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DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH AND FIRE OFFICES' COMMITTEE
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THE BURNING OF FABRICS IN OXYGEN ENRICHED ATMOSPHERES

PART I. COMPARISON OF FABRICS

PART II. COMPARISON OF FLAME RETARDANT TREATMENTS

by

E. H. Coleman and G. H. J. Elkins

SUMMARY

The effect of oxygen enrichment of the atmosphere on flammability has been examined for a number of fabrics, and also some flame retardant treatments have been compared.

Wool fabrics, which did not burn in air, burned readily in atmospheres enriched only slightly with oxygen.

With flame retardant treatments there was a weight of deposit above which there was little or no increase of protection, and also there was a level of oxygen concentration above which all treated fabrics burned.

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Boreham Wood,
Herts.

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PART I. COMPARISON OF FABRICS

INTRODUCTION

The clothing of persons engaged in operations where a fire hazard exists, may be of material of low flammability such as wool or a flammable material such as cotton, but treated to make it flame resistant. The testing and performance of industrial clothing is specified in British Standard 1547 : 1947[1] and American Society for Testing Materials Standard D626/41 T. These specifications relate to fabrics burning in air and, although it is recognized that the hazard is increased if the atmosphere contains more than the normal oxygen content (20.9 per cent), little published information is available concerning the extent to which the protection is reduced by a higher oxygen concentration.

The results of some demonstrations in U.S.A.[2] have been published, but the information was qualitative and insufficient to permit the hazard to be assessed.

Some experiments have been made to examine and assess the effect of enrichment of the atmosphere on the flammability of fabrics.

EXPERIMENTAL

From the results of previous work at the Joint Fire Research Organization it was decided that the best criterion of flammability was the vertical flame speed, as measured on a strip of fabric 6 ft by 1½ in. and hanging vertically.

Fabrics

The experiments were made with fabrics used industrially. These were heavy and medium weight wool fabrics, cotton drills as used for boiler suits or overalls and heavy terylene fabrics. It was considered that no useful purpose would be served by testing light weight dress fabrics.

The fabrics are described in Tables 1 - 3. Before being tested the strips were conditioned for 24 hours in air at 67°F and 67 per cent relative humidity.

Apparatus

The strip of fabric was suspended from the arm of a torsion balance in a sheet steel, glass fronted cabinet 7 ft 6 in. x 1 ft x 1 ft. Mixtures of air and oxygen were introduced at the base of the cabinet and passed out at the top.

The flow of the gases was adjusted to give 40 changes of atmosphere per hour, giving a lineal speed of 0.06 m.p.h. This was considered to be too slow to produce a "forced draught" effect.

The oxygen concentrations used ranged between 21 and 50 per cent. No information could be obtained concerning actual concentrations likely to be encountered but it was assumed that 50 per cent would be a reasonable practical limit.

The compositions of all of the gas mixtures were checked by chemical analysis.

The strips were ignited by a 2 in. high luminous gas flame from a $\frac{3}{8}$ in. bore burner manipulated into position under the strip from outside the cabinet, and extinguished after the strip was ignited.

These conditions were thus different from those of the previous Joint Fire Research Organization experiments where the specimens were burnt in free air, but duplicate tests showed that the results obtained in the cabinet were reproducible, although they varied from the results obtained in free air.

The loss of weight as the fabric burned was recorded photographically from the movement of the torsion balance arm and the vertical flame speed was calculated from the trace so obtained. The results are given in the tables, the effect of oxygen concentration on the flame speed is shown in Fig. 1 and the effect of oxygen concentration on the solid residue is shown in Fig. 2.

RESULTS

Woollen fabrics (Table 1, Figs. 1 and 2)

Two woollen fabrics were examined, one a heavy Melton (or box) cloth and the other a lighter serge uniform cloth.

In air, both of the fabrics were difficult to ignite, they burned very slowly, and only whilst in contact with the igniting flame.

When oxygen was added to the atmosphere both fabrics ignited more readily, and at first the flame speeds increased with increasing oxygen content, as shown in Fig. 1. In the range of oxygen concentrations between approximately 30 and 40 per cent with the Melton cloth and 23 and 37 per cent with the serge, the flame speeds remained approximately constant, and at oxygen concentrations above 40 per cent the flame speeds increased again. The lighter serge was ignited more readily and burned faster than the heavier Melton cloth.

Both fabrics left a plastic, frothy residue which hardened on cooling. The proportion of residue decreased as the oxygen concentration was increased (Fig. 2).

Terylene and a terylene mixture (Table I(a))

Two fabrics were examined, one was a heavy canvas type material of pure terylene, and the other was a wool/terylene mixture as used for suitings. Both materials burned in air. The pure terylene canvas melted and dropped to the floor of the cabinet where the molten mass continued to burn. This made it difficult to measure the actual flame speed and the figures given in the table are thus rates of disintegration of the fabric rather than combustion rates. The wool/terylene mixture burned rapidly without melting or falling away. The wool appeared to form a matrix on which the molten terylene was supported while it burned.

