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

Paper for Annual Conference of Plastic Surgeons
14th July, 1956, in Sheffield

THE PROPAGATION OF FLAME OVER TEXTILES

by

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Fire Research Station,
Boreham Wood,
Herts.

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INTRODUCTION

Textiles are flexible woven materials. The spinning and weaving processes associated with their manufacture ensure that the finished materials are more or less a well aerated mass with good thermal insulating properties; unfortunately, this leads to conditions which are favourable to ignition and to the propagation of flame. Textiles, being flexible and subject to the usual gravitational forces, usually hang vertically; it is in this position that flame is most readily propagated and the heat transfer from the flame to the unburnt fabric ahead of the flame is greatest.

MEASUREMENT OF VERTICAL FLAME SPEED

In assessing the danger of any fabric, it will be necessary to measure the vertical flame speed, as this is a measure of the time available, either for extinguishing the flames or for discarding the burning fabric. As burning is a continuous process of ignition, any such measurement will also take into account the ease of ignition of fabrics.

It is not easy to measure vertical flame speed over fabrics directly, as the flame front is not well defined. It is, however, possible to measure the vertical flame speed indirectly by weighing the fabric continuously on a torsion balance while it is burning (1). From the rate of loss of weight, the initial weight of the fabric and the weight of the residue, the vertical flame speed is readily calculated. The apparatus is shown in Figure 1, and some typical results are given in Table 1.

TABLE 1

VERTICAL FLAME SPEED OF TYPICAL FABRICS

Fabric	Weight/unit area oz/yd^2	Vertical flame speed in./s
Cotton net	0.7	12.6
Cotton	2.3	4.1
Rayon	3.4	3.0
Lingerie silk (Acetate rayon)	2.9	2.7
Wool cotton mixture 40/60	3.5	2.4
Wool cotton mixture 60/40	3.75	2.3
Vinceyette	4.6	2.2
Wool	5.6	2.2
Cotton	7.3	1.4
Terylene rayon	9.0	1.2
Rayon	5.6	1.1
Wool	7.5	0.7
Wool nylon mixture 50/50	8.5	0.5
Wool serge	19	nil
Nylon	1.5	nil
Terylene	5.0	nil

All cellulosic materials, wood, paper and textiles, propagate flame at a rate which is inversely proportional to their weight per unit area, as shown in Figure 2. In fact, a useful formula to have in mind is:-

$$VW = 9{\cdot}3$$

where W is the weight in oz/yd^2
and V is the vertical flame speed in in./s.

The torsion balance apparatus is, of course, quite unsuitable for everyday use, and this has led to the development of simpler apparatus (Figure 3) consisting of a semi-circular arched track over which the fabric to be tested is stretched. The sample is lit at one end and the final distance of burning D is noted, together with the time taken T. From these two quantities the vertical flame speed V, as measured by the torsion balance, can be estimated from the expression, shown graphically in Figure 4:-

$$V = \frac{0{\cdot}31\ D^{2{\cdot}5}}{T}$$

The correlation between the vertical flame speed calculated in this way, and with that measured using a torsion balance is shown in Figure 5.

The semi-circular apparatus is described in B.S. 476 : Part 2 (2), in which a figure of merit, M, is assigned to the sample under test. This is the time taken for flame to propagate 100 in. vertically, and it is derived from the distance and time of burning by the expression:-

$$M = \frac{320\ T}{D^{2{\cdot}5}}$$

which is shown graphically in Figure 6. Typical values for various materials are shown in Table 2.

TABLE 2

FIGURE OF MERIT OF TYPICAL FABRICS

Fabric	Figure of merit
Cotton net	8
Cotton	24
Rayon	33
Lingerie silk (Acetate rayon)	37
Wool cotton mixture 40/60	42
Wool cotton mixture 60/40	45
Winceyette	45
Wool	45
Cotton	71
Terylene rayon	90
Rayon	90
Wool	143
Wool nylon mixture 50/50	200
Wool serge	over 1000
Nylon	over 1000
Terylene	over 1000

THE FIGURE OF MERIT OF COMMON FABRICS

Nylon and terylene fabrics do not propagate flame because their melting temperature is below the temperature of ignition, and when a flame is applied the fabric shrinks away from the flame. An exception must be made in the case of nylon nets stiffened with melamine resins; these resins have a high melting point and form a matrix on which the nylon can burn, and the propagation of flame over such nets is about that of cotton net (figure of merit 8). Recently, nylon nets stiffened with a low melting thio-urea resin have come into common use. These do not propagate flame, and in fact, it is possible to use these fabrics in the construction of spark guards for domestic fires.

