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ADDITIONAL DATA ON THE COMBUSTIBILITY RATING OF BUILDING MATERIALS USING THE B.S.I. FURNACE

by

K. Sumi and J.R. Jutras

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PREFACE

This is a supplement to DBR Report No. 43 and records an extension of the work undertaken by the Fire Research Section of the Division of Building Research in assisting a subcommittee of the CSA Committee on Fire Prevention and Protection. This Committee has been charged with the preparation of a new combustibility test specification for Canada and the report now presented is a further record of investigations undertaken in this connection.

One of the authors, Mr. Kik Sumi, initiated the work before he left for Great Britain for special studies in fire research from which he will be returning at the end of 1956. The work has been continued by his colleagues in the Fire Research Section, notably by his co-author, Dr. J.R. Jutras. This co-operative endeavour is a pleasing feature of this important work in a singularly complex field.

Ottawa
September 1956.

R.F. Legget,
Director.

ADDITIONAL DATA ON THE COMBUSTIBILITY RATING OF BUILDING MATERIALS USING THE B.S.I. FURNACE

by K. Sumi and J.R. Jutras

In a previous report "Comparison of Combustibility Test Procedures" (1), results of tests were given on the combustibility of seven different building materials for the purpose of guiding the Canadian Standards Association's Subcommittee on Noncombustibility in the preparation of a new specification for the combustibility rating of materials.

Two of the main conclusions of the work concerned the reliability of the criteria used for combustibility rating: the maximum temperature rise above the temperature in the furnace at the beginning of the test, and the integrated area under the time-temperature curve above the line $T = T_1$, where T_1 represents the stabilized temperature of the furnace at the time of introduction of the specimen. Results of tests seemed to indicate that the temperature elevations were not consistent enough, through repeat tests on a given material, to serve as a basis for the grading of materials relative to their degree of combustibility. The use of this quantity however may be quite valid for the identification of materials as combustible or noncombustible (2). The use of the integrated areas as a standard for combustibility rating appeared to be justified, as measured values were fairly reproducible and led to a classification of materials that seemed consistent with experience.

Subject to the Subcommittee's approval, a proposed specification was prepared by one of the authors (K.S.), in which the integrated areas served as a measure of combustibility. This specification provided for the classification of building materials within three different groups: noncombustible, low combustible, and combustible. Area values of 100 and 1300 minutes-degrees Fahrenheit were specified as respective demarcation points between the "noncombustible" and "low combustible " groups on the one hand, and the "low combustible" and "combustible" groups on the other. A similar classification had been used previously in German Standard DIN-4102 (3). It was suggested for use in the proposed specification to provide a means of segregating from the readily combustible wood-based, or similar materials, those composed mainly of noncombustible substance which would add sufficient heat to a fire to debar them from the noncombustible group.

The test procedure recommended in this specification varied somewhat from that used in tests performed previously with the British Standards Institution furnace (1). The modifications concerned the pilot flame burner on the apparatus, as well as the method of conditioning the specimens.

It had been noted in former tests that the pilot flame was often extinguished, and that it was difficult to re-ignite. It was feared this might have some adverse influence on the reproducibility of the measurements. The use of an auxiliary flame was therefore suggested as a further means of standardizing the procedure for re-igniting the flame. Preliminary tests on a system where the auxiliary flame was located on the same level as, and ¾ inch away from the first, had proved very successful. The auxiliary flame remained lit, providing a continuous source of re-ignition for the pilot flame. It was therefore thought desirable to include such a modification inthe proposed specification.

Curing conditions adopted in previous tests (1) were, as specified in British Standard 476:1953 (2). This standard stipulates that "three of the (six) test specimens should be dried by heating to a temperature of 100°C. (212°F.) for six hours... The remaining three specimens should be kept for a period of one week in a desiccator containing calcium chloride, before testing."

From experience gained by S.H. Ingberg, formerly of the National Bureau of Standards in Washington, however, it was believed that curing conditions could be improved by exposing specimens to a temperature of 60°C. (140°F.) for a period of 24 to 48 hours. The selection of this arbitrary temperature seems to have been based on the facts that maximum relative humidity under such conditions could not greatly exceed 16 per cent, and that the distillation rate of volatiles from some of the specimens would not be excessive (4). Since these curing conditions are favoured in the United States in the preparation of a similar test method for determining the combustibility of materials (5), the use of similar conditions was suggested in the proposed specification.

At a meeting of the Subcommittee, the proposed specification was throughly scrutinized. The threefold combustibility grouping, as well as the modifications concerning the pilot flame and the conditioning of specimens, were agreed upon unanimously. There was, however, uncertainty about the suitability of the area values being specified as demarcation points between the combustibility groups, since the selection of these values had been based on only a few test results from a relatively small number of materials. Additional tests were thought desirable as a further check. The Subcommittee recommended (6) that the Fire Research Section undertake tests on the following materials, adhering to the procedure outlined in the proposed specification:

1. <u>3/8-inch plasterboard and mineral wool batt (paper backed)</u>
   Both these materials had been tested (1) according to the procedure described in BSI 476:1953 and were selected to permit an evaluation of the effect of changes made in the testing procedure;

2. Glass wool batt (paper backed)

This material was included in the group to obviate a situation existing previously (1) whereby no conclusions could be drawn from a comparative analysis of results of tests on two insulating materials. One, mineral wool batt, was paper backed whereas the other, glass wool batt, was composed exclusively of glass wool.

