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THE REPEATABILITY OF A PROPOSED FLAMMABILITY TEST

by

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JOINT FIRE RESEARCH ORGANIZATION

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SUMMARY

A flammability test, which is a modification of the present British Standard tests, is described and the results for twenty-two slow burning fabrics, each tested by five laboratories, are given. The results are analysed statistically and their variability discussed. There is evidence that there are differences between laboratories greater than can be accounted for by the inherent variation in the specimens of any one fabric. Types of performance requirements are considered.

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INTRODUCTION

Every year about 300 people die and about 1 000 are badly injured as a result of their clothes becoming ignited, very often by a small source of heat. The primary effort in preventing these accidents should clearly be to remove the sources of ignition or make them safe by, for example, using closed stoves or fireguards. Where this is not possible, and when very young and old people are involved, clothing should be made from a safe fabric (one that is difficult to ignite, spreads flame slowly if at all, and emits such small quantities of heat that the skin is not burnt). A test which measures the safety of a fabric is therefore needed.

Prima facie the most suitable design for such a test is one in which the fabric is hung vertically and ignited at the base, since this is the position in which it is most likely to be dangerous, but with fabrics made from thermoplastic fibres other positions may be more hazardous.

Both the present British Standard tests[1,2] do in fact use vertical specimens, one test being for fabrics which burn, but only slowly, and the other for those which do not burn at all, or only to a very limited extent. (Appendix I).

In 1959, The Board of Trade issued Regulations, under the Fabrics (Misdescription) Act of 1913, which had the effect of making it an offence to describe a fabric as 'flameproof' unless that fabric met the performance requirement laid down in B.S. 3120/1959[3] when tested by the method of test described in B.S. 3119/1959, or to describe a fabric as of 'low flammability' unless that fabric met the performance requirements laid down in B.S. 3121/1959[4] when tested by the methods described in B.S. 2963/1958.

A number of difficulties discussed elsewhere[5] have however, arisen from these tests, due to (i) the test methods, (ii) the performance requirements and (iii) the difference in behaviour of a strip of fabric compared with a whole garment and a modified test has been proposed. The latter, used by five laboratories on a number of slow burning fabrics, is discussed below. An interim report of the work has already been published[5] but as a result of the final analysis, there have been a few modifications to the interim conclusions. The present report analyses the results, discusses their variability and considers the present performance requirements[3,4].

MODIFIED TEST METHOD

Full details of the present tests and the modifications are given in Appendix I. The modified test was as follows:

The fabrics were conditioned in an atmosphere of 65 per cent relative humidity and at room temperature. Strips 36 in long and 3 in wide were suspended in a three-sided box with an open front. The top of a bunsen burner of $\frac{3}{8}$-in internal diameter was placed $\frac{1}{2}$ in below the edge of the strip which was ignited by a $1\frac{1}{2}$-in flame. One set of experiments was done with the flame applied for 6 seconds, and another with it applied for 12 seconds, six specimens of fabric being tested in each set. If the first 10 in of the fabric burnt, the time for the flame to spread the next 20 in was measured.

The fabrics tested fell into three groups:

(A) Flame spread over the whole fabric

(B) Partial or no flame spread over the fabric

(A/B) As for (A) in some specimens and as for (B) in others.

Different measurements were made for the A and B groups, five types of measurements being made in all.

Group A

(i) The time for the base of the flame to travel 20 in was measured. This has been called Burning Time.

Group B

(ii) The time for which flaming persisted after withdrawal of the igniting flame was recorded. This has been called the Duration of Flaming.

(iii) The distance from the point of ignition travelled by the base of the flame has been called the Extent of Flaming.

(iv) Char Length was determined by measuring the extent to which the charred material could be pulled apart by hand.

(v) The existence of any Afterglow and how far it extended beyond the area originally charred was noted.

The travel of the base of the flame rather than the tip was observed because it was more difficult to follow the passage of the flame tip. However, the distance the tip of the flame reaches is obviously important and this distance is given roughly by the char length.

It is important to recognize the distinction between the burning time for Group A and duration of flaming for Group B. A fabric in Group A with a rapid flame spread could burn for only a short time but so could a Group B fabric with very little flame spread.

SELECTION OF FABRICS

Preliminary experiments showed that the test was not suitable for thermoplastic fabrics. The non-thermoplastic fabrics which were selected for test were those thought most likely to give variable results. Details of twenty-two fabrics are given in Table 1. Seventeen were of cellulose, most of them treated, and one of these was a very lightweight cotton net (2).

One fabric was wool (1) and the other four (3, 4, 9, 22) were mixtures of nylon with other fibres. One fabric was tested washed and unwashed (15 and 14) and for two fabrics (6 and 16) the 'add-on' (the amount of fire-retardant) was deliberately below normal.

PLANNING OF TESTS

Each fabric was cut into strips, of which twelve were distributed in a random fashion to each of the five participating laboratories. Laboratories 1, 2 and 3 completed the whole series of tests, but laboratory 5 did not test fabrics 1, 2, 8, 9 and 16. Laboratory 4 did not test fabric 8, and it was agreed that it need only carry out the tests using the 12-second flame application time. Laboratories 1 and 2 carried out some repeat tests on fabric 1 and their tests on this fabric are coded a, b and c in Tables 3 and 5.

The position on the original piece of fabric of each strip was recorded so that if it appeared that any treatment had been applied unevenly across the fabric this could be detected when the results were analysed.

GENERAL COMMENTS

EXPERIMENTAL METHOD

The only experimental difficulty noted was that a few specimens curled away from the flame in spite of the use of pins to hold the edges. This feature of the test increased the variability of the results.

In general, participants had no serious difficulty in making the measurements although it was found easier to measure the 'duration of flaming' and the 'char length' which had definite end points than the 'extent of flaming' and the 'burning time' where the position of the base of the flame was uncertain.

Laboratory 1 reported no spread during the afterglow period for all but one of the less flammable fabrics. The other four laboratories recorded some afterglow but they had recorded the extent measured from the base of the specimen and not the extent beyond the area originally charred. This was due

to an ambiguity in the instructions for the tests.

With some specimens of fabric 9, isolated sections of the flame front sometimes continued to burn and the flame front ceased to be continuous; with others the whole length was flaming at the same time. Flaming droplets also fell away from the other fabrics containing synthetic fibres (fabrics 3, 4 and 22) and often burnt on the floor of the box although the whole length of some specimens of fabric 22 flamed continuously.

Two types of char length were obtained, a conical type confined to the centre of the sample and due to the application of the bunsen flame, and a char covering the whole of the width of the fabric and due to the flaming of the fabric itself. No difficulties in obtaining char length measurements were reported.

EXPERIMENTAL RESULTS

Five fabrics fell into Group A, complete spread, thirteen into Group B, partial flame spread, and four were A/B where flame spread all the way on some specimens but not on others. As might be expected, the 12-second ignition time was usually more severe than the 6-second one, but five fabrics were exceptions. With three of them there was sometimes complete flame spread with the 6-second time on more specimens than with the 12-second time and with two fabrics there was a slightly longer duration of flaming. A summary of the results is given in Table 2.

As a first step, the mean value $\bar{x}$, and the variance σ^2, of each measurement, for each laboratory and each fabric, were calculated for the 12-second ignition time. The results are discussed below.

RESULTS

DURATION OF FLAMING

Table 2 shows that of the fabrics only partially spreading flame (Group B) the duration of flaming was zero for all but fabrics 1, 12 and 19.

For the latter two there were fewer zero values for the 6-second ignition time. Since fabric 1 was not tested in laboratory 5 the results for this fabric are incomplete. Not all specimens of fabrics 2, 3, 6, 20 had partial flame spread and so complete results are not available for these. The results are given in Table 3 but have not been analysed statistically because of their incompleteness. They are plotted in Fig.1 which indicates that the distribution is logarithmic.

EXTENT OF FLAMING

Of the fabrics with partial flame spread (Group B) the extent of flaming was zero in laboratories 2 to 5 for all except fabrics 1, 12 and 19. Laboratory 1 recorded some extent of flaming on all the fabrics and also higher values on fabrics 1, 12 and 19 than the other laboratories. Partial results are available for fabrics 2, 3 and 20 and mean values and variances have been calculated for those specimens with partial flame spread. The results are given in Table 4 and Fig.2. The large variation in results between laboratories, particularly laboratory 1, suggests that extent of flaming is not a useful measurement.

CHAR LENGTH

The mean char lengths, $\bar{x}$, and the variances, σ^2, for fabrics with partial flame spread (Group B) are given in Table 5 and plotted against each other in Fig.3(a). The results for fabrics 2, 3, 6 and 20, where flame spread was complete on some specimens, are also given, and the char length has been taken as 30 in for these instances. For fabric 21 the char lengths taken are those before penetration by glowing into the uncharred area started. The mean char lengths for the 6 and 12-second application times are compared in Fig.3(b). To a fair approximation, the mean char lengths for the 12-second tests are twice those for the 6-second tests.

The char length distribution in Fig.3(a) appears to be logarithmic.

Taking log values eliminates the dependence of the variance upon the mean and the means and variances of the log values are given in Table 5(a). Because with fabric 6 the 6-second ignition time was generally so much more severe than the 12-second ignition time, the results for this fabric have not been included. A standard two factor analysis with six replicates was carried out on the results for all the thirteen fabrics tested in all laboratories, i.e. fabrics 1, 2 and 16 have been omitted. The variance table is Table 5(b); the interaction between fabrics and laboratories and the variation between laboratories and between fabrics are all highly significant. Because a significant interaction was not expected the variations within the fabrics themselves were examined. Fabric 3, with complete spread on some specimens, is obviously variable and it is shown in Appendix II that fabrics 18 and 20 also have significant variation in performance according to the position of the specimen in the original piece of fabric, which implies that the treatment was uneven.