Pure woollen materials usually have a figure of merit of 100 upwards, depending on the weight per unit area of the fabric. Cotton and rayon fabrics have figures of merit in the range 8 - 60, the precise value again depending on the weight of the fabric.

The figure of merit of mixtures of fibres is at least as bad as the worst component. For example, wool/cotton mixtures containing more than 20 per cent cotton have a figure of merit corresponding to cotton material of a similar weight.

BURNS IN RELATION TO THE FIGURE OF MERIT OF FABRICS

In order to get information on the relation between the figure of merit and burning accidents, the Ministry of Health have been asked if they would enlist the co-operation of the Burns Units of hospitals in Great Britain in supplying both information regarding the accident and a sample of the fabric first ignited. The questionnaire in use is shown in Figure 7. This is printed on the back of the envelope into which a sample of fabric is placed.

When the envelope is received at the Fire Research Station, the figure of merit of the fabric is measured and recorded. The information is then coded on to punched cards by the Statistical Section.

From this survey it is hoped to answer three main questions:-

(1) What is the distribution of the number of burning accidents in relation to the figure of merit of the fabrics first ignited?

(2) Is there any correlation between the extent and severity of burns and the figure of merit of the fabric involved?

(3) What would be the effect on the pattern of burning accidents of encouraging the use of garments having a figure of merit higher than those in use at present?

From an examination of the fabrics received so far from hospitals and from the Fire Service, it has been possible to prepare a distribution diagram of the number of burning accidents with respect to the figure of merit of the materials first ignited. This is shown in Figure 8, where it will be seen that the bulk of the accidents involve fabrics having figures of merit in the range 25 - 65. The more flammable fabrics are not responsible for the bulk of burning accidents, probably because they are not so frequently used or because such light-weight materials are usually worn in summer when fires are not generally used. Whatever the cause, the implication is clear that it would be useless to prohibit only the most flammable fabrics as has been done in the United States.

It is probable that it would be more profitable to encourage the use of flame-retardant treated fabrics. Those now on the market and those which are likely to be produced within the next year have figures of merit of several hundreds, and the treatments resist laundering as well. Unfortunately, the cost of these is a big obstacle in the way of their general adoption. It has been suggested (3) that the increased cost of producing flame-retardant treated fabrics might be offset by a subsidy as their general use would reduce the expenditure by the Health Services in treating burns cases. Before this could be done it would be necessary to estimate the effect of changing the clothing habits of the nation on the number and severity of burns. This is a difficult problem but it is made easier to some extent by the fact that burning accidents are confined mainly to dresses and nightdresses.

Colebrook and Colebrook have repeatedly pointed out (4) that the first tasks are to see that all open fires are guarded and that flowing nightwear for children should be avoided. Parents can be urged to take these measures now and until such time as flame-retardant treated fabrics are generally available.

REFERENCES

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2) Flammability test for thin flexible materials. British Standard 476 : Part 2 : 1955.

3) COLEBROOK L. et al. The prevention of burning accidents. Brit. med. J., 1956, 1 (4930) 1379-86.

4) COLEBROOK, L. and COLEBROOK, V. The prevention of burns and scalds. Lancet, 1949, 2 (6570) 181-8.

PC.