3. Asbestos paper with organic binder

This new material was selected to obtain data on the behaviour of one well recognized incombustible compound when tested under the present procedure.

EXPERIMENTAL DETAILS

Apparatus

The apparatus used for the tests was the same as the apparatus of the British Standards Institution (1), except for the minor modification to the pilot flame burner, shown in Fig. 1.

Testing Procedure

Prior to testing, specimens were dried at 140°F., ± 5°F., for not less than 24 hours, nor more than 48 hours, and allowed to cool to room temperature in a desiccator over calcium chloride. Size and details of specimens, their method of support and the method of test, were similar to those described previously (1) pertaining to the use of the BSI furnace.

RESULTS

The progress of each test was followed by noting the sequence of the visually observable events while temperatures at the thermocouple were being recorded automatically at regular 30-second intervals.

Visual Observations

Since two secondary objects of these tests were to evaluate the performance of the pilot flame when provided with an automatic re-igniter, and to determine the influence of the new ignition system on the progress of the combustion, the visual observations are reported in Table I. Although these data have been averaged over a number of repeat tests, close agreement was found between individual tests.

Good agreement is also evident between these data and similar observations made in previous tests (also included in Table I) except for the times of re-ignition of the pilot flame. The deviation is particularly great in the case of plasterboard, but, in the authors' opinion, this should not be of great concern since, in the development of a standard method of testing, one must aim at a simple procedure that can be made as uniform as possible through repeat tests. On these grounds, the use of an auxiliary flame must be recommended.

Temperature Records

The recorded temperatures were read off the chart at each minute mark and plotted against time for each test on each of the four materials tested (Figs. 2, 3, 4, and 5). The areas under the curves above the initial furnace temperature T_i (ca. 1382°F.) were integrated from the graphs, using a planimeter. Their values are tabulated in Table II (column A) with the corresponding maximum temperature rises measured directly off the recorder's chart (column D). Similar readings, obtained in previous tests on the same materials, have also been listed to permit a comparative analysis of results from tests on a given material under various conditionings.

It is noted that the results given for glass wool batt do not refer in all cases to the same commercial product. The specimens tested, under the conditions detailed in this report, were backed with paper, whereas those tested formerly were composed entirely of glass wool.

In Figs. 6 and 7, use is made of time-temperature curves published in DBR Report No. 43 to measure the influence of curing conditions on the evolution of the combustion with time. These curves have been obtained from temperatures averaged at each minute mark over repeat tests on plasterboard and mineral wool. In Fig. 8, similar curves are given for glass wool to estimate the heat contributed by the paper when such material is used as backing, and also to measure its influence on the maximum elevation of the temperature during the tests.

DISCUSSION

Although the main object of this work was merely to test further the suitability of the area values tentatively set as limits between three arbitrary combustibility groups for building materials, additional conclusions on secondary aspects of the work can also be drawn from an analysis of the test results. Such conclusions concern the variability of area values through repeat tests on a given material, the effect of the modifications to the previous testing procedure on the results, and the heat contributed by the paper when paper-backed specimens of otherwise incombustible materials are tested.

Limit Values for the Combustibility Groups

Of the four materials tested, the asbestos paper is the only one known to be of a noncombustible nature. Zero values (Table II) for the area under the curve, as well as for the temperature rise, are therefore to be expected for this material.

The three other materials had a paper backing which will, under normal conditions, impart to them some degree of combustibility although they are mainly composed of ingredients accepted as noncombustible. Nevertheless, the paper backing forms only a small proportion of the products as such, and could not contribute enough heat to justify the classification of these materials with such combustible building products as wood and wood fibreboard. In all fairness, therefore, a combustibility test method should allow for a special class, within which materials of low combustibility could be grouped.

Mean area values, resulting from the last series of tests on plasterboard, mineral wool and glass wool (paper backed), extend from 331 to 913 minutes-degrees Fahrenheit (Table II, column A), this range being increased to limit values of 222 and 1280 minutes-degrees Fahrenheit when results from individual tests are taken into consideration. Most of the results obtained previously on the same materials (including glass wool without paper backing), under other types of conditioning, fit within that range of values. Therefore, it becomes evident that the three materials would fall into the "low combustibility" group should the present tentative limits of 100 and 1300 minutes-degrees Fahrenheit be accepted as demarcation values between the three combustibility groups.

