DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH AND FIRE OFFICES' COMMITTEE JOINT FIRE RESEARCH ORGANIZATION

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RIFERENCE F.R. Note No. 209/1955 AGGER Research Programme

Objective

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THE FLAMMABILITY OF FABRICS PART 2

' by

C. T. Webster

SUMMARY

Further work on the flammability of fabrics is described and an empirical equation is given for a relationship between vertical flame speed and distance and time of spread of flame round the semi-circular apparatus. This relationship is considered to be more reliable than the equation for vertical speed and distance of spread given in F.R. 107.

September, 1955.

File No. E/4/3/CP

Fire Research Station, Boreham Wood, Herts.

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THE FLAMMABILITY OF FABRICS PART 2

by

O. T. Webster

Introduction

An earlier paper (1) reported a relation between the vertical spread of flame of a fabric and the performance in the semi-circular test. The relation could be expressed in terms of the time for the flame to spread round the semi-circular track as

 $V = \frac{1655}{\pi^{1} \cdot 03}$ (1)

or in terms of the final distance of spread of flame as

$$V = 1.81D^{0.4}$$
 (2)

V = vertical flame speed in om/seo

D = final distance of spread in in.

T = time to spread the distance D. (sec).

Equation (2) was not sufficiently accurate to permit the semi-circular test to be used with confidence as an indication of vertical flame spread, and an investigation has now been made of the relation between the vertical flame speed, the time to reach the final distance of spread and the distance of spread when the specimen was not completely consumed.

In order to obtain data from which this relation could be studied, it was necessary to carry out further tests. The experimental methods were the same as described in F.R. 107.

Results

A list of the fabrics used, together with the results of the experiments are given in Table 1. The relation between vertical flame speed and the time to reach the final distance of spread of flame (Fig. 1) is given by

 $v = \frac{0.800^{2.5}}{T}$, (3)

This expression approximates to (1) with D = 21 in.

The tests with fabrics were supplemented by others on paper with which the specimens of various thicknesses were built from single sheets using the minimum amount of a flour paste (equal volumes of water and flour) to obtain good adhesion the results are given in Table 2.

Further confirmation of the relationship may be seen from the results of the tests of the papers in various thicknesses. In F.R. 107 it is indicated that for the cellulosic material there is an inverse relationship between vertical flame speed V and weight/unit area, W, if this is expressed as

WV = K

and substituted in equation (3) then

 $\frac{\mathrm{K} \mathrm{T}}{\mathrm{W}} = 0.800^{2.5}$

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where

For w, n the number of layers of paper stuck together may be substituted. This gives

$$\frac{K_T}{n} = 0.80D^{2.5}$$

If T is plotted against $D^{2.5}$ a straight line is obtained as in Figure 2.

Discussion of results

It may be seen that there is less scatter in Figure 1 where distance and time of spread of flame are taken into account, than in Fig. 6 F.R. 107 where distance of spread only is noted. The vertical flame speeds calculated from equation (3) have been plotted against the measured vertical flame speeds in Fig. 3. It may be seen that the points tend to lie on a line at 45 degrees which confirms that the relation is reasonably good. The greatest deviation from equation (3) is shown by the material from the Japanese silk scarves and this may be because of the open texture of the fabrics. Other results, indicate that materials with open texture tend to give anomalous results when compared with other materials of the same chemical composition. For example, in tests on cotton muslin weighing 3.9 mgm. per sq. cm. the measured vertical flame speed was 15.2 cm per sec. These two figures multiplied together give a value of just under 60, from earlier tests on cotton fabrics, (see F.R. 107), the constant would be expected to be 80.

The results with paper of different thicknesses confirm equation (3) and the inverse relation between weight per unit area and vertical flame speed.

When more materials have been tested a statistical analysis would be worthwhile to establish the standard percentage deviation from equation (3).

Conclusions

Some further work on the flammability of fabrics is described and an empirical equation is given for a relationship between vertical flame speed and distance and time of spread of flame round the semi-circular apparatus. This relationship is considered to be more reliable than the equation for vertical speed and distance of spread given in F.R. 107 and has the advantage that in formulating a classification for fire risk of fabrics, a homogeneous method may be derived where the same criteria time and distance are used throughout.

 F.R. Note No. 107/1954. The Flammability of Fabrics by D.I. Lawson, C. T. Webster and J. Gregsten.

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Lab. Ref. No.	Material and percentage composition	Weight per unit area	Distance of spread D	Time to spread D T	Calculated vertical flame speed by Eqn. $V = \frac{0.80}{T} \frac{D_2^5}{2}$	Calculated vertical flame speed by Eqn, V=1.81D ^{0.4}	Measured vertical flame speêd
	1	mgm cm ⁻²	inches	sec.	V cm.sec1	V1	V -1 cm.sec.
28ъ	Artificial winceyette (fibre composition)	13	21 1 3 ³ 19 ¹ / ₂ 21 21 21 1	301 95 274 319 293 298			
117	Dacron Fibro	30,2	Av 19 2 21 21 21 21 21 21 21 21	Av 263.3 516 509 523 481 503 495	5.1	5.9	4.7 2.6 2.9 1.6 2.9 2.6 3.0
113	Fibro 1	27•4	21 13년 13년 13년 14 14 13년 13년 五子	Av 504 166 178 180 183 164 182 Av 175	3.2	2•5 5•1	Av 2.6 2.9 2.4 2.7 2.8 2.8 <u>3.0</u> Av 2.8
114	Fibro	10.1	$ \begin{array}{c} 20 \\ 16\frac{1}{2} \\ 18\frac{1}{2} \\ 18\frac{1}{2} \\ 18\frac{3}{4} \\ 17 \\ 16\frac{1}{2} \\ \hline \text{Av 17.8} \end{array} $	191 115 182 166 140 131 Av 154	7	5.7 .	7.3 7.3 7.3 Av 7.3
115	Fibro 1	18.9	15 18 ¹ / ₂ 15 ² / ₄ 18 15 ¹ / ₂ 15 ¹ / ₂ 15 ¹ / ₄ Av 16.3	173 322 206 279 191 187 Av 226	3.8	5.5	4.2 4.2 4.1 Av 4.2
116	Fibro	1.8	21 21 21 21 21 21 21 ' Av 21	125 126 115 126 129 126 Av 125	12.9	11	15.8 16.1 <u>14.9</u> Av 15.6

