Fire Research Note 739

FIRE
RESEARCH
STATION

Fire Research Note No. 739

THE FIRE PROPAGATION TEST : ITS DEVELOPMENT AND APPLICATION

by

BARBARA F. W. ROGOWSKI

April 1970

FIRE RESEARCH STATION

F.R. Note No. 739.
April, 1970.

THE FIRE PROPAGATION TEST : ITS DEVELOPMENT AND APPLICATION

by

Barbara F. W. Rogowski

SUMMARY

The development of the 'Fire Propagation' test from work on fires in full and small-scale rooms, finished with different lining materials, is reviewed. The assessment of the contribution of these materials to the growth of fire in a compartment and the possible application in legislation of the derived 'performance index' is discussed.

KEY WORDS: Wall linings, flammability test, compartment, fire growth, test.

MINISTRY OF TECHNOLOGY AND FIRE OFFICES' COMMITTEE
JOINT FIRE RESEARCH ORGANIZATION

F.R. Note No. 739.
April, 1970.

THE FIRE PROPAGATION TEST : ITS DEVELOPMENT AND APPLICATION

by

Barbara F. W. Rogowski

INTRODUCTION

Fire in a building, whilst governed by many factors, is dependent to a large extent on the combustible materials available, either incorporated in the structure of the building or in the form of contents; the nature and configuration of such materials can affect the initial rate of growth, whereas the amount present, the fire load, can affect the duration and severity of the fire. Fire spread beyond the compartment of origin can be limited by requiring the elements of building construction which enclose it to have appropriate fire resistance, this being the ability of such an element to provide, for a certain period of time under standard fire conditions, resistance to collapse, flame penetration and excessive heat transmission. Combustible materials may be incorporated in a suitably designed fire-resisting structure, and indeed, use of non-combustible materials alone is no guarantee of the element providing satisfactory fire resistance.

The use of combustible materials in the building structure, however, must be carefully controlled and tests are devised to assess the fire hazard of materials as well as the fire resistance of entire elements of construction. A test of the former type is not usually designed to give any indication of the effect on fire resistance of using a given material.

During the early stages of a fire, one of the factors having an immediate effect upon the rate of growth is the nature of the internal linings of both walls and ceilings. These may be of a combustible or non-combustible nature: if the latter, no direct heat contribution is made to the fire spread but their thermal insulation can affect the development of the fire by conserving heat and leading to earlier ignition of any combustibles present. The term 'non-combustible' as defined in the Building Regulations is not as rigid as implied by the term itself.

In general, organic materials are combustible, but a combination of organic and inert materials may result in a product having such a negligible combustible content that it may be used with safety in any situation. A test[1] is in general use to distinguish between combustible and non-combustible materials; the test criteria allow materials with a low organic content to be rated as non-combustible.

If the internal linings are combustible, the degree of hazard which they present must be assessed in order to judge their suitability for use in various parts of different types of buildings. The properties of linings which influence their performance in fire are the thermal properties, the ease of ignition, the rate of flame spread over the surface and the amount of heat released on combustion.

Until the enforcement of the Building Regulations for Scotland[2] in 1963 and for England and Wales[3] in 1965, restriction of the use of flammable internal linings was enforced only in certain occupancies, for example, schools, factories and places of public entertainment. Under the Building Regulations, control was extended to most occupancies, with highest standards being specified on escape routes.

HISTORY

The rate of spread of flame over the surfaces of wall or ceiling linings has been measured in this country by the 'Surface spread of flame' test[4] since the publication in 1945 of an amendment to British Standard 476. The test was developed as a result of experiments on the development of fires in corridors and corners of buildings. It involves exposing a vertical sample of the lining material, measuring 914 mm x 228 mm (36 in x 9 in)* to the heat from a vertical radiation panel 914 mm (3 ft) square. The radiation gradient is such as to give exposure conditions of 3.7 W/cm^2 at the end of the sample nearest to the panel to 0.75 W/cm^2, 3 ft away from it. A small gas flame playing on the hotter end provides pilot ignition of the material. The rate of flame spread on the surface is measured, and the material is classified in one of four grades, Class 1 representing the best performance.

*In the revision of the 'Surface spread of flame' test (B.S. 476 : Part 7 to be published) the sample size will be altered to 900 mm x 230 mm.

When the Building Regulations were being formulated, it was found that, for situations where a high degree of safety was required, a sub-division of Class 1 was essential. This was not possible using the 'Surface spread of flame' test itself, and an arbitrary distinction, based on the physical characteristics of the material was introduced to define a new class[2,3] termed A or O. This class comprised either non-combustible materials or those obtaining a Class 1 'Surface spread of flame' rating, consisting of either a non-combustible substrate with not more than 0.8 mm ($^1/_{32}$ in) of combustible surfacing, or a combustible substrate with at least 3.2 mm ($\frac{1}{8}$ in) of non-combustible surfacing. This sub-division of Class 1, with its arbitrary specification, was felt to be unduly restrictive towards the further development of lining materials, and in particular of products containing a small quantity of organic material as a homogeneous mixture which marginally failed the non-combustibility test.

Problems were also encountered when testing some thermoplastics products on the 'Surface spread of flame' apparatus because of their tendency to melt and fall away from the specimen holder in advance of the flame front.

A further shortcoming of the 'open' type of test, such as the 'Surface spread of flame' test is that products of combustion are immediately dissipated into the atmosphere and no significant contribution is made by the heat evolved from the test material during its combustion towards its further decomposition, as is likely to occur in an actual fire. At best, therefore, the test provides an incomplete measure of the effect that a given material is likely to have on the growth of fire in a compartment.

In 1949, investigation of the development of fire in full-scale houses[5] lined with different surfaces showed a distinct variation in the time for a fire in a compartment to develop to 'flashover'. This phenomenon is complex, but is usually taken as the point during fire development at which the temperature of all combustible surfaces has risen to an extent such that flammable gases are being evolved, and a merging of flames results in the whole compartment becoming involved. Tests on actual houses were followed by studies of fire development[6] in replicas of the room used as the fire compartment on one-half, one-fifth and one-tenth scale. It was found that good correlation could be achieved between the times taken for a fire to develop to 'flashover' in the full-scale and small-scale rooms. Further, it was found that a similar grading of materials according to their time to 'flashover' on the scale model, could be obtained when the lining material under test was applied only to the walls, or only to the ceiling, the rest of the surfaces being of a non-combustible nature.