Under the conditions of the present tests, different values of combustibility were obtained for the two paper backed materials, mineral wool and glass wool. Tests on the mineral wool specimens resulted in a mean area value almost three times as great as that obtained for the glass wool specimens. This may be due partly to differences in the thickness of the paper backing, the nature of the adhesive compound used to hold the paper to the material and the type of binder in the wool proper.

With regard to the plasterboard, it must be emphasized that the specimens were made up of four thicknesses to conform to the previously specified specimen size (1). Therefore, specimens of this material contained eight layers of paper instead of the two originally found in the commercial product. Although this procedure may not render full justice to plasterboard, this particular material, being partly composed of paper, would fall somewhere within the "low combustibility" group even under ideal test conditions. It fell within this range when tested, as described previously; this procedure for preparing specimens is thus considered satisfactory for the present.

Variability of Results

In DBR Report No. 43 (1), the variability of the results was illustrated only graphically. Curves from repeat tests showed close similarity and it was assumed that area values from individual tests were of a good reproducibility. In the present study, the variation of the temperature with time during repeat tests on a given material, followed very closely the same general pattern (Figs. 2, 3, 4 and 5) except that the plasterboard specimens showed less consistency. It was therefore thought wise at this stage to check more closely the variability of results by measuring areas under time-temperature curves for each test.

The readings showed variations greater than suspected (Table II, column A). Similar measurements were made on graphs from previous tests carried out on the same materials using the BSI apparatus (columns B and C). Although deviations here are not as large as those experienced in the present tests, some closer reproducibility is desirable, since the proportion of the standard deviation of individual area values to the mean value is almost as great as, and in some cases greater than, that of temperature elevations. This, it is believed, is of great importance in the development of a standard method of testing and a further study of the subject will be made in a following report.

Effect of Modifications in the Testing Procedure

Variations in the method of conditioning the specimens seem to have a negligible effect on the sequence and nature of events observed during tests (Table I). The only apparent difference between the two sets of observations is that the pilot flame stays out for a longer period under the conditions of the present tests. This was attributed to the modification made in the procedure for re-igniting the pilot flame. The general pattern of temperature variations during tests is scarcely influenced by the type of conditioning in the cases of mineral wool (Fig. 7) and glass wool (Fig. 8, curves B and C). With plasterboard, a different pattern was observed for each set of curing conditions (Fig. 6).

Of more concern, however, is the effect of conditioning on the actual results of tests. Table II shows that, relative to conditioning, the trend of the variations between area values is similar to that of the variations observed between temperature rises. It differs, however, from one material to another, indicating that materials are not all affected in the same way by the method of conditioning used. Some materials, if dried in an oven at a temperature of 212°F., will lose inflammable volatiles and consequently will show a lower combustibility. In British Standard 476:1953, this is circumvented by conditioning some of the specimens over calcium chloride (7). On the other hand, materials which have a tendency to combine water will show a lower combustibility if conditioned over calcium chloride and a higher one if dried at 212°F. A comparative analysis of the results listed in Table II indicates that the curing conditions used in the present tests (drying at 140°F.) are close to being a practical medium between the two sets of conditions specified in British Standard 476:1953.

Heat Contributed by the Paper Backing

Curves are given in Fig. 8 to illustrate the effect of paper backing on temperature variation during tests on glass wool. When testing paper backed specimens, it is to be expected that, under the severe conditions of the test, flaming will take place as soon as the specimen is placed in the furnace, as evidenced by the small peak appearing at the one-minute mark in curve A. This causes the maximum temperature rise to be much greater than that measured on unbacked specimens; it actually triples the value in the case of glass wool (Table II, columns D, E and F). Since the paper burns rapidly, however, its presence has relatively little influence on the integrated area, the heat contributed by the paper being equivalent to less than one third of the total heat produced by the whole specimen (Table II, columns A, B and C).

CONCLUSION

The results obtained from these tests show that, under the conditions and procedure described, the four materials will exhibit mean area values as follows:

a) Asbestos Paper.................... 0 Min. x °F.
b) Glass Wool Batt (paper backed).... 331 Min. x °F.
c) Plasterboard...................... 833 Min. x °F.
d) Mineral Wool Batt (paper backed).. 913 Min. x °F.

The present method of test, however, has the disadvantage of allowing standard deviations from mean values to be larger than expected, which suggests a need for further refinement and definition of the test conditions.

Finally, there were some indications that the conditions adopted for the curing of specimens are close to simulating a mean of the two sets of conditions specified in British Standard 476:1953, whereas the heat contributed by the paper in the testing of paper backed glass wool amounts to only a small fraction of the total heat liberated by the specimen under the conditions of the test.

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4. Robertson, A.F. Private communication from National Bureau of Standards, Washington, April 1954.

5. Minutes of Meeting of Subcommittee V (Nomenclature and Definitions) of ASTM Committee E-5, Washington, D.C., 4 Feb. 1954.