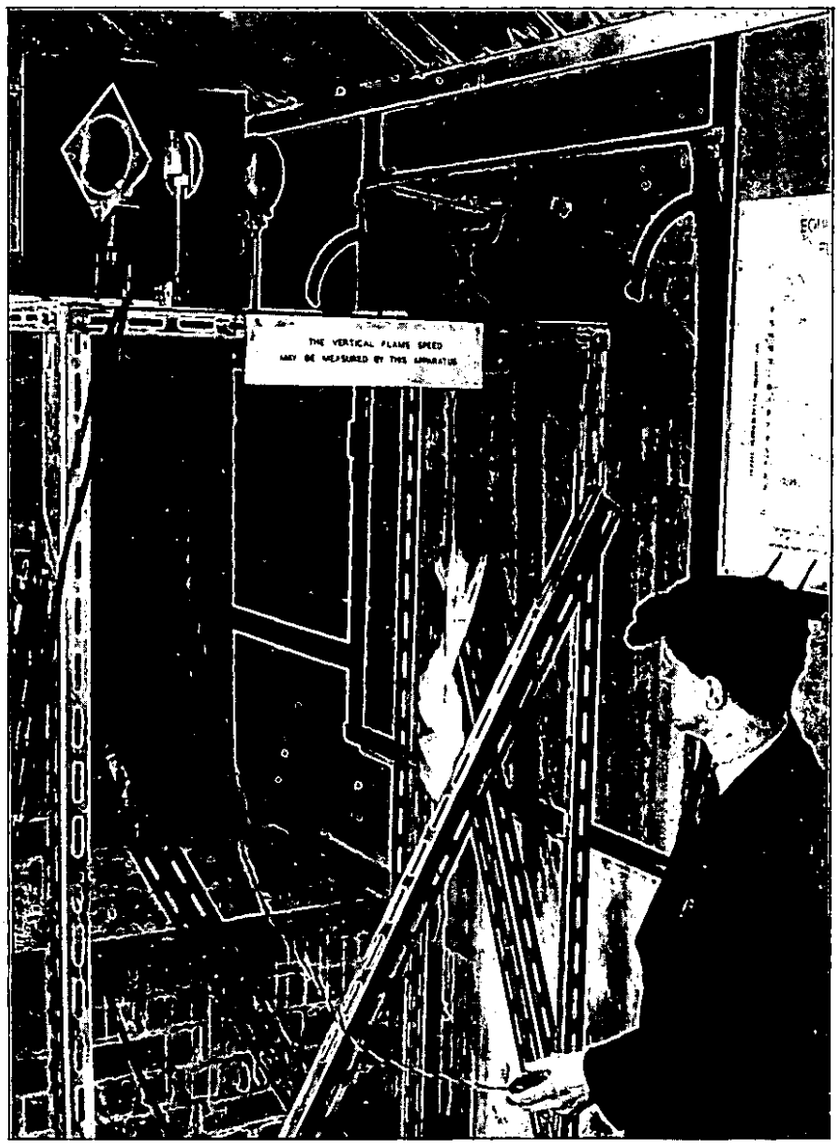


FIG.I. APPARATUS FOR MEASURING VERTICAL FLAME SPEED

