

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

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FLAMMABILITY TESTS ON MATERIALS SUPPLIED BY THE FLAMMABILITY TESTING  
PANEL OF THE TEXTILE INSTITUTE

by

C. T. Webster

Summary

This note gives the results of flammability tests undertaken on fifteen materials for the Flammability Testing Panel of The Textile Institute. The vertical flame speed of each material was measured and the fabric tested on the semi-circular apparatus and on the American Flammability Test.

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Introduction

At the first meeting, 29th March, 1955, of the Flammability Testing Panel of The Textile Institute it was agreed that "The aim of the Panel was to make recommendations leading to a standard method of test, or a related group of methods, but failing this a critical survey of the present methods and their uses should be prepared". It was also agreed at the meeting that members should send samples of fabrics to The Textile Institute for dispatch to other members who would carry out flammability tests. The following report describes flammability tests made by the Joint Fire Research Organization on textiles supplied by the following Organizations:-

British Cotton Industries Research Association.  
Messrs. Courtaulds, Ltd.  
Lace Research Association.  
Joint Fire Research Organization.

Experimental

The flammability results given in this report are from the materials subjected to the following tests:-

- (1) Vertical flame speed test (1).
- (2) Semi-circular test (2).
- (3) The American Federal Test CCC-T191b. (In this test as carried out by the Joint Fire Research Organization a coal gas flame was used instead of a butane flame).

Before testing half the samples conditioned to 57 per cent relative humidity at a temperature of 26°C and the remainder were dried in an oven at 105°C for 30 minutes. The weight per unit area was determined for each material, after conditioning.

Results of tests

The individual results of the tests are given in Appendices 1, 2, 3 and 4. As no identification numbers were found on the Lace Research Association fabrics, samples of the fabrics have been attached to the results in Appendix 3. In Table 1 vertical flame speeds have been calculated from the semi-circular test using the following empirical formulae:-

$$(1) \quad V = \frac{1655}{T^{1.03}} \quad \text{when flame completely spreads round the semi-circle}$$

$$(2) \quad V = \frac{0.078D^{0.72}}{T} \quad \left. \begin{array}{l} \text{) where flame spreads partially} \\ \text{) round the semi-circle} \end{array} \right\}$$

where  $V$  = vertical flame speed  $\text{cm sec}^{-1}$ .  
 $T$  = time seconds.  
 $D$  = distance of flame spread in cm.

In the American Federal Test the times, in seconds, are given for the flame to spread up the 4 in. strip and release the weight.

### Discussion

The mean result for each fabric is shown in Table 1. In Figure 1 the vertical flame speeds calculated from the results of the semi-circular test are shown against the measured vertical flame speed. For the American Test the reciprocal of the time will give a measure of the mean rate of spread along the slope and this is plotted against the measured vertical flame speed (see Fig. 2). Both tests appear to overestimate the vertical flame speed of blue acetate rayon and cotton (3), while the American Test underestimates the vertical flame speed of 40/60 wool cotton and the semi-circular test overestimates that of pink raised viscose rayon with the fluff below.

Apart from the fabrics mentioned the observed and calculated vertical flame speeds for the semi-circular test are in reasonable agreement for specimens conditioned at 26°C. In general, both tests give similar results. This may be seen more clearly if the time of spread for fabrics spreading 21 in. in the semi-circular tests is plotted against the time of spread in the American Test as in Figure 3. This agreement suggests that both tests are in general measuring similar physical properties of the fabrics.