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TABLE I

VISUAL OBSERVATIONS

PREVIOUS TESTS	PRESENT TESTS
PLASTERBOARD	
Pilot flame goes out at start of test.	Pilot flame goes out at start of test.
Flaming accompanied by light smoke during first minute of test.	Flaming accompanied by light smoke during first minute of test.
Pilot flame re-ignited manually at time 4 minutes and about 2 inches high.	Pilot flame re-ignited automatically at time 8 minutes and about 1½ inches high.
Specimen glowing between layers at end of test.	Specimen glowing between layers at end of test.
MINERAL WOOL	
Pilot flame goes out at start of test.	Pilot flame goes out at start of test.
Flaming with generation of black smoke for over 1 minute at start of test.	Intermittent flaming with generation of black smoke during first 30 seconds of test.
Pilot flame re-ignited manually at time 1 minute, 15 seconds and normal.	Pilot flame re-ignited automatically at time 2 minutes and 1¼ inches high.
Specimen glowing at end of test.	Specimen glowing at end of test.
GLASS WOOL (paper backed)	
No data available.	Flash inside furnace and pilot flame goes out.
	Flaming accompanied by black smoke during first 30 seconds of test.
	Pilot flame re-ignited automatically at time 40 seconds and about 1¼ inches high.
	Glowing of specimen at end of test.
ASBESTOS PAPER	
No data available.	Pilot flame about 1 inch high at start of test.
	Pilot flame goes out at time 30 seconds.
	Pilot flame re-ignited automatically at time 3 minutes and about 1 inch high.
	Specimen flows between layers at end of test.

TABLE II

INTEGRATED AREAS AND TEMPERATURE ELEVATIONS AT VARIOUS CONDITIONINGS

MATERIAL	Integrated Areas (minute x °F)			Temperature Elevations (°F)		
Conditioning:	(A) 140 °F	(B) 212 °F	(C) over $CaCl_2$	(D) 140 °F	(E) 212 °F	(F) over $CaCl_2$
PLASTERBOARD						
Test 1	1070	1153	778	110	306	158
Test 2	824	1020	1065	85	216	150
Test 3	843	1065	836	72	296	194
Test 4	594	-	-	65	-	-
MEAN -	833	1079	893	83	273	167
Standard Deviation-	20%	6%	14%	20%	14%	13%
MINERAL WOOL						
Test 1	708	715	841	235	228	280
Test 2	1280	514	1020	260	216	270
Test 3	872	651	935	157	160	294
Test 4	792	-	-	220	-	-
MEAN -	913	627	932	218	201	281
Standard Deviation-	24%	13%	8%	17%	16%	6%
GLASS WOOL	With PB(*)	No PB	No PB	With PB	No PB	No PB
Test 1	436	294	323	112	42	58
Test 2	222	185	179	102	50	30
Test 3	334	-	298	125	-	38
MEAN -	331	240	267	113	46	42
Standard Deviation-	26%	22%	23%	8%	9%	28%
ASBESTOS PAPER						
Test 1	0	-	-	0	-	-
Test 2	0	-	-	0	-	-
MEAN -	0	-	-	0	-	-

(*) PB = Paper back.