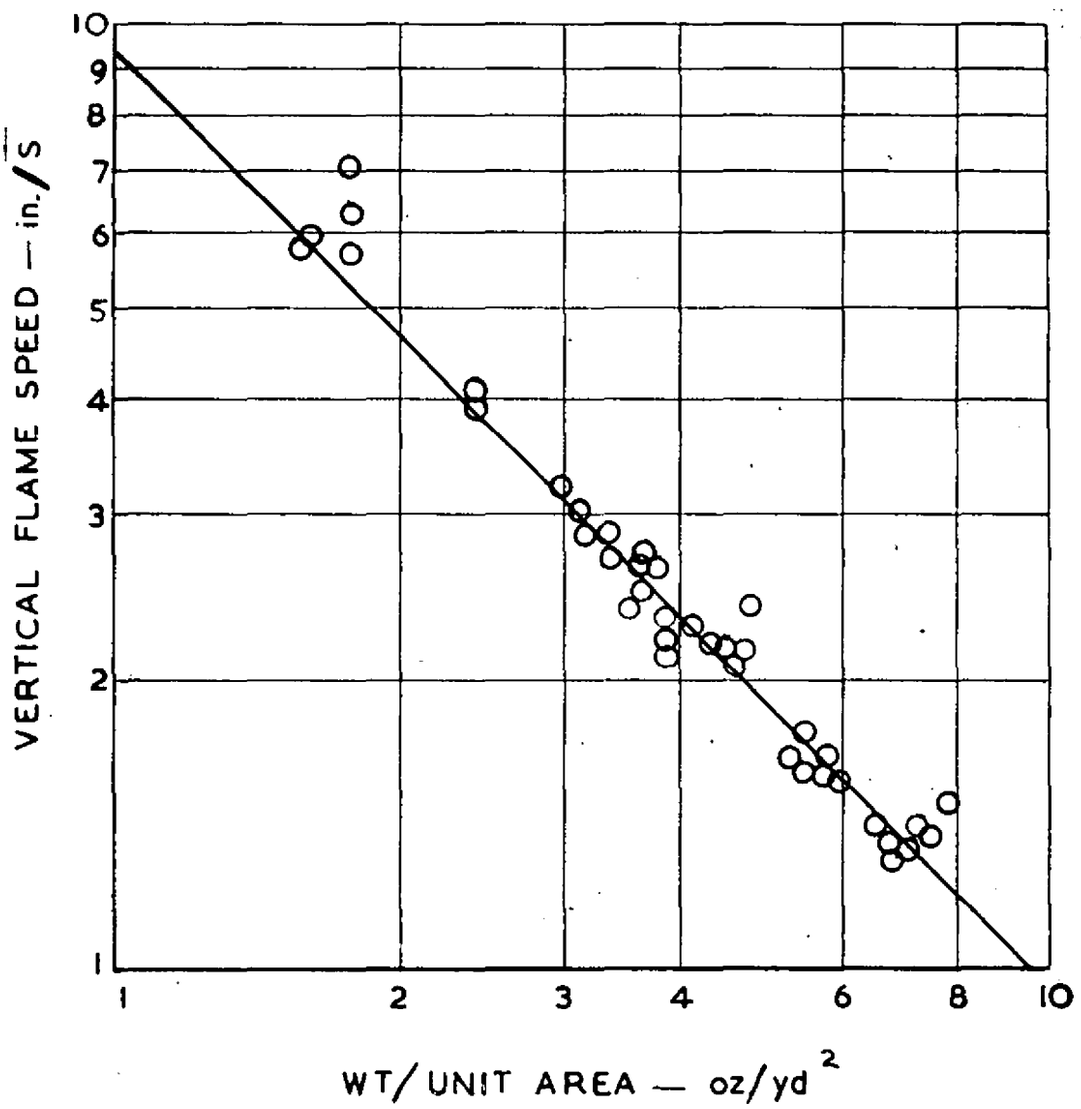


FIG. 2. RELATIONSHIP BETWEEN VERTICAL FLAME SPEED (V) AND WT. PER UNIT AREA (W) FOR