Fire Research Note

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FIRE HAZARD OF EXPANDED POLYSTYRENE LININGS

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SUMMARY

The use of expanded polystyrene wall linings and ceiling tiles has increased in recent years and reports have been made on fires in domestic buildings where the material had been used. The present investigation was undertaken to determine the fire behaviour of linings of expanded polystyrene in the thicknesses used in domestic buildings. The experimental work utilized ad hoc test procedures ranging in scale from 900 mm^3 boxes to full size rooms and covered such factors as the method of fixing, type of material and decorative finishes.

For the range of situations covered by this investigation the tests have established that the behaviour of the material fixed in place by an adhesive is different from that shown by an examination of small samples. It has been concluded that when applied to a suitable substrate with an overall application of adhesive and left undecorated the linings do not present a fire hazard. The use of flame retardant paints is to be recommended for safety but with a matt-finish emulsion paint the finished linings provide an acceptable level of safety for domestic buildings. The use of gloss finishes on this material represents a serious fire hazard and should be avoided.

KEY WORDS: Polystyrene; Domestic; Ceilings; Fire hazard; Lining materials.

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1. INTRODUCTION

Expanded polystyrene is currently being produced at an annual rate of 11,500 tons of which approximately 7,500 tons is used in buildings. About half of this amount is produced in the form of ceiling tiles and boards intended for use as linings. If the density of the material is taken as 24 kg/m^3 and the thickness of the linings as 12.5 mm, this means that about 13 x 10^6 m^2 of surfaces are being covered by this material. Whilst no precise figures are available the indications are that a major outlet is for the use of the 'do it yourself' enthusiast who wishes to improve the insulation of existing buildings and to cover up old defective ceilings. It would seem that 500 to 600,000 houses a year may be so treated if three-quarters of the product is in the form of tiles.

The major attractions of the material are its low cost, decorative effect and the ease of application. The material is available in the shape of moulded or profiled ceiling tiles 300 mm square and in 12.5 and 9.5 mm thicknesses. For application on walls as a substrate for wall paper 3 or 5 mm thick rolls are produced; no estimates are available but the application as a wall paper substrate is not a major use. Panels of material are also produced with factory applied thick paper facings the main use being the insulation of roof decks of single storey factory type buildings.

There have been reports of fires, mainly in domestic buildings, where expanded polystyrene had been employed as a lining. Whilst the role of this material has not been positively and incontrovertibly established in these incidents it has been alleged that it may have been responsible for rapid spread of fire. It was therefore decided that an investigation into the domestic use of the material should be undertaken to establish its behaviour during the initial stages of a fire. Owing to its low melting point characteristics it had not been possible in the past to make an unambiguous comparison with other lining materials using the standard tests specified for this purpose.

2. GENERAL PROPERTIES OF EXPANDED POLYSTYRENE

Expanded polystyrene is manufactured in two different ways, either as a 'bead board' formed by the fusion of pre-expanded beads of polystyrene or by an extrusion process which produces a more regular cell structure. British Standard 3837 : 1965 'Expanded polystyrene board for thermal insulation purposes' covers materials having densities of 16 to 24 kg/m^3 and British Standard 3932 : 1965 'Expanded polystyrene tiles and profiles for the building industry' deals with tiles of cut, extruded or moulded types. The thermal conductivity depends upon the density of the material, and varies between 0.032 and 0.035 Wm/m^2 degC for 16 to 24 kg/m^3 material.

The British Standards describe two grades of the material, a normal or standard grade, and a self-extinguishing grade which has chemicals introduced to make it less flammable. The test used to define the grades is a modification of the 'strip' test in which a small standard size strip has one end exposed to a flame from a bunsen burner.

The material is normally applied to a surface by the use of an adhesive and in view of its low density, under normal conditions of use it is likely to remain in position even if the whole of the surface is not covered with adhesive. This technique is usually employed for ceiling tiles which are attached by means of five 'dabs' of the adhesive. The wall linings, however, require an 'overall' application and the types of adhesive normally used are PVA based. On uneven surfaces, ceiling tiles can also be attached to small timber battens by adhesive or nails.

The exposed surfaces can be decorated with emulsion paints; the direct application of a gloss paint is not recommended owing to the possible solvent effects on polystyrene. Gloss paints however can be applied on surfaces pre-treated with emulsion paint.

3. SCOPE OF THE INVESTIGATION

There are a large number of variables which can influence the behaviour of expanded polystyrene under fire conditions; those listed below were chosen as being the more representative of actual practice.

3.1. Material

3.1.1 Type a. standard grade

b. self-extinguishing grade

3.1.2. Thickness

a. 9.5 mm and 12.5 mm ceiling tiles

b. 3 and 5 mm wall linings

3.1.3. Density - 24 kg/m^3

3.2. Fixing

a. Latex based adhesive for 'dab' application

b. PVA based adhesive for 'overall' application

c. Timber battens

3.3. Substrate

a. Non-combustible: asbestos wood or gypsum plaster

b. Combustible: plasterboard and fibre insulation board

3.4. Configuration

a. Horizontal - ceiling tiles

b. Vertical - wall lining

3.5. Surface treatment

a. None

b. PVA emulsion paint

c. Gloss paint system

d. Flame retardant paints of intumescent and non-intumescent types

e. Wallpaper on vertical linings

3.6. Ignition source

a. Small: small size gas flame, lighted taper or cotton strips

b. Medium: burning alcohol in a cup

c. An oil pan on fire or equivalent timber crib

d. Large: a timber crib

4. EXPERIMENTAL TECHNIQUES

4.1. Nature of tests carried out

Ignition and flame spread tests have been carried out using four different chambers, two representing small scale models and two full size rooms. The model chambers had cross-sections of 900 x 900 mm square; in one case the length was 900 mm with two open sides (Chamber 1) and in the other it was 1,200 mm with one open side (Chamber 2). Both were constructed of 12.5 mm thick asbestos wall board. The full size rooms measured approximately 3 m x 3 m x 2.9 m high and had brick walls with a smooth plaster finish.

Chamber 1 was used for Stage I of the investigation to study the behaviour of ceiling tiles and wall linings when exposed to small and medium sources of ignition. This part of the investigation tried to establish the initiation of sustained combustion under conditions of accidental exposure to a small ignition source and the subsequent possibility of flame spread over the surfaces.

Flame spread along a ceiling was then investigated in fuller detail in Stage II using Chamber 2, exposing the surfaces to a fire from a timber crib designed to produce conditions of a severity similar to an oil pan on fire. In these experiments measurements were made of the flaming

along the ceiling, and the temperature conditions close to the soffit. Comparisons were made with some other known materials representing linings of more traditional types.

Finally in Stage III tests have been repeated on selected arrangements in full size rooms to see if the size of the experimental chamber was likely to have a significant effect. In these experiments only visual observations were made and photographic records prepared of the general behaviour of the material.

Tests have also been carried out on the Fire Propagation test (B.S.476 : Part 6) to see if it would be possible to correlate the findings of the ad hoc tests with performance on this standard so that comparison could be made with other conventional materials. It may also provide a basis for exercising control on the use of this material in buildings.

4.2. Sources of ignition

As a first step in the design of the experiments it was necessary to decide on the sources of ignition. In use the material might be exposed to a small source such as a lighted match, to the flames from an ignited curtain or to the flames from an oil pan on fire.

For a small source, a gas flame 10-15 mm long emitted from an 1.6 mm dia. orifice was used. This was found to be similar in effect to a lighted wax taper. It was possible to manipulate the flame so that it could follow the receding material until ignition occurred. This source was used in the Stage I experiments with Chamber 1. A larger source consisting of a 100 mm x 100 mm tray filled with 50 cc of alcohol was also used in Stage I by holding it about 350 mm below soffit so that flames touched the ceiling tiles.

In the Stage II experiments timber cribs were employed; these consisted of 13 mm square sticks 250 mm long, arranged to give a 250 mm x 250 mm x 170 mm high cribs having an average weight of 1.1 kg. The cribs were designed after some experiments with a chip pan fire and provided an ignition source of about the same severity. The crib fire generated 4140 K cal (20,000 Btu) on combustion and had a normal burning duration of 6 minutes; this it released heat at an average rate of 690 K cal/min (3,333 Btu/min).

In Stage III experiments in full scale rooms, three types of ignition source were used. Light cotton gauze strips 100 mm wide x 600 mm long were pinned at the top end near the ceiling with the lower edge hanging free. Some of the experiments were repeated with newspaper in a metal basket ignited in a corner of the room so that longer flames travelled up towards the ceiling. In four tests a chip pan fire was used to reproduce a typical fire situation.

5. TEST RESULTS

Various factors examined in the three stages are summarised in the tables which follow. The results of the tests are also tabulated and some of the test features are illustrated in the photographs.

5.1. Stage I tests

Polystyrene tiles were applied to the ceiling with either a 'dab' application (25 mm dia. dabs applied at four corners and in the centre) using a latex based adhesive or an overall application of a PVA based adhesive. The wall insulating material was fixed using the latter adhesive applied overall. The majority of the tests were carried out with the material applied directly to an asbestos substrate, and in three cases tests were repeated using a substrate of plasterboard.

In the case of the ceiling tiles, eight tests were performed without any surface finish applied to the tiles, in seven cases a coating of PVA based emulsion paint was applied and in one case an intumescent type flame retardant paint. In five experiments the wall insulation was tested without a finish, an equal number of tests were carried out with an application of medium weight wallpaper and in two cases with an emulsion paint finish.

Of the 27 tests performed, nine were on standard grade ceiling tiles six on self-extinguishing grade tiles, eleven on standard grade and one on self-extinguishing grade wall lining. There was a repeat test on a wall lining.

The appearance of the expanded polystyrene at the end of each test is shown in Plates Nos 1 to 21 and the results are summarised in Tables 1 and 2.

5.2. Stage II tests

In this stage tests were performed in a 900 mm x 900 mm x 1200 mm long chamber with one end open and constructed of 12.5 mm asbestos board. The test material was applied to the ceiling covering the whole area of 900 mm x 1200 mm. The polystyrene tiles were 9.5 mm thick by 300 mm x 300 mm and were applied to a substrate of 12.5 mm plasterboard; 12 tiles were used for each test. At the far end of the chamber a 250 mm x 250 mm square x 170 mm high timber crib was located. The crib was ignited by means of a 20 cc tray of alcohol placed underneath. Thermocouples were inserted through the ceiling, hot junctions projecting 25 mm below the soffit and located at five positions along a centre line as shown in Figure 2.

Each test was of a six minute duration and the output from the thermocouples was fed to a digital recorder. During the tests observations were made of the length of flames along the ceiling and the fall of flaming drops. After each test the length of the ceiling which had suffered ignition was measured from the crib end.

Tests have been carried out on eight traditional materials six of these having known surface spread of flame properties. Twenty-one tests involved the use of 9.5 mm thick ceiling tiles, one of these having a fibre insulating board substrate. The results of the tests are summarised in Tables 3 and 4.

Maximum temperatures, when recorded, were taken at the ceiling level at distances of 300, 600 and 900 mm from the crib and are plotted in the histograms in Figs 3 and 4. Similarly the maximum length of flames and the length of the ceiling ignited in those cases where polystyrene tiles have been used are plotted in Figure 5. Data for the eight traditional linings are plotted in Fig.6 for comparison purposes. In view of the small differences in the length of flame between the tiles fixed by dab and those fixed by an overall application the readings have been averaged before plotting. It should, however, be noted from the table that in most cases, tiles fixed by the dab adhesive became detached during tests.

When a surface treatment was applied to tiles, drops were observed to fall beyond the crib. The worst performance was given by tiles which in addition to the matt emulsion paint and a finish of gloss paint.

Plates 22 and 23 show the sequence of the test for standard grade material without finish (Test No.6) and the SE grade material with an emulsion plus gloss paint finish (Test No.16). Plate 22 shows the flames touching the ceiling at 2 m 15 s with a local softening of the material; ignition in the vicinity of the flames is apparent at 3 m 15 s. The flames spread to the next tile and there was a softening and shrinkage of the tile to the ceiling. After 4 minutes the temperatures passed their peak values. In the case of the tiles painted with gloss paint (Plate 23) as soon as the flames touched the ceiling the polystyrene softened and the paint film started to sag. The film ignited at 2 m 8 s and flames spread rapidly to the front of the chamber with the hanging strips of paint burning (2 m 15 s). Subsequent photographs show the paint film with shrunken polystyrene burning on the floor of the chamber.

5.3. Stage III Tests in a full size room

The Stage III experiments were carried out in brick rooms 3 m x 3 m x 2.9 m high with plastered walls and ceiling. In the initial tests opposing corners of the room had polystyrene linings covering parts of the ceiling and wall surfaces from about 1 m above the floor right up to the ceiling. This technique permitted a number of different arrangements to be installed and tested consecutively. The igniting sources consisted of (a) a 100 mm wide strip of cotton gauze simulating net curtaining which was pinned at the top of the wall and hung down freely to the bottom of the wall lining; (b) loose newspapers in a basket in the corner of the room which provided a larger source of heat with longer flames, and (c) a 250 mm dia. pan containing flaming cooking oil and (d) timber cribs.

Finally in this stage, three tests (Nos 18, 19 and 20) were performed with the whole of the ceiling area covered with polystyrene tiles attached by an overall application of adhesive to a plasterboard substrate. In test No.18, the standard grade tiles were undecorated. In tests 19 and 20, the self-extinguishing grade tiles were decorated with matt emulsion paint and in the last test, a further coating of gloss paint. The igniting source was a pan of cooking oil heated on a gas stove. These tests were carried out in situations representative of a typical domestic kitchen and confirmed the results of earlier tests with similar linings.

Observations were made of the flame spread and photographs were taken during tests to show the progress of flaming.

The tests and the results are summarised in Table 5 and photographic records in Plates 24 to 38.

5.4. Fire propagation tests

Fire propagation and ignitability tests have been carried out on both the standard grade and the self-extinguishing ceiling tiles with and without surface finishes. The majority of the tests were performed on 9.5 mm thick samples and the effect on the performance index for some of the different finishes used in the other stages was examined.

The results of the tests are summarised in Table 6.

6. DISCUSSION OF RESULTS

6.1. Ignition of polystyrene

When a flame is brought close to the surface of a sheet of expanded polystyrene, its temperature is raised followed by the softening and melting of the material into globules. If the molten globules remain close to the source of heat flammable vapours are emitted which can be ignited. Further and continued combustion is dependent upon the availability of the material and the heat balance that can be established. The amount of heat liberated by the material undergoing combustion is small and if this is easily dissipated then sustained ignition is unlikely. If the material melts too readily it is likely to 'move away' from the effective range of the heat source making ignition difficult. This may be a reason for the superior performance of the 'self-extinguishing' grades of materials in the ignitibility test of B.S. 476 : Part 5 and the flammability tests of B.S. 3837 and 3932. The flame retardant additives by the raising of the ignition temperatures, and by the generation of flame inhibiting gases allow the material to recede from the heat source before ignition can take place.

The ad hoc situations examined in this programme were quite different from those simulated by the above standard tests and for this reason the classifications arrived at on the basis of these tests are not necessarily reflected by similar differences in performance in the present series of tests.

6.2. Expanded polystyrene without surface finish

6.2.1. Ignition from a small source

Stages I and III of the investigation explored the possibility of obtaining a sustained ignition from the wall and the ceiling linings without a finish, on exposure to a small flame. In only one case in Stage I (Test No.1) was sustained ignition obtained and this resulted in the burning of only one tile; the flames did not spread over the chamfered edges to the adjacent tiles. With wall linings in general there was no further spread once the test flame was removed and in one case only did flaming spread more than 100-150 mm in the vertical direction.

Stage III full scale tests with the cotton gauze strip gave similar results although below the burning strip, local ignition of polystyrene on the wall was observed, but there was no lateral spread; no sustained ignition of the ceiling tiles was obtained. In one case (Test No.5) slight ignition beyond the source of heat occurred.

The tests have shown that tiles and wall linings when firmly bonded to a substrate and without a surface finish, of either type of material, are unlikely to suffer sustained ignition from a small heat source. There was virtually no difference in the behaviour of the standard grade and the self-extinguishing grade materials under these conditions.

6.2.2. Ignition from a large source

In Stage I tests the larger alcohol flame was able to initiate some flaming particularly when applied in a corner but this did not lead to any marked tendency for flame spread. In the full scale room tests the lighted newspaper in the corner produced ceiling height flames and the general behaviour was similar to that obtained in the Stage I tests. More of the wall lining in the vicinity of the flames was damaged by direct contact but no lateral spread occurred along the wall surface. One or two tiles on the ceiling were damaged by direct contact again without leading to general flame spread.

In the Stage III test (No 18) with the whole of the ceiling lined with the standard grade tiles the oil-pan fire caused a transitory ignition of the tiles just overhead but there was no flame spread. Over the whole of the surface the tiles shrank and receded to the substrate. In test No 17 with the tiles attached to battens and a large crib fire there was no flame spread and a large number of the tiles became detached and fell on the floor.

In Stage II tests measurements were made on the extent of flame spread and the rise in temperature along the ceiling. The flame spread results show that the extent of spread was no greater than that with Class 1 or 2 products tested under identical conditions (Figs 5 and 6). The SE grade gave marginally inferior performance to that of the standard grade product. The temperature measurements (Fig.3 and 4) confirm this slight difference between the two types of materials. Maximum temperatures 300 mm from the cribs reached a slightly higher value with expanded polystyrene than with conventional Class 1 and 2 materials but 900 mm away the differences were marginal.

The measurements and observations of the tests have illustrated that both grades of materials without a finish are unlikely to lead to rapid and extensive flame spread along a ceiling with the types of heat sources used in the investigation.

6.3. Effect of surface finish

Use of matt finish emulsion paint resulted in some sustained ignition of the ceiling tiles in Stages I and III tests. However no unrestricted spread of flame was observed although the tile directly exposed and in some cases the adjacent tiles were partially or fully consumed. The Stage II tests showed a similar pattern and resulted in slightly higher temperatures 300 mm from the crib showing a marginal increase in combustion close to the source of heat.

Test No.19 (Stage III) with the ceiling tiles having a coating of emulsion paint confirmed the findings of the other tests. Except for transitory ignition of tiles above the oil pan fire and the fall of a few burning particles in its immediate vicinity, there was no flame spread. The rest of the ceiling suffered damage similar in nature to the undecorated tiles.

The use of gloss paint has been explored in the Stage II and III tests and it is evident from the results that this type of finish can create a situation favourable for rapid flame spread along the surface. The flame lengths were greater and the temperatures measured in the Stage II tests slightly higher than with other tests on expanded polystyrene. On exposure to the heating conditions the paint film tends to come away from the substrate facilitating its ignition as well as that of polystyrene. Segments of burning paint film fell on the floor and could have ignited a flammable covering material.

Test No 20 (Stage III) showed the rapidity with which the flames can spread along a ceiling having a gloss paint finish. Large strips of the burning material fell on the floor and the emission of flames from the door of the room could have caused a fire in the rest of the building had no preventative action been taken.

When a flame retardant paint of an intumescent type was used in Stage I no ignition of the tiles occurred but in Stage II tests this did not completely prevent ignition of the material. The intumescent type of paint was found to drop off more readily than a non-intumescent finish. In both cases the length of ceiling ignited was more than with tiles having no finish but it was less than with a gloss paint finish. Whilst the paint would have made no contribution to flame spread its presence as a film to which polystyrene can attach itself may have been responsible for the slight flaming which occurred. The use of flame retardant paints to protect those surfaces which had already been decorated with a gloss paint showed an improvement over the original painted surfaces, the most significant effect being the reduction in flaming drops.

The use of matt finish emulsion paint on wall linings had no adverse effect but a covering of wallpaper did increase the possibility of sustained ignition. The ignition of wallpaper was caused by the polystyrene behind it melting and leaving a void. The effect was more pronounced with larger sources of ignition than with the small igniting flame. When an oil pan fire was used in the full scale test it caused greater damage and led to some lateral spread across the wall surface.