The results of both tests suggest that more consistent results are obtained if tests are confined to conditioned rather than oven-dried specimens. This is possibly due to the changes that may occur during the period after drying and during the test. The results for wool cotton 40/60 with the American Tests were dependent on whether the flame actually penetrated the fabric in the 1 second it was in contact with it. For about half the tests with the oven-dried specimen the flame penetrated the fabric giving an average spreading time of 13 seconds, and for the remainder it did not, giving a mean time of 38 seconds. With the conditioned specimen the flame did not penetrate and burnt up the top side only. This resulted in a type of burning different from that when the fabric hangs freely. A similar behaviour has been observed with cellulose nitrate film (4) where the mean spreading times were 3.5 and 11.6 seconds only for tests in which the emulsion was on top and below respectively. In the semi-circular test with raised viscose rayon with the fluff below, the fabric burnt more rapidly on the fluff side than on the reverse side and this appears to have given rise to too great an estimate of vertical flame speed. No detailed statistical analysis has been made of these results so that it is not possible to make a more specific comparison of the two methods of test.

### Conclusions

Both tests in general classify materials in the same way, but there are some anomalous results with both tests when they are related to the vertical flame speed. The American Test may give variable results with some materials due to the fact that the flame does not always penetrate the sample. The British Test gives rapid flame spread over brushed materials when the raised fabric is placed downwards. The times involved in the American Test are about one-tenth of those involved in the semi-circular test.

Conditioned specimens give much more reliable results than oven-dried specimens.

### References

- (1) D. I. LAWSON, C. T. WEBSTER and M. GREGSTEIN. "The flammability of fabrics". Department of Scientific and Industrial Research and Fire Offices' Committee Joint Fire Research Organization. F.R. Note 107/1955.
- (2) British Standard No. 476 Part II Draft Specification.
- (3) United States Department of Commerce. Commercial Standard 191-53.
- (4) F.R. Note in preparation.

TABLE 1

Messrs. Courtaulds. The average test results obtained from fabrics from various sources

Material	Treatment	Weight mg cm <sup>-1</sup>	Vertical flame speed cm sec <sup>-1</sup>	Semi-circular test		Calculated vertical flame speed		American Test time sec
				Distance (cm)	Time sec	Equation 1	cm sec <sup>-1</sup> 3	
Blue acetate rayon	Conditioned	13	4.4	53.5 (21")	146	10.4		9.5
	at 78°F 57% R.H.							
Pink raised viscose rayon	Oven dried	19.1	5.9	"	103	13.8		8.2
	at 78°F 57% R.H.							
Fluff on top	Conditioned	30.9	4.8	"	325	4.3		26.2
	at 78°F 57% R.H.							
Fluff below	Oven dried	30.9	5.6	"	151	9.3		17.2
	at 78°F 57% R.H.							
Dacron fibro	Conditioned	30.9	4.8	"	146	10.4		24
	at 78°F 57% R.H.							
White nylon	Oven dried	4.7	5.6	"	107	13.5		25.3
	at 78°F 57% R.H.							
	Conditioned		2.8	"	527	2.6		27
	Oven dried		3.4	"	451	3.1		23.6
	at 78°F 57% R.H.							
	Oven dried							
BRITISH COTTON INDUSTRIES RESEARCH ASSOCIATION								
B. C. I. R. A. 1	Conditioned	13.8	4.4	53.5 (21")	215	6.6		17.2
	at 78°F 57% R.H.							
B. C. I. R. A. 2	Oven dried	14.0	5.7	"	172	8.3		18.0
	at 78°F 57% R.H.							
B. C. I. R. A. 3	Conditioned	15.5	4.8	"	204	6.9		19.2
	at 78°F 57% R.H.							
	Oven dried		5.9	"	172	8.3		19.2
	Conditioned		4.7	"	242	5.8		17.7
	Oven dried		5.5	"	186	7.6		14.5
LACE RESEARCH ASSOCIATION								
Net A	Conditioned	4.39	4.5	"	40	37		3.2
	Oven dried			4.3	"	39	38	
Net B	Conditioned	2.57	3.5	"	46	33		3.5
	Oven dried			5.8	"	45	33	
Net C	Conditioned	1.62	39.5	"	37	40		3.4
	Oven dried			31	"	27	55	
Net D	Conditioned	2.54	24	"	55	26		5.1
	Oven dried			58	"	40	37	
1 Yellow locknit Rayon	Conditioned	15.5	4.9	45	230		4.6	20.4
	Oven dried			6.3	53.5 (21")	239	5.9	
JOINT FIRE RESEARCH ORGANIZATION								
Cotton 1	Conditioned	15.6	4.9	53.5 (21")	240	5.9		14.0
	Oven dried			5.5	"	201	7.0	
Wool/cotton/40/60 2	Conditioned	12.5	5.9	30.5	70		5.7	45
	Oven dried			6.0	34	94		5.7
1 Cotton 3	Conditioned	6.4	8.8	52.5 (21")	106	13.8		6.6
	Oven dried			10.7	"	94	15.2	