CELLULOSIC MATERIALS

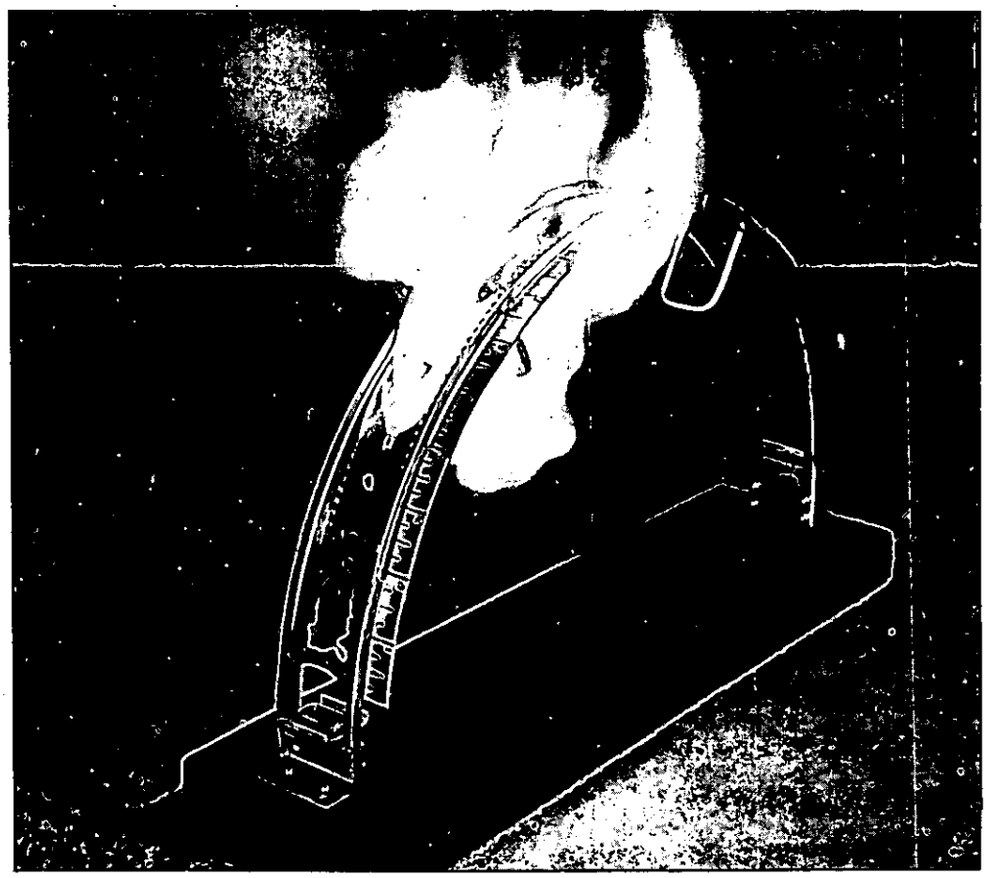
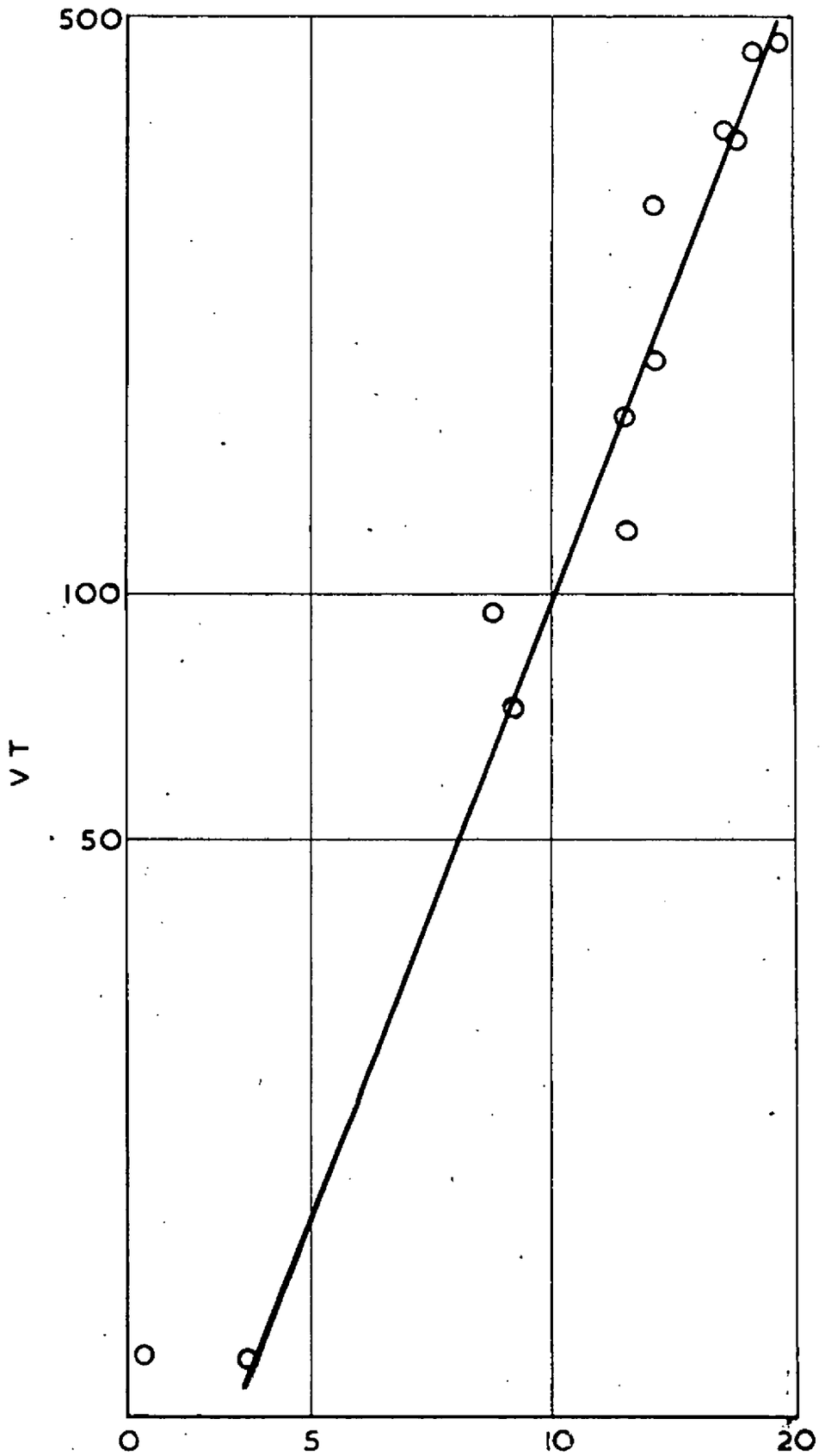