Performances in the full scale tests with a small source was identical to that obtained in Stage I tests. In the fire propagation tests the performance of specimens without a finish was almost identical to the corresponding specimens with a coating of intumescent type flame retardant paint.

6.4. Effect of substrate

Most of the experiments in Stages I and III were performed with expanded polystyrene applied to a non-combustible substrate consisting of either asbestos board or a plastered finish. In Stage II the tiles were attached to a plasterboard ceiling panel except in one instance, when fibre insulating board was used. A few check tests were performed with polystyrene applied to plasterboard in Stage I and the performance was no different than in corresponding tests with asbestos board substrate. The application of SE grade tiles to fibre insulating board substrate (Class 4) gave no improvement in the performance over that obtained with the substrate alone (Fig.23A). In tests Nos 14 and 17 in Stage III, the wall linings were applied directly to the plasterboard and the ceiling lining onto battens attached to a plasterboard substrate providing a 9 mm air gap. Again little difference in performance was observed in comparison with the plastered backing except for the tendency of the tiles on battens to become dislodged. The performance of ceilings was determined by the presence of the polystyrene, its method of fixing and any decorative treatments applied to it rather than by the nature of the substrate.

6.5. Method of fixing

Two methods of fixing tiles were examined, either by an overall application of the adhesive to the substrate or by means of five 'dabs' of the adhesive, except in three cases when the tiles were attached to timber battens with the adhesive applied along the edges. On exposure to the source of ignition when no surface treatment was used the tiles with an overall application softened and receded to the substrate. The area of the ceiling over which this phenomenon occurred depended upon

the size of the igniting source; with the larger timber cribs and the oil pan fires in Stage III high temperature conditions existed over the whole of the ceiling and consequently all of the tiles shrank.

When a surface finish was applied the tendency to shrink to the substrate was observed but the nature of the finish influenced the partial fall of polystyrene; with the matt finish emulsion paint and the flame retardant paints some localised fall of small fragments occurred in the vicinity of the heat source only. With the gloss paint finishes some of the softened polystyrene remained attached to the paint film and fell with the burning material.

The tendency of the tiles to become detached with the 'dab' method of fixing was very pronounced. With small sources of ignition only a few tiles were affected but as the size of fire increased so did the detachment of the tiles. In test No.17 (Stage III) tiles attached to the battens, nearly all the tiles fell down even remote from the point of fire. In the fire propagation test the samples with the 'dab' method of attachment invariably gave a poorer performance.

6.6. Grade of polystyrene

The fire propagation test is able to distinguish between the standard grade and the SE grade products, the latter giving a better performance when used without a finish or an adhesive. However, when the material was attached to the substrate with an overall application of an adhesive, the difference in performance between the two grades diminished. The application of a surface finish had a very marked effect on the behaviour of the test specimens, not only was there a significant increase in the value of the performance index but also the differences between the two grades disappeared, with the self-extinguishing grade specimens giving a slightly lower performance.

The ad hoc tests undertaken were not able to distinguish clearly differences between the two grades of materials. The indications were that without finish the standard grade was marginally inferior. When tested with finishes the differences in performances were negligible so that without a prior knowledge of the type of material employed in an experiment, it would have been very difficult to identify it from the results.

6.7. Burning drops

In only one case in Stage I tests were flaming drops observed with the undecorated polystyrene tiles; in the Stage II and III tests only a few flaming drops fell in the immediate vicinity of the source of ignition. The tendency for the flaming drops to fall increased with the presence of a surface coating, with the flame retardant paints and the emulsion paint the increase was only marginal and still confined to the immediate vicinity of the source of ignition. However with the gloss paint finish particles of burning material consisting mainly of the paint film with some attached polystyrene, fell over the whole of the floor area. These continued to burn and had flammable materials covered the floor it is possible that these would have become ignited.

6.8. Smoke

In most of the tests not enough of the material was involved in combustion to produce any appreciable quantities of smoke. In the full scale tests with the oil pan fires (Stage III tests), the rooms were filled with dense smoke which completely obscured the ceiling. Smoke produced on the ignition of expanded polystyrene is associated with the development of large size carbon particles.

6.9. Performance in the fire propagation test

The sensitive and the discriminating nature of the fire propagation test is clear from the results shown in Table 6. The test has been able to distinguish not only between different finishes but also the method of attachment to the substrate. Without adhesive the polystyrene samples have given an inferior performance compared with that obtained when the material is bonded to a substrate. This is probably due to slightly more rapid decomposition of the unsupported and therefore easily damageable materials. Overall application of adhesive gave the best performance. Use of emulsion paint resulted in a slight deterioration in performance and the worst performance was obtained with a gloss paint finish.

Without a surface finish SE grade material was shown to be better than the standard grade but when any type of finish was used the position reversed and the performance of the SE grade materials was generally inferior. There is no obvious explanation for this phenomenon which was also observed in the ad hoc tests.

7. CONCLUSIONS

A comprehensive investigation has been carried out on the fire hazard associated with the use of expanded polystyrene wall and ceiling linings in domestic buildings. The studies were limited to the type of materials, the methods of fixing and the decorative treatments which are relevant to this type of occupancy, particularly the methods practiced by the 'do-it-yourself' section of the community.

It is shown that in thicknesses up to 12.5 mm there is no significant difference in the fire hazard of the standard grade and the self-extinguishing grade materials when they are attached to a substrate. When the ceiling tiles or the wall linings are firmly attached with an overall application of the adhesive and given no decorative treatment, the material of either grade is difficult to ignite and does not spread flames provided the substrate is non-combustible or of a Class 1 standard (according to the spread of flame test of B.S.476).

The presence of a surface finish produces conditions conducive to the ignition and the burning of the material; the deterioration in performance depends upon the nature of the finish. A flame retardant paint finish makes only a marginal difference and a matt finish emulsion paint can lead to localised flaming but without any danger of rapid flame spread. Finishes consisting of gloss paint, even when applied over an undercoat of emulsion paint, result in surfaces which exhibit very rapid flame spread and produce burning strips capable of igniting combustible materials on the floor. Over-painting such surfaces with flame retardant paints does not provide an acceptable level of safety.

The use of wallpaper on wall linings of up to 5 mm thickness is not considered hazardous as the damage is localised and flames do not spread laterally.

The fire propagation test of B.S.476 : Part 6 gives a realistic assessment of the fire hazard of expanded polystyrene with and without surface finishes.

On the basis of this investigation the users of expanded polystyrene tiles and wall linings, of thickness not exceeding 12.5 and 5 mm respectively, are advised:-

1. to apply the material directly to a non-combustible or a Class 1 substrate;
2. to use adhesive over the whole surface and not to use the 'dab' method of attachment;
3. not to use a decorative paint finish for maximum safety;
4. if ceiling tiles have to be painted it is best to use a flame retardant paint;
5. the use of matt-finish emulsion paint on tiles having an overall application of adhesive, though not as good as a flame-retardant paint, will still provide an acceptable level of safety;
6. never to use a gloss paint finish; if any surfaces are so decorated the tiles should be removed.

8. ACKNOWLEDGMENT

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Table 1. Stage I tests using chamber type I on ceiling tiles

Test No.	Type	Thickness mm	Substrate	Adhesive	Surface treatment	Igniting source	Point of application	Plate No.	Performance
1	Standard grade	9.5	Asbestos	Dab	None	Gas flame	Centre tile	1	Ignition, one tile consumed flaming drops.
2	"	9.5	"	"	None	Alcohol flame	Centre tile	3	No ignition, $\frac{3}{4}$ of a tile melts.
3	"	9.5	"	"	Emulsion paint	Gas flame	Centre tile	2	Ignition, flame spread to six tiles, flaming drops.
4	"	9.5	"	"	Emulsion paint	Alcohol flame	Centre tile	4	No ignition, $\frac{3}{4}$ of a tile melts.
5	"	9.5	"	"	Emulsion paint	Alcohol flame	Corner tile	13	No sustained ignition, one tile melts.
6	"	12.5	"	"	None	Gas flame	Centre tile	11	No sustained ignition on three applications of flame.
7	"	9.5	"	Overall	None	Gas flame	Centre tile	9	No ignition, $1/5$ of tile melts.
8	"	9.5	"	Overall	None	Alcohol flame	Corner tile	10	No ignition, one tile melts.
9	"	12.5	Plaster-board	Dab	None	Gas flame	Centre tile	12	No ignition, $1/5$ of tile melts.
10	S.E.	9.5	Asbestos	"	None	Gas flame	Centre tile	5	No ignition.
11	"	9.5	"	"	None	Alcohol flame	Centre tile	7	No sustained ignition
12	"	9.5	"	"	Emulsion paint	Gas flame	Side tile	6	Ignition, flames spread to adjacent tile, flaming drops.
13	"	9.5	"	"	Emulsion paint	Alcohol flame	Centre tile	8	No ignition, one tile melts.
14	"	9.5	"	"	Emulsion paint	Alcohol flame	Corner tile	14	Ignition, flame spread to four tiles, flaming drops.
15	"	9.5	"	"	Intumescent paint	Gas flame	Corner tile	15	No ignition .

Table 2. Stage I tests using chamber type I on wall linings

Test No.	Type	Thickness mm	Substrate	Adhesive	Surface finish	Igniting source	Point of application	Plate No.	Performance
16	Standard grade	2	Asbestos board	Overall	Wall paper	Gas flame	Face	16	Flame spread to ceiling in a narrow band.
17	"	2	"	"	None	"	"	16	No spread.
18	"	2	"	"	Wall paper	Alcohol flame	Corner	17	No lateral spread, vertical spread up to ceiling.
19	"	2	"	"	None	"	"	17	Vertical spread up to ceiling.
20	"	5	"	"	Wall paper	Gas flame	Face	18	No spread
21	"	5	"	"	None	"	"	18a	No spread
22	"	5	"	"	Wall paper	Alcohol flame	Corner	18b	No spread beyond ceiling.
23	"	5	"	"	None	"	"	18b	No spread beyond ceiling.
24	"	5	"	"	Emulsion paint	Gas flame	Face	19	Slight vertical spread.
25	S.E.	5	"	"	Emulsion paint	"	"	20	Slight vertical spread.
26	Standard	5	Plaster-board	"	Wall paper	"	"	21	Slight vertical spread.
27	"	5	"	"	None	"	"	21	No spread.

Table 3. Stage II tests on various traditional ceilings

Test No.	Ceiling	Finish	Spread of flame classification	Maximum length of flames	Flaming drops	Length of ceiling ignited
1	Asbestos	None	Non-combustible	600 mm	None	None
2	Fibreboard	Intumescent paint	1	900 mm	None	660 mm
3	Plywood	Intumescent paint	2	900 mm	None	550 mm
4	Chipboard	-	3	1200 mm	None	830 mm
5	Fibreboard	-	4	1500 mm	None	1200 mm
6	Plasterboard	Nil	1	800 mm	None	600 mm
7	Plasterboard	Lining paper + undercoat + gloss paint	1	900 mm	None	450 mm
8	Plasterboard	Lining paper + Embossed paper + Undercoat + Gloss paint	1	1200 mm	None	850 mm

Table 4. Stage II tests on 9.5 mm polystyrene tiles

Test No.	Type	Adhesive	Finish	Maximum length of flames	Flaming drops	Length of ceiling ignited	Remarks
9	Standard	Overall	None	600 mm	On crib	600 mm	Last two rows of tiles shrunk in situ.
10	"	Dab	"	760 mm	On crib	600 mm	Unburnt tiles fallen from ceiling.
11	S.E.	Overall	"	900 mm	On crib	710 mm	Last two rows of tiles shrunk in situ.
12	"	Dab	"	900 mm	On crib	780 mm	Unburnt tiles fallen from ceiling.
13	Standard	Overall	Emulsion paint	760 mm	300 mm beyond crib.	550 mm	Last two rows of tiles shrunk in situ.
14	"	Dab	"	760 mm	On crib	660 mm	Unburnt tiles fallen from ceiling.
15	S.E.	Overall	"	900 mm	600 mm beyond crib.	660 mm	Last two rows of tiles shrunk in situ.
16	"	Dab	"	1000 mm	600 mm beyond crib.	660 mm	Unburnt tiles fallen from ceiling.
17	Standard	Overall	Emulsion paint + gloss paint.	1200 mm	1100 mm beyond crib.	1200 mm	Paint film dislodged and burnt traces of polystyrene on ceiling, pieces of burning material on floor.
18	"	Dab	"	"	"	"	"
19	S.E.	Overall	"	1200 mm	760 mm beyond crib.	1200 mm	Paint film dislodged and burnt, pieces of burning material on floor.
20	"	Dab	"	1500 mm	900 mm beyond crib.	1200 mm	"
21	"	Overall	Intumescent F.R. paint.	1000 mm	300 mm beyond crib.	800 mm	Last two rows of tiles shrunk in situ.
22	"	Overall	Non-intumescent F.R. paint.	1000 mm	None	750 mm	"
23	"	"	None. (FIB substrate)	1500 mm	1000 mm beyond crib.	1200 mm	All tiles burnt, traces of polystyrene on ceiling. FIB burnt through over crib, charred elsewhere.

Table 4. Stage II tests on 9.5 mm polystyrene tiles

Test No.	Plate No.	Tiles	Finish	Type of adhesion	Approximate length of ceiling ignited	Maximum length of flame across ceiling	Distance from crib of flaming drops	Condition of ceiling after test
24	-	Std.	1 Coat emulsion 1 Undercoat, Timonox 1 Gloss coat, Timonox	Overall	1000 mm	1200 mm	On crib	½ area of tile and paint film left on last row.
25	-	Std.	2 Coats Timonox Satin lustre	Overall	800 mm	900 mm	On crib	Last row of tiles shrunk complete with paint film.
26	-	Std.	1 Emulsion coat 1 Undercoat 2 Gloss coats 1 Timonox undercoat 1 Timonox gloss coat	Dab.	650 mm	900 mm	None	Last row of tiles shrunk complete with paint film. One tile of previous row hanging.
27	-	Std.	1 Emulsion coat 1 Undercoat 2 Gloss coats 2 coats Timonox Satin lustre	Dab.	850 mm	900 mm	750 mm	Two tiles on last row hanging down with paint film.
28	-	Std.	1 Emulsion coat 1 Undercoat 2 Gloss coats 2 Timonox emulsion	Dab.	1200 mm	1200 mm	900 mm	All paint film down. Shrunk polystyrene on dabs.
29	-	Std.	1 Emulsion coat 1 Undercoat 2 Gloss coats 2 Coats Snuff F.R.P.	Dab.	750 mm	1000 mm	300 mm	All paint film down. Shrunk polystyrene on dabs.

Table 5. Stage III full scale tests

Test No.1

Material	-	Standard grade
Adhesive	-	Dab
Finish	-	None
Igniting source	-	Gauze strip

Performance:-

Wall	-	No sustained ignition, gauze burnt to ceiling.
Ceiling	-	Localized melting of material, no flame spread, tiles shrunk over 0.5 m^2 area.

Test No.2

Repeat of Test No.1

Performance:- Similar performance but with less damage to materials. (Plate No.24).

Test No.3

Material	-	Standard grade
Adhesive	-	Dab
Finish	-	None
Igniting source	-	Newspapers in a basket ignited in a corner.

Performance:-

Wall	-	Flame reached ceiling, lining in contact with flame burnt, no lateral spread.
Ceiling	-	No sustained ignition, about four tiles melted, no spread. Molten drops on floor. (Plate No.25).

Test No.4

Material	-	S.E. Grade
Adhesive	-	Dab
Finish	-	None
Igniting source	-	Gauze strip

Performance:-

Wall	-	Gauze burnt to ceiling, no sustained ignition.
Ceiling	-	Partial damage to one tile, no flame spread.

Cont'd .....

Test No.5

Repeat of Test No.4

Performance:-

Wall	-	Marginally greater damage to lining, no lateral spread.
Ceiling	-	Ignition of a tile but no lateral flame spread, molten drops, non-burning. (Plate 26).

Test No.6

Material	-	S.E. grade
Adhesive	-	Dab
Finish	-	None
Igniting source	-	Lighted newspaper in corner.

Performance:-

Wall	-	No sustained ignition, localized damage.
Ceiling	-	Part of a tile damaged, no ignition. (Plate 27).

Test No.7

Material	-	Standard grade
Adhesive	-	Dab
Finish	-	Emulsion paint on wall and ceiling
Igniting source	-	Gauze strip in the corner

Performance:-

Wall	-	Gauze burnt to top of wall, ignition of material, some spread but flames extinguished after 9 min.
Ceiling	-	0.3 m^2 of ceiling surface damaged, a few burning drops flaming out after 9 min. (Plate 28).

Test No.8

Material	-	S.E. grade
Adhesive	-	Dab
Finish	-	Emulsion paint on wall and ceiling
Igniting source	-	Gauze strip in the corner

Performance:-

Wall	-	No sustained ignition, localized damage
Ceiling	-	Ignition of material, tiles over 0.35 m^2 area consumed. Fall of flaming drops on floor after 6 minutes. (Plate 29).

Cont'd .....

Test No.9

Material	-	Standard grade
Adhesive	-	Dab
Finish	-	Intumescent flame retardant paint on walls and ceiling.
Igniting source	-	Gauze strip in the corner.
Performance:-	-	No ignition of material on the wall or the ceiling, minimum damage. (Plate 28).

Test No.10

Material	-	S.E. grade
Adhesive	-	Dab
Finish	-	Intumescent flame retardant paint on walls and ceiling.
Igniting source	-	Gauze strip in the corner.
Performance:-	-	No ignition of material on the wall or the ceiling, minimum damage. (Plate 29).

Test No.11

Material	-	Standard grade
Adhesive	-	Dab
Finish	-	Walls - medium weight wall paper Ceiling - emulsion paint
Igniting source	-	Gauze strip on wall.
Performance:-		
Wall	-	Shrinkage of polystyrene leads to ignition of loosened wall paper, flames spread vertically in a narrow band up to ceiling, no lateral spread.
Ceiling	-	Local ignition of ceiling tiles, flaming drops, no general spread, flaming out 6 min 20 seconds. (Plate 30).

Test No.12

Material	-	S.E. grade
Adhesive	-	Dab
Finish	-	As in Test No.11
Igniting source	-	Gauze strip on face of wall
Performance:-	-	As in Test No.11 slightly wider band of flame on the wall. All flaming out 8 min 18 seconds. (Plate 31).

Cont'd .....

Test No.13

Material	-	S.E. grade
Finish	-	As in Test No.11
Igniting source	-	Metal pan of 250 mm dia. with burning cooking oil, flames about 1 metre high, located in a corner about 1.2 m below the ceiling.

Performance:-

Wall	-	All wall paper burnt, some lateral spread, polystyrene melted.
Ceiling	-	Tiles loosen from the ceiling and burn, flaming drops around the pan area*. Heat from the fire affected tiles in the other corner of the room which softened and shrank and some became dislodged. (Plate 32).

*About 6 tiles consumed by burning, remainder fell on floor without burning.

Test No.14

Material	-	Standard grade - wall lining fixed directly on plasterboard, ceiling tiles fixed with dab adhesive to 9 mm battens on surface of plasterboard.
Finish	-	None
Igniting source	-	Gauze strip on wall face.

Performance:

Wall	-	Vertical flames along the width of gauze, no lateral spread.
Ceiling	-	Flame touched ceiling, softening of a tile occurred. No spread, no flaming drops. (Plate 33).

Test No.15

Material	-	S.E. grade, fixing as for Test No.14
Finish	-	None
Igniting source	-	Gauze strip on wall face

Performance:-

Wall	-	Vertical flames along the width of gauze, no lateral spread.
Ceiling	-	Flame touched ceiling tile and softening occurred. No spread, no flaming drops. (Plate 34).

Cont'd .....

Test No.16

Material	-	S.E. grade, fixed as in Test No.14.
Finish	-	Emulsion paint and gloss paint
Igniting source	-	Timber crib
Performance:-		
Ceiling	-	Within 15 sec of flame reaching ceiling paint film sagged; within a further 5 sec ignition of paint film occurred. Burning paint film fell to the ground. Whole of ceiling consumed within 1 minute.