Comparison of the grading of materials according to the 'Surface spread of flame' test with the times to 'flashover' using the same materials as linings in the small-scale tests, showed a similar ranking, but the differences between materials were of a different magnitude[6]. Linings achieving a Class 1 performance on the 'Surface spread of flame' test were found to give a wide range of 'flashover' times in the small-scale test, showing the 'Surface spread of flame' test to be only a coarse measure of their suitability for use in situations where a high degree of safety is required.

A test, based on the experience of the full-scale and small-scale room tests, was therefore developed incorporating a non-combustible enclosure lined partially with the material under test. It is interesting to note that, during recent years, tests devised in other countries to assess the hazard of lining materials have also tended towards the use of an enclosure in preference to an unconfined environment.

Within the enclosure selected, the material was subjected to controlled sources of heat leading to decomposition of the combustible constituents; a measure of the liberated heat provided an indication of its performance under fire conditions. The combustion gases were extracted through a chimney and cowl assembly attached to the top of the combustion chamber and the time-temperature curve of the gases obtained with a non-combustible lining, compared with that obtained when one wall of the combustion chamber was lined with the material under test, provided a measure of the heat output from this material. The wide range of performance of different materials, particularly amongst those of low hazard, allowed grading of materials in order of merit to a considerably finer degree than was possible with the 'Surface spread of flame' test. Furthermore the enclosed apparatus overcame the difficulties experienced in testing some plastics on the 'Surface spread of flame' test. The test was called the 'Fire propagation' test, and was published as a standard by the British Standards Institution in June 1968[7].

DESCRIPTION OF APPARATUS

The earliest experiments with the apparatus described in this paper were made in 1955[8]. The test apparatus (Fig.1 and Plate 1) consists essentially of a combustion chamber, constructed of asbestos board 12.5 mm ($\frac{1}{2}$ in) thick of density 1.3-1.45 g/cm^3 (80-90 lb/ft^3), the internal dimensions being 190 mm x 190 mm x 90 mm ($7\frac{1}{2}$ in x $7\frac{1}{2}$ in x $3\frac{1}{2}$ in) wide. One of the larger faces is replaced by a specimen holder, 330 mm x 330 mm (13 in x 13 in) constructed of similar asbestos board into which a sample of the material under test, 228 mm x 228 mm (9 in x 9 in) is inserted.

The back of the specimen holder is 25 mm (1 in) thick, and holders with recesses of varying depths up to 50 mm (2 in) may be constructed. The holder has locating holes at the corners, and is fitted onto four rods fixed to the combustion chamber. An asbestos paper gasket is added to provide a good seal, the assembly being held in position by compression springs and cotter pins.

The face opposite to the specimen holder incorporates a mica observation window, 50 mm x 50 mm (2 in x 2 in) situated in the centre of the wall, above the air inlet opening which is located at the base of the chamber and measures 95 mm x 25 mm ($3\frac{3}{4}$ in x 1 in).

On the top face of the combustion chamber a chimney measuring 38 mm ($1\frac{1}{2}$ in) internal diameter and 190 mm ($7\frac{1}{2}$ in) long made of 1 mm (19 S.W.G.) thick steel is fixed over a 38 mm ($1\frac{1}{2}$ in) diameter central hole and has a removable steel cowl 152 mm (6 in) high x 76 mm (3 in) internal diameter, two bushed holes being provided 21 mm (0.8 in) above the base, to allow insertion of the thermocouples which measure, continuously during the test, the temperature of the flue gases. Further details of the apparatus are given in the British Standard[7].

The heating supply to the combustion chamber consists of both gas and electricity. A stainless steel horizontal tube of 9 mm ($\frac{3}{8}$ in) bore is located in the chamber 25 mm (1 in) above the base, having a row of 14 holes, each of 1.5 mm ($^{1}/_{16}$ in) diameter at 12.5 mm ($\frac{1}{2}$ in) centres, arranged so that the holes are 3 mm ($\frac{1}{8}$ in) from the specimen face, the inlet to the tube being placed centrally in the base of the apparatus and the joint made good.

Two pencil-type electric elements, each of 1000 W rating, 14 mm ($^{9}/_{16}$ in) diameter are supported horizontally with their centres 45 mm ($1\frac{3}{4}$ in) from the face of the specimen, located symmetrically in the chamber at 64 mm ($2\frac{1}{2}$ in) centres. The elements are sheathed with protective transparent silica tubes 1 mm ($^{3}/_{64}$ in) thick of 17 mm ($^{11}/_{16}$ in) internal diameter. The elements are connected in parallel by copper bus bars.

TEST PROCEDURE

The detailed procedure for conducting the tests is given in the British Standard specification; the following notes touch upon some of the more important aspects.

The supply of heat to the combustion chamber is rigidly specified, the gas being metred to supply 530 W (30 Btu/min) from 0-20 min (the duration of the test period), and the electrical supply is switched on 2 min 45 s after the start of the test to give an input of 1800 W. The latter is reduced at 5 min to 1500 W, and retained constant till the end of the test. To ensure that standard heating conditions are obtaining within the apparatus, calibration is effected by testing a sample of 12.5 mm ($\frac{1}{2}$ in) thick asbestos board of density similar to that of the combustion chamber itself. Before any specimens are tested, it is essential to obtain a repeatable time-temperature relationship which for any particular apparatus falls within specified tolerance limits.

After a consistent calibration is achieved, a sample of material under test is inserted into the specimen holder and the temperature rise of the flue gases throughout the 20 min test recorded. The mean temperature rise curve for three specimens is obtained.

Failure to obtain a suitable calibration curve may be due to incorrect construction of the apparatus or to the operating technique; typical faults are listed in Appendix I.