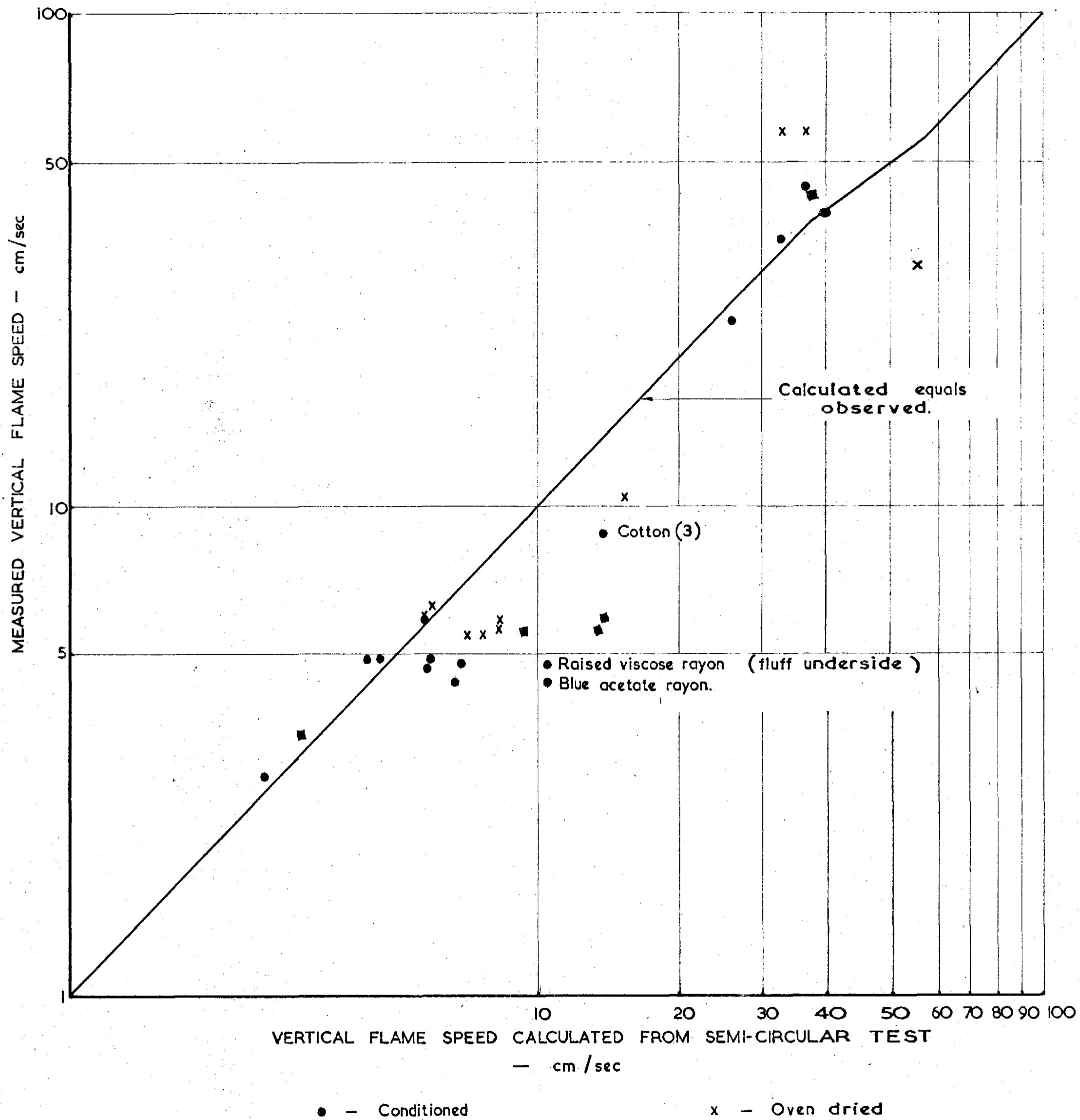


FIG. 1. COMPARISON BETWEEN VERTICAL FLAME SPEED AND SEMI-CIRCULAR TEST RESULT.