Test No.17

Material	-	Standard grade attached with overall adhesive to 9 mm battens on surface of plasterboard.
Finish	-	None
Igniting source	-	Timber crib 4.4 kg
Performance:-	-	Tiles receded from the heat as flames reached ceiling height. By 2 min, all but the farthest tiles had receded or fallen. No flaming drops were observed. (Plate 35).

Test No.18

Material	-	Standard grade attached with overall adhesive.
Finish	-	None
Igniting source	-	Cooking oil on gas stove
Performance:-	-	Flames from igniting source reached ceiling and began to spread out. Flaming drops over stove, local ignition of tiles but no spread. Most tiles had shrunk. (Plate 36).

Test No.19

Material	-	S.E. grade attached with overall adhesive.
Finish	-	2 coats emulsion paint.
Igniting source	-	Cooking oil on gas stove.
Performance:	-	Flames reached ceiling and spread out. Local flaming drops over stove; no spread. Paint film burnt over source and most tiles had shrunk. (Plate 37).

Test No.20

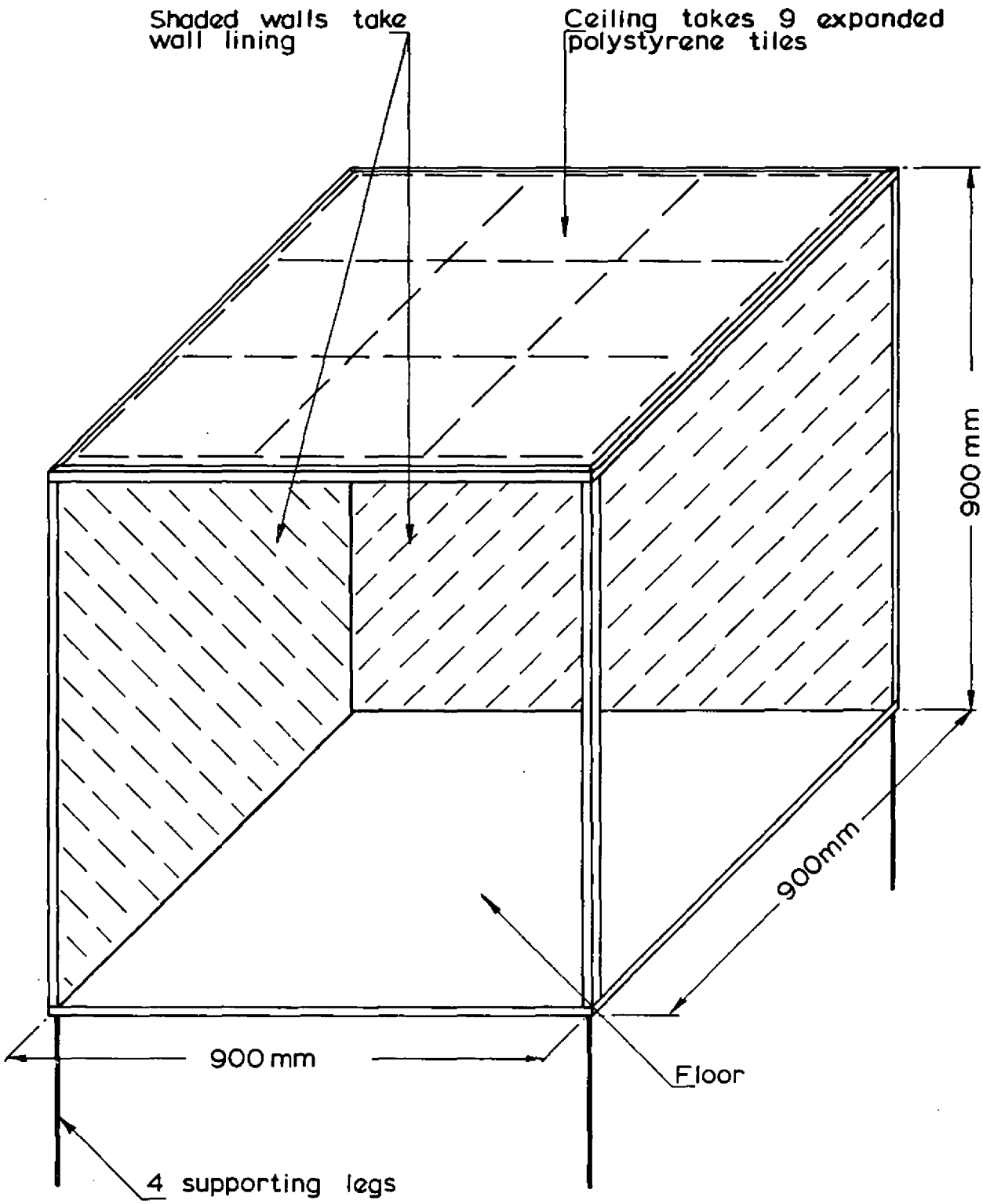
Material	-	S.E. grade attached with overall adhesive.
Finish	-	Emulsion paint and gloss paint.
Igniting source	-	Cooking oil on gas stove.
Performance:-	-	Flames reached ceiling and spread out causing paint film to sag. Sudden ignition of paint film followed by its falling in flaming pieces leaving shrunk tiles on ceiling. Test stopped with water. (Plate 38)

Table 6. Results of the fire propagation tests

Surface finish	Grade	Adhesive	Index	I_1
None	SE	Overall	8.9	5.9
Intumescent F.R. paint	Standard	"	9.1	5.8
None	"	"	9.2	6.1
None (12.5 mm)	SE	None	10.1	7.1
Intumescent F.R. paint	"	Overall	10.6	7.3
None (12.5 mm)	Standard	None	12.2	8.7
2 coats emulsion	"	Overall	13.6	10.0
1 coat emulsion	"	"	14.4	8.4
None	SE	None	14.9	9.8
1 coat emulsion	"	Overall	14.9	10.1
2 coats emulsion	"	"	18.8	13.9
None	Standard	None	18.9	13.0
1 coat emulsion	"	Dab	24.0	15.7
"	SE	"	24.6	15.4
None	Standard	"*	33.5	21.7
1 coat emulsion	SE	None	34.8	29.0
"	Standard	"	35.0	28.5
Emulsion & gloss	"	Overall	37.5	33.5
"	SE	"	45.0	36.2

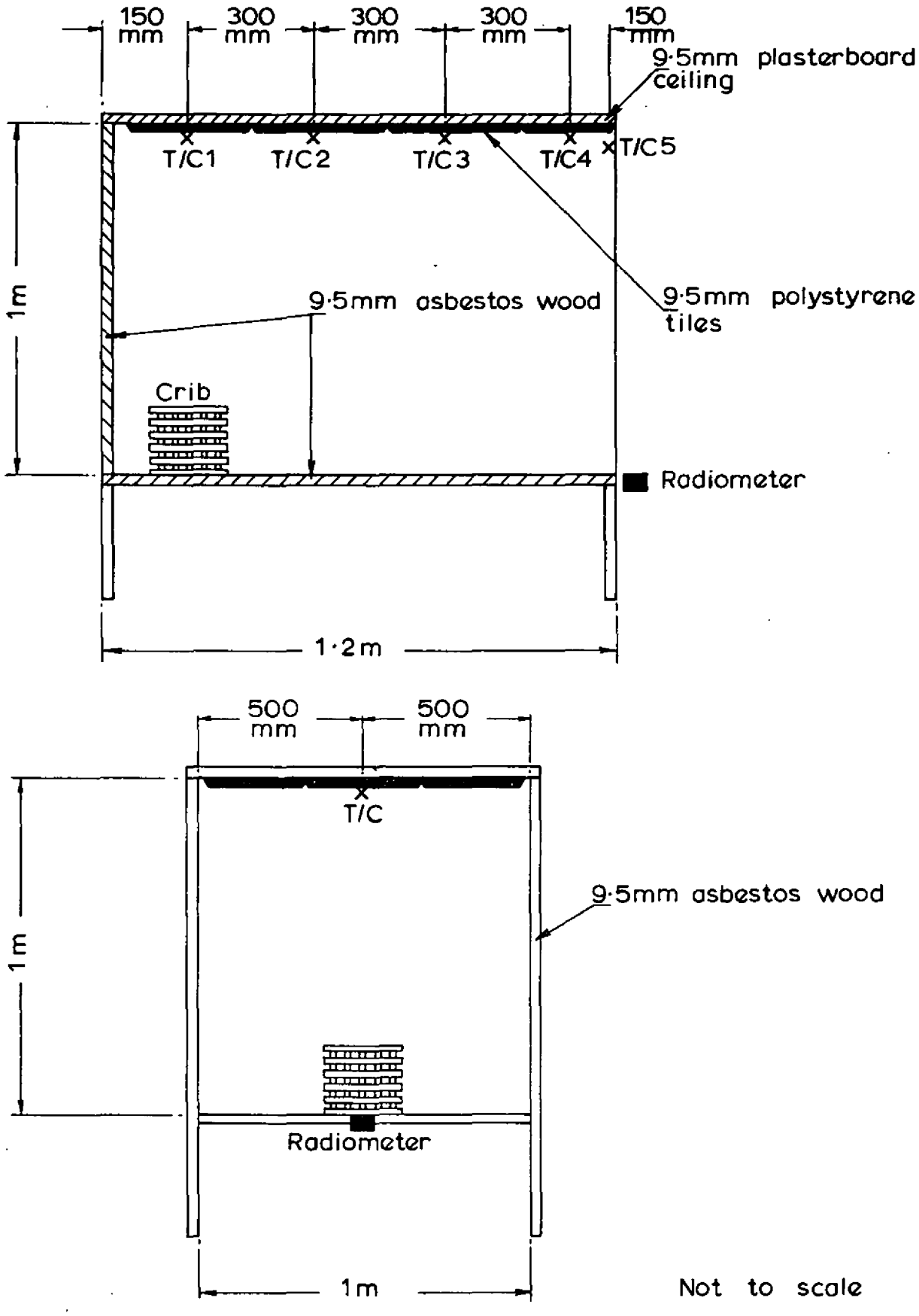
Note: All tiles 9.5 mm thick except where indicated

*Sample fixed to battens



Framework and legs — Dexion
Floor, walls and ceiling — 13mm asbestos wood

FIG. 1. TEST STRUCTURE FOR FLAMMABILITY OF POLYSTYRENE TILES USED IN STAGE 1 TESTS



T/C denotes thermocouple positions

FIG. 2. SKETCH OF CHAMBER USED IN STAGE 2 TESTS

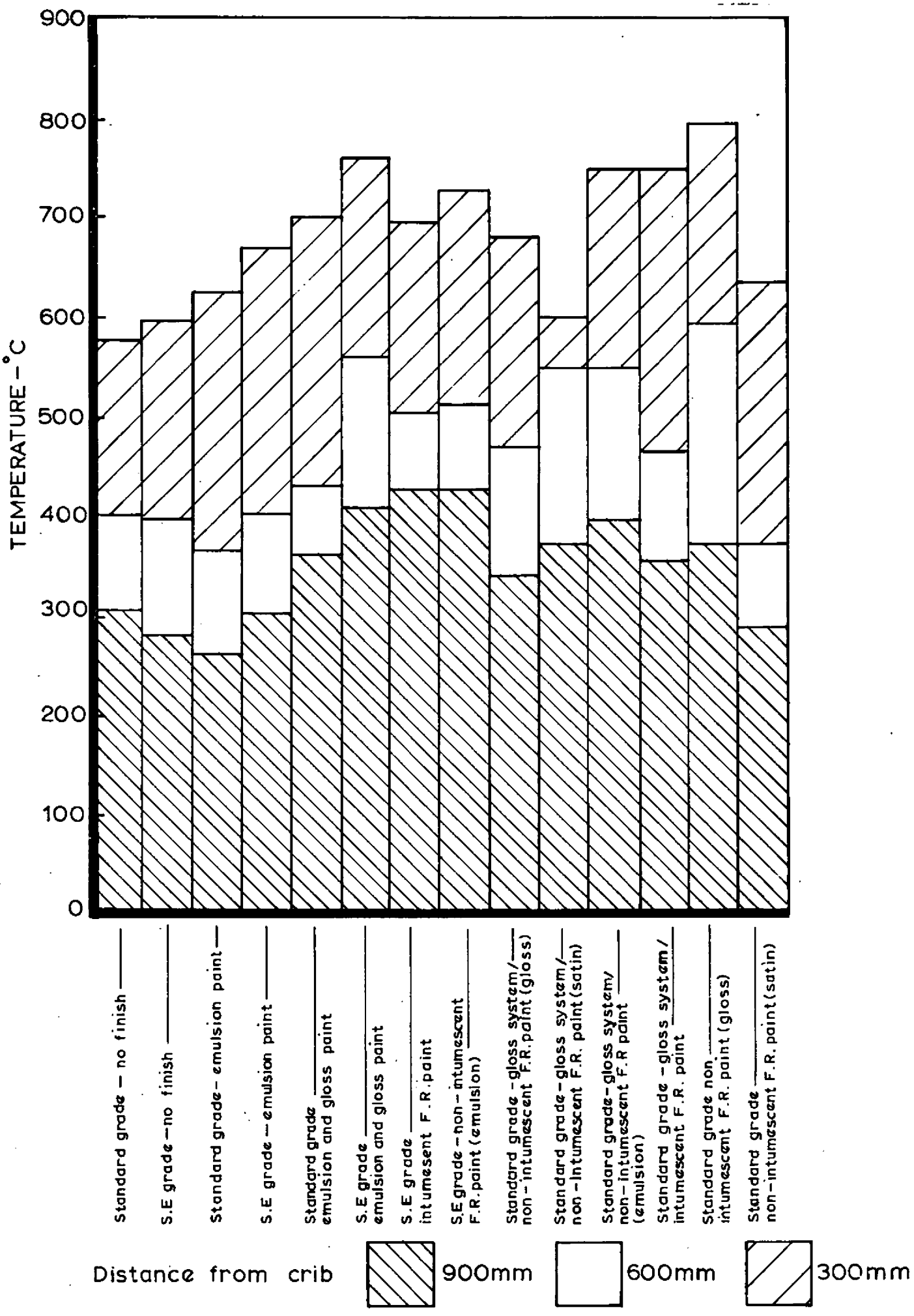


FIG. 3 MAXIMUM TEMPERATURES IN STAGE 2 TESTS
(Polystyrene linings)

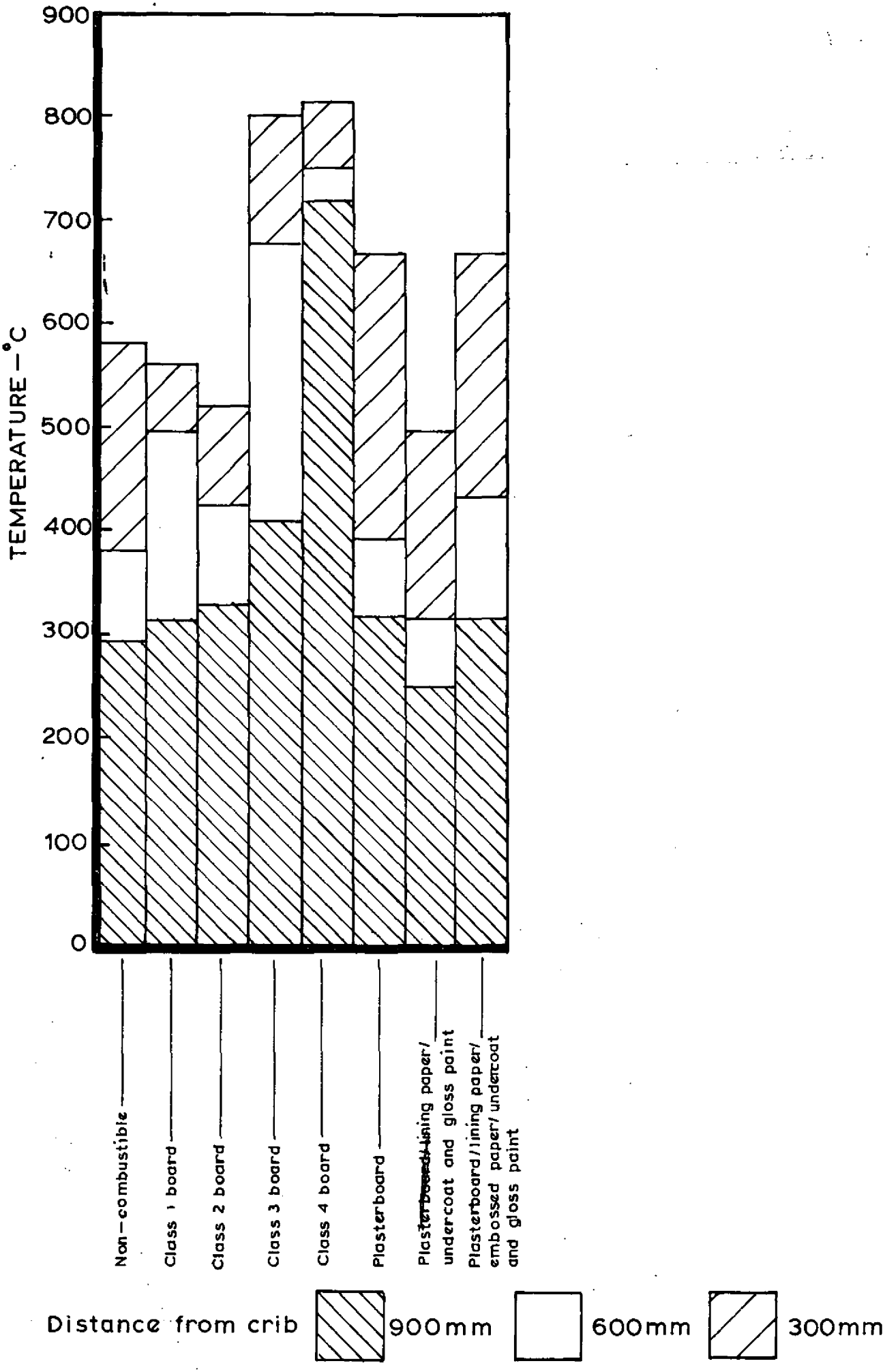


FIG. 4 MAXIMUM TEMPERATURES IN STAGE 2 TESTS (TRADITIONAL MATERIALS)