ASSESSMENT OF PERFORMANCE

Typical temperature-time curves for various materials are shown in Fig. 2. The calibration curve indicates the temperatures in the chimney obtained when the standard asbestos board is tested, and gives a measure of the balance between heat supplied to the apparatus and that lost by radiation and conduction from the combustion chamber. The difference between the calibration and material curves is a measure of the heat generated on combustion of the specimen. The temperature difference will depend also on the thermal properties of the sample; this is likely to be more significant for materials having a low combustible component.

When considering internal linings from the life hazard aspect, the time at which heat release occurs is of major importance; an early release is indicative of ease of ignition and spread of flame. If the time of occurrence of maximum heat release is delayed, i.e. ignition is possible only under more severe heating conditions, then the performance will often be superior, even if the magnitude of this release is greater than that of another material where an earlier peak is exhibited.

Early methods of assessment of performance were directed towards distinguishing materials where the flue gas temperature during test rose more than 50 deg C above the temperatures obtained during calibration. The time at which this 'standard' time-temperature curve (calibration curve + 50 deg C) was crossed by the material curve was used to derive an index of performance; the contribution the material would make to a fire was assessed according to the maximum temperature difference between the material and the standard curve, and the time at which this occurred.

Although this method of assessment graded most materials in an order similar to the observed performance in fires, it was found that a wide variety of materials achieved the highest classification, the material curve throughout the test failing to cross the standard curve. Thus materials whose performance throughout the test was wholly satisfactory were graded with those of heat potential low enough to prevent any crossing of the standard curve, but where, nevertheless, a very early release of heat was exhibited, indicative of ease of ignition and spread of flame.

A revised method of assessment was therefore introduced, which relied upon calculating the difference between the temperature rise obtained with the material and with the calibration samples, and relating this value to the time at which the measurement was taken. By integrating the rates thus obtained an overall assessment not only of the amount, but also of the pattern of heat release from the material was obtained. This method again failed to discriminate adequately between materials which were easily ignited but of low heat potential and those less easily ignited but having a slightly higher heat release throughout the test.

To avoid an overcomplicated method of weighting to increase the importance of the time factor as, for example, by using the square of the time at which measurements were taken, an arbitrary division of the test duration into three distinct periods was attempted. Thus readings during the first 3 minutes of the test were taken at $\frac{1}{2}$ min intervals, at 1 min intervals from 4-10 min and at 2 min intervals from 12-20 min. This method of assessment succeeded in grading materials in an order of merit similar to their observed performance in fires.

Figure 3 shows the relationship between the delay in time to flashover obtained in fires involving small-scale rooms, those fully lined with different materials[6] and their 'performance indices' on the 'Fire propagation' test, calculated as follows:

$$I = \underbrace{\sum_{\frac{1}{2}}^{3} \left(\frac{\theta_m - \theta_c}{10_t}\right)}_{\substack{i_1 \\ \text{at } \frac{1}{2}\text{-min intervals}}} + \underbrace{\sum_{4}^{10} \left(\frac{\theta_m - \theta_c}{10_t}\right)}_{\substack{i_2 \\ \text{at 1-min intervals}}} + \underbrace{\sum_{12}^{20} \left(\frac{\theta_m - \theta_c}{10_t}\right)}_{\substack{i_3 \\ \text{at 2-min intervals}}}$$

where I = index of performance

i_1, i_2 & i_3 = sub-indices for the three time components

θ_m = temperature rise recorded for the material at time t

θ_c = temperature rise recorded for the non-combustible standard at time t

and t = time in minutes from the beginning of test

Thus by summing the i_1 component at $\frac{1}{2}$ min intervals, the importance of early heat release under the influence of gas flames alone is emphasized and the occurrence of heat release only under progressively more severe heating conditions is weighted relatively less.

The revised method also has the added advantage of requiring a temperature reading at $\frac{1}{2}$ min after the start of test, a point of considerable importance when testing certain products, where the initially high rate of heat evolution may have decreased by the 1 min point.

A typical calculation of a performance index is given in Appendix II.

Examination of the comparative values of the three sub-indices of the performance index reveals, by the wide scatter of points, that different properties of the material are being assessed by the i_1 and the i_2 and i_3 components (Fig. 4).

There exists, however, a roughly linear relationship between the i_2 and i_3 indices. Since the numerical value of the i_3 index is small in comparison with i_2 (Table 1), there may be justification for future consideration of using i_2 value alone for assessing the heat evolution from a material after the initial period i_1 (Fig. 5). Such action would result in an improvement of the performance indices of materials having a high heat potential, where however, release of this heat was possible only after prolonged exposure to severe heating conditions.

It must be emphasized that the performance index is relevant only to the system tested, i.e. the thickness of the material, the face exposed, etc. For a complete assessment, the test should be performed on a complete system such as is likely to be exposed in practice to a fire. Thus the product under test may include a surface finish, may be applied to a substrate differing fundamentally from the non-combustible asbestos board backing provided by the specimen holder, or may include an adhesive. Testing of the complete system is particularly important where (i) thin materials are involved, (ii) rapid decomposition occurs, or (iii) the materials have a high thermal conductivity or are of a thermoplastic nature.

APPLICATION OF PERFORMANCE INDEX

The performance index, derived from the 'Fire propagation' test, provides a comparative measure of the contribution a material will make to heat build-up and thus to fire spread within a compartment. Values may range in descending order-of-merit from 0-100 or so. The derivation of the overall index from separate components, moreover, offers a degree of flexibility, and according to the situation in which the material under test is to be used, a limit upon overall performance (I), with or without restriction upon the individual components, may be specified. The use of the initial component i_1 alone may also be considered as an indication of the ignitability and flammability of materials.

The choice of performance limits for various situations is under discussion and data are being accumulated from tests on large numbers of different types of materials.

Results for various materials are included in Table 1 to indicate the behaviour of some typical products; these should not be regarded as applicable to all materials of that type. It is hopedthat publication of results of tests on proprietary materials will follow, as more general use is made of the 'Fire propagation' test.

CONCLUSIONS

Using the 'Fire propagation' test to assess the fire performance of different internal lining materials, it is possible to arrange them in order of merit over a wide scale. This ranking corresponds to that obtained by measuring the times to flashover occurring in fires in full-scale and small-scale rooms, lined with the material under test.

The method of assessment of the performance index gives a degree of flexibility in the specification of limited values for different situations.