The analysis was repeated omitting fabrics 3, 18 and 20 and the analysis of variance in Table 5(c) shows that the removal of these variable fabrics has resulted in effectively removing the significant laboratory fabric interaction. However, care must be taken in interpreting these results since the variances of the fabrics themselves are not completely homogeneous; hence in the present analysis the effect of the interaction term could be under-estimated. The variance of any one specimen of any fabric, if the fabric effect only be removed, is then 0.021.

Variability of char length

Of the variances for fabrics 1, 2 and 16 not included in the analysis, only that for fabric 1 in laboratory 1 and that for fabric 2 in laboratory 4 is significantly different from 0.021; for the latter fabric there was complete flame spread on one specimen. Fabric 1 was the only woollen fabric

tested and in three of the four laboratories its behaviour was reasonably reproducible but in laboratory 1 two samples burnt for much longer than any of the others (laboratory 1a). Laboratory 2 therefore sent 12 of its original samples to laboratory 1 who repeated the test (laboratory 1b). Two specimens out of the twelve again burnt up although when originally suspended from the other end in laboratory 2, both the duration of flaming and the char lengths were short. The reasons for this are unknown but the results are consistent with those of a recent series of tests on a number of slightly heavier woollen fabrics, both washed and unwashed, using the present British Standard B.S. 3119/1959, where unexpectedly, the duration of flaming and char lengths do not decrease with weight per unit area.

If it could be assumed that the results for the fabrics included in the second analysis were typical and if the fabric effect be removed, the variance expected in testing any one specimen is 0.021 and for the mean of n specimens it is $0.021/n$. Thus, on the log scale, if the sample mean is more than $1.65\sqrt{0.021/n}$ above the log of the specification mean there is a 95 per cent chance that the fabric will be classified correctly as failing the specification, e.g. if $n = 6$ and d is the specification mean char length the 95 per cent confidence limit for the sample mean is $(\log_{10} d + 0.1) = \log_{10} 1.25\, d$ and the 95 per cent confidence limit for the maximum value recorded is $\log_{10} 1.7\, d$. However, whether or not the fabrics are typical, and the fabrics were in fact chosen to examine repeatability and not to be typical of fabrics in use, the variances are not completely homogeneous. Some fabrics are more variable than others (see Table 5) so that if, for example, the performance standard specifies the allowable mean char length and the allowable maximum char length the relation between these is open to choice either on the average of these fabrics tested or a larger value to allow for the greater variability of some fabrics or on a smaller quantity to exclude all but the

most consistent. In other words the choice of the pass mark for the maximum and the mean can be made independently.

Any standard based on results of char length must allow for the experimental error which is likely to arise in testing.

Further work is required to trace the sources of laboratory differences but the probable reasons are variations in application time and the size of and the heat output from the bunsen flame.

Char length and weight per unit area

The mean char length for the cellulosic fabrics decreases with increasing weight per unit area (Fig.3(c)); the weights for some treated fabrics are not certain (Table 1).

Effect of washing on char length

Table 5(d) compares the results of char length for fabrics 14 and 15 which are the same fabric, unwashed and washed respectively. Statistical tests show that there is no significant difference in the two sets of results, i.e. there is no washing effect.

AFTERGLOW

The duration of afterglow is shown for the Group B fabrics and the 12-second ignition time in Table 6. Only two fabrics, 1 and 7, had no afterglow. Fabric 21 continued to glow for over 10 minutes and the extent of afterglow recorded by laboratory 1 was of the order of 3 in. Laboratory 3 also recorded an extent of afterglow for fabric 21 but did not give the measurement, but it appears that there was no extension in the other laboratories. For the other fabrics, all laboratories reported some duration of afterglow but it appears there was no extent of afterglow.

BURNING TIME

There was complete flame spread on all the specimens of five fabrics tested (Table 2 Group A) but two of these fabrics (8 and 9) were not tested

in all the laboratories. The mean values and variances are given in Table 7, which also gives the results for those A/B fabrics with complete flame spread on less than six specimens, and the results are plotted in Fig.4.

The distribution appears to be logarithmic: the log values of burning time were therefore taken for analysis and the means and variances for the log values are given in Table 7(a). A standard two factor analysis with six replicates was then carried out on the results for the Group A fabrics 4, 5 and 22, which were tested in all five laboratories.

The analysis of variance given in Table 7(b) shows the interaction between laboratories and fabrics to he highly significant (0.1 per cent level); there are also highly significant differences between laboratories and between fabrics (0.1 per cent level).

In formulating a standard which is based on burning time, it is essential to make some allowance for experimental variability in the test results. Here further work is required to trace the source of the significant laboratory and interaction effects*. However, if these are included and the data are only adjusted for fabric differences then the variance of the log burning time for any one specimen fabric is 0.032 and for the mean of n specimens is 0.032/n. (The variances for the fabrics not included in the analysis are not significantly different from these values). Thus, if the sample mean (on the log scale) is more than $1.65\sqrt{\frac{0.032}{n}}$ below the log of specification mean, on this basis there is a 95 per cent chance that a fabric within the range tested will be classified correctly as failing the specification.

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*It is possible that since two of the three fabrics used in the analysis were mixtures of synthetic and natural fibres, which are known to behave in a very variable manner (melting drops falling away in some specimens), slight variation in test procedure could have led to a high laboratory variability.

PERFORMANCE REQUIREMENTS

The results of the series of tests will now be compared with the performance requirements for the present British Standard test and the variability discussed.

FLAMEPROOF FABRICS

The results for the Group B fabrics, with partial flame spread, are given in Table 8 in terms of the performance requirements for 'Flameproof Fabrics' in B.S. 3120. For the A/B group of fabrics results are given for the 'B' specimens only.

Consider first the thirteen Group B fabrics. Only six fabrics (7, 10, 11, 13, 17, 18) gave the same results in all laboratories, passing all four requirements. The other seven fabrics (1, 12, 14, 15, 16, 19 and 21) gave different results in different laboratories. However, three of them, 14, 15 and 16 had char lengths on the borderline of the requirements and would be expected to just pass in some laboratories and just fail in others. Fabrics 12 and 19 sometimes had long durations of flaming and it is possible their treatment was uneven. Fabric 1 failed the requirements only in laboratory 1. Fabric 21 differed only in the afterglow requirement (see p.9).

There are four A/B fabrics (Table 8). Fabrics 2 and 3 gave the same results in all laboratories and failed at least two of the requirements; hence if by chance all six specimens of these fabrics had only partial flame spread they would still not be classified as flameproof. However, the results for fabrics 6 and 20 gave different results in different laboratories (Table 8a). Fabric 20 failed at least one of the requirements in every laboratory, but fabric 6 in three of the laboratories failed for the 6-second ignition time only. There is thus some evidence with fabrics 6 and 20 that there is undue variability in satisfying the performance requirements and hence the probability of an incorrect classification is quite high.

Effect of weight

All the Group B fabrics which satisfied the requirements for duration of flaming had in fact zero values (Table 2). Fabric 2, which was almost a B fabric, had zero values in two laboratories and less than 8 seconds in the other two for the 12-second ignition time (Table 3); for the 6-second ignition time it had zero value in one laboratory and less than 8 seconds in the other three (Table 3). It was lightweight (1.8 oz/yd^2) and the mean value of char length was nearly 6 in. Because char length is an inverse function of the weight per unit area for thin fabrics (Fig.3(c)) this value is near the maximum likely to be found with any fabric likely to purport to be flameproof, although a full investigation of lightweight fabrics would be necessary to confirm this. The mean and maximum char lengths for the fabrics with zero duration of flaming are given in Table 9.

LOW FLAMMABILITY FABRICS

British Standard 3121 specifies that for a fabric of low flammability the time for flame to travel a vertical distance of 50 in must be at least 75 seconds. For the present test, with a distance of 20 in, the corresponding value of burning time is approximately 30 seconds. It is only approximate because the strip used is 3 in wide instead of 1½ in and because there is evidence that the rate of flame spread is still rising over short distances. The results are given in Table 10 in terms of this performance requirement for those nine fabrics with complete flame spread on some or all specimens. (All the Group B fabrics are of low flammability and have not been listed).

Six fabrics gave the same results in all laboratories but fabrics 2, 4 and 6 passed in some and failed in others. For fabric 2 both cases of failure, one for the 6-second and one for the 12-second ignition time, were due to a single specimen spreading rapidly when all the other specimens gave only partial flame spread and it may be that its treatment was uneven. Fabric 4 failed in one laboratory only with a mean time of 25 seconds for

the 12-second ignition time and a mean of 29 seconds for 6-second ignition.

GENERAL DISCUSSION

The fabrics used in the trial were chosen to examine the repeatability of the test method and are not a representative selection of those in use or in production.

The modified test method appears to be easily carried out. The one difficulty was that specimens occasionally curled away from the igniting flame. This could be resolved by discarding that result and inserting additional specimens.

None of the prescribed measurements was sufficient by itself to serve as a measure of the 'between laboratory' and 'between fabric' variations.

(1) Some fabrics which completely burnt and some which hardly burnt at all had the same values for the duration of after-flaming with the intermediate group having larger values.

(2) All fabrics which completely burnt had by definition the same values (the maximum) for char length and extent of flaming.

(3) Many fabrics had no 'burning time' since the lower edge (base) of the flame did not reach the upper marker wire but with some of the heavier fabrics the whole specimen flamed at the same time although no movement of the base of the flame occurred.

Inspection of the results showed that:-

(1) In general, the 12-second application time was more severe than that of 6 seconds but there were six exceptions. The char lengths were roughly twice as long on the 12-second as on the 6-second test for all but fabrics 2 and 6, and the duration of flaming was sometimes longer on the 6-second application for fabrics 2, 3, 6, 12, 19 and 20. Each analysis was confined to 12-second test data (omitting the above exceptions as appropriate) but it is essential to include two

application times in a new test.

