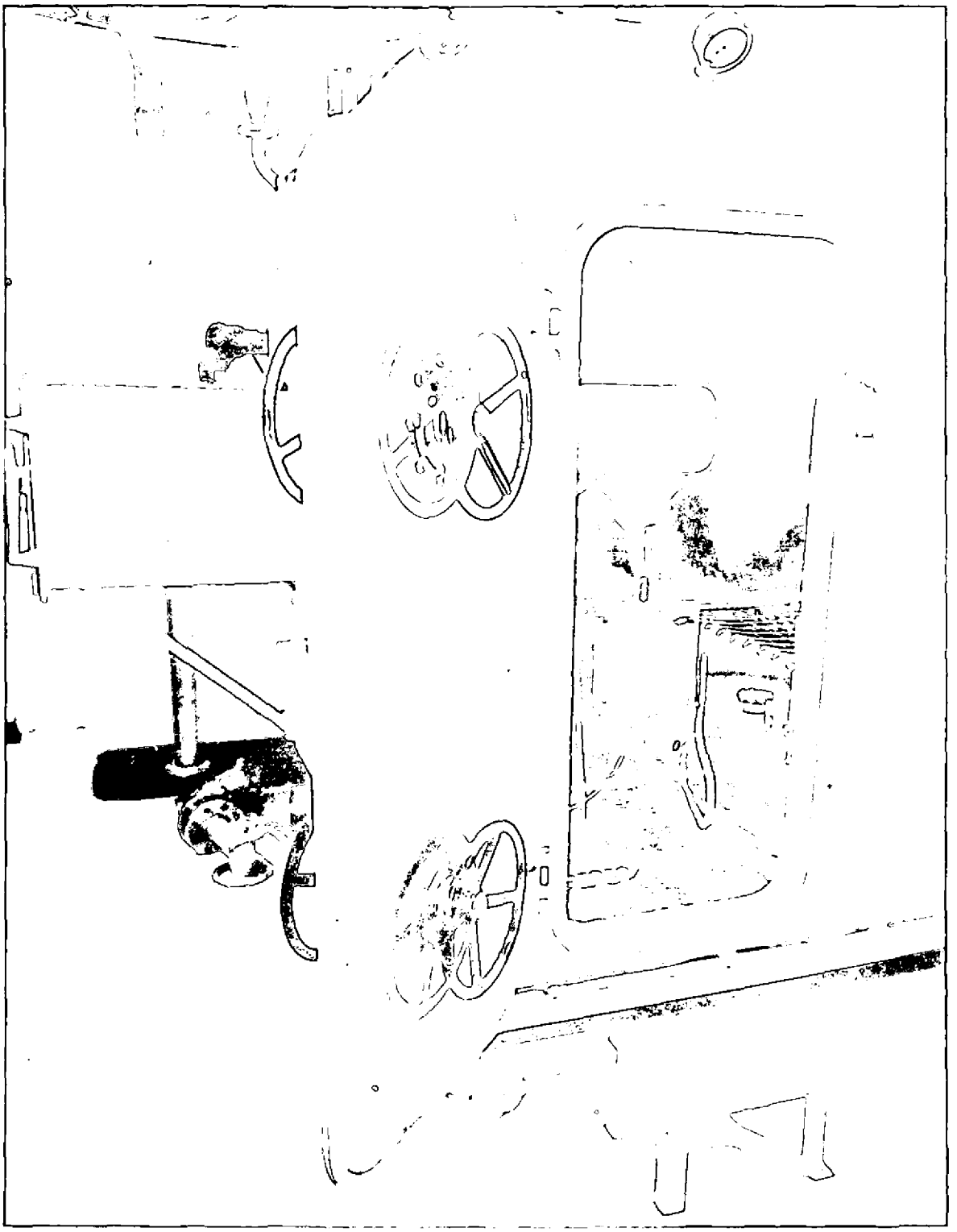

PLATE 1. FIRE PROPAGATION TEST APPARATUS IN POSITION

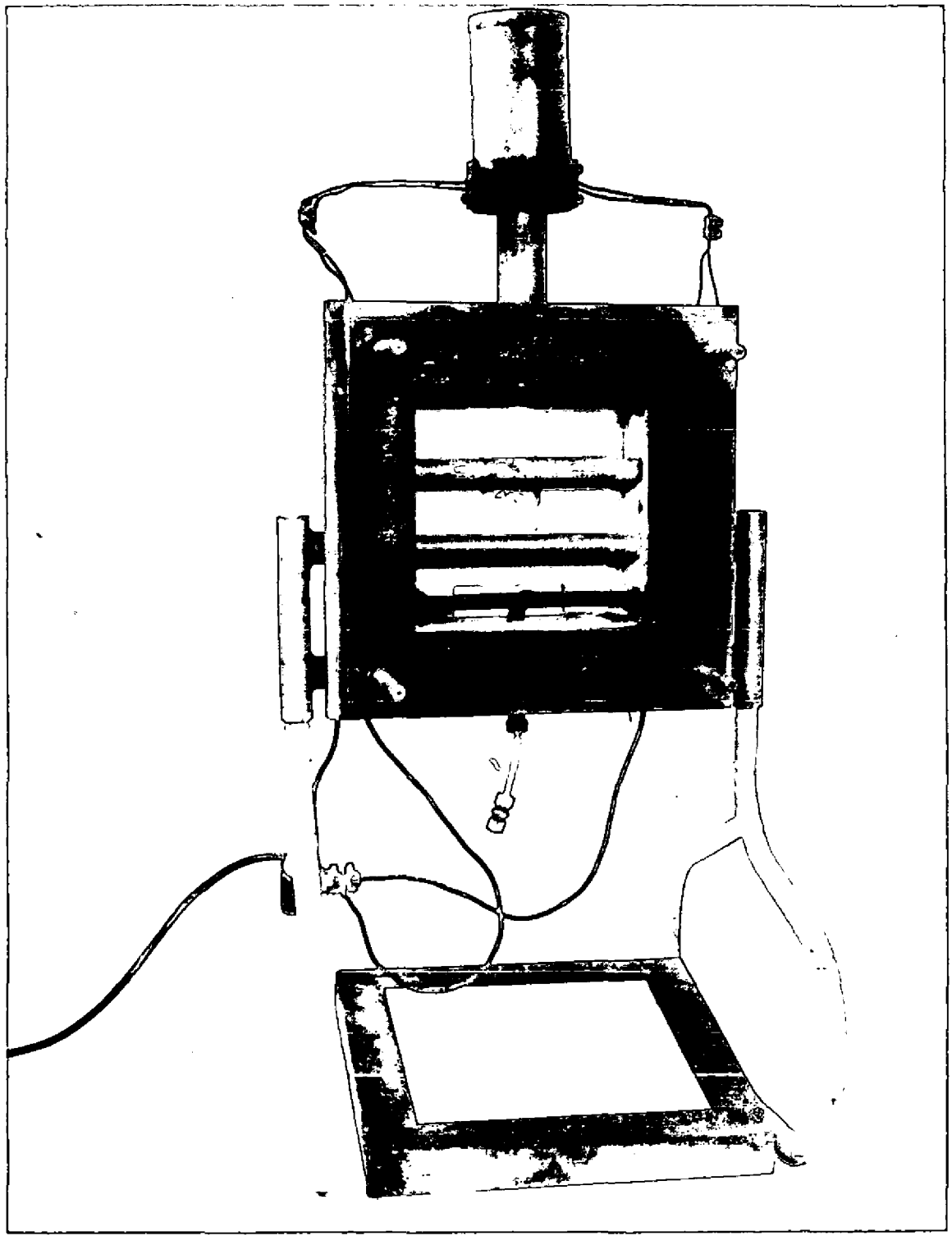

PLATE 2. FIRE PROPAGATION TEST APPARATUS FROM B.S. 476 Pt 6

Printed in England for Her Majesty's Stationery Office by Studio Trade Plates Ltd., Watford WD1 8SA 10/75