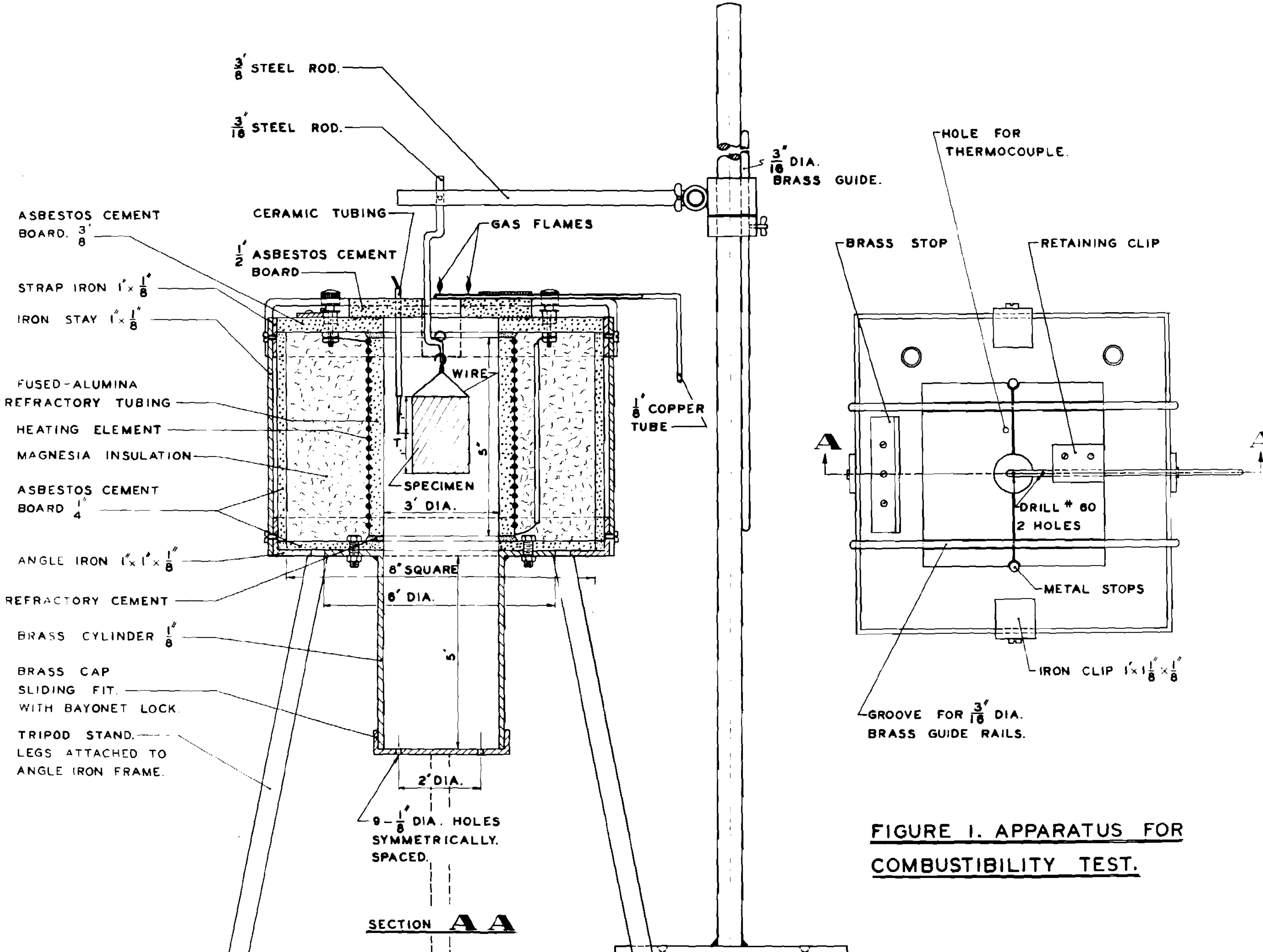

FIGURE 1. APPARATUS FOR COMBUSTIBILITY TEST.