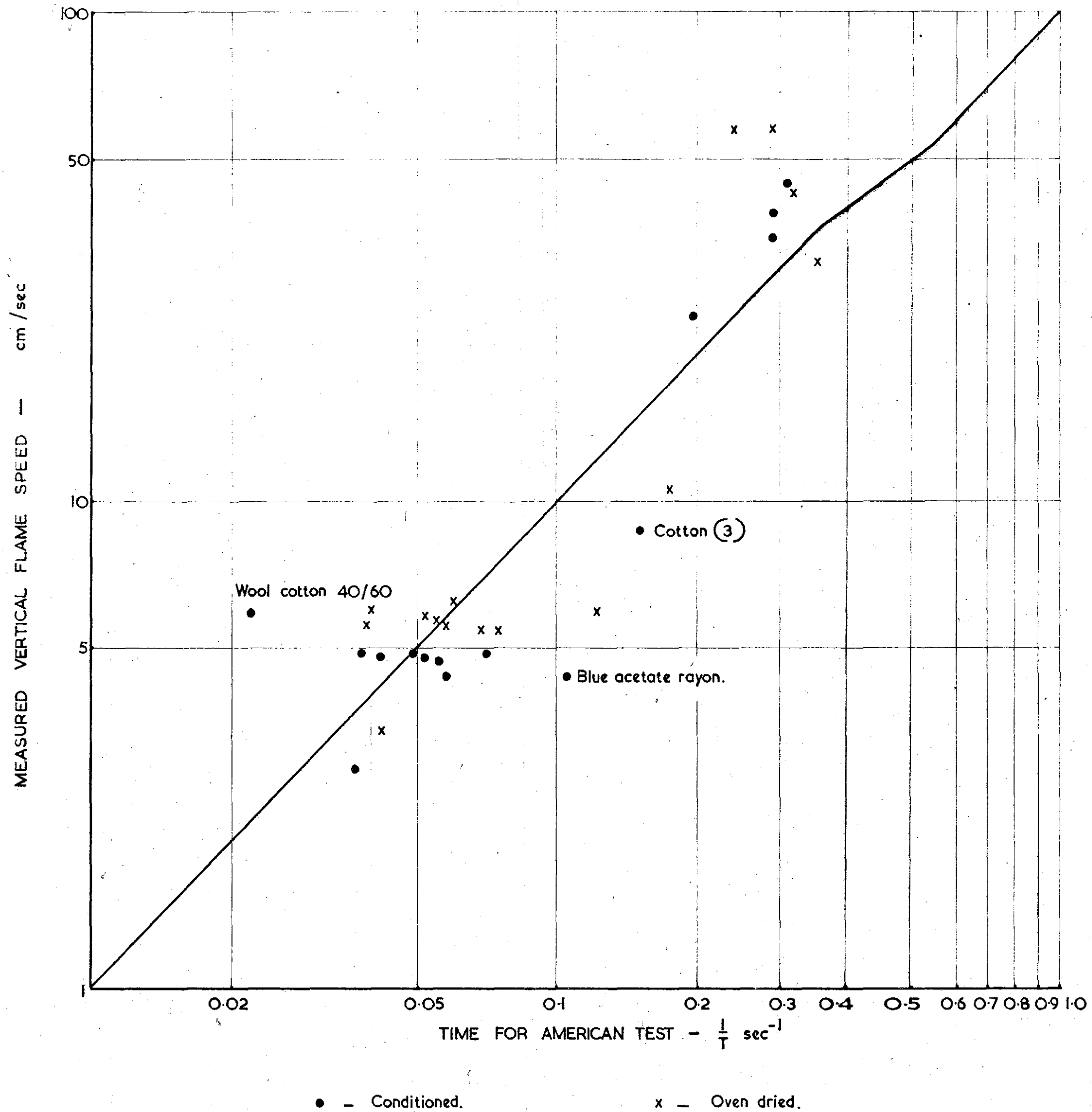


FIG. 2. COMPARISON BETWEEN VERTICAL FLAME SPEED AND AMERICAN TEST RESULT.