(2) Laboratory 1 registered more results for extent of flaming than the other laboratories and, where comparisons were possible, its values were much higher; it would seem therefore that there was some difference in interpretation of test method in this laboratory. The measurement as it stands is clearly unsatisfactory.

(3) With the exception of fabric 21, the extent and duration of 'afterglow' was small.

(4) The durations of flaming were reasonably repeatable for some fabrics; ten fabrics did not continue to flame in any laboratory. However, the variation 'between specimens' and 'between laboratories' for the six other fabrics for which a duration of flaming could be measured was rather large.

(5) The mean char length increased with decreasing weight per unit area.

(6) The mean value, $\bar{x}$, and the variance σ^2, for each measurement in each laboratory have been calculated and plotted against one another. This has shown that the distribution of results is logarithmic for all four measurements.

A two factor analysis with six replicates has been performed on the results for burning time on those three fabrics for which a full set of results was available. The results for the char lengths of ten fabrics have also been analysed.

(1) The analysis of the results for 'burning time' showed that there were laboratory and interaction effects for these fabrics. Slight variations in laboratory testing procedure could have led to a high laboratory variability, particularly as two of the three fabrics were mixtures of synthetic and natural fibres which are known to behave in a very variable manner (on some

specimens melting drops fell away). The estimated variance of the mean of the log values of the burning time for these three fabrics, if the laboratory and interaction effects are not removed, is $\frac{0.032}{n}$ where n is the number of specimens. If this is taken as a representative figure for fabrics and a fabric has a 'true' mean value for its burning time of t, there is a 5 per cent probability that the mean value for any six samples in any laboratory would have a mean of less than 0.75 t. Conversely, in order to be 95 per cent certain that a fabric will meet the specification, t, in any laboratory the mean of six samples should exceed 1.33 t.

(2) The analysis of the measurements of char length showed that the 'between laboratories' effect was significant. This means that a fabric which passes the British Standard requirements in one laboratory could fail them in another. If, therefore, one laboratory is undertaking tests and it is desired to pass a fabric which is near the border line and there is a chance that it would fail in another laboratory, then the testing laboratory must work to more stringent requirements than are given in the present British Standard.

Two possible sources of variation are the application time of the burner and the size of the flame.

The average variance of the mean of the log values of char length in these tests (if the fabric effect only is removed) is $\frac{0.021}{n}$. If a fabric has a 'true' mean value of d for its char length, there is a 5 per cent probability that the mean value for any six samples in any laboratory will be greater than 1.25 d and the

maximum value of the char length for any one specimen will be greater than 1.7 d. Conversely, in order to be 95 per cent certain that a fabric will meet the specification mean, d, and its specified maximum, m, in any laboratory the mean char length of any six samples should not exceed 0.8 d, and the maximum char length 0.6 m.

A lower variance could be chosen to derive a performance criterion failing some of the fabrics tested here on account of undue variability; alternatively a higher variance could be chosen which would pass them.

The behaviour of the only wool fabric was highly variable in laboratory 1. This raises the question of whether the test is suitable for woollen fabrics since this weight of wool fabric is generally considered safe. Richards[6] found that the ignition time, using a similar test, was proportional to the weight per unit area of the cellulosic fabric. This is consistent with the view that ignition occurs at a constant ignition temperature. Wool has a higher ignition temperature than cellulosic materials, and hence takes longer to ignite than an equal weight of cellulosic fabric.

Strictly, it is not possible to compare the burning time, t, as measured in the present test and the flame-resistance rating of B.S.2963/1959, since the widths of the specimens and the distances over which the flames travel are different. However, if it be assumed that the results are equivalent, then a comparison of the results in the different laboratories shows reasonable consistency for the performance requirements of B.S.3121/1959 except for fabrics 2, 4 and 6; fabric 2 is very lightweight and fabric 6 is known to have insufficient flame-retardant treatment, whilst fabric 4 is a mixture containing a synthetic fibre. However, the variability is high and with a larger group of 'marginal' fabrics many more anomalies would probably have been obtained. Those fabrics where the whole

specimen was flaming ought to be taken to have failed the performance requirements of B.S. 3121/1959 but with the present form of words this is doubtful.

Comparing the results of duration of flaming and the mean and maximum char length with the performance requirements of B.S. 3120/1959 (Flameproof fabrics) shows that there are a number of fabrics which pass in one laboratory and fail in another*, which is clearly undesirable, and this group includes fabrics for which the duration of flaming is zero. These fabrics have a weight per unit area of 4 oz/yd^2 or more.

There are large variations within and between the different laboratories for fabrics 1, 2**, 12, 19 and 20. That in fabric 1 is unexplained, but those for fabrics 2, 12 and 19 are probably due to an uneven application of treatment and that for fabric 20 almost certainly so. This obviously suggests the importance of strict quality control in treating the fabrics.

CONCLUSIONS

1. The modified method appears to be easily carried out.
2. A clear distinction can be made between 'burning time' for fabrics with complete flame spread and 'duration of flaming' for fabrics with partial or no flame spread.
3. In general the 12-second application time of the bunsen burner flame gave more severe results than the 6-second application time but there were exceptions and in any new test it is essential to include both times.

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*Despite the fact that the preliminary experiments showed that the modified test is more repeatable than the original version.

**Fabric No.2 has a weight per unit area of only 1.8 oz/yd^2.

4. As a measurement 'extent of flaming' appears unsatisfactory.

5. The variation in 'duration of flaming' between specimens and between laboratories was large for some fabrics.

6. There was confusion over the method of measuring 'afterglow'.

7. The one woollen fabric gave particularly variable results between one laboratory and the others.

8. There were high laboratory and interaction effects for the results of 'burning time' which may partly be due to these fabrics being mixtures of natural and synthetic fibres.

9. There was uneven treatment on some fabrics and this emphasises the need for strict quality control.

10. Tearing the fabric by hand appears to be a satisfactory method of determining char length and gives very similar results to tearing by weights.

11. The measurements for char length show a significant variation between laboratories.

12. With certain heavy fabrics the whole specimen flames at once and no burning time can be recorded.

13. As long as there are differences between laboratories, there are bound to be fabrics which pass in some laboratories and fail in others, but the risk can be minimized by manufacturers deliberately aiming to meet a higher specification than that laid down in a British Standard. The numerical values given for variation are only valid for the fabrics tested in the participating laboratories. Before they could be applied generally it would be necessary to test whether both the fabrics used and the participating laboratories were typical.

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APPENDIX I

PRESENT TESTS AND MODIFICATIONS

The three factors determining the fire hazard of a fabric are:

(i) Ease of ignition

(ii) Rate of flame spread

(iii) Amount of heat liberated

For cellulosic materials, and probably for most other materials, these three factors are linked. By measuring either of the first two, estimates of the other and hence of the hazard of the fabric can be obtained.

In both the present British Standard tests for the flammability of fabrics[1,2] a strip of fabric is hung vertically and a bunsen burner* is applied to the bottom edge of the strip for 12 seconds and then removed. The progress of the flame over the fabric and the resultant damage are then noted. B.S. 3119 is for fabrics which burn to a limited extent, if at all, and B.S.2963** for fabrics which burn the full extent.

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* The minimum rate of heat transfer required to ignite the group of fabrics that are likely to reach or come close to the performance requirements for flameproof fabrics is about 2 cal $cm^{-2}s^{-1}$[6], (which is therefore the rate of heat transfer required from the luminous bunsen burner) and this rate of heating has to be sustained for several seconds. The heat output from the fabrics themselves is almost certainly negligible compared with this, being at most 0.7 cal $cm^{-2}s^{-1}$[7].

**B.S. 2963. This also contains the U.S.A. 45° test which has been found to give anomalous results with wool/cotton mixtures[8].

Different measurements are therefore listed in the two Standards.

(i) The extent of flaming, i.e. how far the flame reached on the specimen (B.S. 2963/1958.

(ii) The rate of spread of flame up the specimen (B.S. 2963/1958).

(iii) The time for which flaming continues after the removal of the igniting flame (B.S. 3119/1959).

(iv) The length of the specimen charred or melted (B.S. 3119/1959).

In addition the existence of glowing and whether it extends the area of damage is also noted.

The two performance requirements relating to the above and set out in B.S. 3121/1959 and B.S. 3120/1959 are based on different principles:

(i) In B.S. 3121/1959, where the rate of flame spread is used as the criterion the pass mark of a flame-resistance rating of at least 150[x] is imposed. This was chosen following a survey of the flame-resistance ratings of clothing fabrics first ignited in burning accidents[7] and gives an ample margin of safety. Two higher categories are also listed, 'self-extinguishing' and 'flame not propagated' and here the extent of flaming is recorded, i.e. how far the base of the flame spread up the fabric.

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[x]The flame-resistance rating is the time for the flame to spread 100 in on the vertical strip; thus the value of 150 is equivalent to a rate of spread of $\frac{2}{3}$ in/s.

(ii) In B.S. 3120/1959, which was intended to be a stringent standard, the fabrics must satisfy three criteria:-

(a) The time for which flaming continues (afterflaming), must not exceed 8 seconds for any one specimen[xx]

(b) The mean value of the char length may not exceed $3\frac{1}{2}$ in and the maximum value $4\frac{1}{2}$ in

(c) Glowing may not extend the area already damaged.

The limitation on the duration of after flaming ensures that the fabric is difficult to ignite, and if the length of fabric charred or melted is small then the heat output of the flame is small, regardless of its duration. If no flaming at all occurs, the length charred is simply a measure of the area likely to be damaged by the source of heat used. It is difficult to measure flame height[6] but char length can be used to give an indirect measure of it.

TEST MODIFICATIONS

The major interest is in those fabrics which burn slowly, and preliminary experiments were carried out using the test method of B.S. 3119/1959* to find possible sources of variation. These led to the following modifications to the test method and to the measurements made.