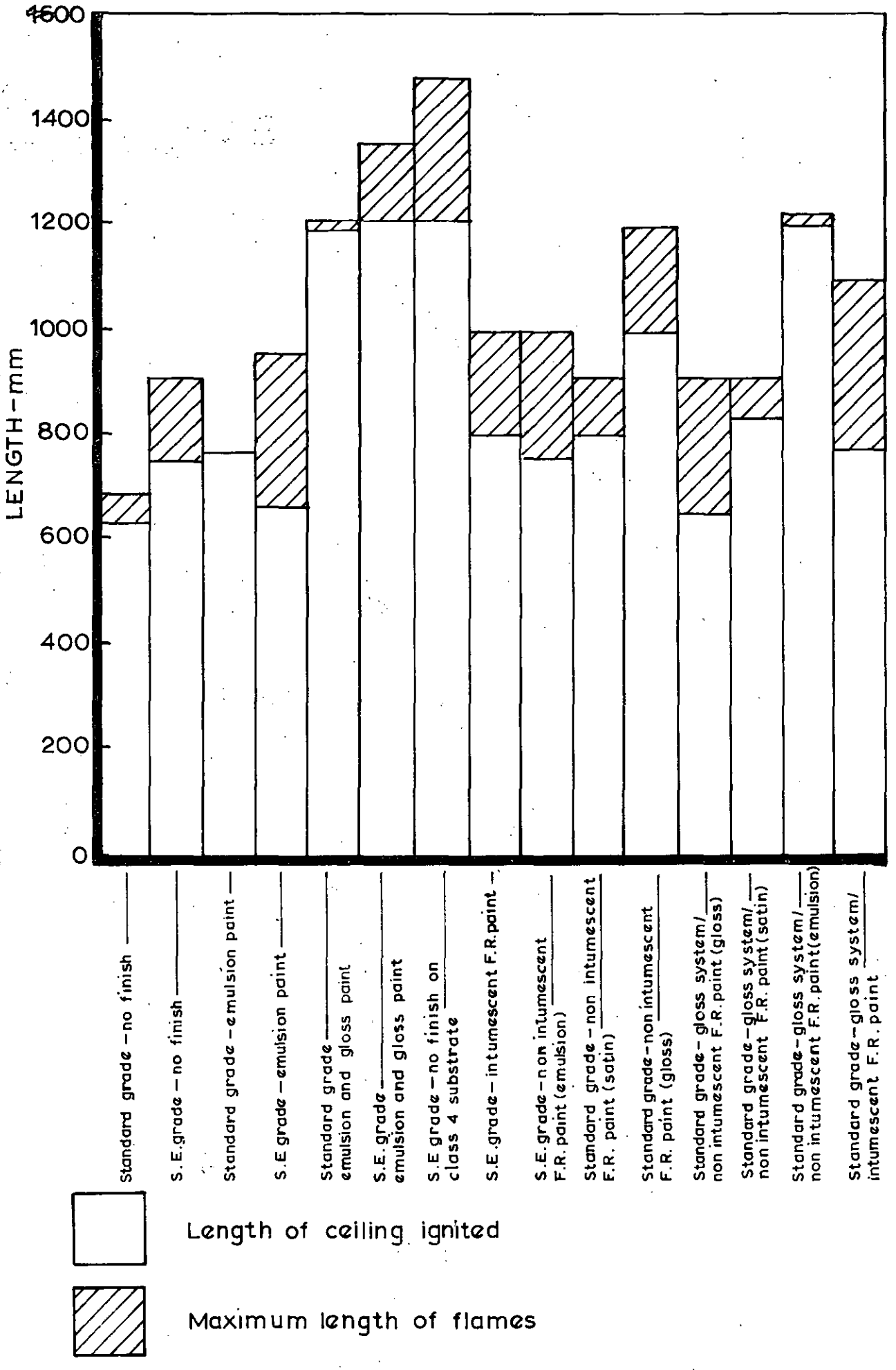


FIG. 5 LENGTH OF FLAMES AND IGNITION OF CEILING (POLYSTYRENE LININGS)

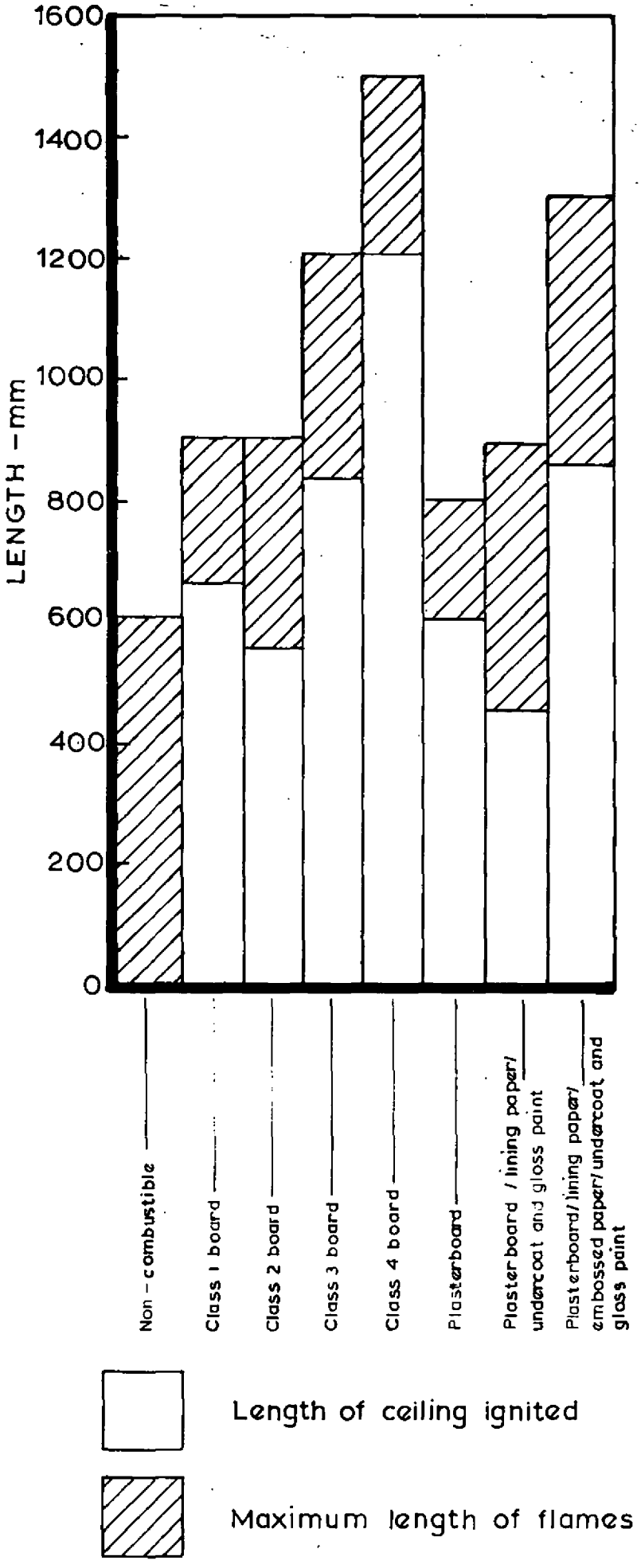


FIG.6 LENGTH OF FLAMES AND IGNITION OF CEILING (TRADITIONAL MATERIALS)