REFERENCES

1. Non combustibility test. British Standard 476:Part 4:1970(To be published).

2. The Building Standards (Scotland) Regulations 1963. House of Commons Statutory Instrument 1963 No.1897 (S102). London, 1963. H.M. Stationery Office.

3. The Building Regulations 1965. House of Commons Statutory Instrument 1965. No.1373. London, 1965. H.M. Stationery Office.

4. Surface spread of flame test for materials. British Standard 476 : Part 1 : 1953 (to be revised).

5. Fires in houses. pp.24-8 Fire Research 1950. London, 1951. H.M. Stationery Office.

6. HIRD, D. and FISCHL, F. Fire hazard of internal linings. National Building Studies Special Report No. 22. London, 1954. H.M. Stationery Office.

7. Fire propagation test for materials. British Standard 476 : Part 6 : 1968.

8. HIRD, D. and KARAS, G. C. A method for classifying the fire hazard of internal linings. Joint Fire Research Organization Fire Research Note 166/1955.

APPENDIX I

OPERATING NOTES

Failure to achieve a calibration curve within the tolerance limits may be due to any of the following causes:

(i) Asbestos board other than of the specified density, may have been used in the construction of the combustion chamber and/or of the calibration sample

(ii) The chimney assembly may be overweight or underweight

(iii) The hot junction of the thermocouple may not be placed centrally between the chimney and cowl. This can be avoided to a great extent by using a thermocouple without twists beyond the hot junction. The hot junction should project 3 mm ($\frac{1}{8}$ in) beyond the porcelain insulator, and the fixing of rigid distance pieces on the insulator will ensure central positioning

(iv) The heat supply to the combustion chamber may not be within the tolerance limits specified. Changes in the calorific value of the gas should be balanced by altering the flow rate

(v) The silica tubes protecting the elements may not be of the specified dimensions

(vi) The apparatus may be exposed to draughts; a fume cupboard is not a satisfactory location, because of turbulence caused by forced convection.

The ability to obtain a repeatable calibration curve within the tolerance limits specified in B.S. 476 : Part 6[7] is essential before testing samples of materials. Renewal of worn sections of the apparatus or other structural modifications may result in a slightly different calibration curve, but this again must be repeatable. The calibration should be checked before each test is undertaken, or if in continuous use, after testing three sets of specimens. Any sudden alteration to the curve, even within the tolerance limits, should be investigated. This could be due to any of the following defects:

(i) Misplacement of the thermocouples within the cowl. The hot junctions must be located centrally. This can be ensured by rigid fixing of a distance piece over the thermocouple insulator to engage with the bushed hole to the cowl

(ii) Deterioration of the silica tubes over the elements due to exposure to acids

(iii) Deterioration of the walls of the combustion chamber. This is more likely to be a gradual process

(iv) Failure of the sealing of joints.

Once the operator is satisfied that the apparatus is functioning satisfactorily, specimens may be exposed to test. Certain types of materials have combustion features that present difficulty to the operator.

(i) Production of vast quantities of smoke. Deposition of carbon particles on the thermocouples may give anomalous temperature readings and cleaning of the hot junction during the intervals between taking readings is recommended

(ii) Evolution of flammable gases from the cowl due to insufficient air supply to the combustion chamber. Ignition of these is normally prevented by the provision of the protective shelf at the top of the chamber, but if it occurs, a further sample should be tested*.

---

*Although the full temperature rise which would be obtained with complete combustion is obviously not being recorded with materials such as these, the overall performance is so poor that the loss is unimportant

APPENDIX II

CALCULATION OF PERFORMANCE INDEX

The method of calculating the performance index of 5 mm (3/16 in) hardboard, one of the materials for which the mean temperature curve is given in Fig. 2, is illustrated below.

Time t min	θ_m °C	θ_c °C	$\theta_m - \theta_c$	$\frac{\theta_m - \theta_c}{10t}$	
½	13	11	2	0.4	$i_1 = 10.5$
1	25.7	16.5	9.2	0.9	
1½	39.3	22	17.3	1.2	
2	64	25.5	38.5	1.9	
2½	98.5	30	68.5	2.7	
3	136.7	34	102.7	3.4	
4	208.5	70.5	138.0	3.4	$i_2 = 16.8$
5	246.2	109	137.2	2.7	
6	285.5	133	152.5	2.6	
7	328.7	154.5	174.2	2.5	
8	357.6	170.5	187.1	2.3	
9	354.8	183	171.8	1.9	
10	337.3	194.5	142.8	1.4	
12	316.5	210	106.5	0.9	$i_3 = 2.8$
14	313	222	91.0	0.7	
16	308.7	229	79.7	0.5	
18	306.8	235.5	71.3	0.4	
20	309	240	69.0	0.3	

Performance index = 30.1

Table 1

Performance indices for typical materials

Material	Treatment/facing	Thickness mm	Thickness in	I	i_1	$i_2 + i_3$
Wood and wood-based materials						
Fibre insulating board	-	13	0.5	66.4	41.0	25.4
Softwood	-	18	0.7	42.5	17.2	25.3
Fibre insulating board	Emulsion painted	13	0.5	42.0	18.0	24.0
Plywood	-	6	0.2	41.2	19.5	21.7
Hardboard	Stove-enamelled coating	9	0.4	37.3	13.5	23.8
Particle board	-	18	0.7	36.3	12.8	23.5
Hardwood	-	19	0.7	34.9	9.5	25.4
Hardboard	-	5	0.2	30.1	10.5	19.6
Semi-compressed hardboard	Plastic coating	13	0.5	24.3	5.5	18.8
Hardboard	Impregnated	5	0.2	24.3	7.2	17.1
Fibre insulating board	Intumescent flame-retardant coating	13	0.5	20.0	5.9	14.1
Fibre insulating board	Impregnated	13	0.5	18.4	6.4	12.0
Softwood	Flame-retardant varnish	19	0.7	18.1	4.9	13.2
Fibre insulating board	Asbestos paper faced	13	0.5	16.5	3.8	12.7
Hardboard	Intumescent flame-retardant coating	5	0.2	16.4	4.0	12.4
Softwood	Intumescent flame-retardant coating	19	0.7	15.1	5.8	9.3

NOTE

Values given in this table are indicative of performance indices likely to be obtained from different types of linings and treatments. They are not intended to be used as values for specific materials.