(i) The width of the specimen was increased to 3 in from 2 in; this makes it easier to pin the specimens at their base to prevent them curling away from the flame and it reduces the

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[xx]Originally in B.S. 1547/1949[10] the maximum duration of after flaming allowed was only 2 seconds. However, a number of fabrics with an excellent safety record were failing this performance requirement because small spots of flame persisted on the already damaged parts of the fabric surface without extending into the undamaged part.

* This differs in only minor respects from the test method of Appendix A of B.S. 2963/1958 for fabrics over which flame is known to spread slowly.

possibility of the flame creeping up one edge which is an effect not likely to occur in practice. It is also likely that some fabrics will continue to burn with the wider strip where they would not with a narrower one.

(ii) The length of the specimen was increased to 36 in from 15 in (B.S. 3119/1959) which is still much less than the 60 in used in B.S. 2963/1958. This represented the maximum area of a 3 in wide specimen that could be accommodated in the washing machine used (B.S. 3121/1958).

(iii) The box in which the specimens were hung was three-sided with a lid and an open front instead of the partially closed front of B.S. 3119/1959 (or the draught-free enclosure of B.S. 2963/1958).

(iv) The igniting source was a bunsen burner of internal diameter $\frac{3}{8}$ in, with a luminous flame of length $1\frac{1}{2}$ in which was placed with the top of the burner 1 in below the middle of the lower edge of the specimen as in B.S. 2963/1958 instead of $\frac{3}{4}$ in below specified in B.S. 3119/1959. Small variations in the position and size of the flame did not appear to be critical.

(v) The igniting source was applied for 6 seconds as well as the present 12 seconds since it has been found that with some flame-retardant treatments the shorter application time was far more severe[6,11,12].

(vi) A ruler was placed on the wall of the box behind the specimen in order to determine the extent of spread of flame more precisely.

(vii) Two marker wires placed parallel to the lower edge, one 10 in and the other 30 in above it instead of their being 50 in apart as in B.S. 2963/1958.

(viii) The char length was determined visually (after tearing by hand): this method was found to give as repeatable a reading as tearing with weights.

APPENDIX II

VARIABILITY OF FABRICS 18 and 20

Tables 11(A) and 12(A) give the char lengths of fabrics 18 and 20 (on the log scale) adjusted for laboratory biases. These were calculated from all the data for all fabrics and biases for each fabric were obtained (Table 13(A)).

The char lengths of the central portion of these fabrics were compared with the char lengths of the end portions. For fabric 18, Student's t test showed that the char lengths of the end portions were significantly different (2 per cent level) from those of the central portion and for fabric 20, the variance of char lengths of the central portion was found to be significantly greater (0.1 per cent level) than that of the ends.

Table 1

Details of fabrics used and code number

Fabric No.	Fabric	Weight per unit area oz/yd^2	Treatment
1	Dyed worsted suiting	11 (12)	None
2	Bleached cotton net	(1.8)	'Treated'
3	Dyed 64 per cent nylon, 36 per cent wool	8.6	None
4	Dyed 52 per cent nylon, 48 per cent viscose	6.9	None
5	Printed cotton winceyette	4	None
6	" " "	4½	Low add-on THPC
7	" " "	4½	Proban finish
8	Loomstate cotton drill	8	
9	Dyed 45 per cent nylon 55 per cent cotton	7.5	None
10	Unbleached flax tow	21	Fire, rot and waterproof
11	Cotton duck	15	" " "
12	Boiled flax line canvas	22¼	" " "
13	Khaki cotton drill	8	Timonox finish
14	Dyed cotton sateen	8	" "
15	" " "	8	" " washed
16	Cotton tent lining	9	Low add-on antimony oxide finish
17	Cotton duck	15 (20)	Antimony oxide/chlorinated paraffin finish
18	Dyed cotton drill	10 (12)	Timonox finish
19	Dyed flax canvas	18 (21)	Antimony oxide/chlorinated paraffin finish
20	Dyed canvas	9 (11)	" " "
21	Dyed cotton duck	15 (20)	" " "
22	Bleached 52 per cent nylon, 48 per cent cotton	3.3	None

Figures in brackets give the weights for the treated fabrics, where known; for the other treated fabrics it is not known if the weight is for treated or untreated fabric.

Table 2

Summary of results

Group	Fabrics in group	Result	Comments on results	
			Comment	Fabrics
A	4, 5, 8, 9, 22	Complete flame spread on all specimens		
A/B	2, 3, 6, 20	Complete flame spread on some specimens, partial flame spread on others	6-second ignition time sometimes more severe (Complete flame spread on more specimens)	2, 3, 6
B	1, 7, 10, 11, 12 13, 14, 15, 16, 17, 18, 19, 21	Partial flame spread on all specimens	6-second ignition time sometimes more severe (Duration of flaming slightly longer)	12, 19
			Duration of flaming zero	7, 10, 11, 13, 14, 15, 16, 17, 18, 21
			Extent of flaming zero (except in laboratory 1; this laboratory recorded some extent on all fabrics)	7, 10, 11, 13, 14, 15, 16, 17, 18, 21
			Afterglow zero	1, 7

Table 3

Duration of flaming in seconds (12-second ignition)
(Six specimens in each sample)

Fabric No.		Laboratory							
		1a	2a	3	4	5	2b	2c	*1b
1	Variance	400	10	5.4	2.0	N.T.	22	7.0	310
	Mean	29	4.8	3.8	1.5		3.7	3.8	15
**2	Variance	*6.3	*0	0	2.8	N.T.			
	Mean	1.5	0	0	1.0				
	N				1				
**3	Variance	N.A.	*580	*830	N.A.	N.A.			
	Mean		83	60	68				
	N	6	4	3	5	6			
**6	Variance	*0	*833	*735	114	*0			
	Mean	0	16.7	15.7	10	0			
			3	3	2	5			
12	Variance	*0	9.5	*4.2	220	84			
	Mean	0	2.5	0.83	8.3	7			
19	Variance	0	*0	9.36	0	*2.8			
	Mean	0	0	3.8	0	1.0			
**20	Variance	*0	360	31	240	270			
	Mean	0	12	12	17	18			
	N			3					

*Twelve specimens in sample

**N is number of specimens with complete flame spread

*6-second ignition test more severe

N.A. denotes "not applicable"

N.T. denotes "not tested"

Table 4

Extent of flaming in inches (12-second ignition)

(Six specimens in each sample)

Fabric No.		Laboratory				
		1	2	3	4	5
1	Variance	42	0	0.08	0.35	N.T.
	Mean	10	0	1.18	0.28	
**2	Variance	*4.4	*0	0	180	N.T.
	Mean	3.0	0	1.8	7.7	
	N				1	
**3	Variance	N.A.	*72	*28	N.A.	N.A.
	Mean		15	5	6	
	N	6	4	3	5	6
**6	Variance	*2.05	*51.0	*133	159	*0
	Mean	3.6	6.8	6.7	8.3	0
	N		3	3	2	2
7	Variance	0.14	0	0	0	0
	Mean	6.4	0	0	0	0
10	Variance	0.24	0	0	0	0
	Mean	3.4	0	0	0	0.5
11	Variance	0.34	0	0	0	0
	Mean	4.9	0	0	0	0
12	Variance	0.37	0.05	0	0.04	0.08
	Mean	2.8	0.78	0	0.13	1.2
13	Variance	0.04	0	0	0	0
	Mean	1.1	0	0	0	0
14	Variance	1.1	0	0	0	0
	Mean	7.5	0	0	0	0
15	Variance	0.24	0	0	0	0
	Mean	7.4	0	1.0	0	0
16	Variance	3.1	0	0	0	N.T.
	Mean	8.7	0	0	0	
17	Variance	1.4	0	0	0	0
	Mean	4.8	0	0	0	0
18	Variance	1.6	0	0	0	0
	Mean	7.5	0	0	0	0
19	Variance	1.1	0	0.07	0	0.12
	Mean	4.5	0	0.75	0	1.3
**20	Variance	6.8	19	0.3	3.8	12.0
	Mean	6.0	4.3	2.7	2.1	3.5
	N			3		
21	Variance	4.0	No	0	No	0
	Mean	5.0	results	0	results	0

**N is number of specimens with complete flame spread

*6 second ignition test more severe

N.A. denotes "not applicable"

N.T. denotes "not tested"

Table 5

Char length in inches (12-second ignition)

(Six specimens tested)

Fabric No.		Laboratory							
		1a	2a	3	4	5	1b	2b	2c
1	Variance	43	14	0.08	0.24	N.T.	110*	1.5	0.86
	Mean	10	3.5	1.8	1.7				
**2	Variance	1.2	*0.53	0.42	170	N.T.			
	Mean	5.7	5.8	4.2	13				
	N				1				
**3	Variance	N.A.	74.4	12	81.2	N.A.			
	Mean	30	25	20	26	30			
	N	6	4	3	5	6			
**6	Variance	*0.15	*0.52ø	*145	114	*1.17			
	Mean	2.6	2.6	10.1	14.5	4.0			
	N	0	3	3	2	2			
7	Variance	0.067	0.19	0.26	0.16	0.13			
	Mean	2.8	3.5	2.5	3.0	3.5			
10	Variance	0.002	0.034	0	0.02	0.01			
	Mean	0.78	0.5	0.20	0.33	0.47			
11	Variance	0.02	0.02ø	0.09	0.07	0.02			
	Mean	1.2	0.88	1.0	0.91	0.96			
12	Variance	0.02	0.09	0.01	0.83	0.26			
	Mean	0.58	0.73	0.37	0.75	1.1			
13	Variance	0.25	0.28	0.24	0.14	0.38			
	Mean	2.6	2.8	1.9	1.9	2.1			
14	Variance	0.17	0.13	0.23	0.11	0.15			
	Mean	4.1	3.0	2.8	2.5	3.0			
15	Variance	0.14	0.25	0.51	0.04	0.65			
	Mean	3.2	3.1	3.1	2.6	3.8			
16	Variance	0.25	0.29	0.52	0.41	N.T.			
	Mean	3.9	4.3	3.2	3.4				
17	Variance	0.05	0.03	0.02	0.02	0			
	Mean	1.4	1.1	0.80	0.91	0.75			
18	Variance	0.34	0.07	0.30	0.14	0.17			
	Mean	2.7	2.7	2.3	1.4	2.0			
19	Variance	0.07	0.03	0.21	0.02	0.10			
	Mean	1.3	0.88	1.0	0.67	1.0			
**20	Variance	ø0.47	16	210	2.0	10			
	Mean	3.9	4	17	3.0	4			
	N			3					
≠21	Variance	0.45	0.37	0.85	0.39	1.0			
	Mean	2.8	2.5	1.7	2.3	3.1			

*Twelve specimens tested
**N is number of specimens with complete flame spread
N.T. denotes "not tested"
N.A. denotes "not applicable"
ø One missing result
* 6 second ignition test more severe
≠ These values are for the char length after the removal of the flame, the final char length was much greater.