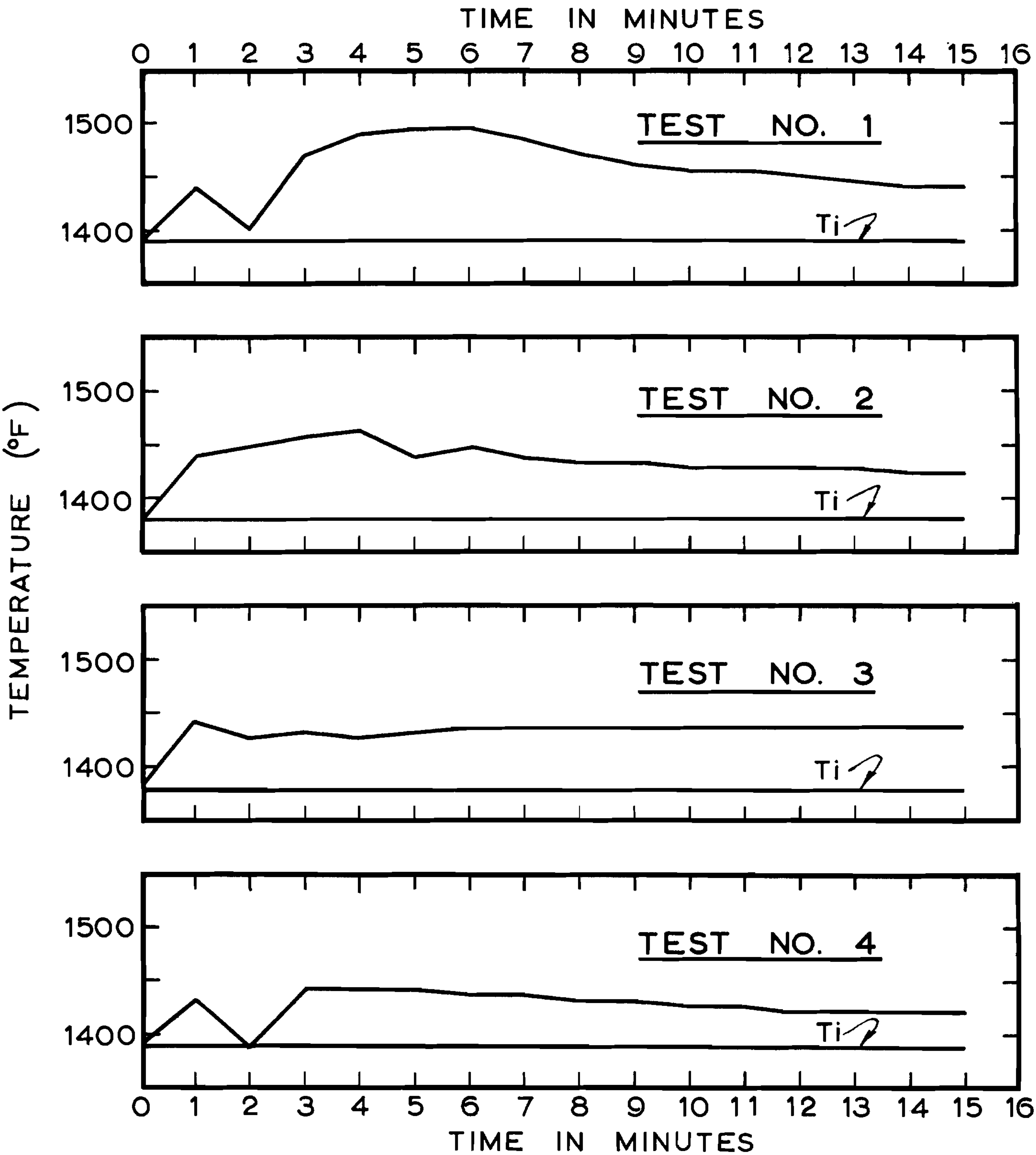

FIGURE 2

VARIATION OF TEMPERATURE AT THERMO-COUPLE DURING INDIVIDUAL TESTS ON PLASTERBOARD.

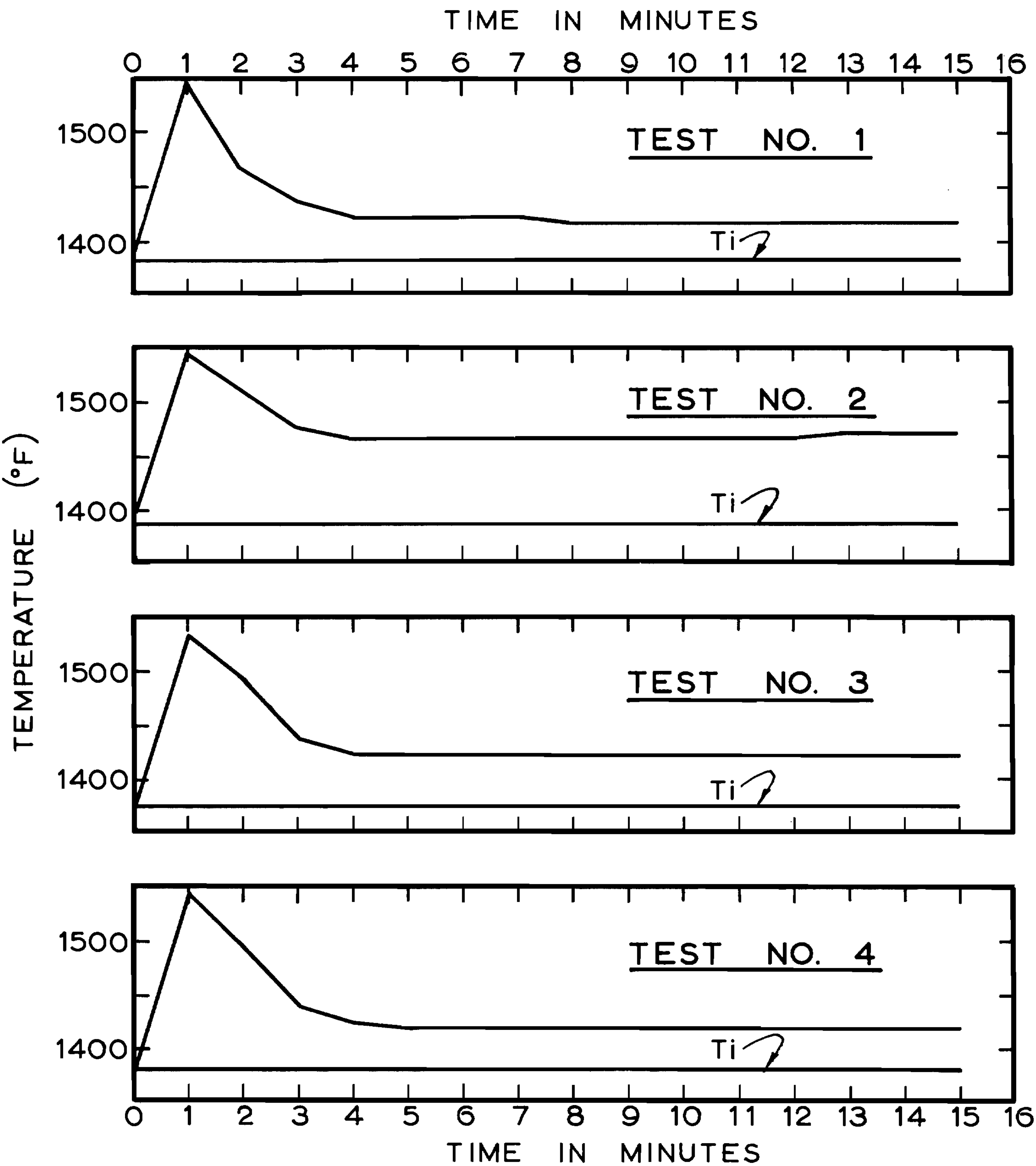

FIGURE 3

VARIATION OF TEMPERATURE AT THERMOCOUPLE DURING INDIVIDUAL TESTS ON MINERAL WOOL.