The results of the tests indicated that the traditional low flammability of wool in air affords only a limited protection when the oxygen concentration is increased above the atmospheric level and some experiments were made with fabrics treated with flame retardants.

TABLE 1

Results of flammability tests on fabrics in atmospheres enriched with oxygen

(a) Wool, Terylene, P.V.C. treated cotton, and cotton treated by a proprietary process

Description of sample	Total oxygen content per cent. vol. (Air taken as 21%)	Carbon and Ash per cent. wt.	Vertical flame speed cm./sec.	Rating secs./100 in.	Comments
Blue Melton Cloth (Wool) waterproofed 0.0738 gm/cm^2 21.8 oz/yd^2	21.0	49.0	0.51	500	Only a few centimetres burnt.
	22.4	41.0	0.63	400	" " " " "
	24.6	34.0	1.26	202	Flame travelled 60 cm.
	25.6	32.0	1.23	206	" " 90 cm.
	30.0	12.6	1.85	137	Burnt completely (180 cm).
	40.8	12.6	2.10	120	" "
	47.8	8.0	4.06	62.5	" " Ignited very readily.
Blue Wool Serge Uniform Cloth 0.0517 gm/cm^2 15.7 oz/yd^2	21.0	62.0	0.76	335	12 cm. burnt.
	22.4	51.0	2.40	106	155 cm. burnt.
	25.8	32.0	2.60	98	Burnt completely.
	30.0	22.0	2.60	98	" "
	40.8	12.7	3.10	83	" "
	47.4	11.5	7.00	36	" " Very rapid spread along edges.
White Terylene Canvas 0.0393 gm/cm^2 11.6 oz/yd^2	26.2	n.d.	1.17[m]	217	The material melted and dropped to the base of the cabinet where it burned fiercely. The fabric tended to produce loose fibres where it had been cut and the flame travelled along these loose ends. ([m] See note in text.)
	30.0	"	0.95[m]	268	
	38.4	"	1.44[m]	176	
Terylene/wool mixture 55/45 0.0247 gm/cm^2 7.3 oz/yd^2	21.0	40.0	1.96	130	85 cm. burnt. The flame travelled very quickly along the loose strands on the cut edges.
	26.6	41.0	3.32	77	Burnt completely. " "
	36.6	24.0	5.45	47	" " " "
P.V.C. Coated Cotton Cloth 0.0550 gm/cm^2 16.2 oz/yd^2	21.0	-	-	-	End charred but did not burn.
	26.2	29.5	2.60	98	72 cm. burnt. Appeared to be extinguished by fumes.
	25.2	21.0	2.90	88	110 cm. burnt. Flow rate increased to 55 changes/hr.
P.V.C. Coated Canvas 0.0769 gm/cm^2 22.7 oz/yd^2	26.0	54.0	1.60	159	Burnt completely.
Green Cotton Drill 0.0256 gm/cm^2 7.6 oz/yd^2	21.0	3.2	3.80	67	
	25.6	2.3	5.00	51	
	30.2	2.2	5.70	44	
Green Cotton Drill treated with proprietary flame retardant 0.0309 gm/cm^2 9.1 oz/yd^2	21.0	-	-	-	Did not burn. (Treatment increased weight by approximately 20 per cent.
	25.4	50.4	5.00	51	
	30.0	32.3	6.40	40	

TABLE 2

Results of flammability tests on fabrics in atmospheres enriched with oxygen

Tests with Khaki Cotton Drill (0.0343 gm/cm^2, 10.4 oz/yd^2)

Treatment		Total oxygen content per cent. vol. (Air taken as 21.0%)	Carbon and Ash per cent. wt.	Vertical flame speed cm./sec.	Rating secs./100 in.	Comments
Description	Added weight per cent. of fabric					
As received	-	21.0	40.0	1.10	230	60 cm. burnt.
		25.3	40.0	2.75	92	
		29.6	5.8	3.60	70	
Washed	lost 12.5	21.0	6.0	2.10	120	Strip hung in free air: burnt completely.
"	lost 13.5	21.0	4.5	1.40	180	96 cm. burnt.
"	lost 13.5	25.4	5.8	3.80	67	Burnt completely.
	lost 13.5	30.0	6.1	4.80	53	" "
Boric acid 30) Borax 70)	8.6	21.0	-	-	-	Did not burn.
	8.6	29.6	-	-	-	" " "
	8.6	34.0	16.8	1.16	219	175 cm. burnt.
	8.4	38.0	15.1	1.15	220	150 cm. "
	8.6	48.0	10.0	1.10	230	
	19.0	34.8	28.6	0.50	510	39 cm. burnt.
	19.0	39.6	22.5	0.90	282	Burnt completely. } Pronounced
	19.3	46.6	20.4	0.90	282	" " } after glow.
	28.3	34.6	n.d.	less than 0.30	-	Only 11 cm. burnt.
	28.3	38.0	35.2	0.73	345	Burnt completely.
Monammonium Phosphate $(NH_4)H_2PO_4$	10.1	21.0	-	-	-	Did not burn.
	10.1	43.0	n.d.	2.90	88	Burnt completely.
	13.0	24.0	22.0	2.10	120	" " Strong after glow.
	26.3	24.4	-	-	-	Did not burn.
	26.5	25.5	-	-	-	" " "
	27.3	26.4	57.4	1.20	212	35 cm. burnt.
	26.5	29.8	48.5	1.30	196	Burnt completely.
	30.7	28.0	-	-	-	Did not burn.
	30.7	29.0	-	less than 0.30	-	Small flame travelled 8 cm.
	30.7	35.0	50.0	1.00	254	Burnt 10 cm.