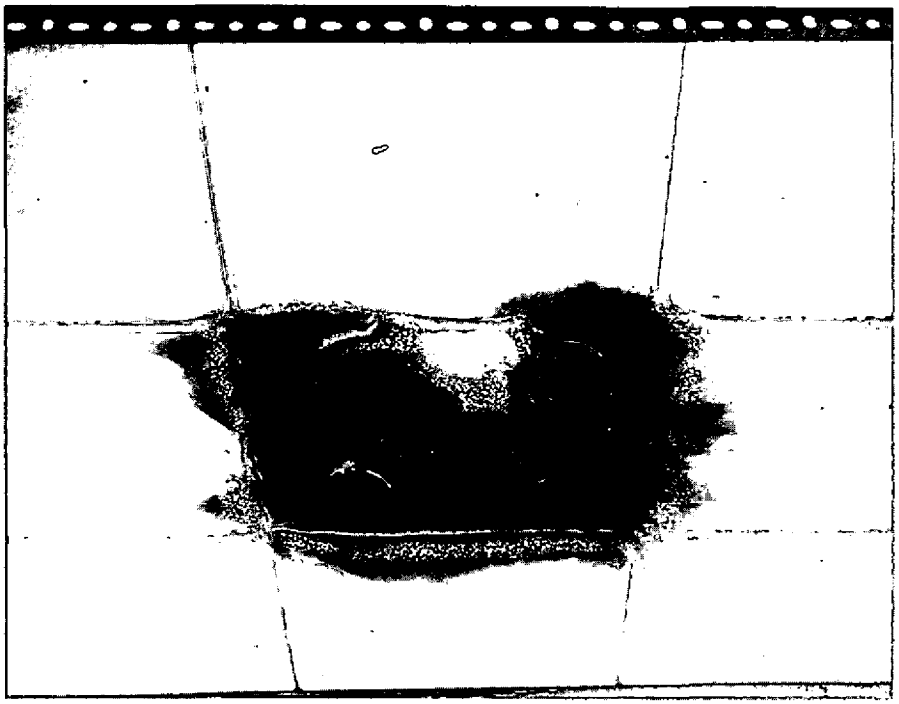


PLATE 1 STANDARD GRADE EXPOSED TO GAS FLAME

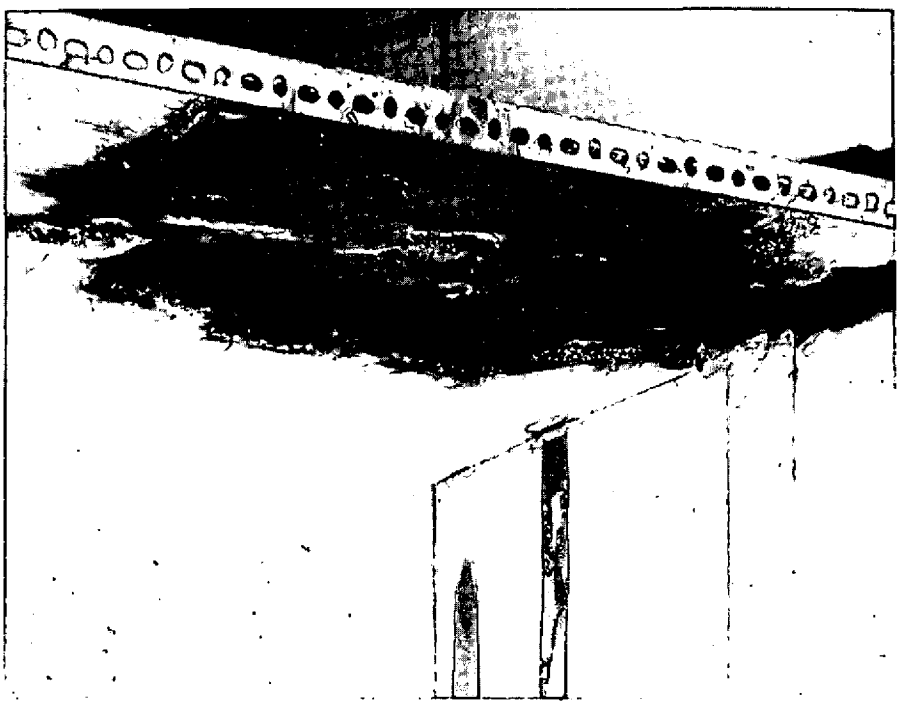


PLATE 2 EFFECT OF TREATING WITH EMULSION PAINT

PLATE 3 STANDARD GRADE EXPOSED TO ALCOHOL FLAME

PLATE 4 EFFECT OF TREATING WITH EMULSION PAINT

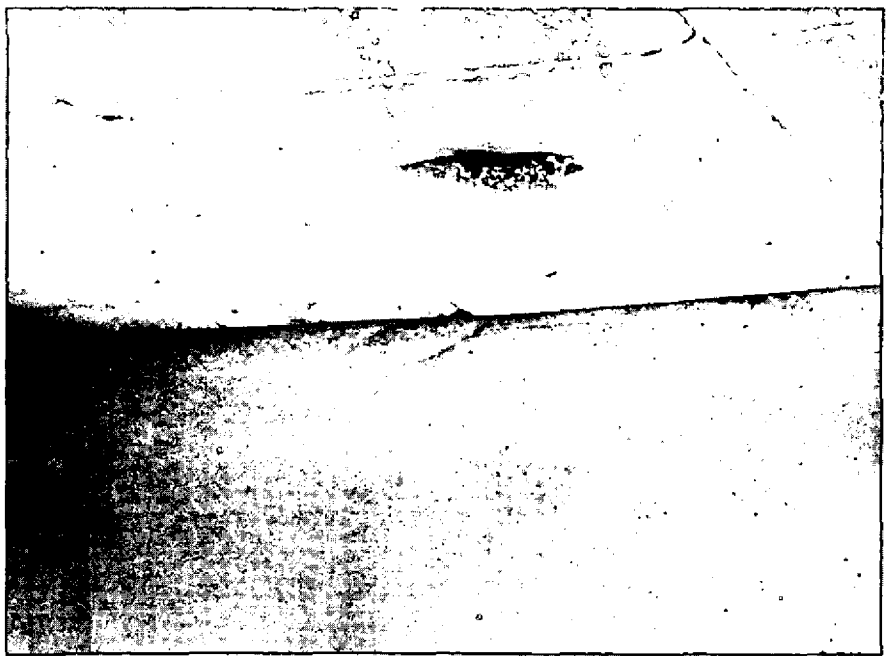


PLATE 5 SELF EXTINGUISHING GRADE EXPOSED TO GAS FLAME

PLATE 6 EFFECT OF TREATING WITH EMULSION PAINT

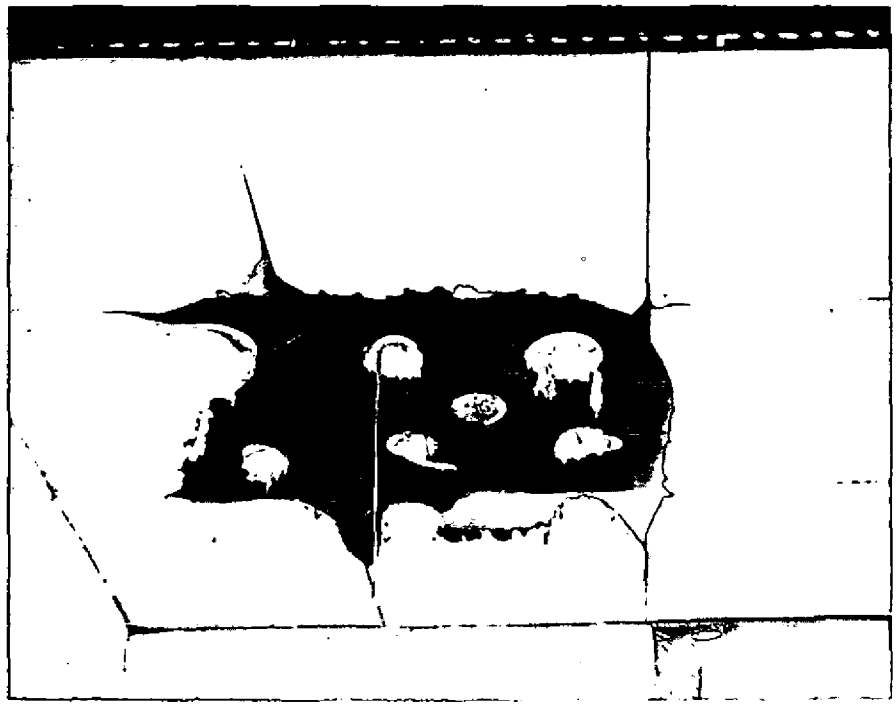


PLATE 7 SELF EXTINGUISHING GRADE EXPOSED TO ALCOHOL FLAME

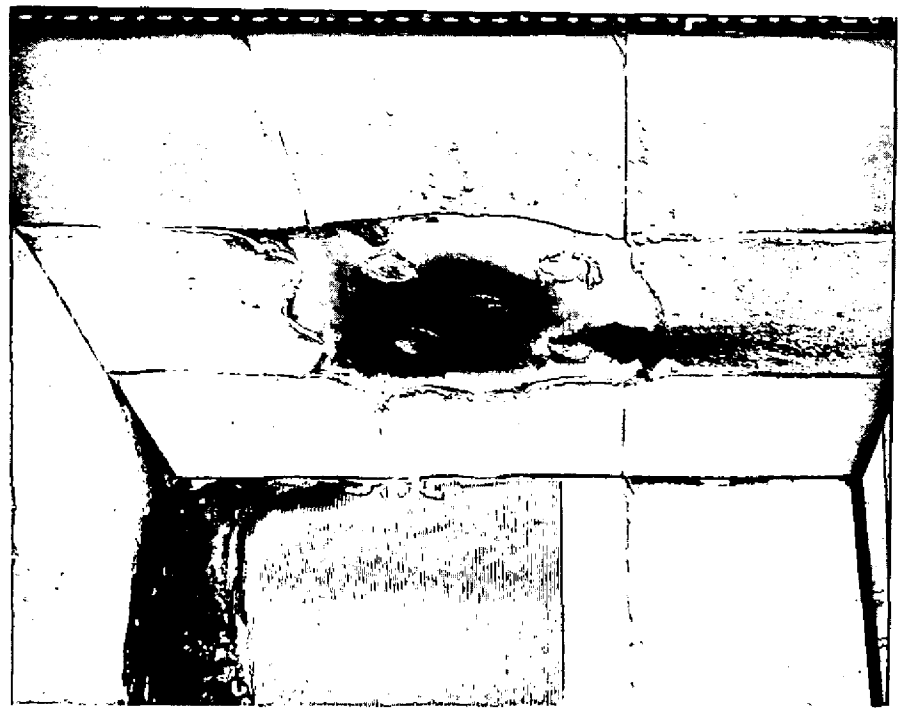


PLATE 8 EFFECT OF TREATING WITH EMULSION PAINT

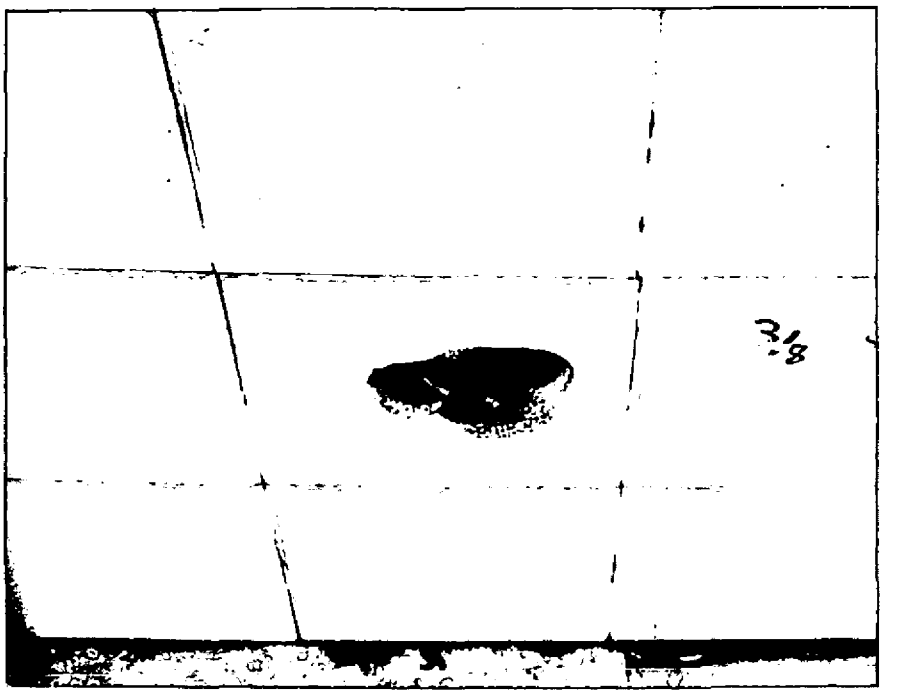


PLATE 9 STANDARD GRADE. OVERALL ADHESIVE, EXPOSED TO GAS FLAME

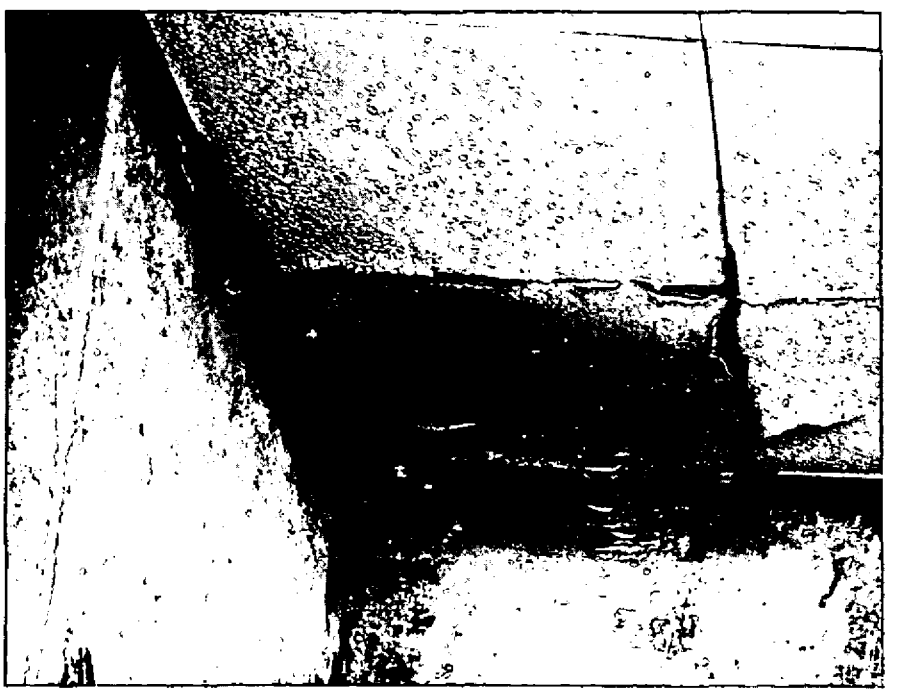


PLATE 10 EFFECT WHEN EXPOSED TO ALCOHOL FLAME

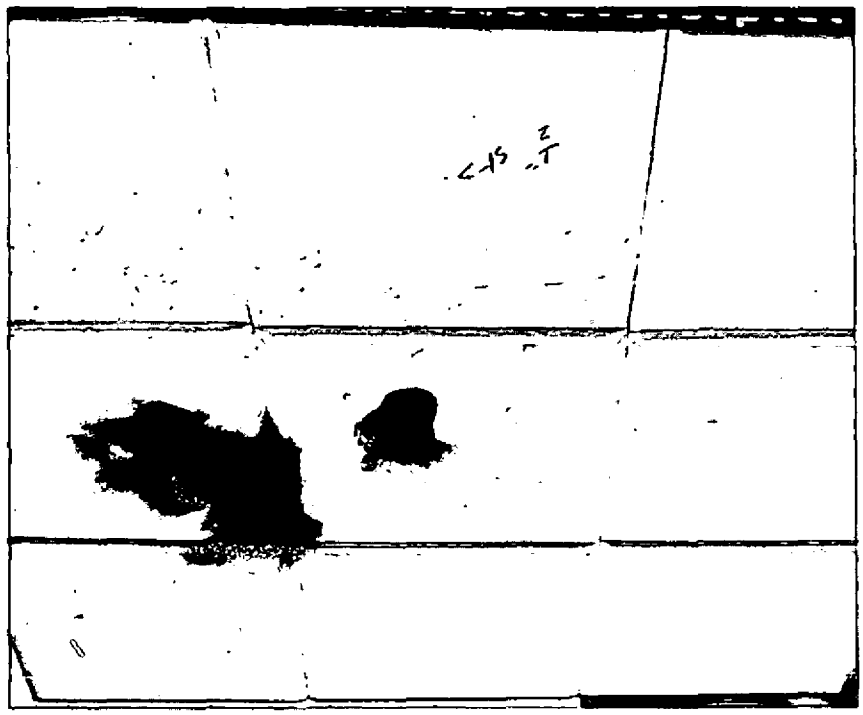


PLATE 11 13 mm STANDARD GRADE, ASBESTOS SUBSTRATE, EXPOSED TO GAS FLAME

PLATE 12 EFFECT WITH PLASTERBOARD SUBSTRATE

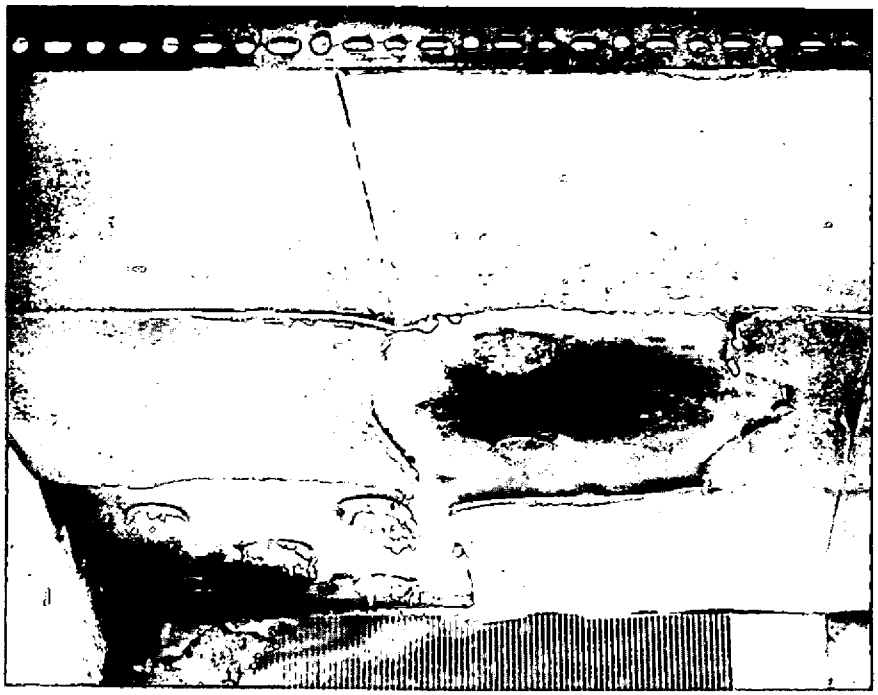


PLATE 13 STANDARD GRADE WITH EMULSION PAINT. ALCOHOL FLAME ON CORNER

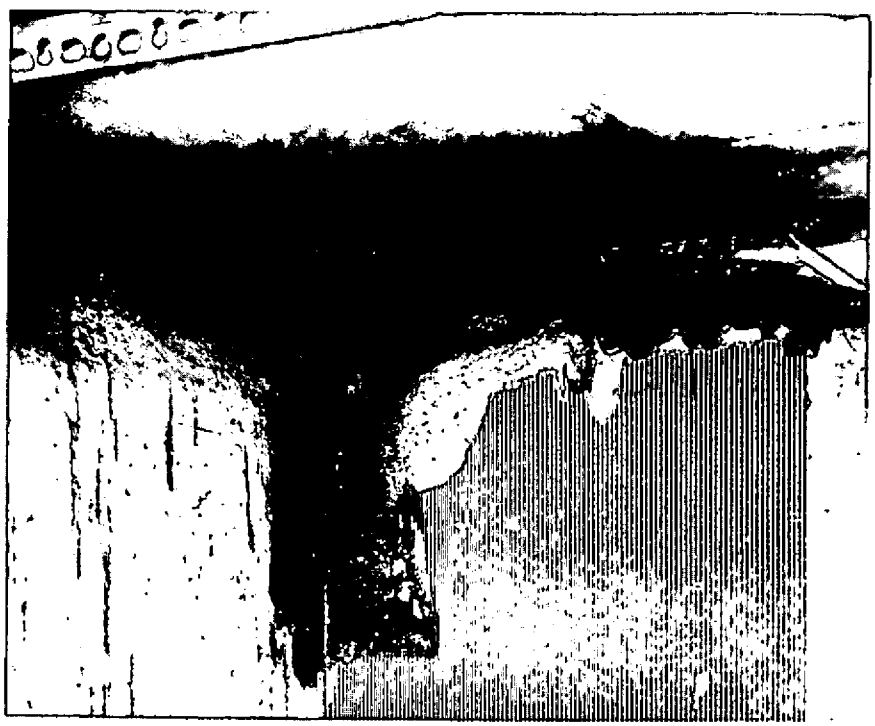


PLATE 14 EFFECT WHEN USING SELF EXTINGUISHING GRADE

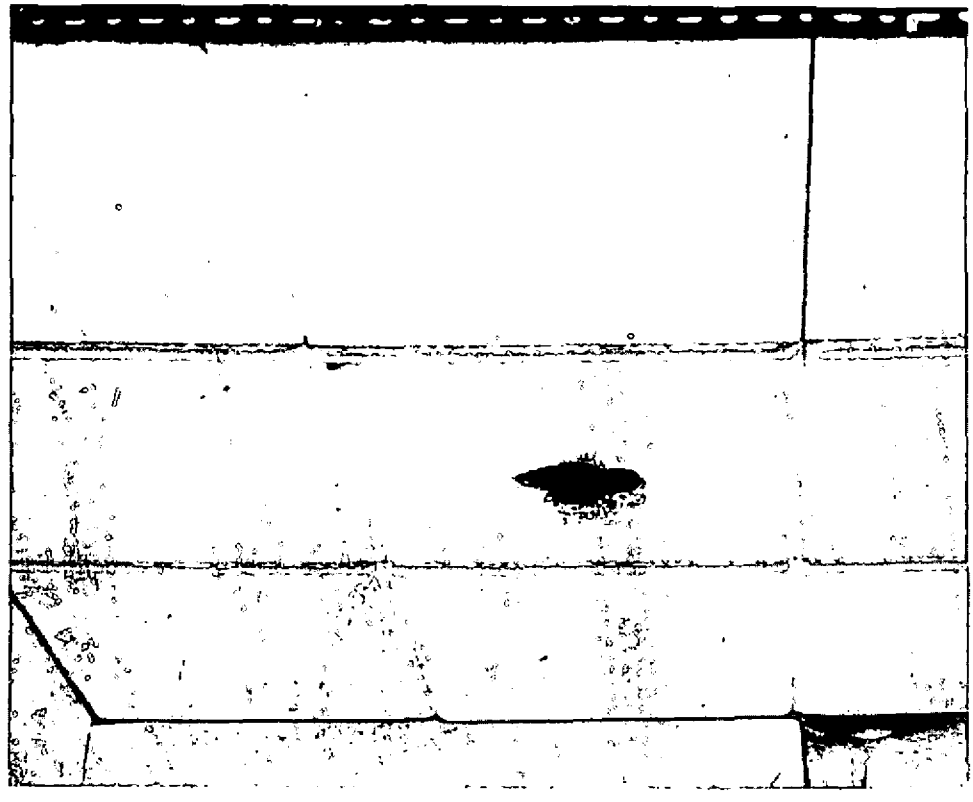


PLATE 15 SELF EXTINGUISHING GRADE WITH INTUMESCENT PAINT EXPOSED TO GAS FLAME

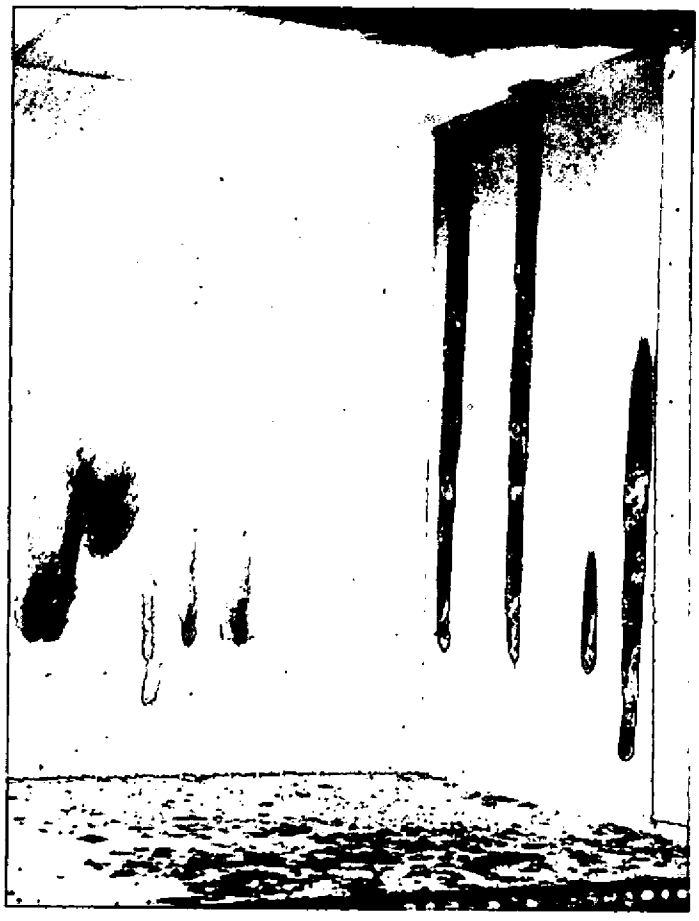


PLATE 16 2 mm STANDARD GRADE WITH AND WITHOUT WALLPAPER EXPOSED TO GAS FLAME

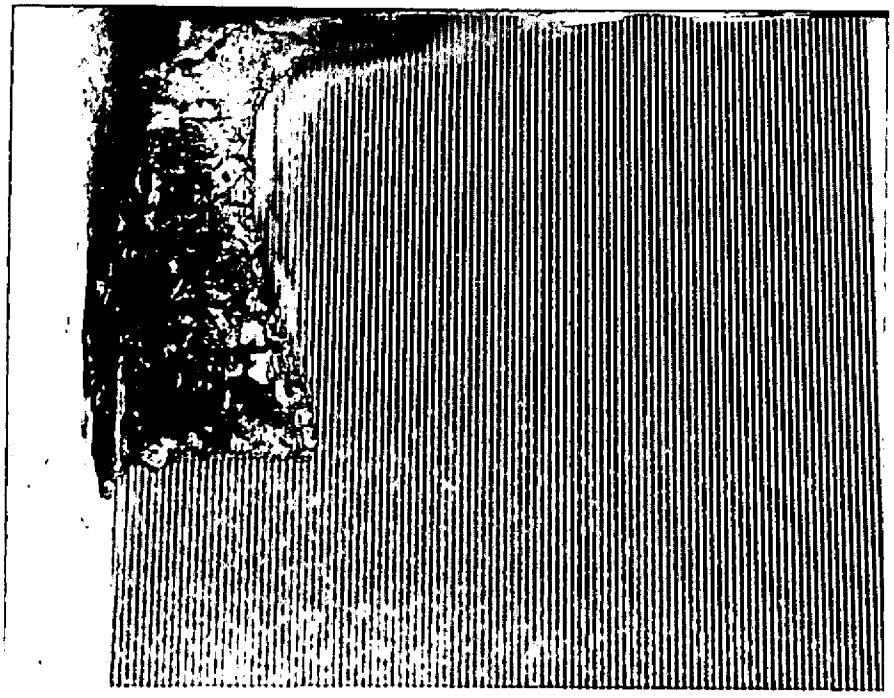


PLATE 17 2 mm STANDARD GRADE WITH AND WITHOUT WALLPAPER EXPOSED TO ALCOHOL FLAME IN CORNER

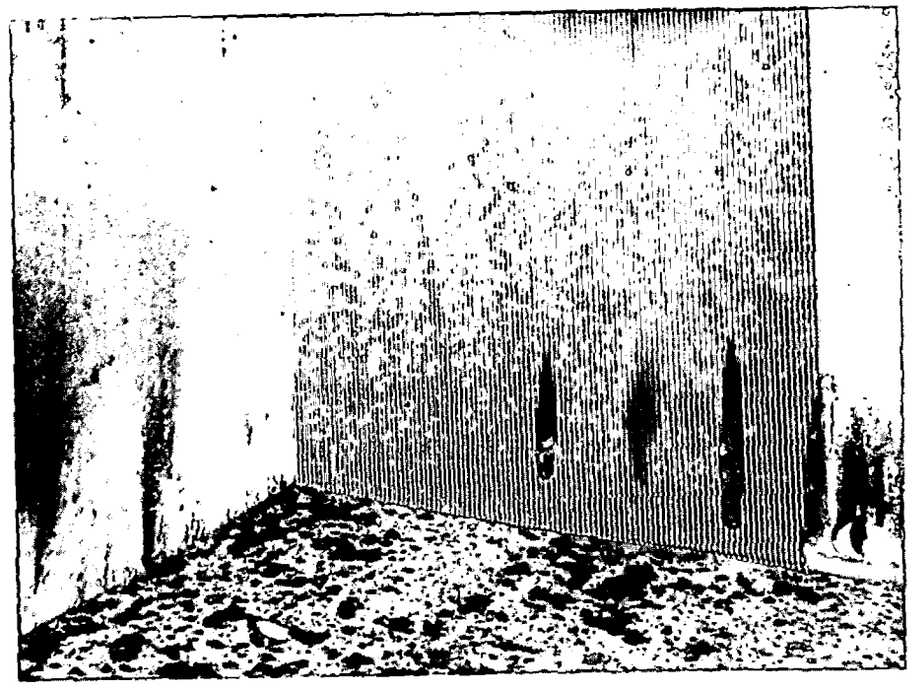


PLATE 18(a) 5 mm STANDARD GRADE WITH AND WITHOUT WALLPAPER EXPOSED TO GAS FLAME

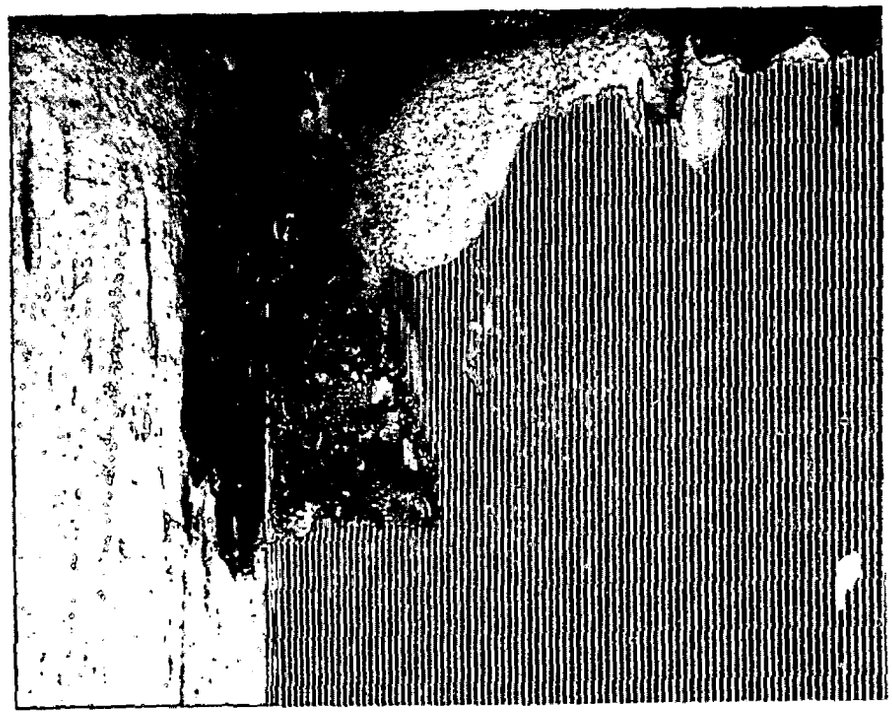


PLATE 18(b) 5 mm STANDARD GRADE WITH AND WITHOUT WALLPAPER EXPOSED TO ALCOHOL FLAME IN CORNER

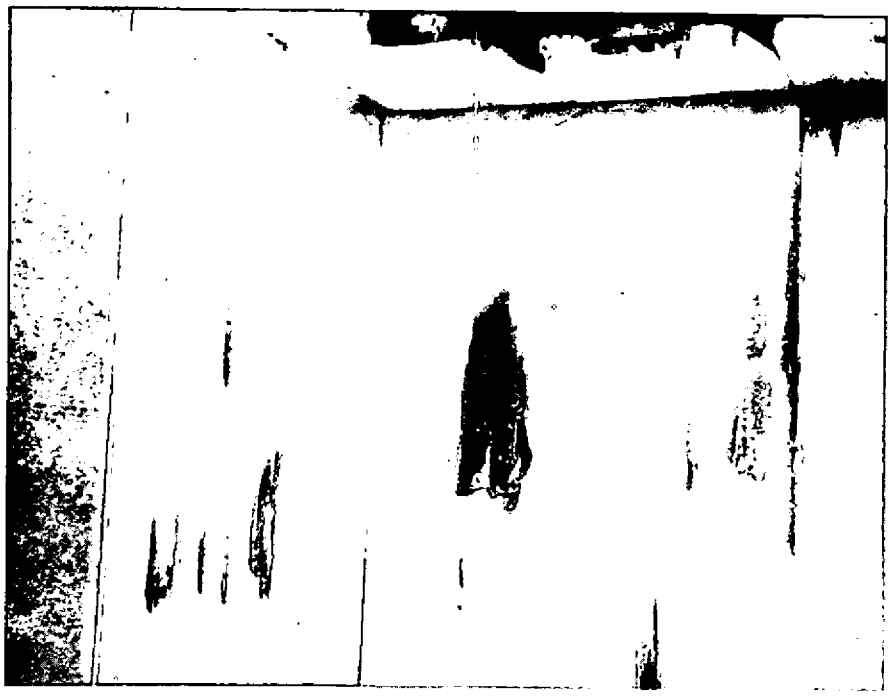


PLATE 19 5 mm STANDARD GRADE WITH EMULSION PAINT EXPOSED TO GAS FLAME

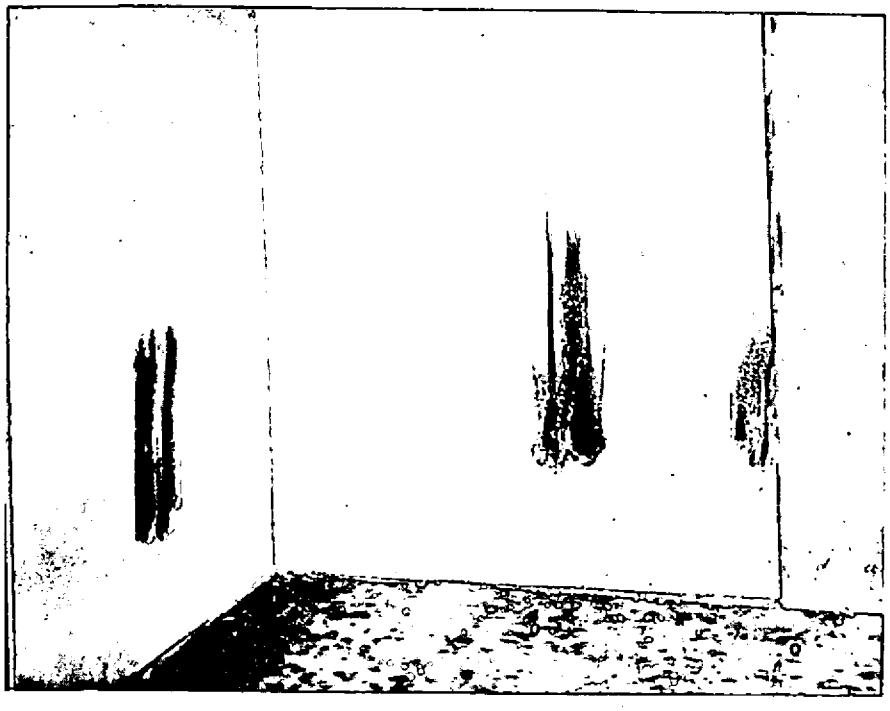