FIG. 3. SEMI-CIRCULAR APPARATUS FOR CLASSIFYING FABRICS



$VT = 0{\cdot}31D^{2{\cdot}5}$

V = vertical flame speed in in./s

T = time in sec to spread distance D in.

FIG. 4. ESTIMATION OF VERTICAL FLAME SPEED

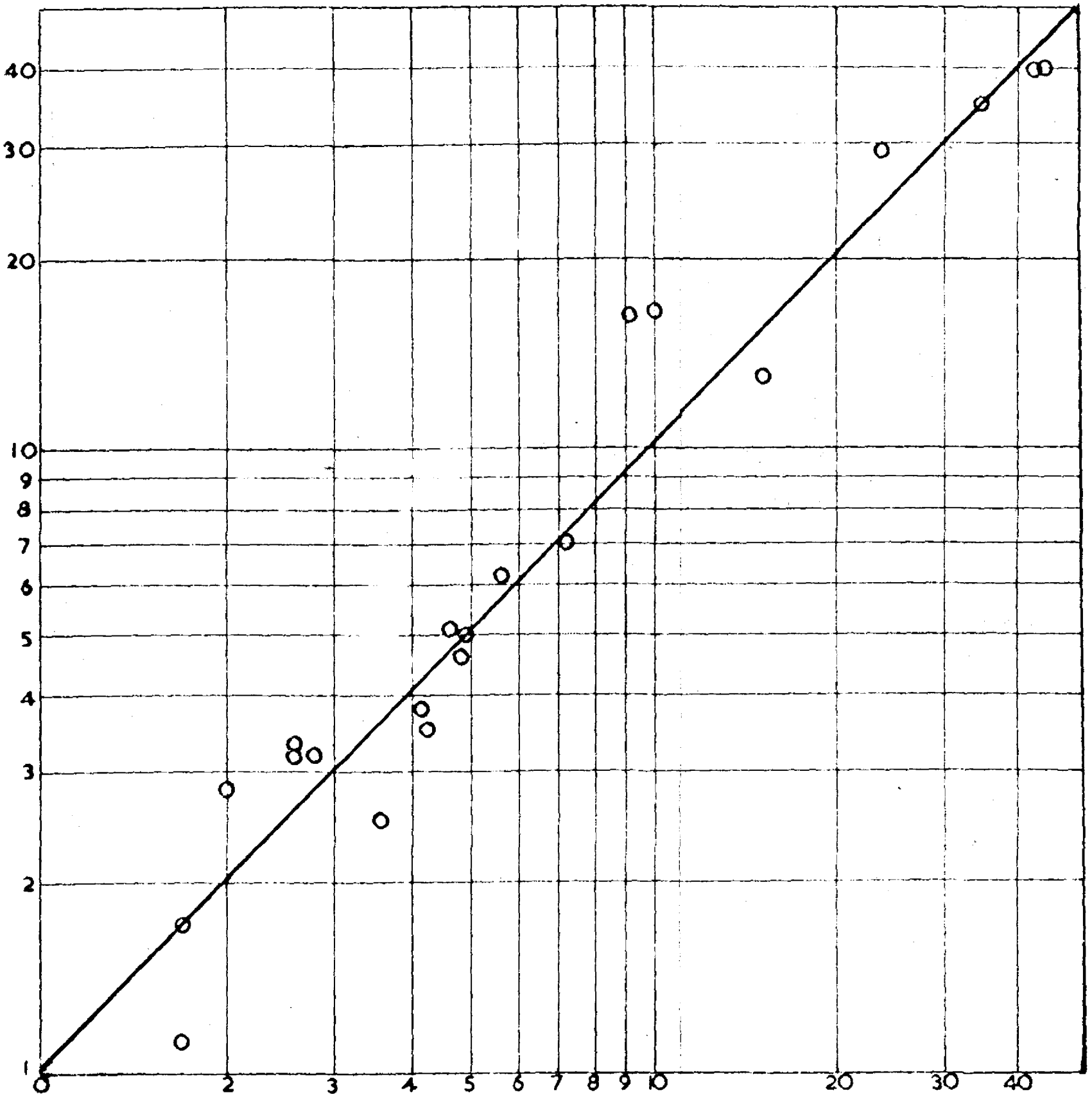


FIG. 5. COMPARISON OF MEASURED AND CALCULATED VERTICAL FLAME SPEEDS

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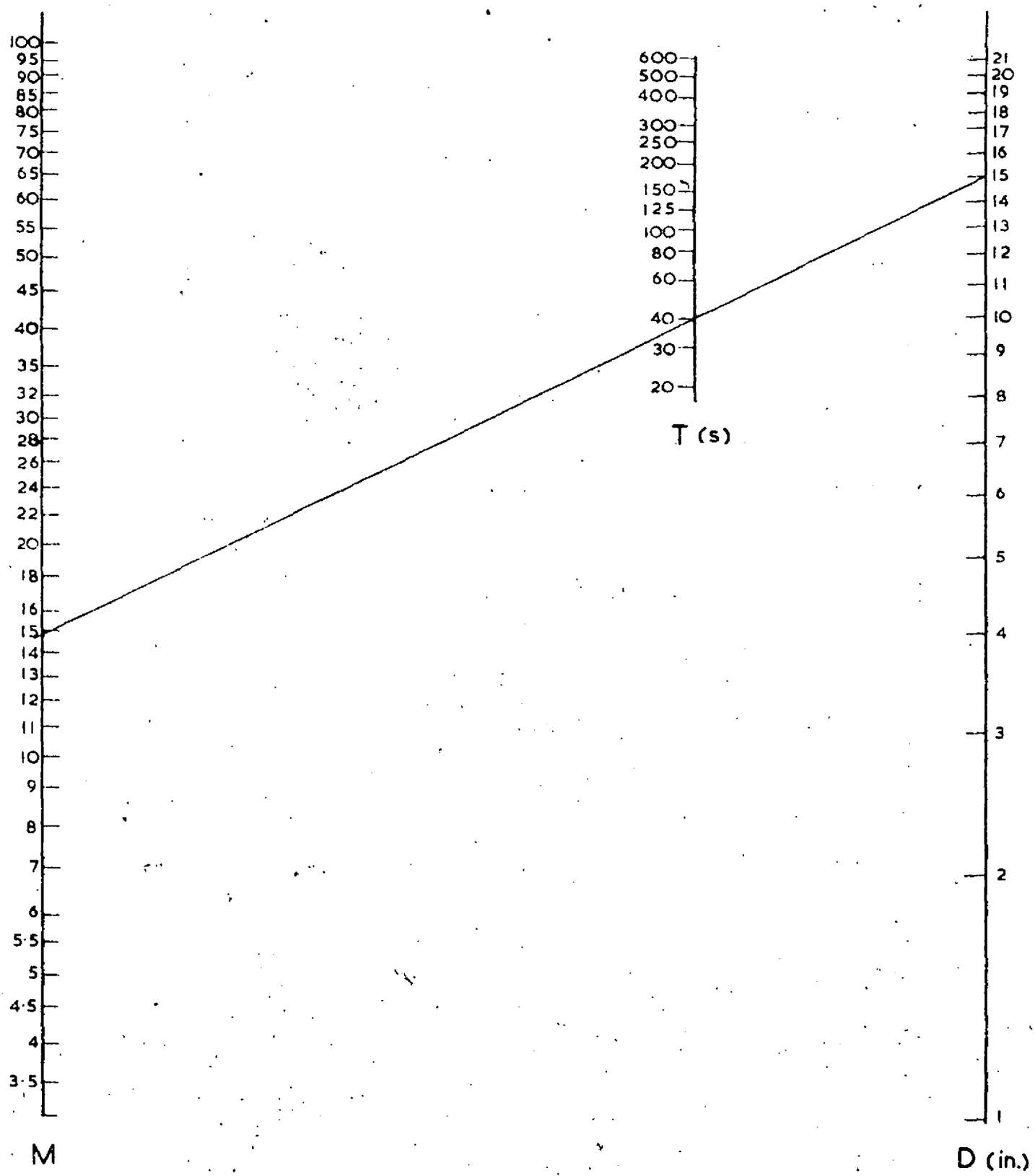

FIG. 6. NOMOGRAM OF $M = \frac{320\,T}{D^{2.5}}$

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DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH AND FIRE OFFICES' COMMITTEE
JOINT FIRE RESEARCH ORGANIZATION
Station Road, Boreham Wood, Herts.

REPORT FORM FOR INVESTIGATION ON BURNS DUE TO FABRICS

(For notes on completing form see back of envelope)

Name of patient .....

Address .....

CODE	ITEM	COLS
	Report No.	1-5
	Date	6-11
	SEX	12
1	Male	
2	Female	
	Age (years)	13-14
	TYPE OF CASUALTY	15
1	Fatal	
2	Non-fatal	
	PARTS OF BODY BURNED (Indicate all parts burned)	
1	Head	16
1	One arm	17
2	Both arms	
1	One leg	18
2	Both legs	
1	Trunk, upper front	19
1	Trunk, lower front	20
1	Trunk, upper back	21
1	Trunk, lower back	22
	AREA OF BURNS (% of body area)	23-24
01	Less than 5%	
02	5-10%	
03	10-15%	
04	15-20%	
05	20-25%	
06	25-30%	