Material	Treatment/facing	Thickness		I	i_1	$i_2 + i_3$
		mm	in			
Plastics-based materials						
Expanded rubber		51	2.0	99.8	80.1	19.7
Polyether foam		51	2.0	88.6	68.4	20.2
Expanded polystyrene	Gloss paint finish	9	0.4	45.1	36.2	8.9
Acrylic sheet		3	0.1	39.8	20.0	19.8
Polyurethane foam	Flame-retardant grade	35	1.4	38.7	27.3	11.4
Melamine-faced hardboard		6	0.2	32.3	12.4	19.9
Expanded polystyrene	Standard grade	25	1.0	29.4	22.1	7.3
Polyurethane foam	Flame-retardant grade	13	0.5	28.6	23.4	5.2
Glass-reinforced polyester resin		3	0.1	26.4	10.4	16.0
Melamine phenolic laminate	Flame retardant	2	0.1	18.3	5.4	12.9
Glass-reinforced polyester	Inert filler finish	5	0.2	16.9	5.5	11.4
Polyvinyl chloride		3	0.1	16.8	5.9	10.9
Glass-reinforced polyester resin	Flame retardant	3	0.1	11.2	4.0	7.2
Expanded polystyrene	Self-extinguishing grade	13	0.5	10.1	7.1	3.0
Melamine Phenolic laminate	Flame retardant	2	0.1	7.2	1.5	5.0
Coated non-combustible sheet materials						
Asbestos board	Wood veneer, > 0.8 mm thick	19	0.7	22.2	12.2	10.0
Steel sheet	Resin-coated impregnated asbestos	3	0.1	11.9	3.9	8.0
Asbestos board	Polyvinyl chloride film 0.4 mm thick	9	0.4	7.4	5.1	2.3
Steel sheet	Polyvinyl chloride coat, 0.3 mm thick	1	0.1	5.5	2.2	3.3
Steel sheet	Painted, one coat			1.7	1.3	0.4
Mineral and glass fibre wool, tiles, etc						
Mineral fibre tile with organic binder	Emulsion paint coat	22	0.9	16.6	7.7	8.9
Glass fibre, resin-bonded on steel sheet	Neoprene coated	25	1.0	10.5	5.0	5.5
Mineral fibre tile with plaster, resin-bonded		19	0.7	9.8	5.0	4.8
Glass fibre, resin-bonded, on steel sheet		25	1.0	9.6	5.1	4.5
Mineral fibre tile, organic binder		13	0.5	8.1	4.6	3.5
Glass fibre, resin-bonded		25	1.0	7.5	3.6	3.9
Mineral fibre, resin-bonded		25	1.0	6.5	4.1	2.4

Material	Treatment/facing	Thickness mm	Thickness in	I	i_1	$i_2 + i_3$
<u>Miscellaneous materials</u>						
Woodwool slab (high density)		25	1.0	11.5	5.2	6.3
Woodwool slab (low density)		51	2.0	10.3	5.2	5.1
Plasterboard	Polyvinyl chloride facing 0.2 mm	9.5	0.4	10.0	5.4	4.6
Plasterboard		13	0.5	9.9	5.8	4.1
Plasterboard		9.5	0.4	9.7	5.7	4.0
Plasterboard	Emulsion painted	13	0.5	9.0	5.2	3.8