PLATE 20 EFFECT WITH SELF EXTINGUISHING GRADE

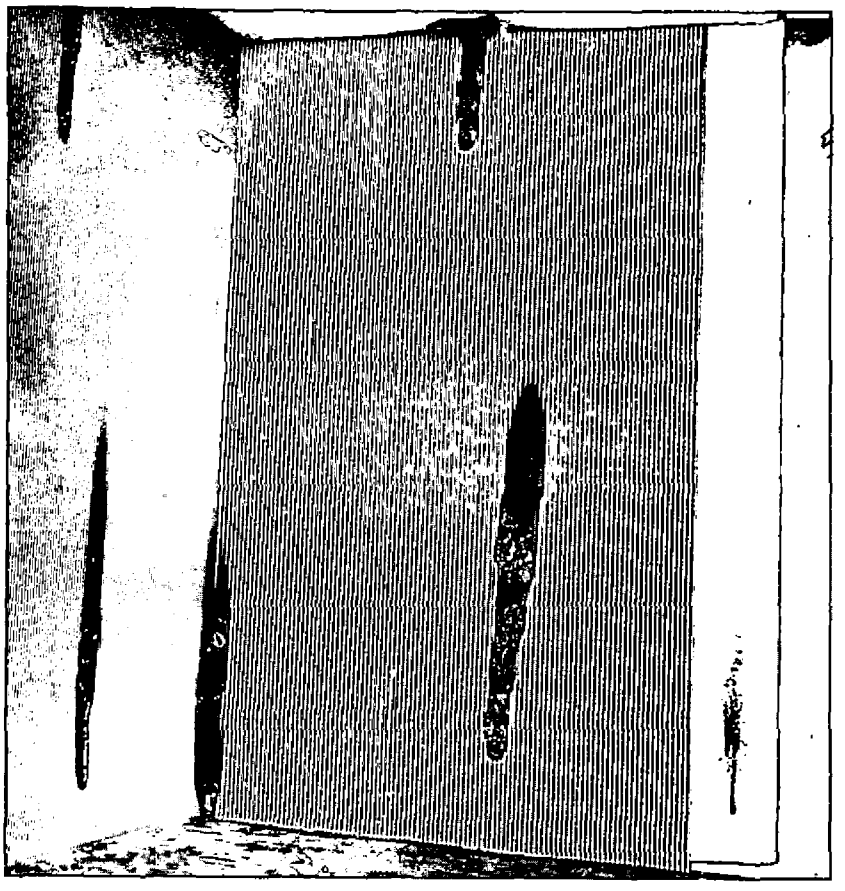
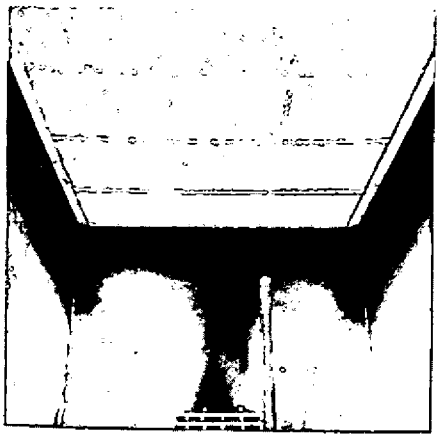


PLATE 21 5 mm STANDARD GRADE, PLASTERBOARD SUBSTRATE. WITH AND WITHOUT WALL PAPER, EXPOSED TO GAS FLAME



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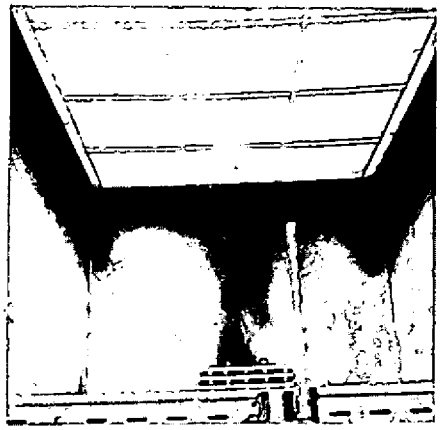

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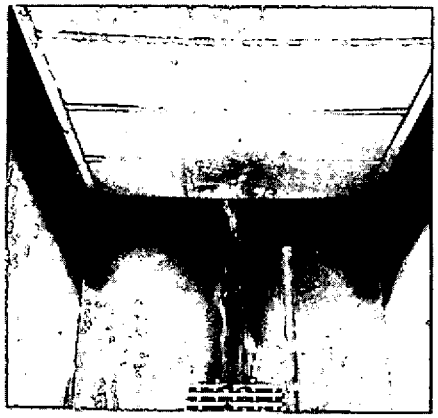
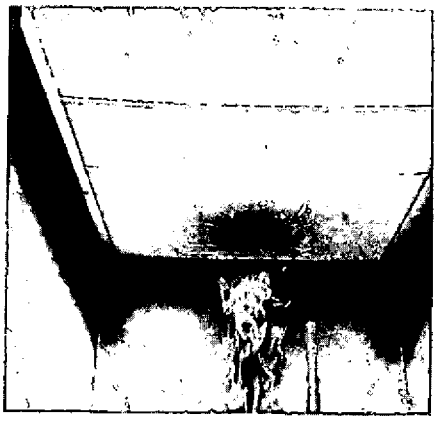
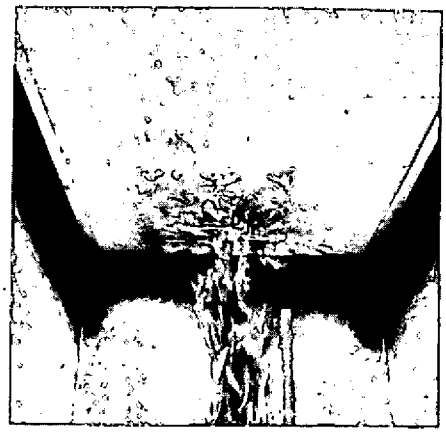


2 m 15 s



2 min 55 s

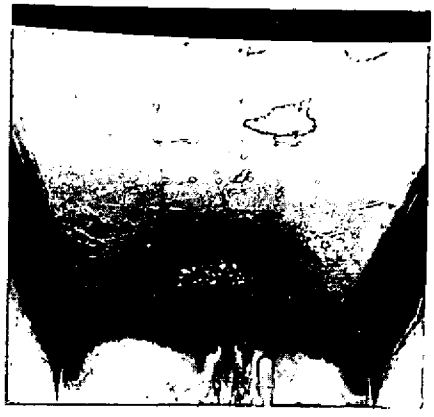


3 min 15 s

PLATE 22 STANDARD GRADE, OVERALL ADHESIVE STAGE 2.

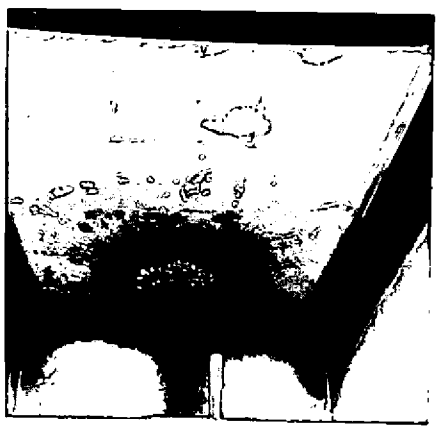
3 min 55 s

4 min 55 s

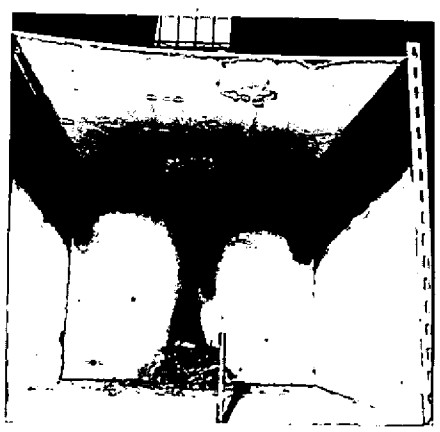


5 min 10 s

6 min

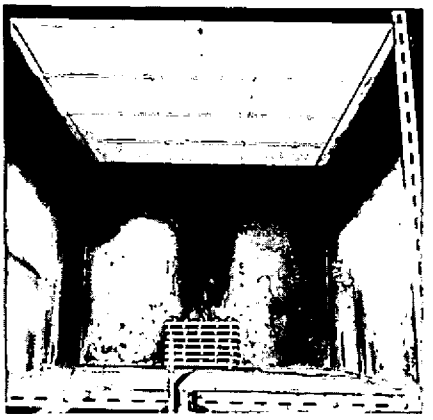


7 min

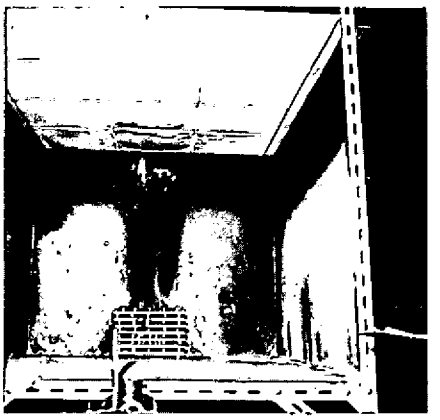


After test

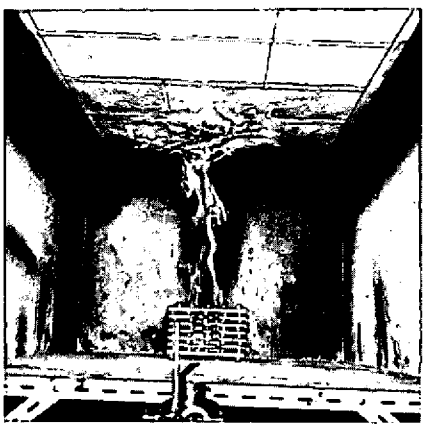
PLATE 22 (cont'd) STANDARD GRADE OVERALL ADHESIVE
STAGE 2



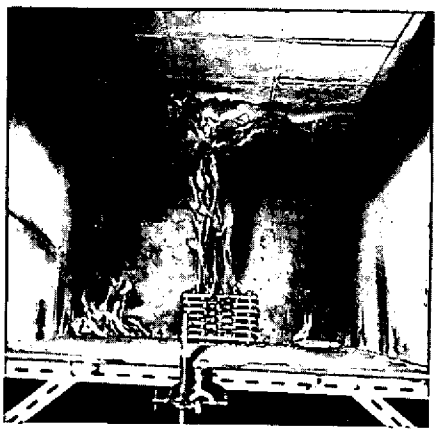
1 min 10 s



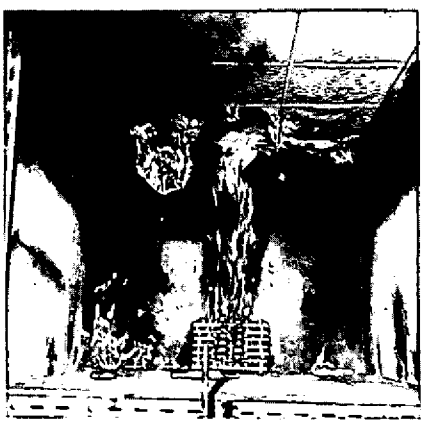
1 min 37 s



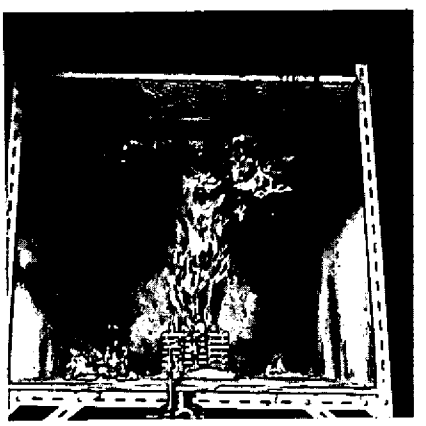
2 min 8 s



2 min 10 s

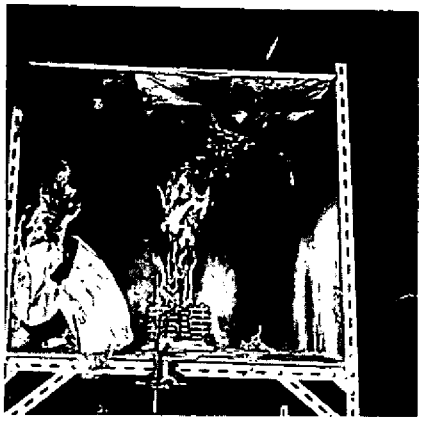


2 min 15 s

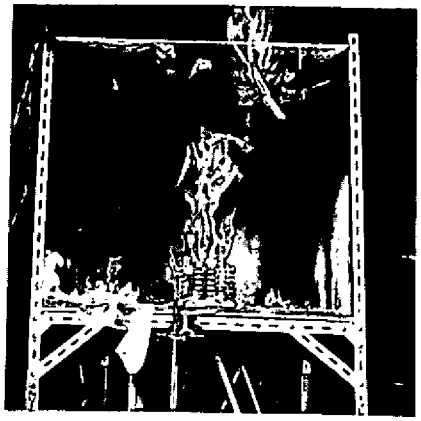


2 min 22 s

PLATE 23 SELF EXTINGUISHING GRADE. DAB ADHESIVE
GLOSS PAINT FINISH
STAGE 2

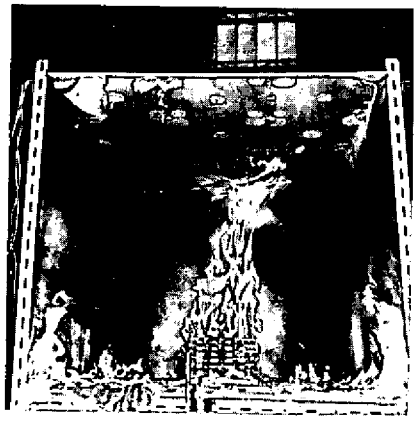


2 min 30 s

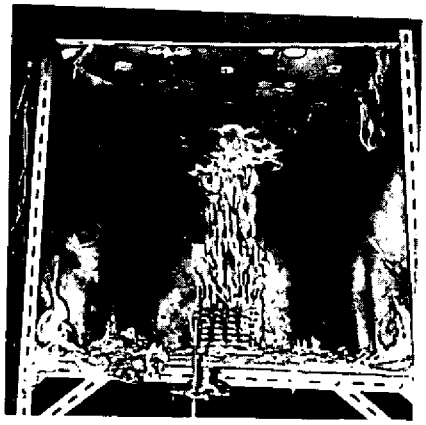


2 min 35 s

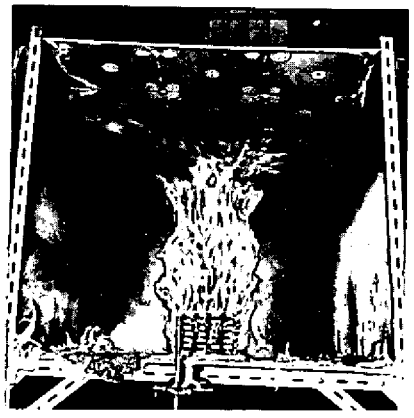
2 min 40 s



2 min 50 s

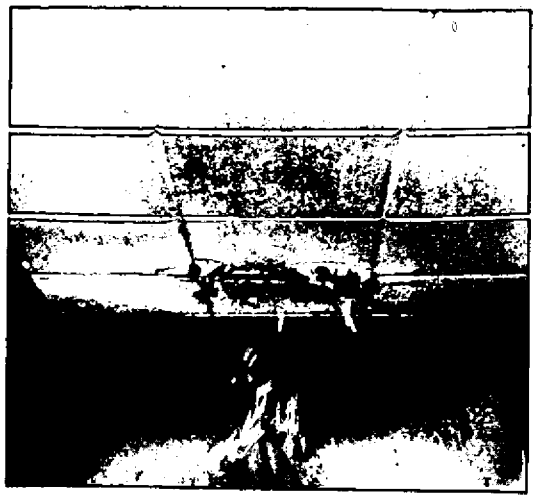


3 min



3 min 30 s

PLATE 23 (cont'd) SELF EXTINGUISHING GRADE. DAB ADHESIVE GLOSS PAINT FINISH
STAGE 2



1 min 45 s

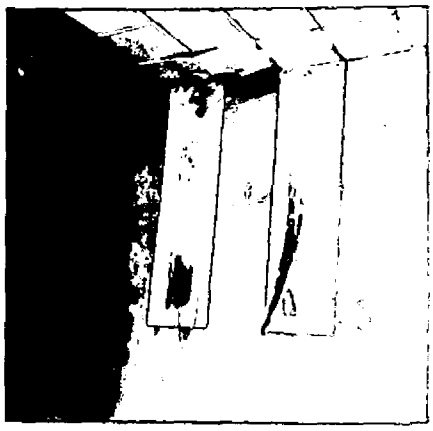
2 min 21 s

2 min 44 s

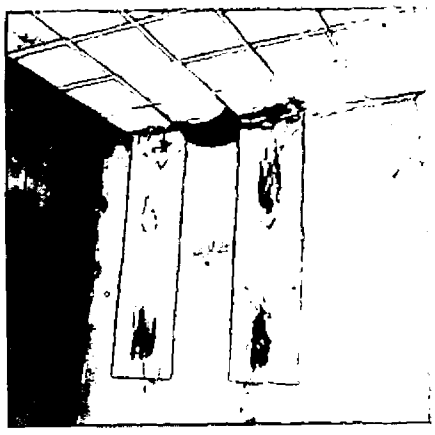
11 min 45 s

PLATE 23A. SELF EXTINGUISHING GRADE ON FIRE INSULATING BOARD SUBSTRATE

STAGE 2



(a) start



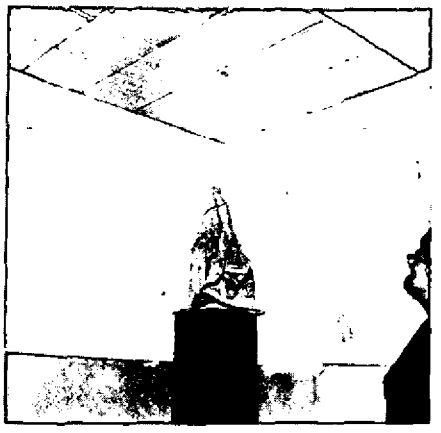
(b)