07	30-35%	
08	35-40%	
09	40-45%	
10	45-50%	
11	More than 50%	
	DEPTH OF BURN	25
1	Full skin thickness	
2	Partial skin thickness	

CODE	ITEM	COLS
	GARMENT FIRST IGNITED	26-27
01	Nightgown	
02	Pyjamas	
03	Dressing gown	
04	Underwear	
05	Dress or frock	
06	Trousers	
07	Skirt	
08	Shirt	
09	Blouse	
10	Cardigan or pullover	
11	Coat or jacket	
12	Bedding	
	Other than above	
	.....	
	.....	
	.....	
99	Unknown	

THIS SECTION FOR USE OF FIRE RESEARCH STATION

	FABRIC	
	Type	28-29
	Wt./cm2(mg)	30-31
	Distance of spread	32-33
	Time round whole arc (sec)	34-36
	Vert. flame speed (cm/sec)	37-38

CODE	ITEM	COLS
	LOCATION OF ACCIDENT	39
1	At home	
2	At work	
3	Out of doors	
4	Elsewhere	
5	Unknown	
	SOURCE OF IGNITION	40-41
01	Open coal fire	
02	Gas fire	
03	Electric fire	
04	Oil stove	
05	Closed stove (coal or coke)	
06	Gas cooker or ring	
07	Electric cooker or ring	
08	Smoking materials	
09	Matches	
10	Matches - children playing with	
11	Candle or taper	
	Other than above	
	.....	
	.....	
99	Unknown	
	USE OF GUARDS (Complete if source) of ignition was any heating appliance)	42
1	Guard in use	
2	Guard not in use	
3	Unknown	
	ASSISTANCE TO INJURED PERSON	43
1	Other persons present to assist	
2	No-one present to assist	
3	Unknown	
	Remarks	
	.....	
	.....	
	.....	