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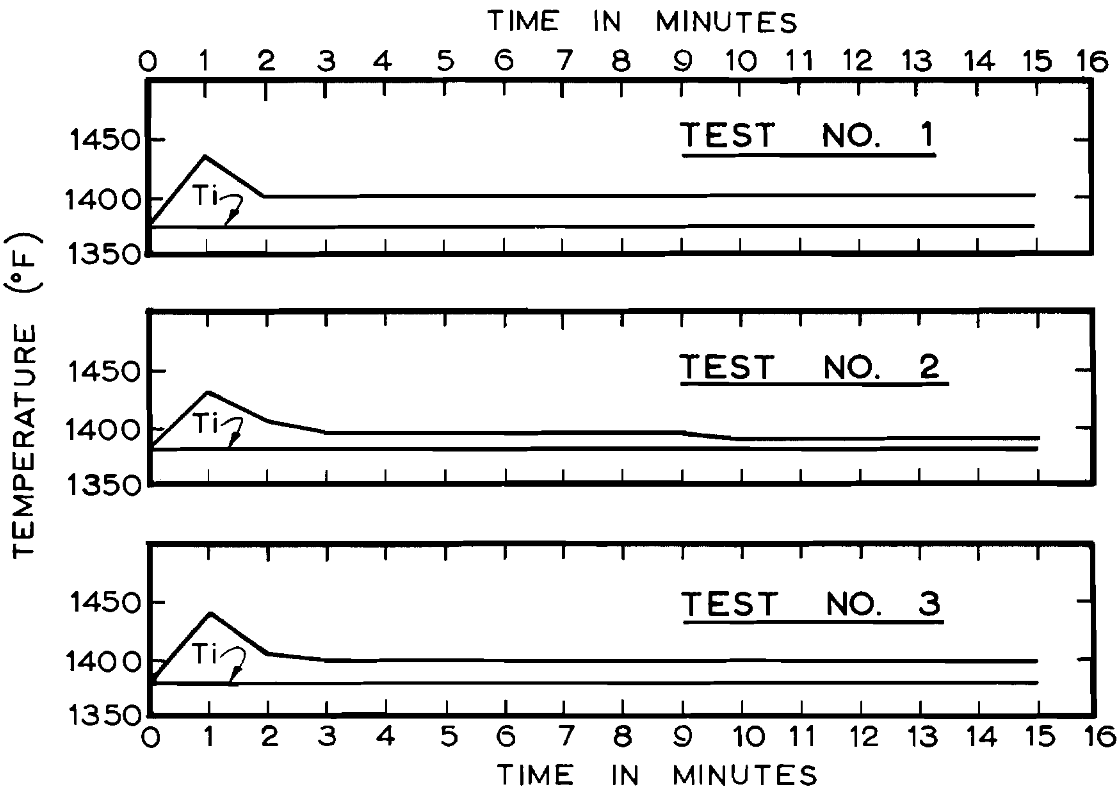

FIGURE 4

VARIATION OF TEMPERATURE AT THERMOCOUPLE DURING INDIVIDUAL TESTS ON PAPER - BACKED GLASS WOOL.