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Table 1 cont'd

Lab. Ref. No.	Material and percentage composition	Weight per unit area	Distance of spread D	Time to spread D T	Calculated vertical flame speed by Eqn. V = 0.8005	Calculated vertical flame speed by Eqn. V= 1.81D ^{0.4}	Measured vertical flame speed
n bay		ngm om→2	inches	sec.	V v1 om.seo1	V cm.sec. ⁻¹	v1
_107)	Rayon D	30.9	$ \begin{array}{r} 12\frac{1}{2} \\ 13 \\ 13\frac{1}{2} \\ 13 \\ 13\frac{1}{2} \\ 13\frac{1}{2} \\ 13\frac{1}{2} \\ 13\frac{2}{3} \\ \overline{Av} 13.2 \end{array} $	262 183 196 170 197 210 Av 203	2.5	5.1	3.6
104	Rayon Lambspun	16.1	$ \begin{array}{r} 15\frac{1}{4} \\ 17 \\ 16 \\ 17\frac{3}{4} \\ 17 \\ 16\frac{1}{2} \\ \overline{4 \times 16.6} \end{array} $	149 209 166 254 205 189 Av 195	4-6	5-6	4.8 4.9 <u>4.9</u> <u>4.9</u> Av 4.9
31	Japanese silk Soarf 1	2.9	21 21 21 21 21 21 21 <u>21</u> <u>Av 21</u>	69 75 70 75 76 <u>75</u> 76 <u>75</u> Av 73	2,2		8.5
•	Scarf 2	1.3	4 8 10 9 2 3 Av 6	4 6 7 2 2 Av 4.2	16.6	3.7	11.5
	Scarf 3	1.9	$ \begin{array}{r} 9\frac{1}{2} \\ 9\frac{1}{2} \\ 8\frac{1}{2} \\ 2 \\ 6 \\ 5 \\ \overline{\text{Av}} 6, 8 \end{array} $	7 9 8 2 6 3 Av 6	16.0	3.9	9.2
1a-	Wool	26.5	$ \begin{array}{r} 3\\ 4\\ 6\\ 4\\ 4\frac{1}{2}\\ \frac{31}{2}\\ \overline{32}\\ \overline{4v} 4.2 \end{array} $	20 20 22 14 18 14 Av 18	1.7	3.2	2.4 1.7 1.7 1.5 1.4 <u>1.5</u> Av 1.7
15	Wool Polyacrylonitrile	29.4	12 $12\frac{3}{4}$ $12\frac{1}{4}$ 13 $12\frac{1}{2}$ $12\frac{1}{2}$ $12\frac{1}{4}$ $12\frac{1}{5}$	165 140 132 210 150 131 Av 154	2.8	.5•0	2.1 1.8 2.3 2.0 1.9 <u>2.1</u> Av 2.0

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Table 1 contid

Lab. Ref. No.	Material and percentage composition	Weight per unit area	Distance of spread D	Time to spread D T	Calculated vertical flame speed by Eqn.5 V=0.80D2	Calculated vertical flame speed by Eqn. V= 1.81D ^{0.4}	Measured vertical flame speed
		mgm cm ⁻²	inches	seo.	v cm.sec,~1	V cm.sec1	v cm.sec.~1
1 <i>3</i> a	Wool cotton 55/45	13.3	$ \begin{array}{r} 11\frac{1}{4}\\ 11\frac{1}{2}\\ 6\\ 4\frac{1}{2}\\ 12\\ \end{array} $	50 52 15 12 68	5.0		4.8 5.6 4.6 Av 5.0
11	Wool cotton 40/60	15,00	AV 9 135 123 123 <u>123</u> Av 12.7	AV 59 84 83 <u>83</u> Av 83	5.5	4• <i>5</i>	5.1
9	Wool/viscose/nylon	26.0	63 5 42 4 11	34 22 18 19 85			1.2
			$\frac{11\frac{7}{2}}{\text{Av} 7.2}$	91 Av 45	2.4	4.0	-
							-
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Material	Weight per`unit	Distance of spread D	Time to spread D T	Calculated vertical flame speed 5 by Eqn. V=0.80D2 V	Measured vertical flame speed
	mgm.cm	inches	sec.	cm.sec, "]	cm.sec.
Chart Paper 1 Layer	6.4	21	84	19.2	17.4
. 2 11		19 18	147 127	8.6 8.7	
3 "		. 18 <u>1</u> 18 17	203 190 171	5.8 5.8 5.6	
5 "		14 1 <u>3</u> 1 14	155 1 <i>3</i> 0 153	3.8 4.1 3.7	
6 "		12 <u>1</u> 11 <u>2</u> 12 <u>1</u>	123 91 122	3.6 4.0 3.6	
		12 11 1 12	149 118 126	2.7 3.0 3.2	
) <u>10</u> " }		9 11 <u>5</u> 11 <u>5</u>	77 114 148	2.5 3.2 2.4	
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Table 2

Result of Test on Paper of Various Thickness

DS 95741/2/143 50 9/55 R

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F.R.209. 1/1839



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FIG.2.

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F.R.204 1/1840



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