(c)

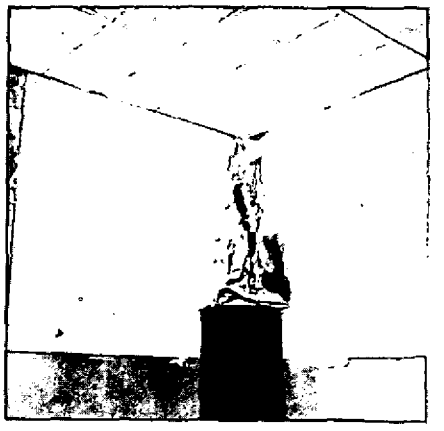
(d)

(e)

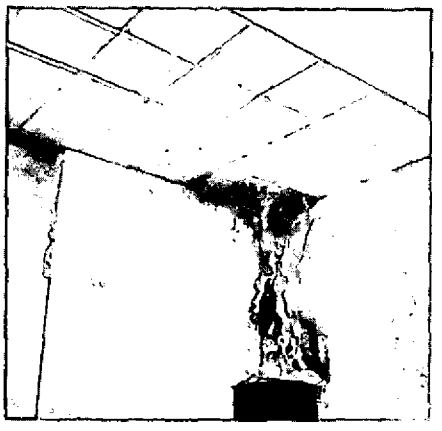
PLATE 24 TESTS 1 and 2 STANDARD GRADE
TEST 1 LEFT HAND PANEL
TEST 2 RIGHT HAND PANEL
STAGE 3



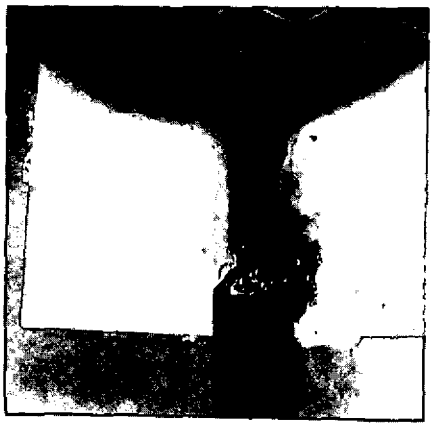
(a) Start



(b)



(c)



(d)

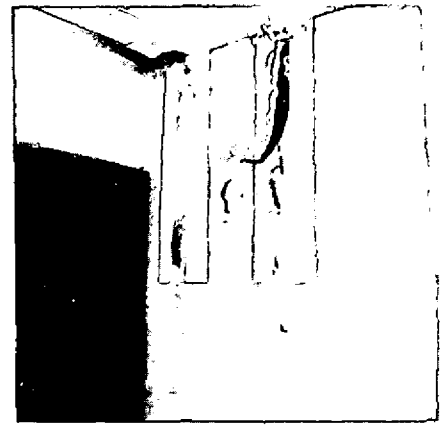
(e)

(f)

(g)Finish

PLATE 25 TEST 3. STANDARD GRADE
STAGE 3.

(a) Start



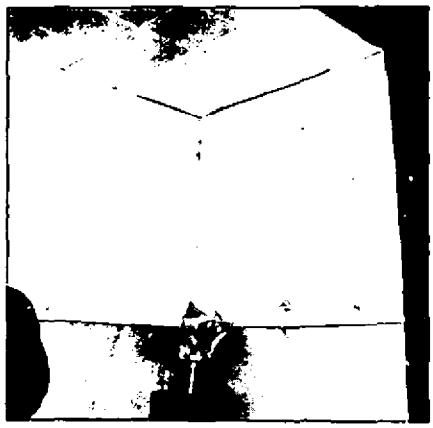
(b)

(c)

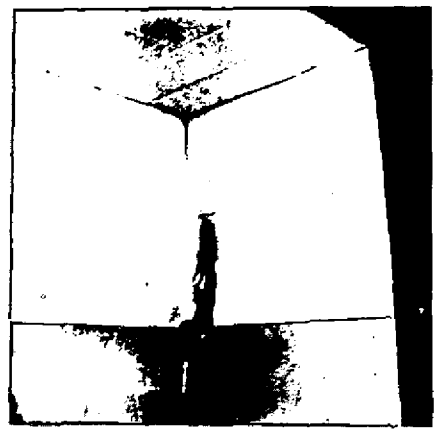
(d)

(e) Finish

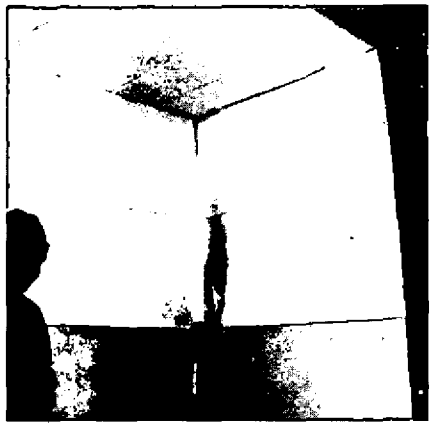
PLATE 26 TESTS 4 and 5 SELF EXTINGUISHING GRADE
TEST 4 LEFT HAND PANEL
TEST 5 RIGHT HAND PANEL
STAGE 3



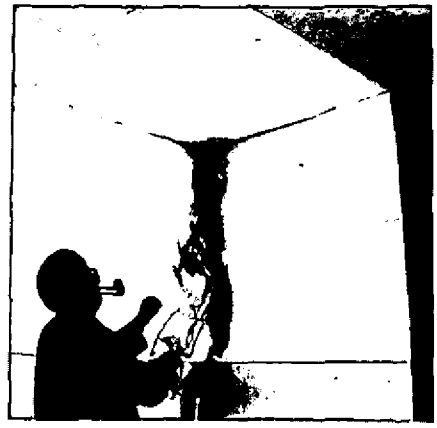
(a) Start



(b)



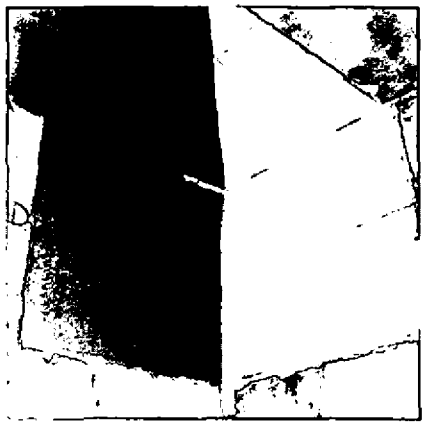
(c)



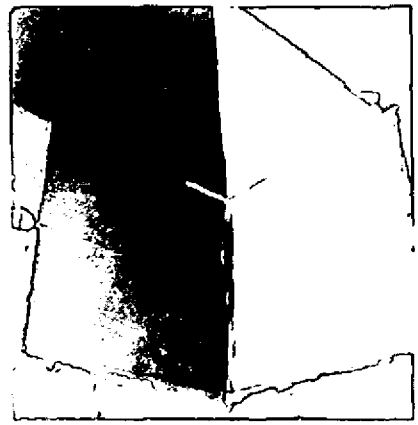
(d)

(e)

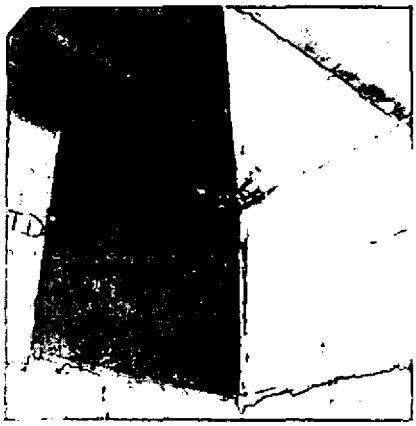
PLATE 27 TEST 6 SELF EXTINGUISHING GRADE
STAGE 3



(a) Start



(b)

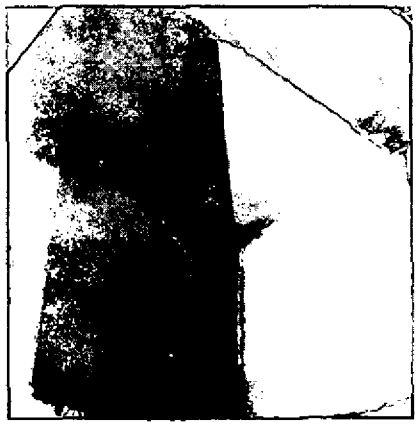


(c)

(d)

(e)

(f)



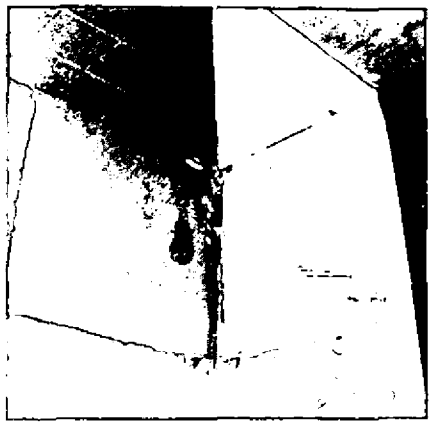
(g)

(h)

PLATE 28 TEST 7 STANDARD GRADE WITH EMULSION PAINT DARKER SECTION

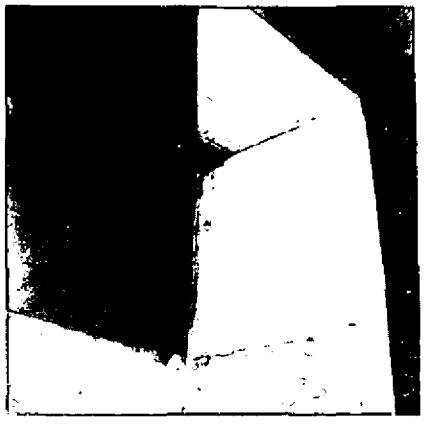
TEST 9 STANDARD GRADE WITH INTUMESCENT PAINT.

(a) Start

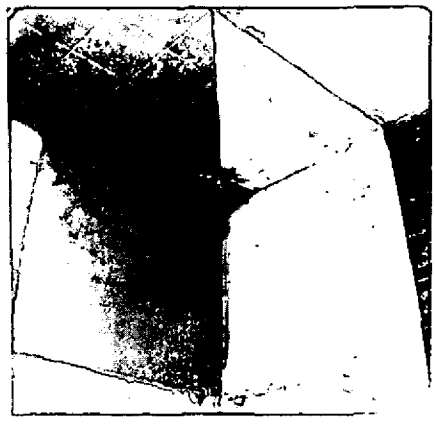


(b)

c) 30 s

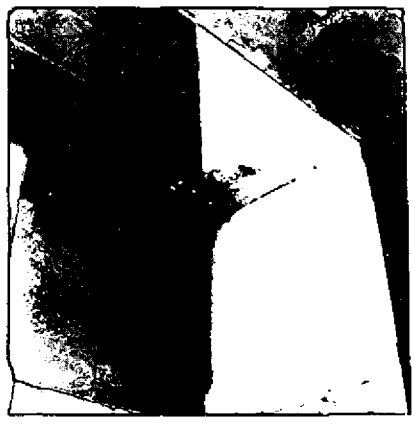


(d) 45 s

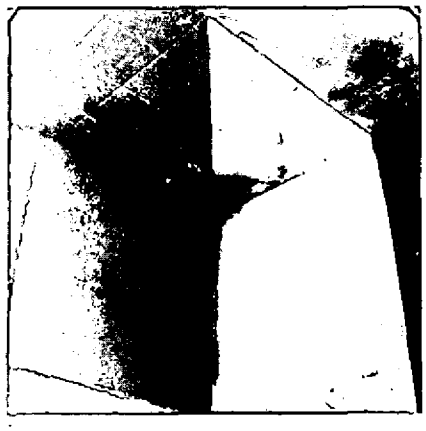


(e) 1 min

f) 1 min 15 s



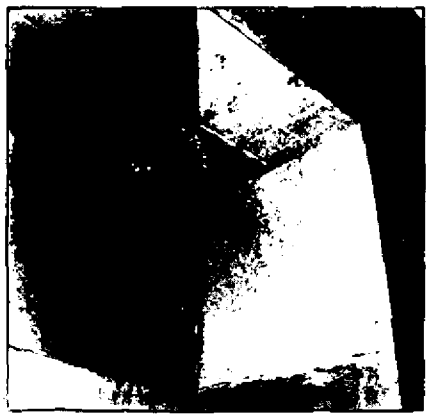
(g) 1 min 30 s



(h) 2 min

PLATE 29 TEST 8 SELF EXTINGUISHING GRADE WITH EMULSION PAINT (DARKER SECTION)
TEST 10 SELF EXTINGUISHING GRADE WITH INTUMESCENT PAINT.

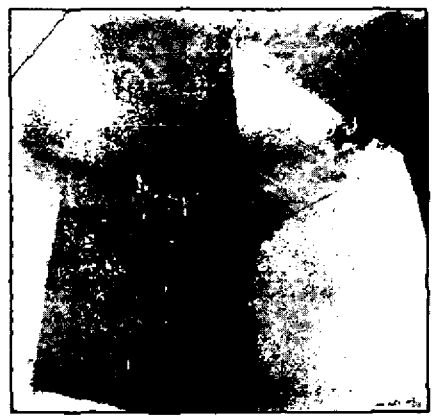
STAGE 3



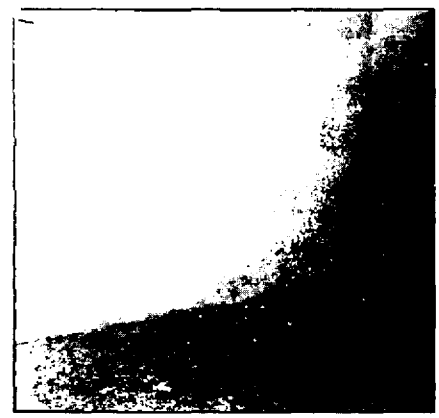
(i) 2 min 45 s

(j) 3 min 30 s

(k) 4 min 30 s

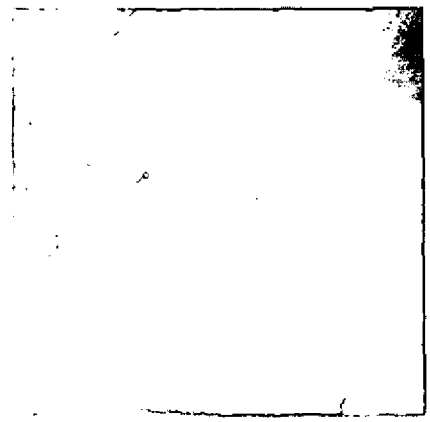


(l) 5 min 15 s

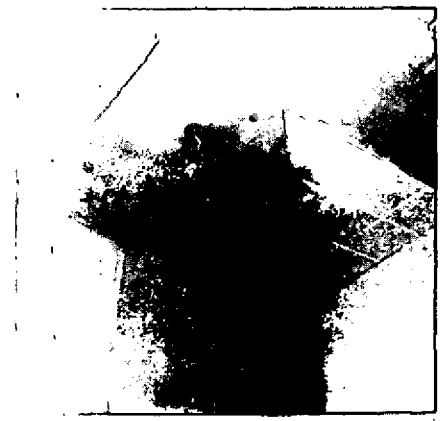


(m) 6 min 10 s

(n) 12 min



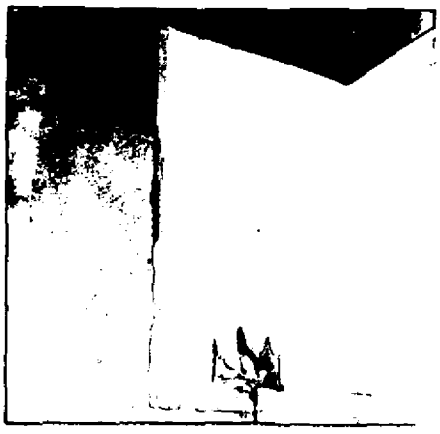
(o) 13 min 45 s



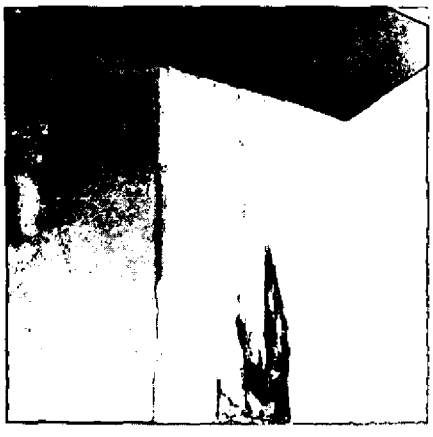
(p) 15 min 35 s end.

PLATE 29 (cont'd) TEST 8 SELF EXTINGUISHING GRADE WITH EMULSION PAINT (DARKER SECTION)
TEST 10 SELF EXTINGUISHING GRADE WITH INTUMESCENT PAINT

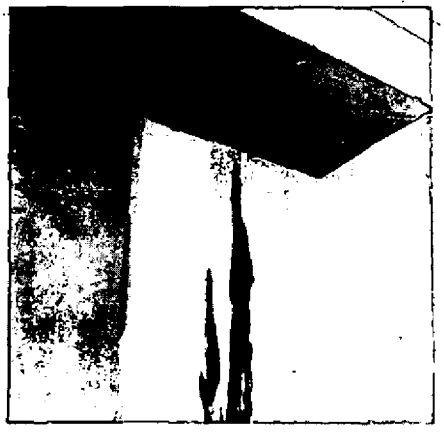
(a) Start



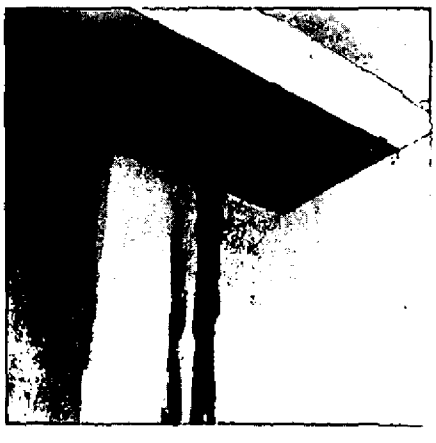
(b) 35 sec



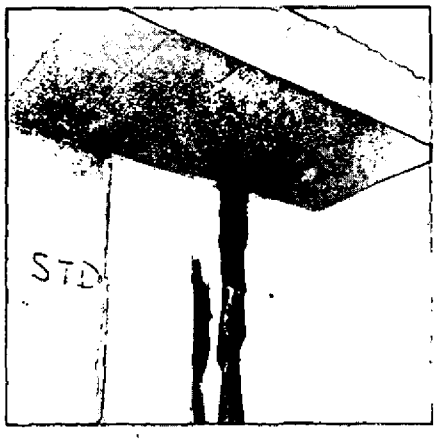
(c) 1 min 30 sec



(d) 3 min



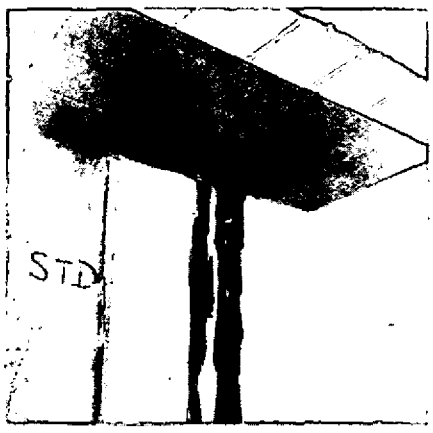
(e) 3 min 50 sec



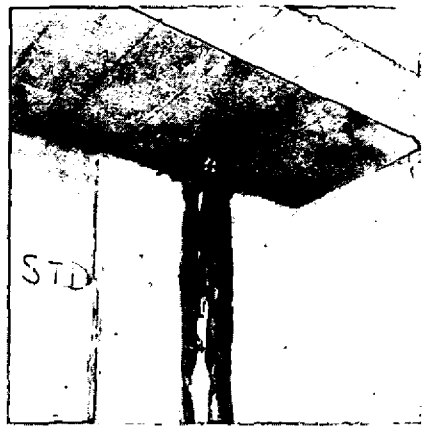
(f) 4 min 5 sec

PLATE 30 TEST 11 STANDARD GRADE. CEILING WITH EMULSION PAINT, WALLS WITH MEDIUM WEIGHT PAPER.