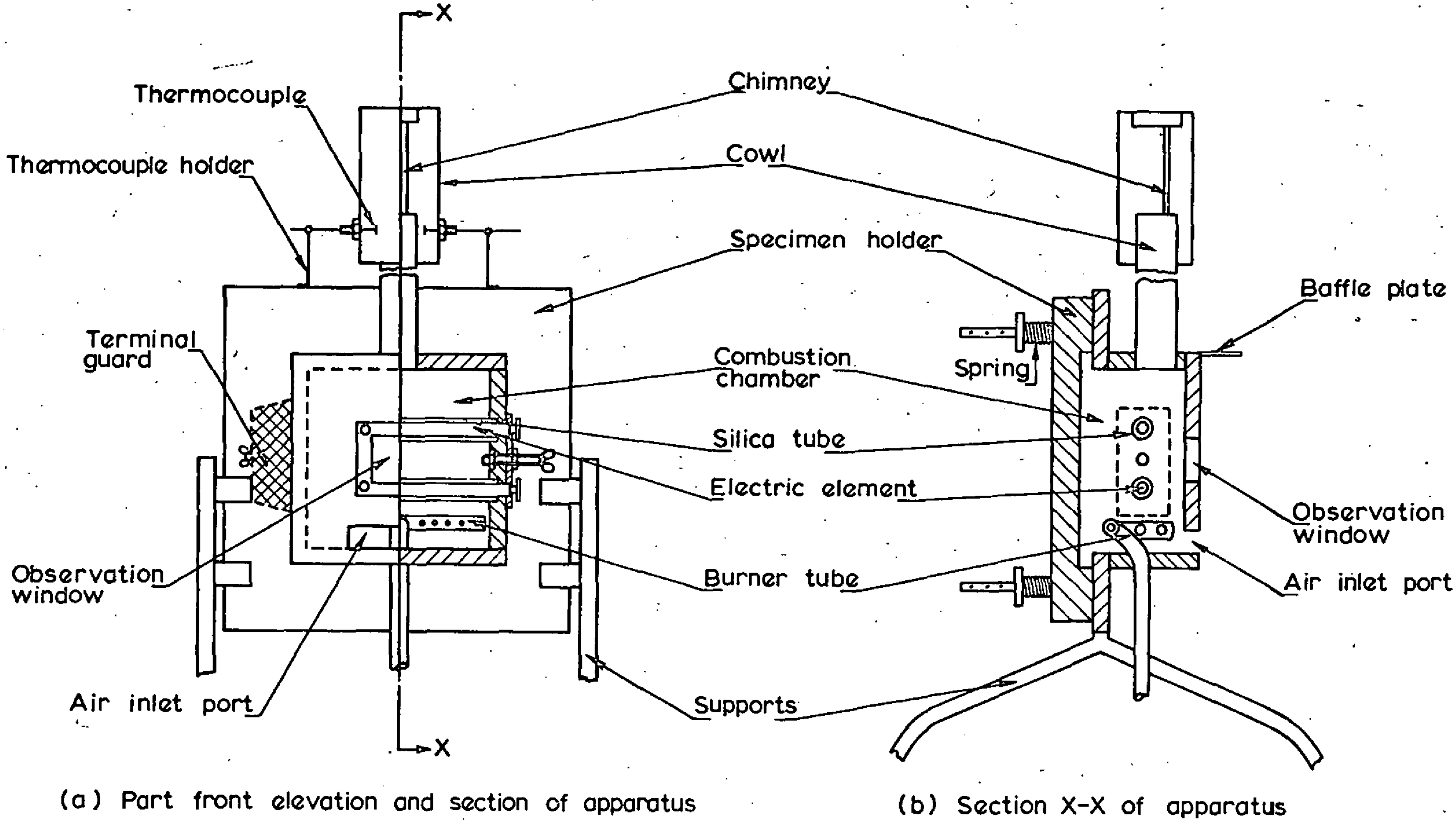


FIG. 1. 'FIRE PROPAGATION' APPARATUS

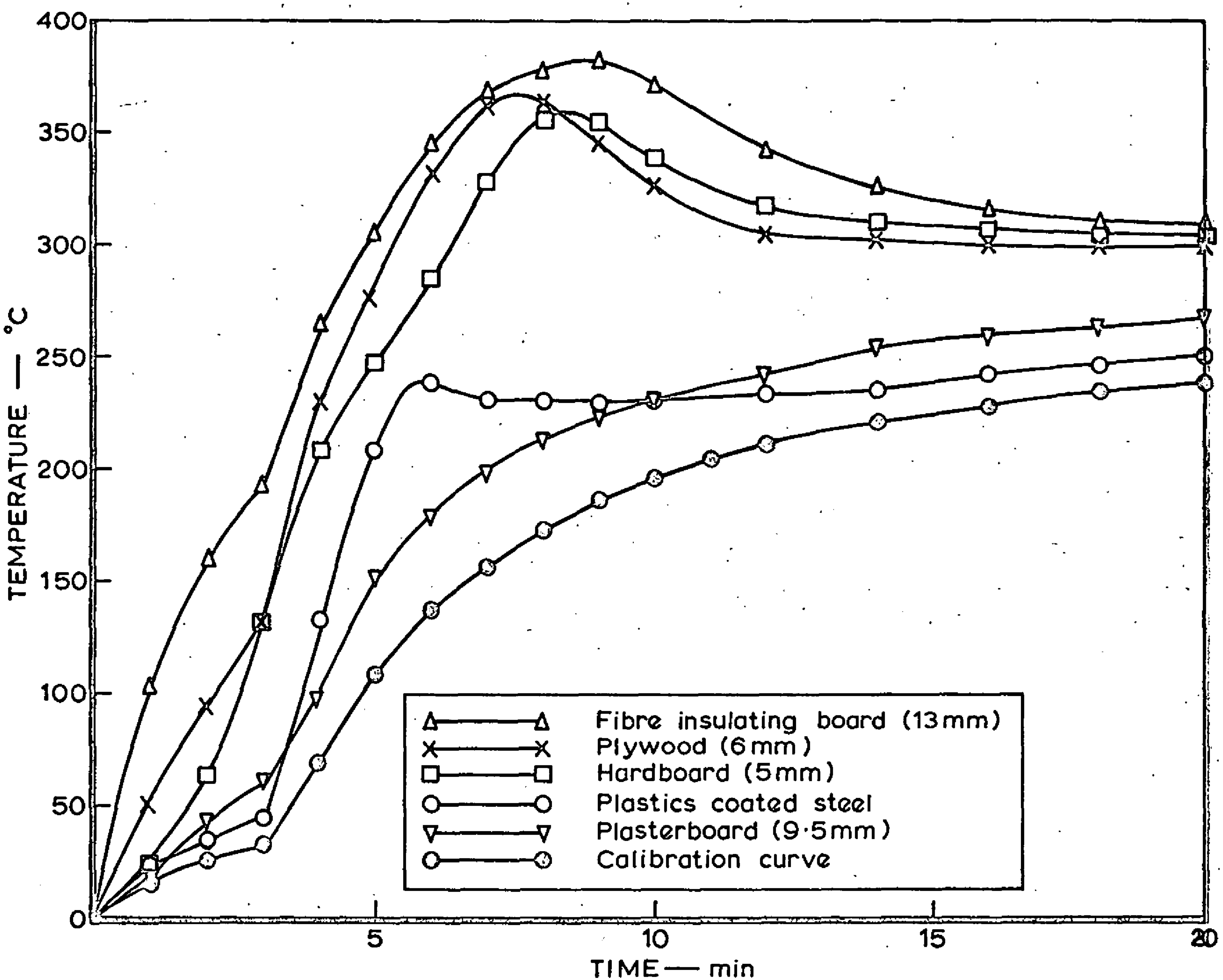


FIG. 2. TEMPERATURE-TIME CURVES FOR VARIOUS MATERIALS

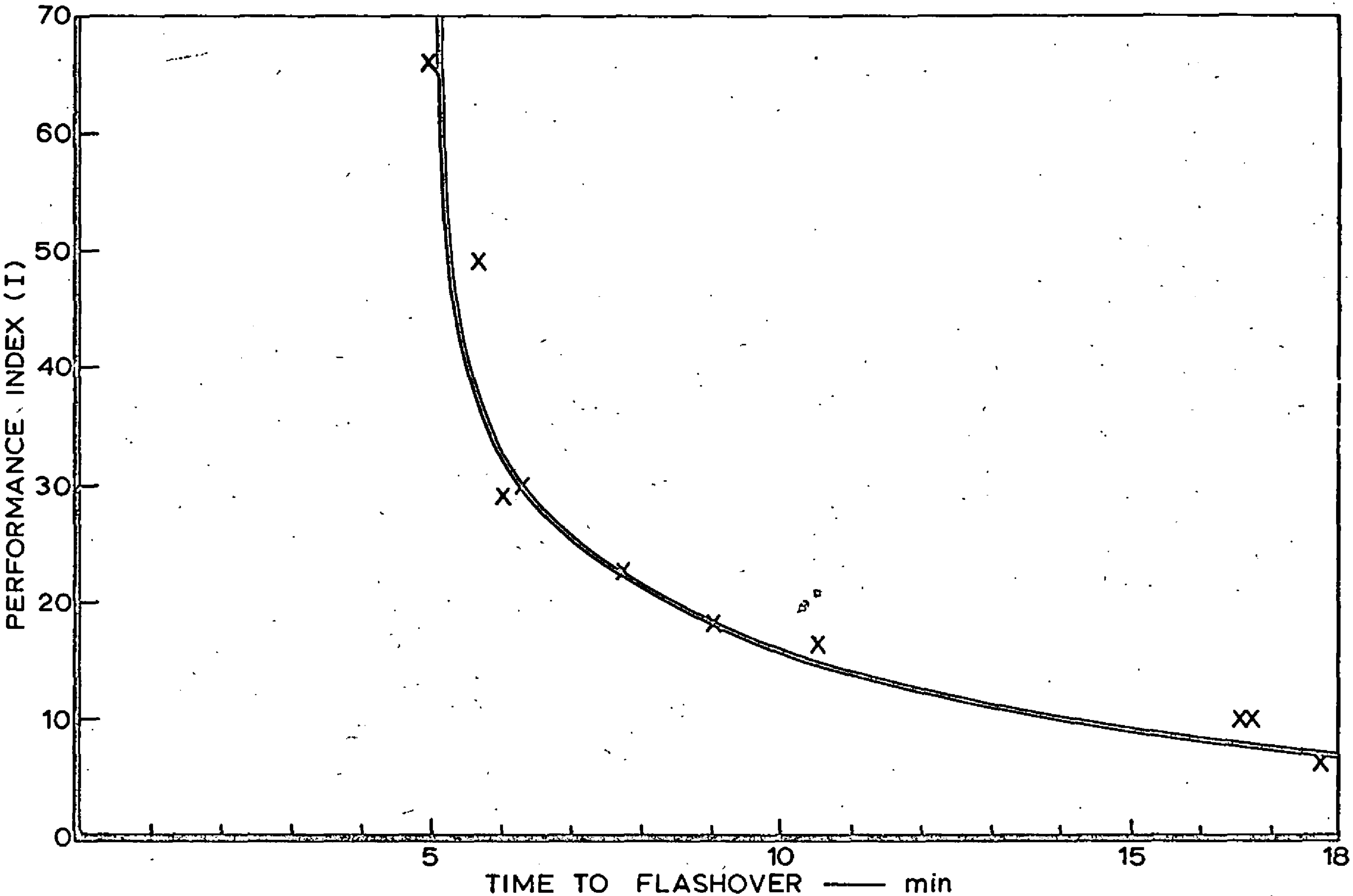