Table 5(a)

$2 + \log_{10}$ (char length in inches), (12-second ignition)

(Six specimens tested)

Fabric No.		Laboratory				
		1	2	3	4	5
1	Variance	0.098	0.027	0.005	0.017	N.T.
	Mean	2.92	2.53	2.26	2.21	
2	Variance	0.006	0.003	0.004	0.19	N.T.
	Mean	2.75	2.76	2.62	2.94	
3	Variance	0.000	0.044	0.089	0.055	0.000
	Mean	3.48	3.36	3.23	3.38	3.48
7	Variance	0.001	0.003	0.007	0.004	0.002
	Mean	2.45	2.54	2.40	2.47	2.54
10	Variance	0.001	0.036	0.000	0.024	0.016
	Mean	1.89	1.63	1.30	1.50	1.66
11	Variance	0.001	0.005	0.013	0.020	0.007
	Mean	2.08	1.93ø	1.99	1.95	1.98
12	Variance	0.008	0.048	0.015	0.187	0.045
	Mean	1.76	1.77	1.55	1.67	1.98
13	Variance	0.006	0.007	0.015	0.007	0.019
	Mean	2.41	2.43	2.27	2.28	2.31
14	Variance	0.001	0.003	0.006	0.004	0.003
	Mean	2.61	2.40	2.44	2.39	2.50
15	Variance	0.003	0.005	0.010	0.001	0.010
	Mean	2.50	2.49	2.50	2.41	2.57
16	Variance	0.003	0.003	0.009	0.002	N.T.
	Mean	2.59	2.62	2.50	2.53	
17	Variance	0.002	0.003	0.006	0.004	0.000
	Mean	2.14	2.07	1.90	1.96	1.88
18	Variance	0.010	0.002	0.013	0.014	0.012
	Mean	2.42	2.42	2.34	2.14	2.30
19	Variance	0.006	0.006	0.032	0.008	0.019
	Mean	2.11	1.97	1.98	1.82	1.96
20	Variance	0.007	0.096	0.290	0.033	0.088
	Mean	2.59ø	2.47	2.30	2.45	2.50
21	Variance	0.007	0.011	0.036	0.019	0.017
	Mean	2.43	2.39	2.18	2.35	2.47

ø One missing result

N.T. denotes "not tested"

Table 5(b)

Analysis of variance of fabrics in Table 5(a)
omitting fabrics 1, 2 and 16
$2 + \log_{10}$ (char length), 12-second ignition

Source of variation	Degrees of freedom	Sums of squares	Mean squares
Fabrics	12	74.493	6.208*
Laboratories	4	1.329	0.332*
Interaction	48	3.670	0.076*
Error	325	6.627	0.020
Total	389	86.119	

*Significant at the 0.1 per cent level

Table 5(c)

Analysis of variance of fabrics in Table 5(a)
omitting variable fabrics 3, 18
and 20 as well as fabrics 1, 2 and 16
$2 + \log_{10}$ (char length), 12-second ignition

Source of variation	Degrees of freedom	Sums of squares	Mean squares
Fabrics	9	29.231	3.248*
Laboratories	4	1.465	0.366*
Interaction	36	0.705	0.020
Error	250	3.806	0.015
Total	299	35.207	

*Significant at the 0.1 per cent level

$$\sigma^2 = 0.021$$

Table 5(d)

Effect of washing

Comparison of char length (on $\log_{10}$ scale) of fabrics 14 and 15

Fabric No.	Grand mean	Grand variance
14	2.48	0.0059
15	2.49	0.005

Table 6

Duration of after-glow
12-second ignition time group B fabrics

(Duration - seconds)

Fabric No.	Lab. 1		Lab. 2		Lab. 3		Lab. 4		Lab. 5	
	Mean	Max.	Mean	Max.	Mean	Max.	Mean	Max.	Mean	Max.
1	0	0	0	0	0	0	0	0	N.T.	
7	0	0	0	0	0	0	0	0	0	0
10	104	116	58	96	67	98	81	101	71	77
11	250	294	186	198	250	276	251	320	186	235
12	154	180	111	166	148	179	187	326	203	306
13	109	135	118	150	82	113	151	174	108	150
14	203	230	171	221	148	187	191	223	166	180
15	166	> 200	143	210	172	198	174	239	183	242
16	144	177	165	216	135	148	158	198	N.T.	
17	193	215	183	211	223	248	180	213	164	174
18	149	184	150	215	195	248	56	88	107	131
19	183	247	154	168	209	328	142	166	188	195
21	714	1020	740	972	> 300	930	646	839	834	1419

N.T. denotes not tested

Table 7

Burning time - seconds

(Six specimens tested (12-second ignition))

Fabric No.		Laboratory				
		1	2	3	4	5
**2	N	*0	0	0	1	N.T.
	Time	-	-	-	3	
**3	Variance	120	6.9	840	31	230
	Mean	64	52	87	57	120
	N	6	4	3	5	6
4	Variance	13	6.2	23	10	13
	Mean	46	25	35	41	67
5	Variance	3.2	0.26	0.70	5.0	0.66
	Mean	7.0	6.7	8.5	11	13
**6	Variance	-	13	212	12.5	0.5
	Mean	-	21	19	14.5	32.5
	N	*0	*3	3	2	2
8	Variance	0.96	2.7	2.3	N.T.	N.T.
	Mean	15	13	16		
9	Variance	No results	10	7.9	*16	N.T.
	Mean		14	23	27	
**20	Variance	-	-	360	-	-
	Mean	-	-	48	-	-
	N	0	0	3	0	0
22	Variance	0.70	9.8	8.6	5.6	6.0
	Mean	4.5	7.2	6.8	13	16

*On one specimen the fabric fell away before the top marker was reached.

**N is number of specimens of A/B fabrics with complete flame spread.

*6-second ignition more severe.

N.T. denotes 'not tested'

Table 7(a)

1 + $\log_{10}$ (Burning time in seconds) (12-second ignition)

Six specimens tested

Fabric No.		Laboratory				
		1	2	3	4	5
**3	Variance	0.0048	0.0004*	0.0200*	0.0017	0.0030
	Mean	2.80	2.72	2.92	2.76	3.07
	N	6	4	3	5	6
4	Variance	0.0098	0.0020	0.0025	0.0001	0.0013
	Mean	2.65	2.40	2.54	2.62	2.83
5	Variance	0.0113	0.0019	0.0013	0.0079	0.0016
	Mean	1.84	1.83	1.93	2.04	2.10
8	Variance	0.008	0.0003	0.0019	N.T.	N.T.
	Mean	2.18	2.12	2.20		
9	Variance	No results	0.0140	0.0028	0.0340*	N.T.
	Mean		2.13	2.37	2.41	
**20	Variance	-	-	0.0260	-	-
	Mean	-	-	2.66	-	-
	N	0	0	3	0	0
22	Variance	0.0082	0.0299	0.0316	0.0064	0.0044
	Mean	1.65	1.83	1.80	2.10	2.20

*One missing result

**N is number of specimens with complete flame spread

*6-second ignition more severe

N.T. denotes 'not tested'

Table 7(b)

$1 + \log_{10}$ (Burning time in seconds) (12-second ignition)

Fabrics 4, 5, 22

Variance table

Source of variation	Degrees of freedom	Sums of squares	Mean squares
Fabrics	2	9.122	4.561*
Laboratories	4	1.691	0.423*
Interaction	8	0.512	0.064*
Error	75	0.604	0.0081
Total	89	11.929	

*Significant at the 0.1 per cent level

$\sigma^2 = 0.032$

Table 8

Performance requirements in B.S. 3120 "Flameproof fabrics"

(Only if there is a P in every box in a column would the fabric be expected to pass the Standard)

Requirement	Group B fabrics - partial flame spread													Group A/B fabrics. Results only for specimens with partial flame spread			
	Fabric													Fabric			
	1	7	10	11	12	13	14	15	16	17	18	19	21	2	3	6	20
(a) Maximum duration of flaming not exceeding 8 s	P/F	P	P	P	P/F	P	P	P	P	P	P	P/F	P	P	F	F	P/F
(b) Mean char length not exceeding 3.5 in	P/F	P	P	P	P	P	P/F	P/F	P/F	P	P	P	F	F	F	P/F	P/F
(c) Maximum char length not exceeding 4.5 in	P/F	P	P	P	P	P	P/F	P	P/F	P	P	P	F	F	F	P/F	P/F
(d) Afterglow confined to charred area	P	P	P	P	P	P	P	P	P	P	P	P	P/F	P	P	P	P