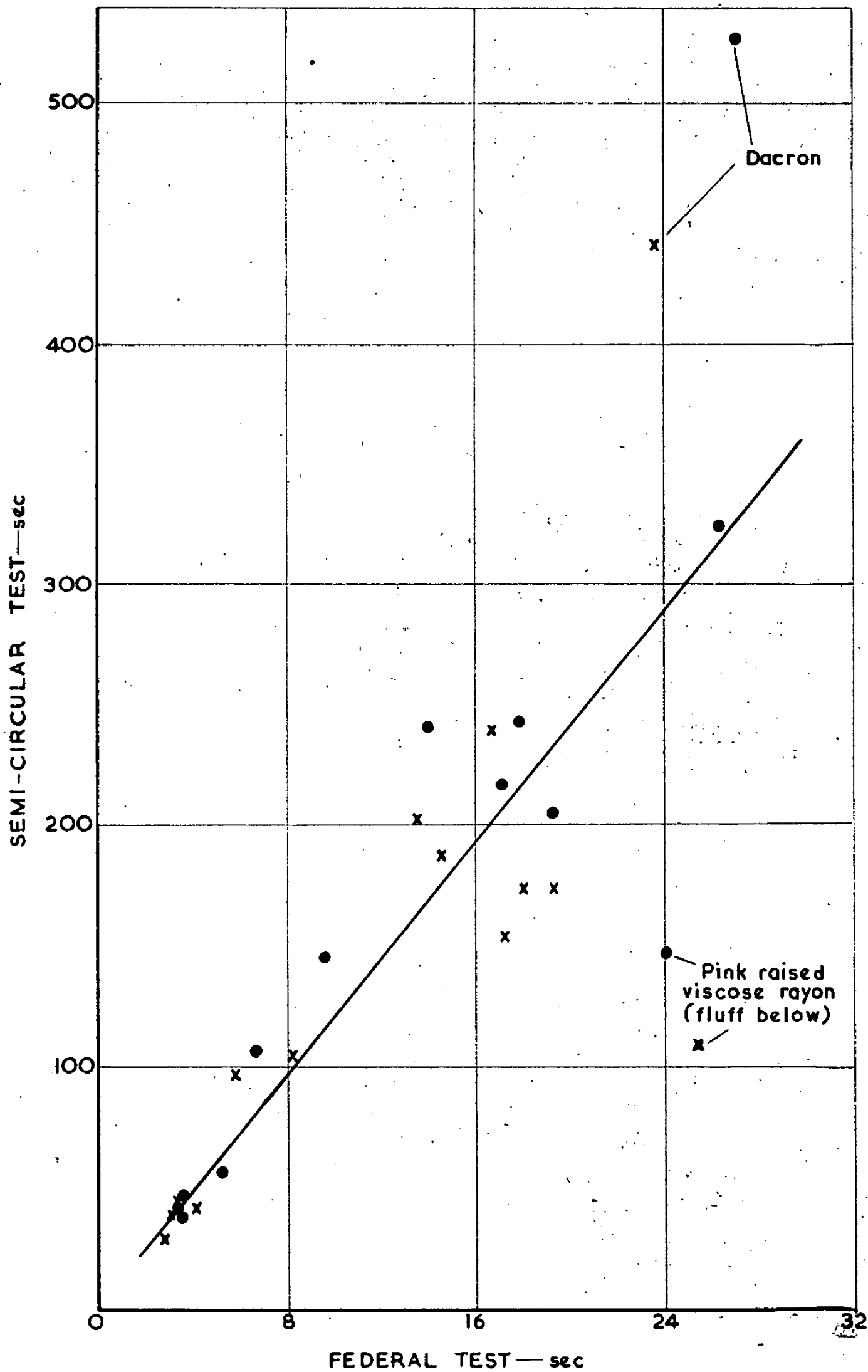


FIG.3. COMPARISON OF SEMI-CIRCULAR TEST AND AMERICAN FLAMMABILITY TEST

APPENDIX 1

DETAILED TEST RESULTS ON FABRICS SUBMITTED BY MESSRS. COURTAULDS

MATERIAL	TREATMENT	WEIGHT mg. cm <sup>-2</sup>	SEMICIRCULAR TEST		MEASURED V.F.S. cms. sec <sup>-1</sup>	CALC. V.F.S. V.	AMERICAN TEST TIME : SECS.
			TIME SECS.	DISTANCE			
Blue Acetate Rayon (Courtaulds)	Conditioned at 78°F and 57% Relative Humidity	13.00	139	53.5 cm(21")	4.4	10.4	10.0
	150		"	9.5			
			154	"			8.7
			140	"			9.5
			137	"			9.7
			155	"			
			mean = 14.6 secs mean = 53.5 cm				
	Oven Dried		104	53.5 cm(21")	5.9	13.8	8.5
			102	"			8.5
			104	"			8.1
			107	"			8.2
			100	"			7.9
			99	"			
			mean = 102.7 mean = 53.5 cm				
Pink raised viscose rayon (Courtaulds)	Conditioned	19.10	<u>Fluff on top</u>		4.9	4.3	27.0
			323	53.5 cm(21")			26.0
			325	"			27.5
			310	"			25.0
			320	53.0			26.0
			337	53.5			26.0