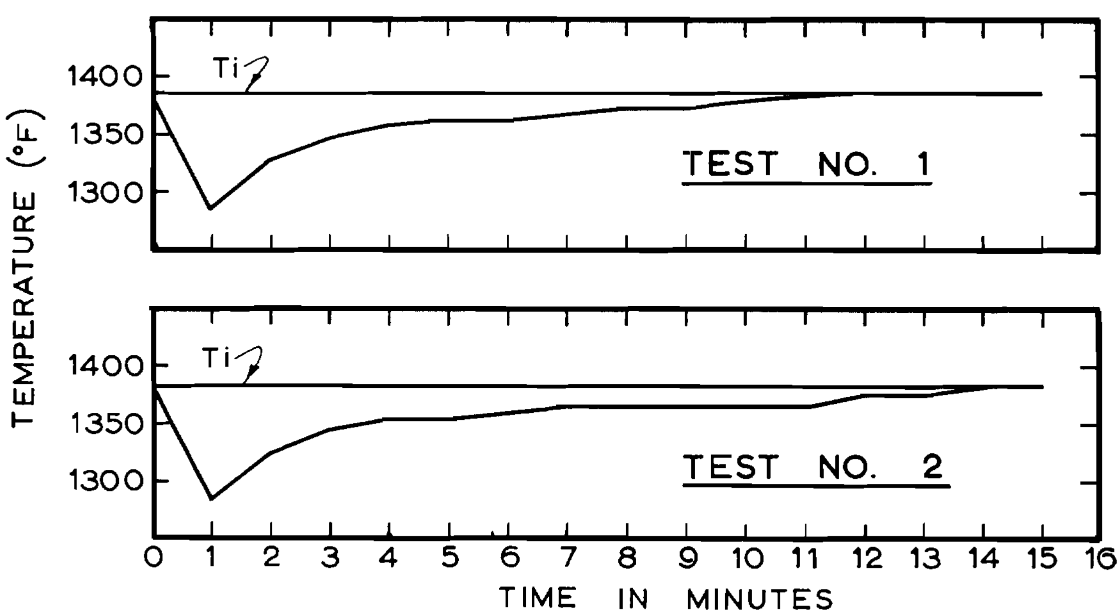

FIGURE 5

VARIATION OF TEMPERATURE AT THERMOCOUPLE DURING INDIVIDUAL TESTS ON ASBESTOS PAPER.

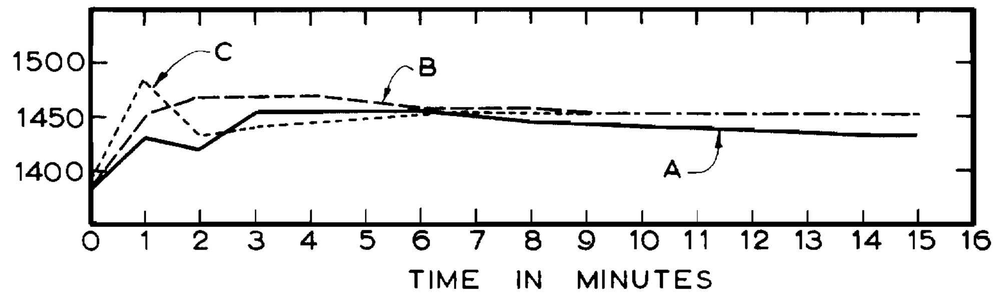

FIGURE 6

TEMPERATURE AT THERMOCOUPLE DURING TESTS ON PLASTERBOARD (AVERAGE OF 3 OR 4 REPEAT TESTS)

A- CONDITIONED AT 140°F; B- CONDITIONED AT 212 °F;
C- CONDITIONED OVER $CaCl_2$

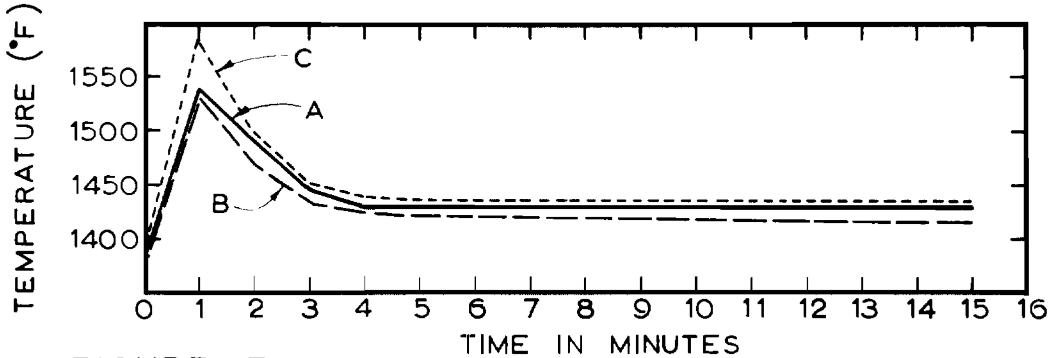

FIGURE 7

TEMPERATURE AT THERMOCOUPLE DURING TESTS ON MINERAL WOOL (AVERAGE OF 3 OR 4 REPEAT TESTS)

A- CONDITIONED AT 140 °F; B- CONDITIONED AT 212 °F;
C- CONDITIONED OVER $CaCl_2$

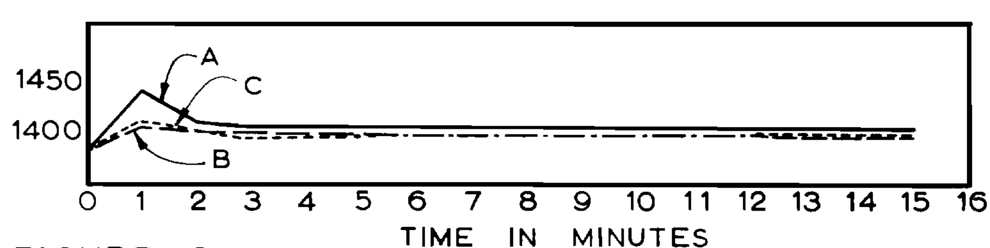

FIGURE 8

TEMPERATURE AT THERMOCOUPLE DURING TESTS ON GLASS WOOL (AVERAGE OF 3 OR 4 REPEAT TESTS)

A- PAPER- BACKED SPECIMEN CONDITIONED AT 140 °F
B- UNBACKED " " " 212 °F
C- " " " OVER $CaCl_2$