P = pass F = fail P/F = pass in some laboratories only

Table 8(a)

Results for each laboratory for variable A/B fabrics in Table 8

(Only if there is a P in every box in a column would a fabric be expected to pass the standard)

Requirement	Fabric									
	6					20				
	Laboratory					Laboratory				
	1	2	3	4	5	1	2	3	4	5
Maximum duration not exceeding 8 seconds	F+	F	F	F	F+	P	F	F	F	F
Mean char length not exceeding 3.5 in	F+	P	F+	F	F+	F	F	P	P	F
Maximum char length not exceeding 4.5 in	F+	P	F+	F	F+	F	F	P	F	F

+Fails only with 6-second ignition time

Table 9

Mean and maximum char lengths in inches

(For fabrics with zero duration of flaming, 12-second ignition time)

Fabric No.		Laboratory 1	2	3	4	5	Weight oz/yd^2
2	Mean	-	5.8	4.2	-	N.T.	18
	Maximum	-	6.8	5.5	-		
7	Mean	2.8	3.5	2.5	3.0	3.5	4½
	Maximum	3.3	4.0	3.5	3.5	4.0	
10	Mean	0.75	0.5	0.2	0.33	0.5	21
	Maximum	0.9	0.75	0.2	0.5	0.6	
11	Mean	1.2	0.88	1.0	0.91	0.96	15
	Maximum	1.2	1.0	1.6	1.3	1.3	
13	Mean	2.6	2.8	1.9	1.9	2.1	8
	Maximum	3.5	3.5	2.5	2.5	3.0	
14	Mean	4.1	3.0	2.8	2.5	3.0	8
	Maximum	4.6	3.5	3.4	3.0	3.3	
15	Mean	3.2	3.1	4.0	2.6	3.8	8
	Maximum	3.8	4.0	3.3	3.0	4.8	
16	Mean	3.9	4.3	3.2	3.4	N.T.	9
	Maximum	4.6	5.0	4.5	4.0		
17	Mean	1.4	1.1	0.8	0.9	0.75	20
	Maximum	1.8	1.4	1.0	1.0	0.75	
18	Mean	2.7	2.7	2.3	1.4	2.0	12
	Maximum	3.3	3.0	3.3	2.0	2.5	
19	Mean	1.3	-	-	0.67	-	21
	Maximum	1.8	-	-	0.75	-	

N.T. denotes "not tested".

Table 10

Performance requirements - burning time of at least 30 seconds

Group	Fabric No.	Laboratory					All laboratories
		1	2	3	4	5	
A/B	2	+F	P	P	F	N.T.	P/F
A/B	3	P	P	P	P	P	P
A	4	P	F	P	P	P	P/F
A	5	F	F	F	F	F	F
A/B	6	P	F	F	F	P	P/F
A	8	F	F	F	N.T.	N.T.	F
A	9	F	F	F	F	N.T.	F
A/B	20	P	P	P	P	P	P
A	22	F	F	F	F	F	F

+ Fails only on 6-second test. One specimen burnt

P/F = pass in some laboratories only

N.T. denotes 'not tested'.

Table 11(A)

Fabric 18

Log_{10} char lengths in inches corrected for laboratory bias

(12-second ignition)

Class A contains first and last four specimens cut from the strip of fabric

Class B contains specimens cut from the centre of the strip of fabric

A	B
0.41	0.26
0.38	0.16
0.32	0.38
0.42	0.49
0.33	0.30
0.38	0.35
0.42	0.47
0.42	0.14
0.46	0.14
0.39	0.14
0.61	0.07
0.07	0.37
0.28	0.26
	0.36
	0.13
	0.40
	0.13

There is no difference in the variances between Class A and Class B but the means of Class A and Class B are significantly different at the 2 per cent level.

Student's 't' = 2.25

Table 12(A)

Fabric 20

Log_{10} char lengths in inches corrected for laboratory bias

(12-second ignition)

Class A contains specimens cut from the ends of the strip of fabric

Class B contains specimens cut from the centre of the strip of fabric

A	B
0.56	0.33
0.51	0.75
0.51	1.57
0.34	1.57
0.50	1.57
1.06	0.42
0.46	0.81
0.28	0.47
0.33	0.13
0.22	0.96
0.39	
0.70	
0.37	
0.67	
0.37	
0.36	
0.56	
0.20	
0.44	

The variances of Class A and B are:

$\sigma_A^2 = 0.039$

$\sigma_B^2 = 0.299$

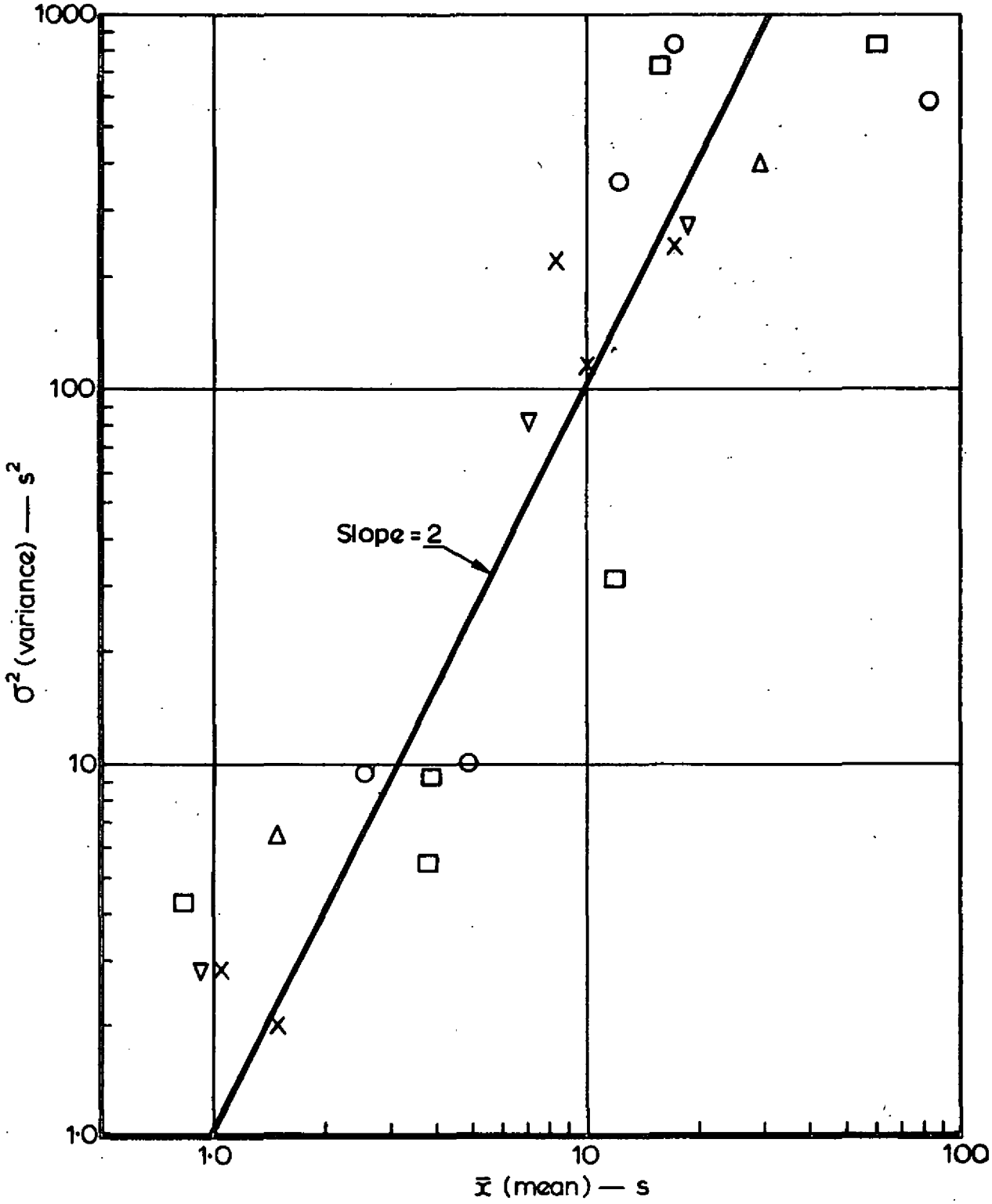
The variance ratio, F is 7.6.

Hence variances of Class A and Class B are significantly different at the 0.1 per cent level.

Table 13(A)

Difference between mean (2 + $\log_{10}$ (char length)) and grand mean (2 + $\log_{10}$ (char length))

Fabric No.	Grand mean	Laboratory				
		1	2	3	4	5
3	3.39	0.09	-0.03	-0.16	-0.01	0.09
7	2.48	-0.03	0.06	-0.08	-0.01	0.06
10	1.60	0.29	0.03	-0.30	-0.10	0.06
11	1.99	0.09	-0.06	0.00	-0.04	-0.01
12	1.73	0.03	0.04	-0.18	-0.13	0.25
13	2.34	0.07	0.09	-0.07	-0.06	-0.03
14	2.47	0.14	-0.07	-0.03	-0.08	0.03
15	2.49	0.01	0.00	0.01	-0.08	0.08
17	1.99	0.15	0.08	-0.09	-0.03	-0.11
18	2.32	0.10	0.10	0.02	-0.18	-0.02
19	1.97	0.14	0.00	0.01	-0.15	0.01
20	2.46	0.13	0.01	-0.16	-0.01	0.04
21	2.36	0.07	0.03	-0.18	-0.01	0.09
Means	2.28	+0.099	+0.022	-0.093	-0.68	+0.042



Laboratory	Symbol
1	Δ
2	O
3	□
4	X
5	∇

FIG. 1. DURATION OF FLAMING (12 s IGNITION)