FIG. 3. RELATIONSHIP BETWEEN FLASHOVER TIME AND PERFORMANCE INDICES FOR ELEVEN MATERIALS

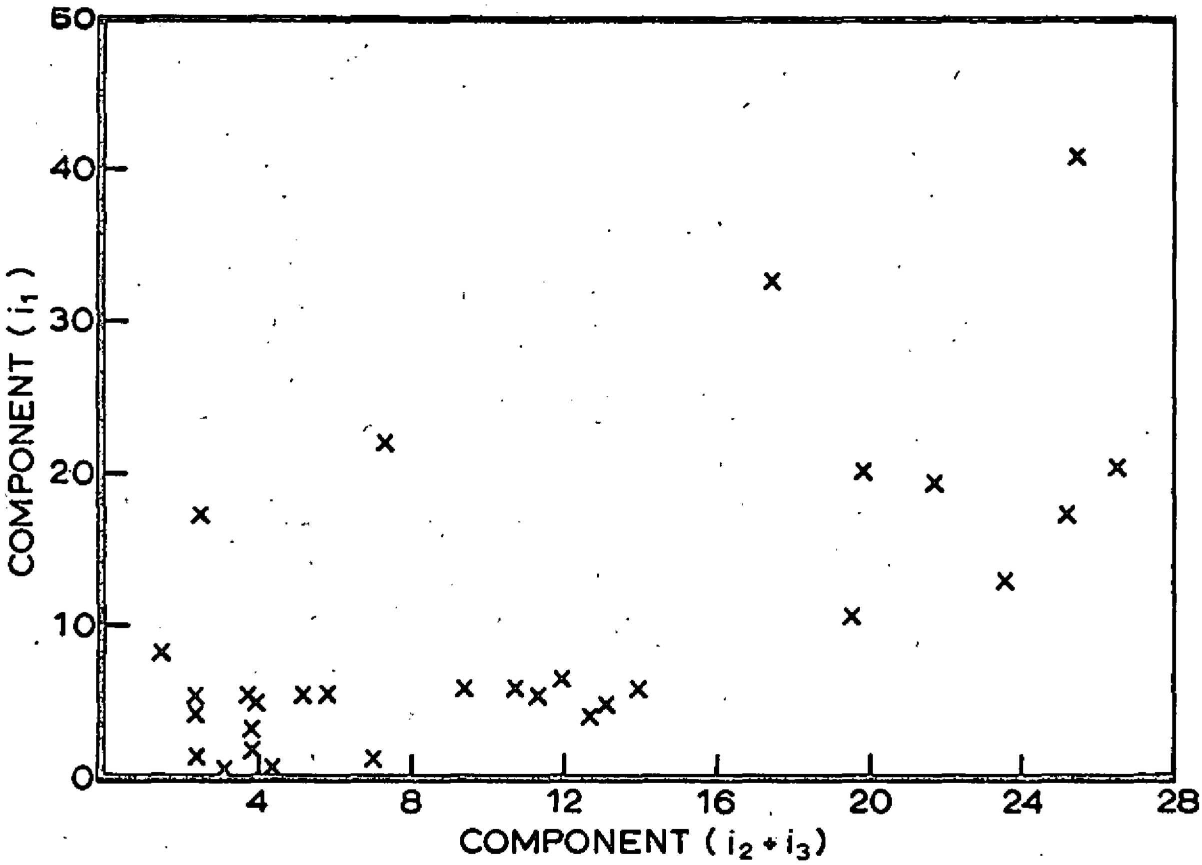


FIG. 4. RELATIONSHIP BETWEEN i_1 AND $i_2 + i_3$ COMPONENTS FOR THIRTY MATERIALS

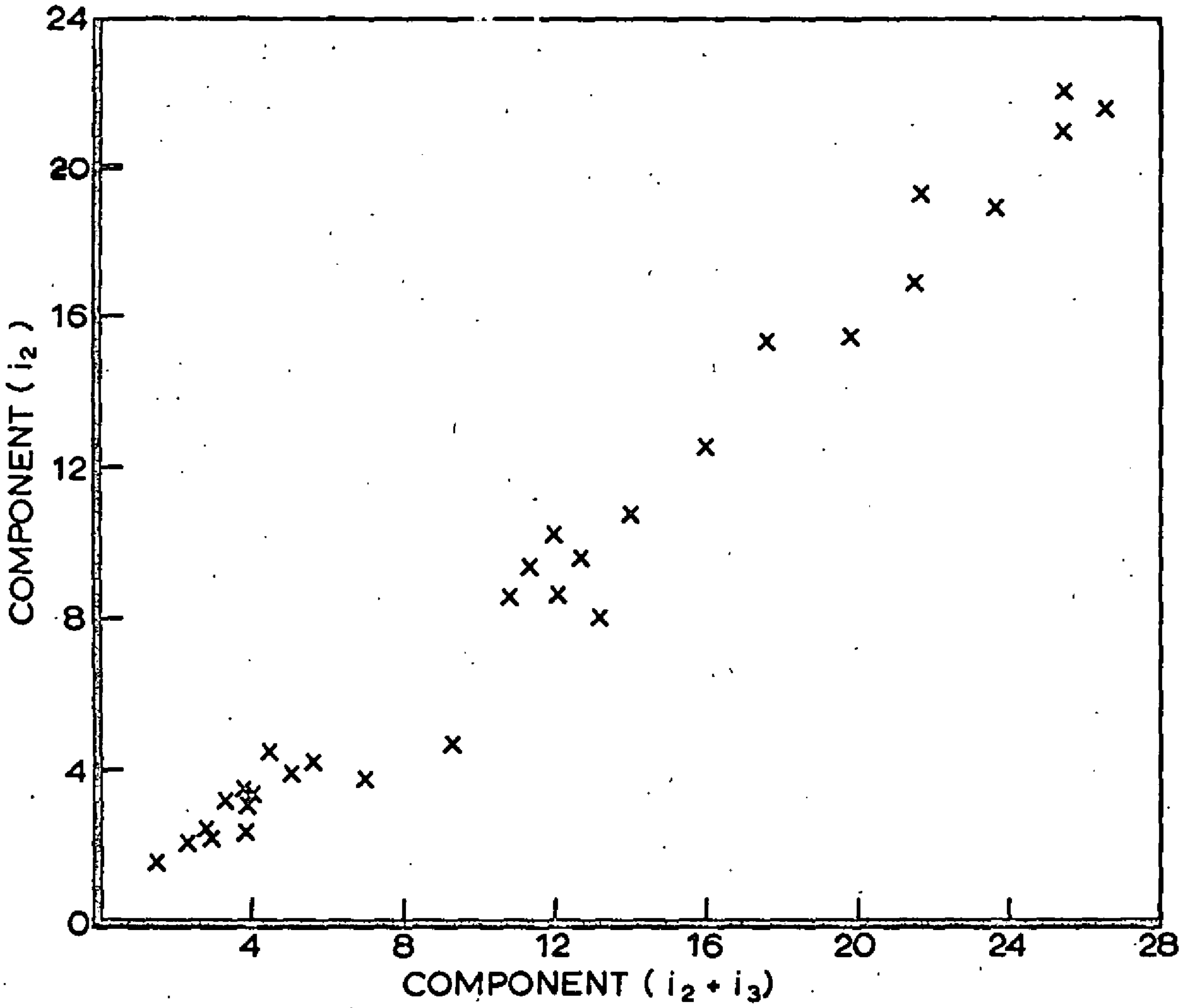