			337	"			26.0
			mean = 325.3 mean = 53.5 cm				
(Fluff on top)	Oven Dried		149	53.5 cm(21")	5.6	9.3	18.5
			219	"			20.0
			123	"			18.5
			109	"			14.5
			175	"			14.5
			133	"			
			mean = 151.3 mean = 53.5 cm				
(Fluff below)	Conditioned		<u>Fluff underneath</u>		4.9	10.4	26.5
			139	53.5 cm(21")			22.0
			150	"			21.0
			154	"			26.0
			140	"			24.5
			137	"			
			155	"			
			mean = 14.6 mean = 53.5 cm				
	Oven Dried		108	53.5 cm(21")	5.6	13.5	25.0
			93	"			30.0
			105	"			25.3
			115	"			22.0
			64	"			24.0
			156	"			
			mean = 107 mean = 53.5 cm				
Dacron-fibro	Conditioned	30.9	517	53.5 cm(21")	2.8	2.6	27.0
			519	"			27.0
			538	"			26.0
			54.6	"			28.0
			521	"			26.0
			522	"			26.5
			mean = 527 mean = 53.5 cm				
	Oven Dried		465	53.5 cm(21")	3.9	3.1	22.0
			458	"			25.5
			469	"			23.0
			448	"			24.5
			452	"			22.0
			412	"			24.5
			mean = 450.7 mean = 53.5 cm				



APPENDIX 1 contd.