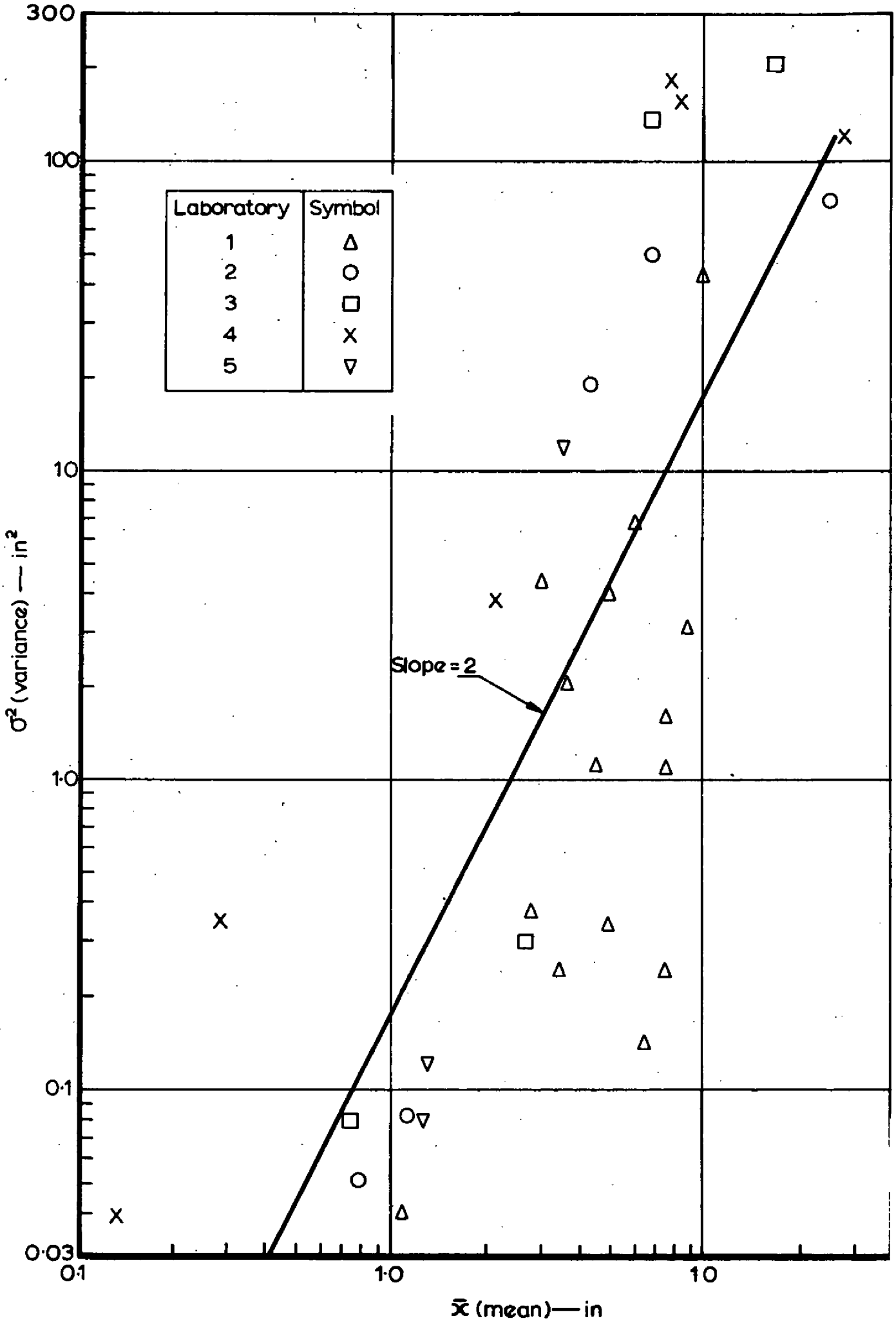


FIG.2. EXTENT OF FLAMING (12s IGNITION)

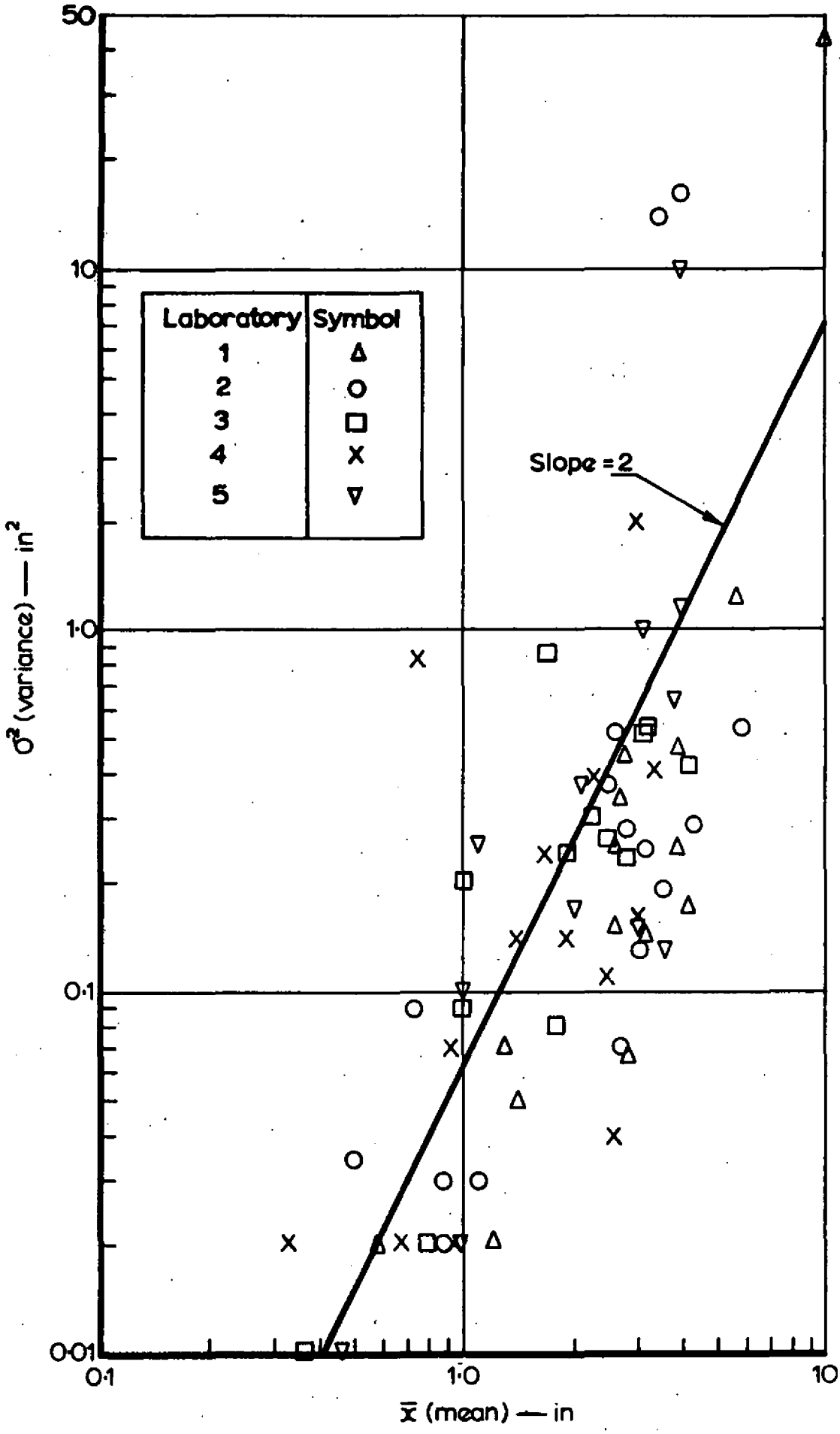


FIG. 3a. CHAR LENGTH (12 s IGNITION)