FIG.7. REPORT FORM FOR INVESTIGATION OF BURNS DUE TO FABRICS

DS45007/1 180 60 7/56CL

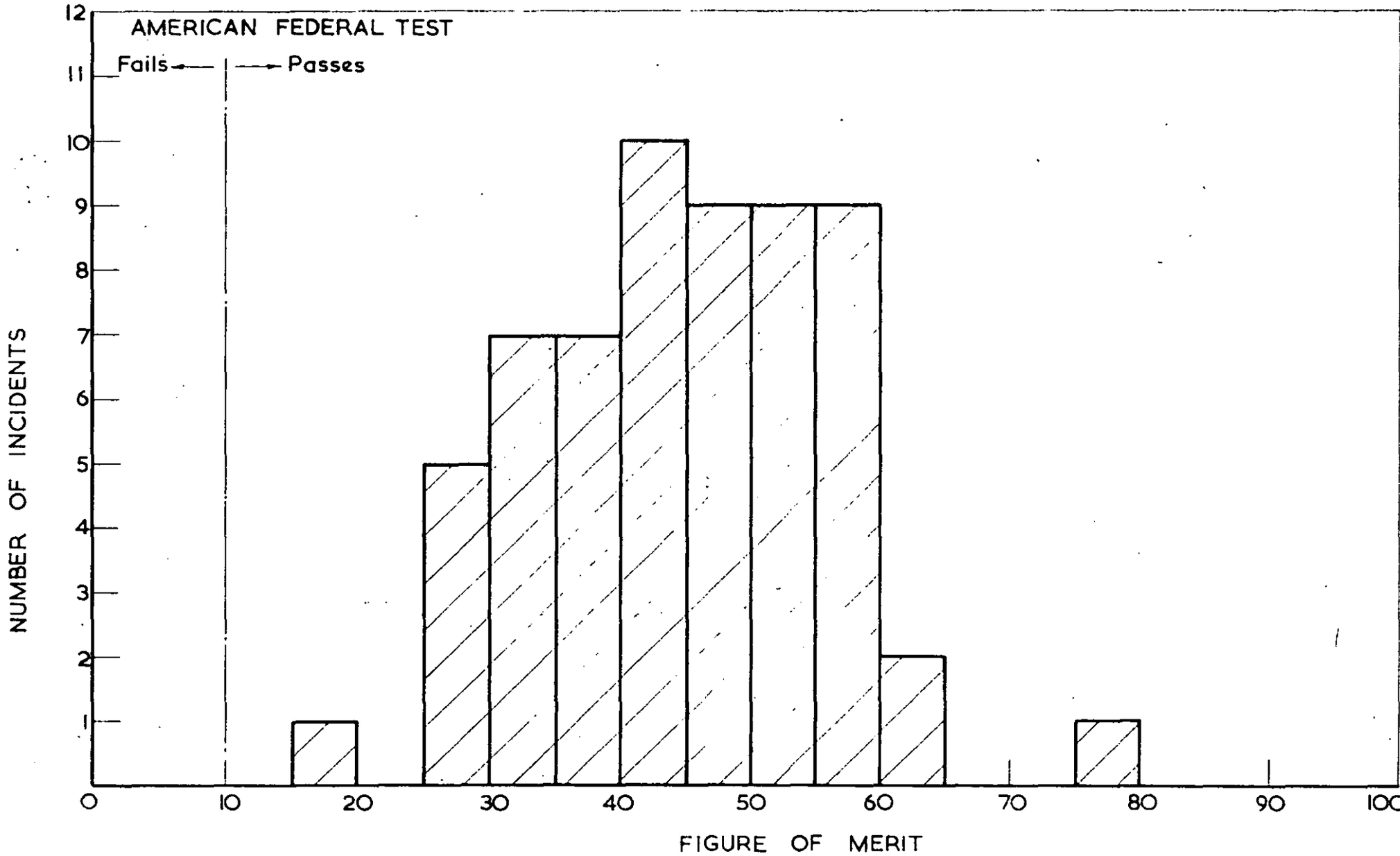

FIG. 8. VARIATION OF NUMBER OF INCIDENTS WITH FIGURE OF MERIT

INCLUDING R.F.I.B. INCIDENTS AND ALL OTHERS.

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