TABLE

Results of flammability tests on fabrics in atmospheres enriched with oxygen

Tests with White unbleached drill (0.0327 gm/cm^2, 9.6 oz/yd^2)

Treatment		Total oxygen content per cent. vol. (Air taken as 21.0%)	Carbon and Ash per cent. wt.	Vertical flame speed cm./sec.	Rating secs./100 in.	Comments
Description	Added weight per cent. of fabric					
None	as received	21.0	9.2	2.86	89	Two tests in cabinet. 45 and 49 cm. burnt. Burnt completely in free air.
		25.5	1.8	4.04	63	Flame flickered. Burnt completely.
		29.4	1.8	5.24	48	Steady flame. " "
		34.0	0.9	5.50	46	
		40.4	0.9	14.80	7	"Flash burn".
Boric Acid 30 per cent.						
Borax 70 " "	5.4	21.0	-	-	-	Did not burn.
	5.6	23.8	35.4	0.40	560	23 cm. burnt.
	5.4	25.6	12.8	1.74	146	110 cm. "
	6.3	28.4	9.9	1.89	134	134 cm. "
	5.1	32.0	7.5	2.83	90	Burnt completely.
	5.4	34.6	6.5	2.80	90	" "
	4.8	38.0	6.3	4.10	62	" "
	7.8	29.6	-	-	-	Did not burn.
	7.8	34.8	15.5	1.14	236	120 cm. burnt.
	7.3	41.8	5.0	2.88	88	Burnt completely.
	10.3	28.2	-	-	-	6 cm. burnt.
	10.3	30.8	-	-	-	16 cm. "
	10.3	31.9	-	-	-	Burnt very slowly.
	10.7	34.6	11.1	1.82	139	
	11.3	35.8	14.5	1.56	163	
	10.0	39.6	8.9	2.17	117	
	10.7	42.0	8.5	1.85	137	
	13.9	42.4	17.1	1.24	205	
	16.6	39.0	14.3	1.11	230	
	18.5	35.0	-	-	-	16 cm. burnt very slowly.
	18.5	37.0	32.4	0.80	318	Burnt completely.
	19.3	36.0	26.0	0.50	520	36 cm. burnt.
	20.0	35.0	33.0	0.40	670	64 cm. "
	19.3	37.0	29.0	0.80	318	130 cm. "
	23.5	36.4	37.9	0.70	350	Burnt completely.
	23.9	37.2	31.6	0.80	300	" "
	23.4	46.2	7.6	1.36	186	" "
	28.0	36.8	17.5	less than 0.30	-	25 cm. burnt.
	28.0	37.4	29.2	0.81	314	Burnt completely.
Boric Acid 60 per cent.						
Monosodium dihydrogen phosphate 40 per cent.	8.7	21.0	-	-	-	Did not burn.
	8.7	22.6	43.2	1.10	231	89 cm. burnt.
	10.6	21.0	-	-	-	Did not burn.
	10.6	24.6				Burnt slowly but trace spoiled.
	17.5	24.6	35.3	1.13	226	67 cm. burnt.
	18.7	24.4	-	less than 0.30	-	33 cm. charred and burnt.
	18.7	25.4	39.3	0.96	265	
	24.8	26.4	31.8	1.40	182	
	25.0	28.6	26.5	1.50	169	
	27.3	25.4	30.0	0.55	460	28 cm. burnt.
	30.0	26.2	34.0	1.05	241	

TABLE 3 (Cont'd)

Tests with White unbleached drill (0.0327 gm/cm^2, 9.6 oz/yd^2) (Cont'd)