MATERIAL	TREATMENT	WEIGHT mg. cm <sup>-2</sup>	SEMIPERFORATED TEST		MEASURED T.F.S. cm. sec <sup>-1</sup>	ORIG. V.F.S. V.	AMERICAN TEST TIME : SECS
			TIME secs	DISTANCE			
White Nylon (Courtaulds)	Conditioned at 78°F and 57% Relative Humidity	4.70	: did not burn, only melted	Distance melted 5.1 cm 4.5 cm 4.5 cm 6.3 cm 5.1 cm 5.7 cm mean= 5.2 cm	: - did not burn.		
	Oven Dried		: did not burn.	7.0 cm 5.1 cm 5.1 cm 5.4 cm 5.7 cm 5.1 cm mean= 5.5 cm			

APPENDIX 2  
DETAILED TEST RESULTS ON FABRICS SUBMITTED BY BRITISH COTTON INDUSTRIES RESEARCH ASSOCIATION

B.C.I.R.A. 1.	Conditioned	13.80	220 210 210 216 215 217 mean= 215	53.5 cm (21") " " " " " mean= 53.5 cm	4.4	6.6	16.6 16.4 17.8 15.0 17.0
	Oven Dried		172 172 173 170 172 172 mean= 172	53.5 cm " " " " " mean= 53.5 cm	5.7	8.3	19.2 18.5 18.0 20.6 17.5 16.5
B.C.I.P.A. 2.	Conditioned	14.00	209 198 205 204 205 205 mean= 204.3	53.5 cm (21") " " " " " mean= 53.5 cm	4.8	6.9	18.6 19.0 21.0 18.8 16.5
	Oven Dried		166 172 171 175 175 175 mean= 172.3	53.5 cm (21") " " " " " mean= 53.5 cm	5.9	8.3	17.2 17.5 19.7 20.3 20.8 17.8
B.C.I.R.A. 3.	Conditioned	15.50	245 250 246 243 242 230 mean= 242.5	53.5 cm (21") " " " " " mean= 53.5 cm	4.7	5.8	17.3 17.0 16.6 19.2 18.1 17.9
	Oven Dried		171 182 185 191 190 195 mean= 185.7	53.5 cm (21") " " " " " mean= 53.5 cm	5.6	7.6	15.0 14.2 13.7 13.1 15.6 15.7

APPENDIX 3  
DETAILED TEST RESULTS ON FABRICS SUBMITTED BY LACE RESEARCH ASSOCIATION

MATERIAL	TREATMENT	WEIGHT	SEMICIRCULAR TEST		MEASURED V.F.S. cms. sec.	CALC. V.F.S. V.	AMERICAN TEST TIME : SECS	
			TIME Secs	DISTANCE ins.				
Net A	Conditioned at 78°F and 57% Relative Humidity	4.39	41	53.5 cm(21")	45.00	37	3.4	
			40	"			3.2	
			40	"			3.1	
			40	"			3.0	
			41	"			3.4	
			40	"			3.2	
			mean= 40.3	mean= 53.5 cm				
	Oven Dried			41	53.5 cm(21")	43.00	38	2.8
				40	"			2.9
				38	"			3.2
				39	"			3.4
				38	"			3.2
39				"	3.4			
		mean= 39	mean= 53.5 cm					
Net B	Conditioned	2.57	51	53.5 cm(21")	34.6	33	3.9	
			47	"			3.1	
			46	"			3.4	
			46	"			3.5	
			45	"			3.7	
			44	"			3.7	
			mean= 46.5	mean= 53.5 cm				
	Oven Dried			45	53.5 cm(21")	58.0	33	3.5
				47	"			3.3
				45	"			3.5
				44	"			2.3
				45	"			3.5
46				"	4.1			
		mean= 45.3	mean= 53.5 cm					
Net C	Conditioned	1.62	33	53.5 cm(21")	39.5	40	3.2	
			41	"			3.3	
			38	"			3.6	
			37	"			3.2	
			38	"			3.5	
			36	"			3.5	
			mean= 37.0	mean= 53.5 cm				
	Oven Dried			30	53.5 cm(21")	31.0	35	2.9
				26	"			2.5
				26	"			2.8
				27	"			2.7
				28	"			2.6
28				"	2.9			
		mean= 27.3	mean= 53.5 cm					
Net D	Conditioned	2.54	55	53.5 cm(21")	24.0	26	4.8	
			57	"			5.7	
			54	"			5.1	
			57	"			5.1	
			55	"			5.2	
			52	"			4.8	
			mean= 55	mean= 53.5 cm				
	Oven Dried			39	53.5 cm(21")	58.0	37	4.6
				40	"			3.9
				40	"			4.2
				39	"			4.1
				40	"			3.8
40				"	4.1			
		mean= 39.7	mean= 53.5 cm					