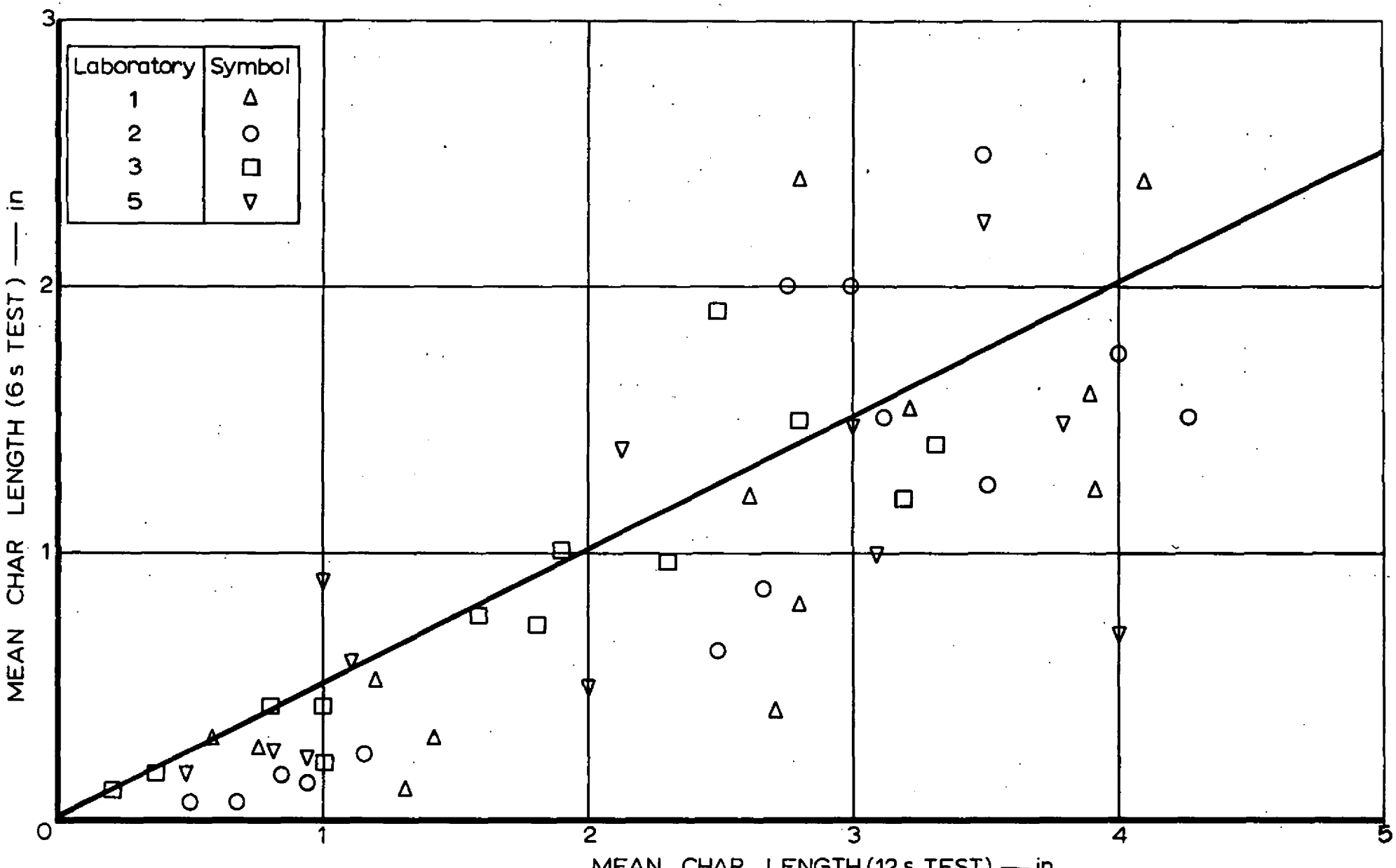
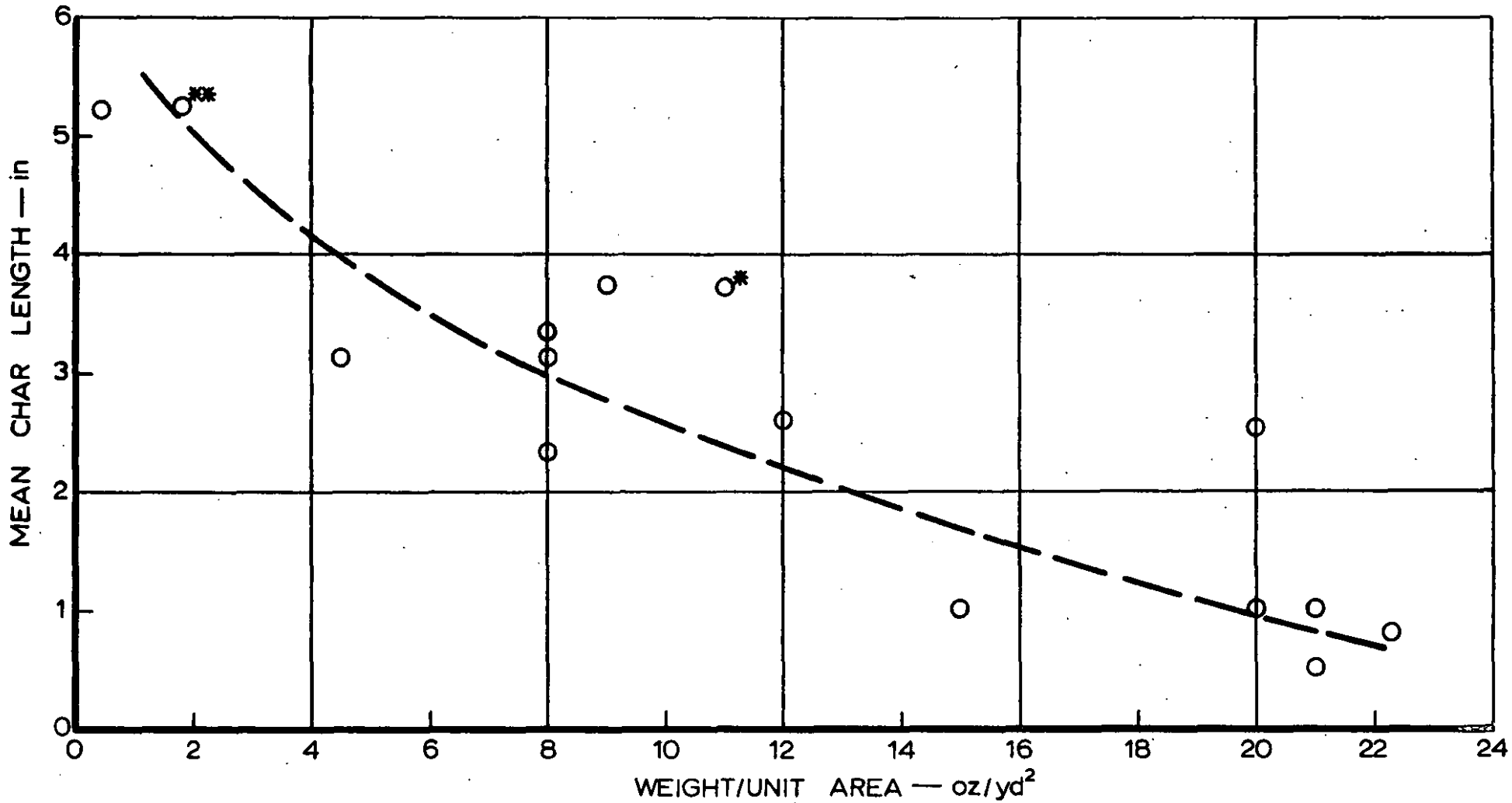


FIG. 3b. COMPARISON OF CHAR LENGTHS FOR 6 s AND 12 s IGNITION TIMES



* Omitting result for laboratory 3
** Omitting result for laboratory 4

FIG. 3c. VARIATION OF MEAN CHAR LENGTH WITH WEIGHT (CELLULOSIC FABRICS)

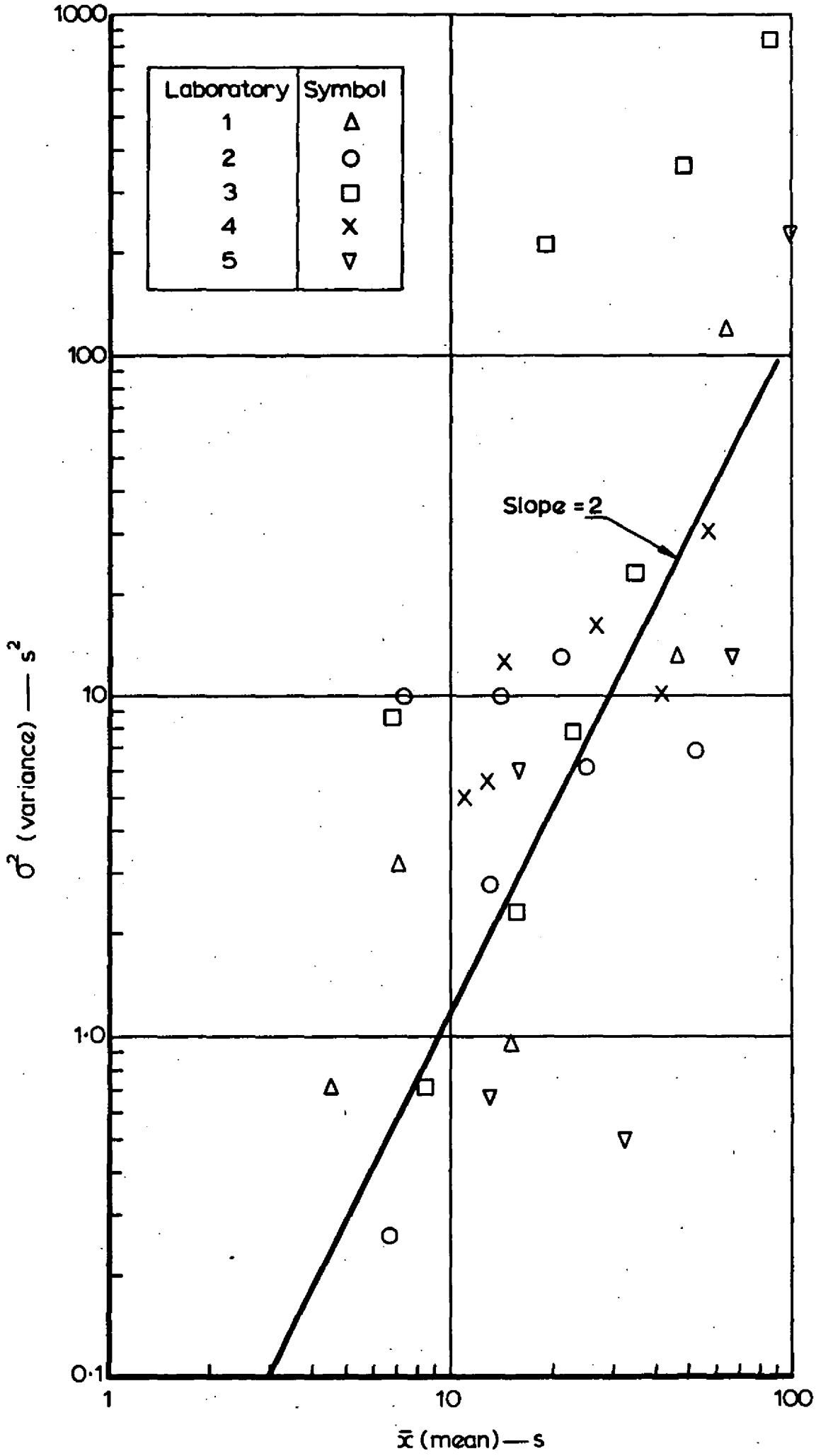


FIG.4. BURNING TIME (12s IGNITION)