Treatment		Total oxygen content per cent. vol. (Air taken as 21.0%)	Carbon and Ash per cent. wt.	Vertical flame speed cm./sec.	Rating secs./100 in.	Comments
Description	Added weight per cent. of fabric					
Boric Acid 60 per cent. Disodium hydrogen phosphate 40 per cent.	11.5	21.0	-	-	-	Did not burn.
	12.4	23.2	13.8	1.10	231	
	12.0	24.4	17.8	1.10	231	103 cm. burnt.
	11.5	25.4	19.5	1.77	144	
	11.5	27.0	23.5	1.73	147	
	9.8	30.6	13.9	2.13	119	
	10.9	34.0	12.6	2.45	104	
	18.0	24.4	-	-	-	Did not burn.
	18.0	27.2	35.0	0.65	361	28 cm. burnt.
	18.1	28.8	34.2	1.00	254	
	27.8	27.8	-	-	-	Did not burn.
	27.8	28.8	-	Very slow	-	21 cm. burnt.
	28.8	29.8	40.4	0.81	314	
Boric Acid 60 per cent. Trisodium phosphate 40 per cent.	11.3	21.0	-	-	-	Did not burn.
	11.3	23.0	19.4	1.50	169	83 cm. burnt.
	14.5	25.1	30.6	1.32	193	
	16.6	27.4	-	-	-	Did not burn.
	17.6	27.6	21.2	0.88	289	62 cm. burnt.
	17.6	28.6	19.4	1.26	202	
	20.1	24.6	25.0	1.20	212	
	31.2	33.0	25.8	1.03	246	
	33.2	33.4	-	-	-	Did not burn.
	34.5	30.0	-	-	-	21 cm. burnt very slowly.
	35.4	30.2	-	-	-	20 cm. " " "
	35.4	31.0	-	-	-	23 cm. " " "
Boric Acid 60 per cent. Monoammonium dihydrogen phosphate 40 per cent.	8.5	21.0	42.5	1.44	177	109 cm. burnt.
	13.2	21.0	36.9	1.16	219	
	14.0	24.6	36.9	1.38	184	
	15.5	21.0	40.8	-	-	113 cm. burnt very slowly.
	16.4	27.0	31.2	1.50	169	
	17.2	28.0	38.8	1.28	198	
	21.8	25.0	36.6	1.20	212	
	24.2	23.8	38.6	1.20	212	
	25.7	24.4	-	-	-	Did not burn.
	25.9	26.8	56.5	0.88	289	47 cm. burnt.
	28.2	27.8	-	-	-	10 cm. burnt.
	28.2	28.4	43.0	0.93	273	
	28.9	28.1	43.6	1.37	185	138 cm. burnt.
	31.8	29.0	39.2	1.13	225	

PART II. COMPARISON OF FLAME RETARDANT TREATMENTS

FLAME RETARDANT TREATMENTS

A considerable amount of work on flame retardant treatments of textiles has been carried out by Ramsbottom and Snoad[4] and Little[5] and the present position is summarized in a British Standards Committee report[6]. The results, however, are concerned with fabrics burning in air.

Many fire retardant treatments are available; some are proprietary, while others can be applied simply by dipping the fabrics in the appropriate solution, and of these the most effective are those containing boric or phosphoric acids, or their salts, either singly or mixed.

Some fabrics, treated commercially with flame retardants, were available and the preliminary experiments were made with them.

PRELIMINARY EXPERIMENTS

P.V.C. coated fabrics (Table I)

Some tests were made with two P.V.C. coated cotton fabrics, one a heavy material as used for wagon covers, and the other a lighter material more suited for aprons and such types of protective clothing. The weights of the P.V.C. coatings are not known. The lighter fabric burned in 26 per cent oxygen with the production of copious acrid fumes which appeared to extinguish the flames. A test was then made in a rather lower oxygen concentration (25.2 per cent) but with an exhaust fan fitted to the top of the cabinet and the total gas flow increased to the limit of the apparatus, viz. 55 changes per hour. The flame speed increased slightly from 2.6 to 2.9 cm/sec. The length of the strip burned also increased and there was a reduction in the weight of carbon and ash. In these conditions the heavy canvas burned completely, although the flame speed was lower than that of the lighter material.

Cotton drill treated with a proprietary flameproof treatment (Table I)

An examination was made of green cotton drill, untreated, and also after treatment with a proprietary flameproof treatment. The treatment had added 20 per cent to the weight. The treated material did not burn in air, but in both 25 and 30 per cent of oxygen there was little difference between the flame speeds of the treated and untreated fabrics both of which burned readily. There were, however, differences between the proportions of ash and carbon.

From these results it appeared that, broadly, the protection afforded by fabrics treated with P.V.C. or the proprietary treatment, was of a similar order to that for wool fabrics of comparable weight.

A further series of tests was then made with treatments with soluble salts which could be applied in the laboratory.

COMPARISON OF SOLUBLE RETARDANTS

The tests were made with two types of cotton drill as used for overalls and warehouse coats. In one series a khaki drill was used and in the other series, which included the majority of the tests, a white unbleached drill was used.

Strips of fabric were soaked in a solution of the retardant, dried and weighed, and the treatment repeated until the required weight of deposit had been obtained. As with the earlier tests, the specimens were conditioned for 24 hours at 67°F and 67 per cent relative humidity, and loose fibres on the edges of the strips were cut away before they were tested.

The retardants have been suggested by previous workers[4][5] and some, especially Nos. 1 and 5, have found a place in official publications. The mixtures used were:-

(1) 70 per cent borax and 30 per cent boric acid.
(2) 60 per cent monammonium phosphate and 40 per cent boric acid.
(3) 40 per cent monosodium phosphate and 60 per cent boric acid.
(4) 40 per cent disodium phosphate and 60 per cent boric acid.
(5) 40 per cent trisodium phosphate and 60 per cent boric acid.
(6) Monammonium phosphate.