APPENDIX 4  
DETAILED TEST RESULTS ON FABRICS SUBMITTED BY JOINT FIRE RESEARCH ORGANIZATION

MATERIAL	TREATMENT	WEIGHT	SEMICIRCULAR TEST		MEASURED V.F.S. cm. sec <sup>-1</sup>	CALC. V.F.S. V.	AMERICAN TEST TIME : SECS MEAN OF 5 SPECIMENS	REMARKS
			TIME secs	DISTANCE				
Cotton No. 1	Conditioned at 71.6°F and 57% Relative Humidity	15.58 mg. cm <sup>-2</sup>	246	53.5 cm(21")	4.9	5.9	14.0	
	241		"					
			242	"				
			241	"				
			232	"				
			240	"				
			mean= 240 secs mean= 53.5 cm					
	Oven Dried		193	53.5 cm(21")	5.5	7.0	13.4	
			201	"				
			202	"				
			195	"				
			204	"				
			210	"				
			mean= 201 secs mean= 53.5 cm					
60% Wool 40% cotton No. 2	Conditioned	12.52 mg. cm <sup>-2</sup>	60	30.5 cm	5.9	5.7	45	No penetration of fabric by flame in American test
			66	32				
			80	33				
			56	31				
			93	25				
			65	29				
			mean= 70 secs mean= 30.5 cm					
	Oven Dried		75	34	6.0	5.7	25	13, secs mean when flame penetrated fabric, 38, when flame did not penetrate fabric.
			138	42				
			85	25.5				
			91	35.5				
			96	36				
			81	34				
			mean= 94.3 secs mean= 34.5 cm					
Cotton No. 3	Conditioned	6.44 mg. cm <sup>-2</sup>	105	53.5 cm(21")	8.8	13.8	6.6	
			106	"				
			106	"				
			105	"				
			106	"				
			106	"				
			mean= 106 secs mean= 53.5 cm					
	Oven Dried		96	53.5 cm(21")	10.7	15.2	5.7	
			95	"				
			93	"				
			95	"				
			94	"				
			94	"				
			mean= 94.5 secs mean= 53.5 cm					

APPENDIX 3 contd.

MATERIAL	TREATMENT	WEIGHT	SEMICIRCULAR TEST		MEASURED V. P. S. Cms. sec.	CALC. U. F. S. V.	AMERICAN TEST TIME : SECS
			TIME secs	DISTANCE ins.			
Yellow Locknit Rayon	Conditioned at 78°F and 57% Relative Humidity	15.5	148	39.5 cm	4.9	4.6	23.0
			177	41			20.4
			203	43			20.0
			234	46			19.1
			294	50			19.2
			325	51			21.0
			mean= 230.2	mean= 45			
	Oven Dried	15.5	252	53.5 cm(21")	6.3	5.9	14.8
			219	"			17.0
			240	"			17.0
			257	"			16.7
			241	"			17.1
			224	"			17.1
			mean= 239	mean= 53.5 cm			

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