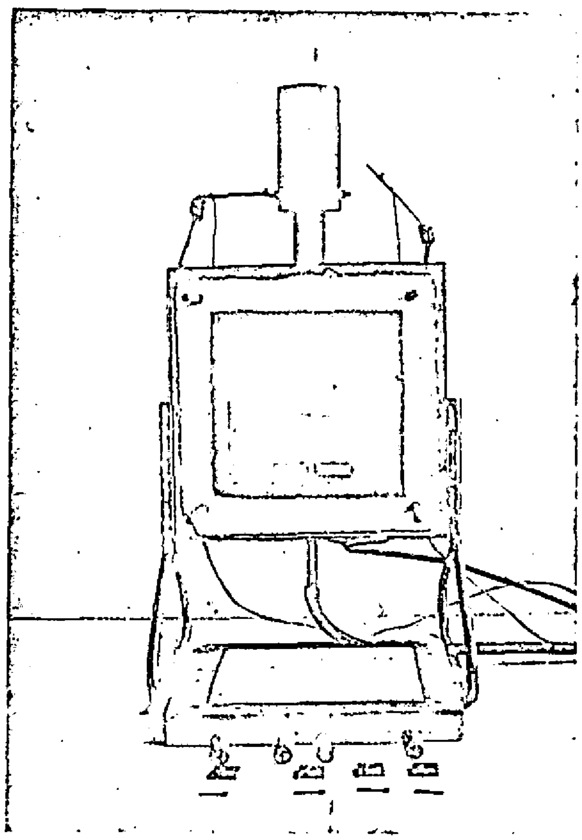


FIG. 5. RELATIONSHIP BETWEEN i_2 AND $i_2 + i_3$ COMPONENTS FOR THIRTY MATERIALS



FIRE PROPAGATION TEST APPARATUS

PLATE 1.

Fire Research Note

FIRE
RESEARCH
STATION