RESULTS

Khaki Drill (Table 2, Fig. 3)

Tests were made on the fabric in different concentrations of oxygen, and before and after treatment with monammonium phosphate or a mixture of 30 per cent boric acid and 70 per cent borax. It was evident that the boric acid/borax treatment was superior to the monammonium phosphate, and also, over the range of oxygen concentrations used, there appeared to be an upper limit to the flame speed of the treated fabrics, beyond which, increasing the oxygen concentration produced no change of flame velocity. The limit was different for each retardant and concentration. The ash contained notable amounts of chromium compounds, presumably from the dye or mordant, and also the ash increased with rising oxygen concentrations. This may have been due to more complete oxidation of the chromium compounds. It thus seemed probable that this was interfering with the combustion, and the conclusion was confirmed when the flame speed of washed fabric was shown to be higher than that of the original fabric. Accordingly, subsequent tests were made with a white, unbleached drill of similar weave.

White unbleached drill (Table 3, Figs 4 and 5)

Flammability tests were made with the white drill as received, and after treatment with a mixture of 70 per cent borax and 30 per cent boric acid. The results of the tests are given in Table 3 and the variations of flame speed with oxygen concentration are plotted in Fig. 4. As with the khaki drill the curves indicated that, with each concentration of the retardant, there was an upper limit to the flame speed, whatever the oxygen concentration. It also seemed that there was an oxygen concentration above which the fabric would burn, whatever the concentration of retardant. These points were examined more fully and comparisons were also made of different mixtures of boric and phosphoric acid compounds.

Comparison of treatments

In the experiments to compare different treatments it was decided not to use flame speed as a criterion to assess the effects of oxygen concentration, because it required the use of replicate strips with closely controlled weights of deposit. It was difficult to achieve this control with the facilities available and accordingly, different criteria were adopted. These were (a) the oxygen concentration above which the fabric burned, however much retardant had been deposited, and (b) that weight of retardant above which the retardant had little further effect. These measurements could be made without using replicate strips and a large number of tests was unnecessary.

The results of tests with the white drill and using mixtures of boric acid with either borax, monammonium phosphate, or one of the three sodium phosphates are given in Table 4 and plotted in Fig. 5.

In Fig. 5, strips in oxygen concentration and with retardant concentrations on the hatched sides of the curve did not burn and those to the right burned. For each of the mixtures, there was a level of oxygen concentration above which the strips burned whatever the weight of retardant and also there was little advantage in increasing the weight of deposit above a certain value.

TABLE 4

Limiting values of oxygen concentration and weight of deposit

Retardant	Limiting value	
	Concentration of oxygen above which the retardant is ineffective, per cent.(vol.)	Weight of deposit above which increased protection is low per cent.
Boric acid 30 per cent. Borax 70 per cent.	37	9
" " 60 " " Monosodium Phosphate 40 per cent.	36	12
" " 60 " " Disodium Phosphate 40 " "	28	14
" " 60 " " Trisodium " 40 " "	24	19
" " 60 " " Monammonium " 40 " "	28	25

The mixture containing borax is more effective than any of the others, both with regard to the weight of deposit required and the limiting oxygen concentration.

It will be noted that weight of deposit of the boric acid/borax approximates very closely to the 10 per cent. recommended in many publications. It is probable that the limits of oxygen concentration and weight of deposit will vary with the weight of the fabric.

DISCUSSION AND CONCLUSIONS

The experiments have shown that the traditional low flammability of wool fabrics cannot be relied upon to afford protection in oxygenated atmospheres, and that the P.V.C. coated fabrics and synthetic fibres behave similarly.

Tests of cotton fabrics treated with flame-retardant salts showed that the 30/70 boric acid/borax mixture was better than boric acid/phosphate mixtures.

There is a level of oxygen concentration above which all the treated fabrics burn, and a concentration of retardant above which no improvement in flame resistance is obtained.

In British Standard Specification No. 1547 for flame-proofed industrial clothing, the spread of flame, as measured from the length of char is limited to $3\frac{1}{2}$ ins., but the present work has shown that fabrics which pass this test will burn if the oxygen concentration is above a particular critical level. It is therefore difficult to propose limits of flame speed and flame spread which could be embodied in a specification. It is suggested in this report, however, that in addition to complying with B.S. 1547 the flammability rating of the material in oxygenated atmospheres should not be lower than that recommended in B.S. PD 2777[6] viz. 150 seconds for a flame travel of 100 inches

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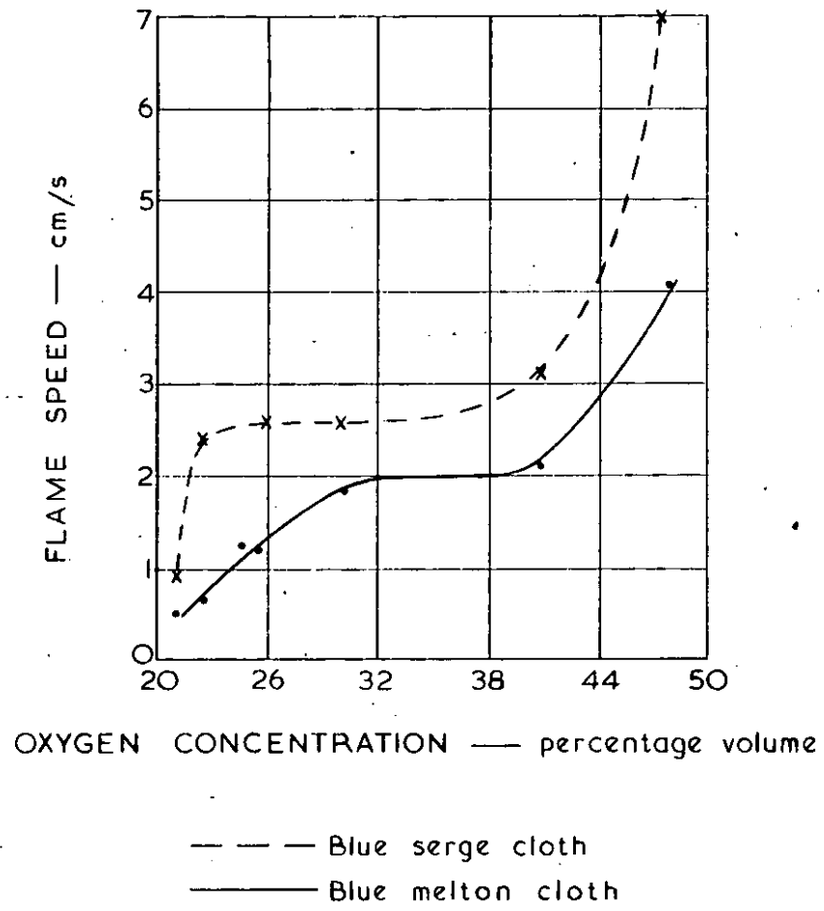


FIG.1. EFFECT OF OXYGEN CONCENTRATION ON FLAME SPEED

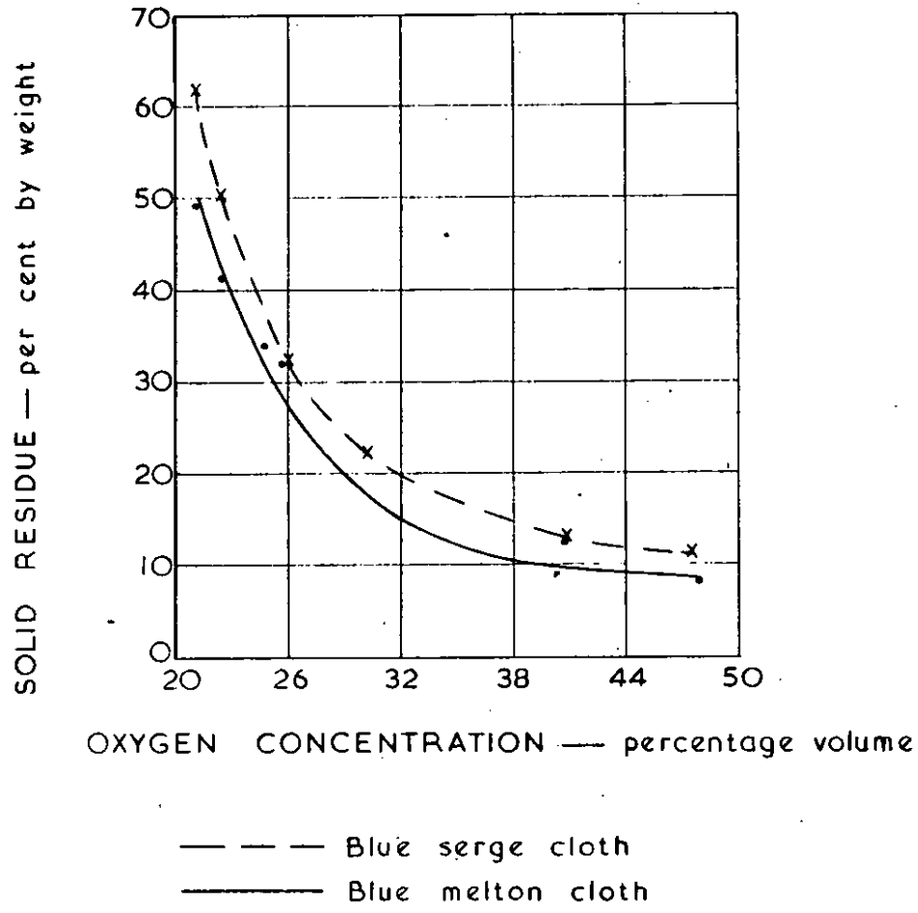


FIG.2. EFFECT OF OXYGEN CONCENTRATION ON SOLID RESIDUE

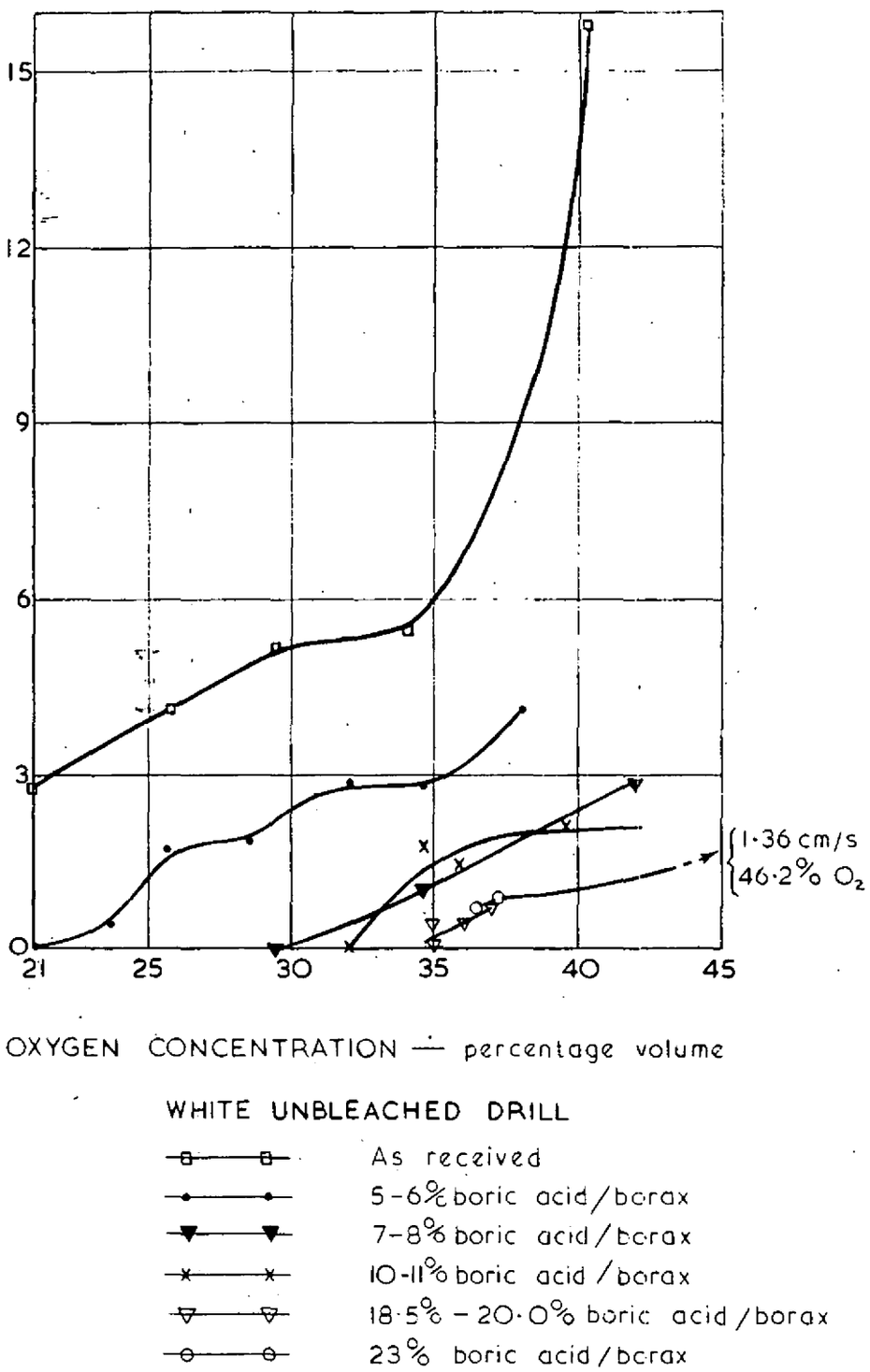


FIG.4. THE EFFECT OF OXYGEN CONCENTRATION ON FLAME SPEED

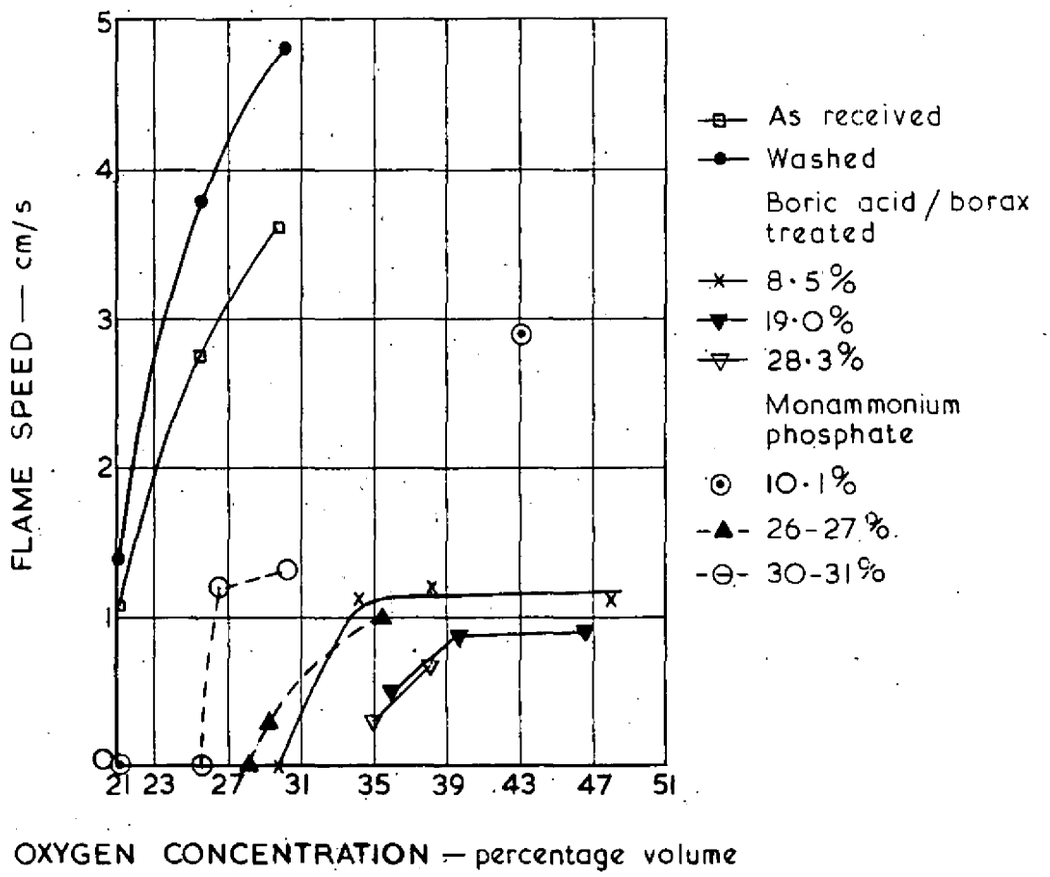
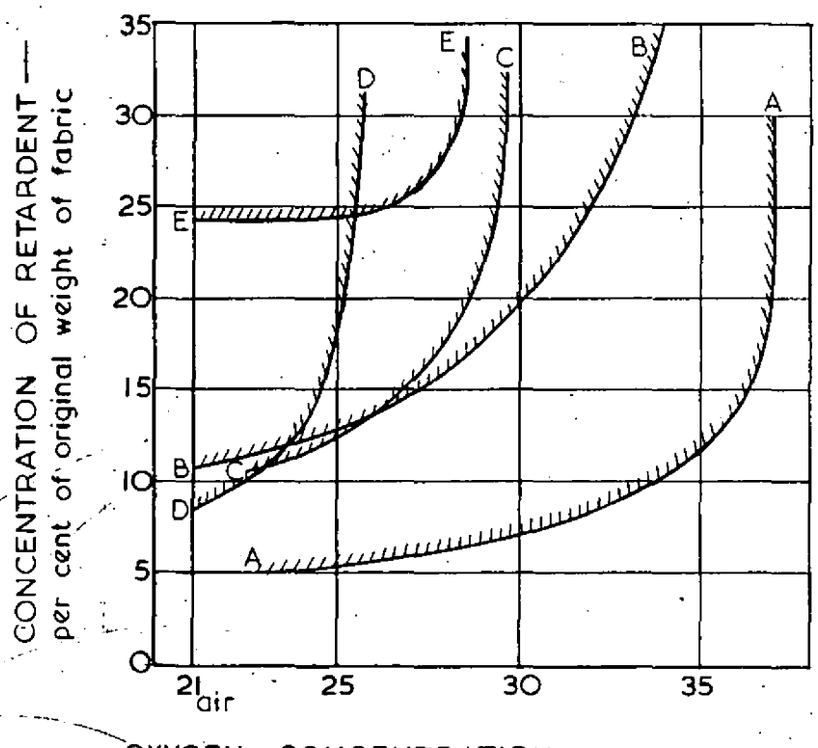


FIG. 3. EFFECT OF OXYGEN CONCENTRATION ON FLAME SPREAD



WHITE UNBLEACHED DRILL

A 30 per cent boric acid
70 per cent borax

B 60 per cent boric acid
40 per cent trisodium phosphate $Na_3PO_4\,12H_2O$

C 60 per cent boric acid
40 per cent disodium phosphate $Na_2HPO_4\,12H_2O$

D 60 per cent boric acid
40 per cent monosodium phosphate $NaH_2PO_4\,H_2O$

E 60 per cent boric acid
40 per cent $(NH_4)H_2PO_4$

The strips of impregnated fabric did not burn under the conditions indicated on the shaded side of the curves.

FIG. 5. OXYGEN AND RETARDANT CONCENTRATIONS AT LIMITS OF FLAMMABILITY