STAGE 3 (cont'd)

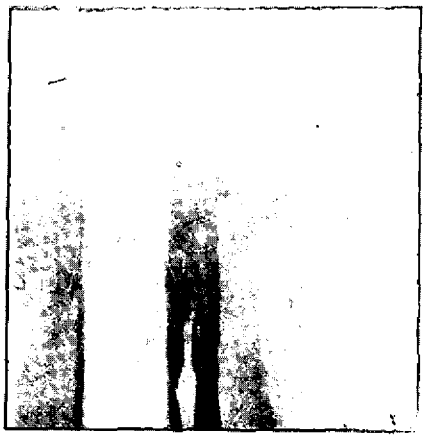


(g) 4 min 40 s

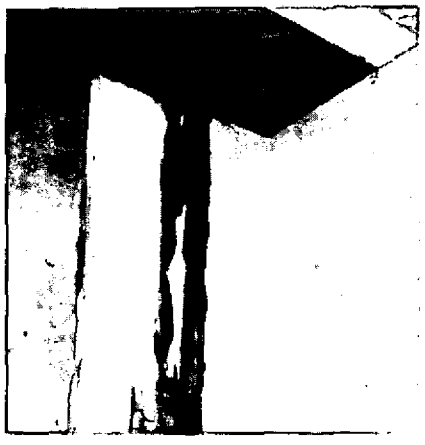


(h) 4 min 55 s

(i) 5 min 30 s



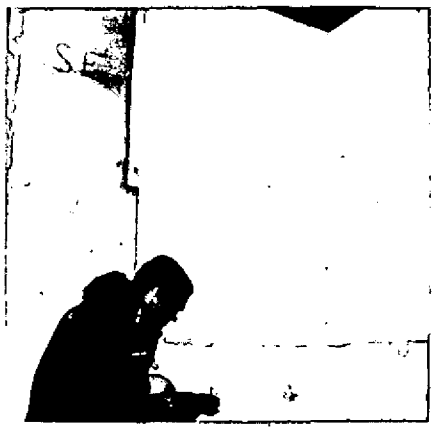
(j) 6 min 20 s



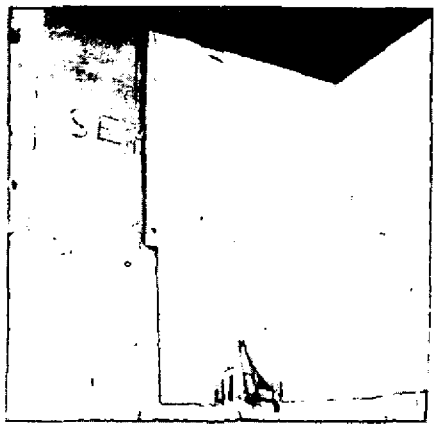
(k) 7 min 20 s Finish

PLATE 30 (cont'd) TEST 11 STANDARD GRADE. CEILING WITH EMULSION PAINT, WALLS WITH MEDIUM WEIGHT PAPER.

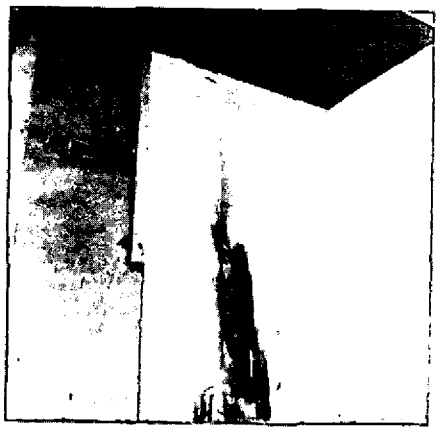
STAGE 3.



(a) Start

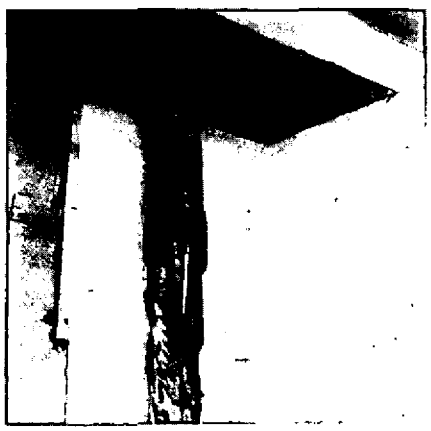


(b) 33 s

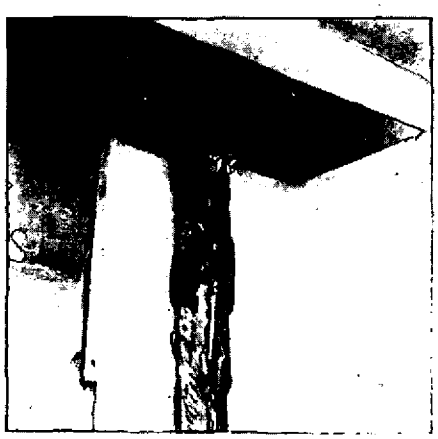


(c) 1 min 30 s

(d) 2 min 15 s



(e) 3 min 25 s

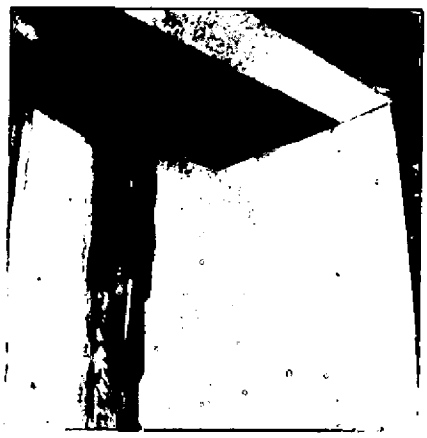


(f) 3 min 35 s

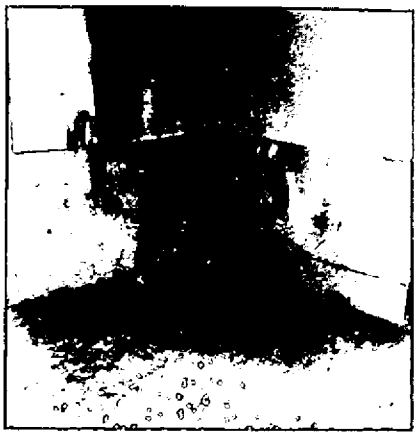
PLATE 31 TEST 12 SELF EXTINGUISHING GRADE. CEILING WITH EMULSION PAINT, WALLS WITH MEDIUM WEIGHT PAPER.

STAGE 3

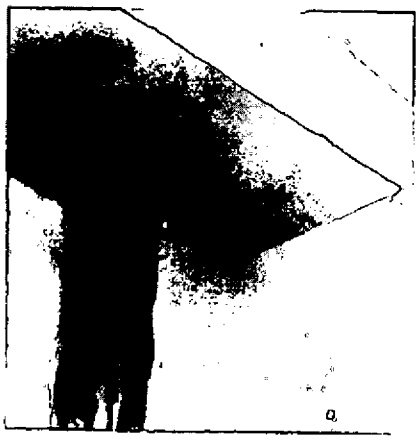
(cont'd)



(g) 4 min 40 s



(h) 4 min 53 s



(i) 6 min 42 s

(j) 7 min 30 s

(k) 8 min 18 s Finish

PLATE 31 (cont'd) TEST 12 SELF EXTINGUISHING GRADE. CEILING WITH EMULSION PAINT, WALLS WITH MEDIUM WEIGHT PAPER.

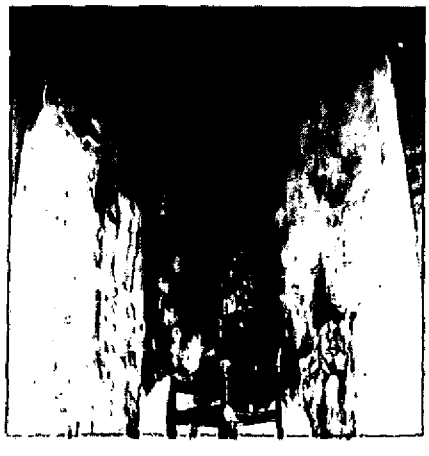
STAGE 3.

Ceiling after test

detached tiles after test

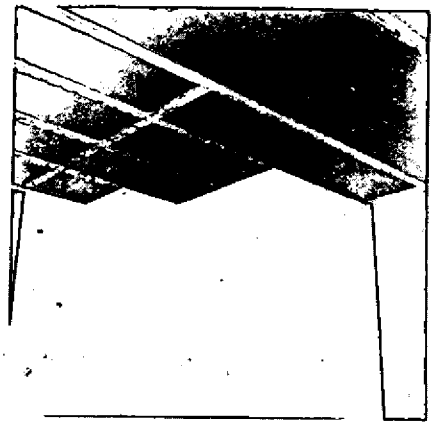
Ceiling over ignition source

opposite corner after test

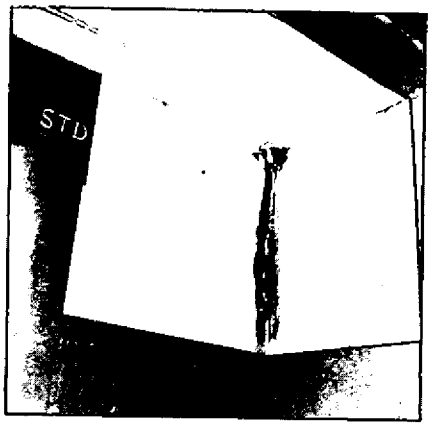


ignition source after test

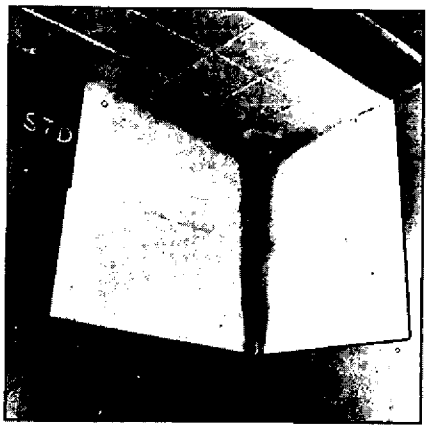
PLATE 32 SELF EXTINGUISHING GRADE, DAB ADHESIVE CEILING WITH EMULSION PAINT, WALLS WITH MEDIUM WEIGHT PAPER. IGNITION SOURCE, COOKING OIL IN PAN.



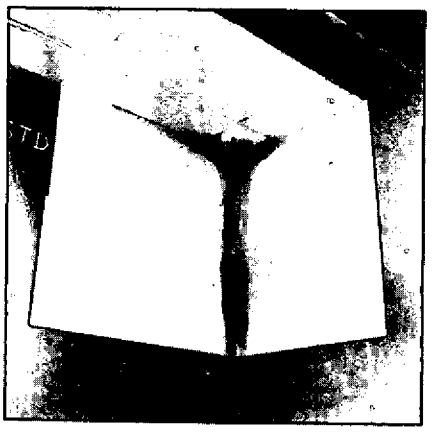
Ceiling construction



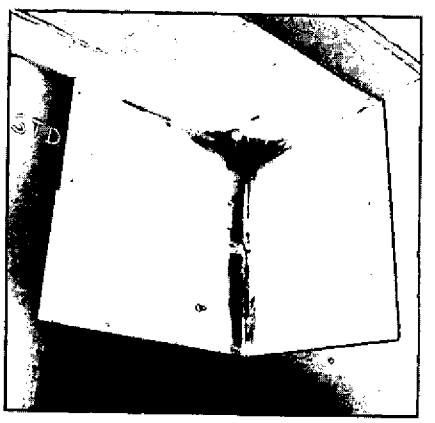
15 s after start of test



30 s



1 min 45 s



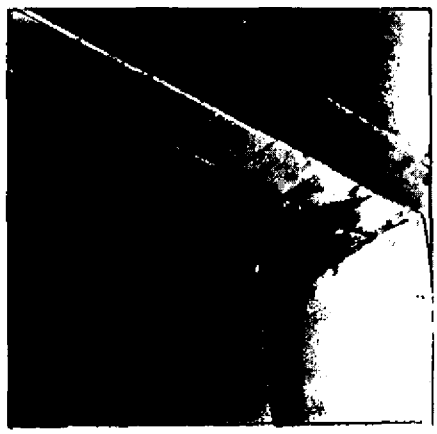
2 min 20 s end of test

PLATE 33, STANDARD GRADE DAB ADHESIVE ON 9 mm BATTENS.

(cont'd)

30 s

1 min

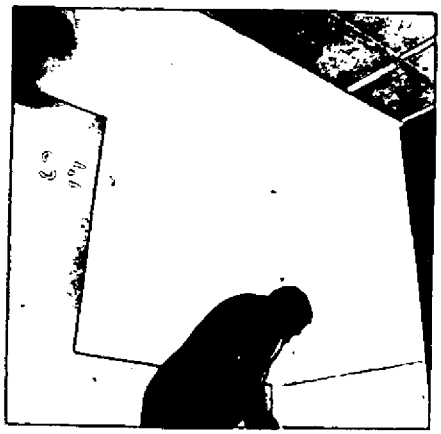


1 min 30 s

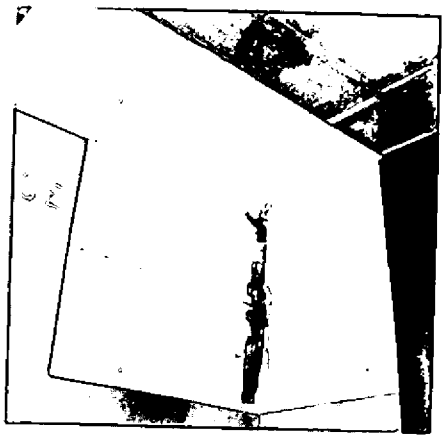
3 min 45 s

3 min 55 s end of test

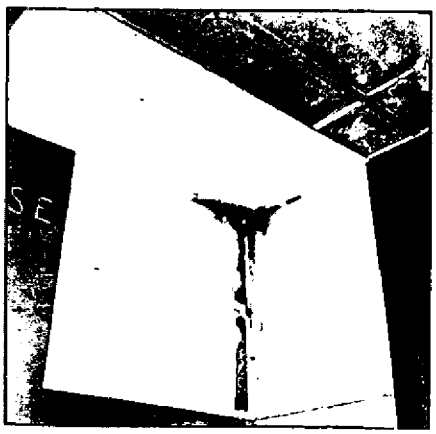
PLATE 33 (cont'd) STANDARD GRADE, DAB ADHESIVE ON 9 mm BATTENS.



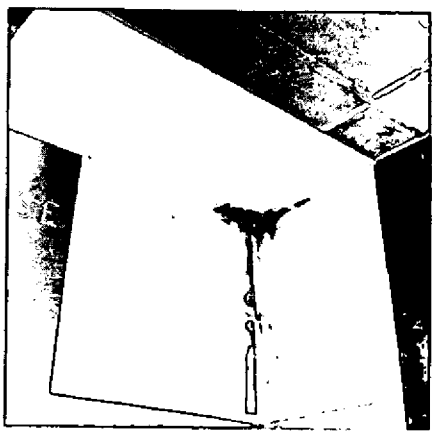
Start



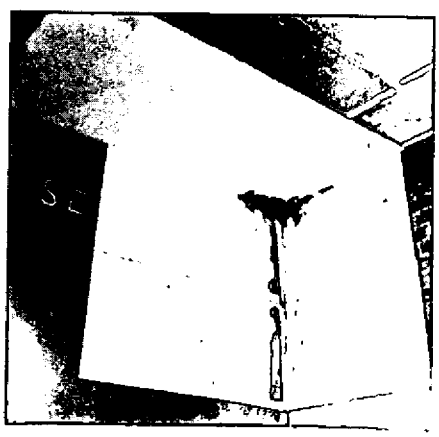
10 s



30 s



1 min



1 min 45 s

PLATE 34 SELF EXTINGUISHING GRADE DAB ADHESIVE ON 9 mm BATTENS

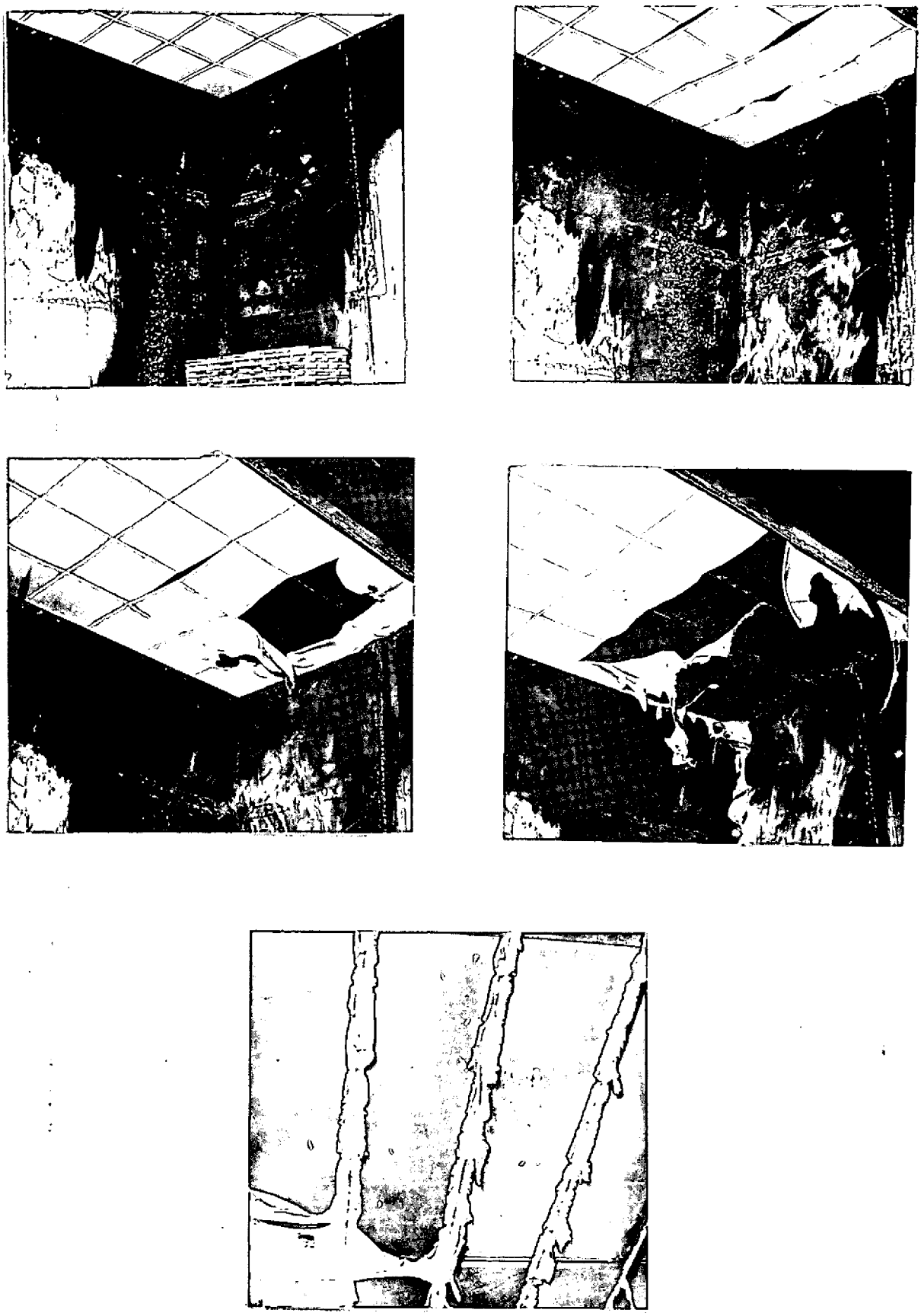
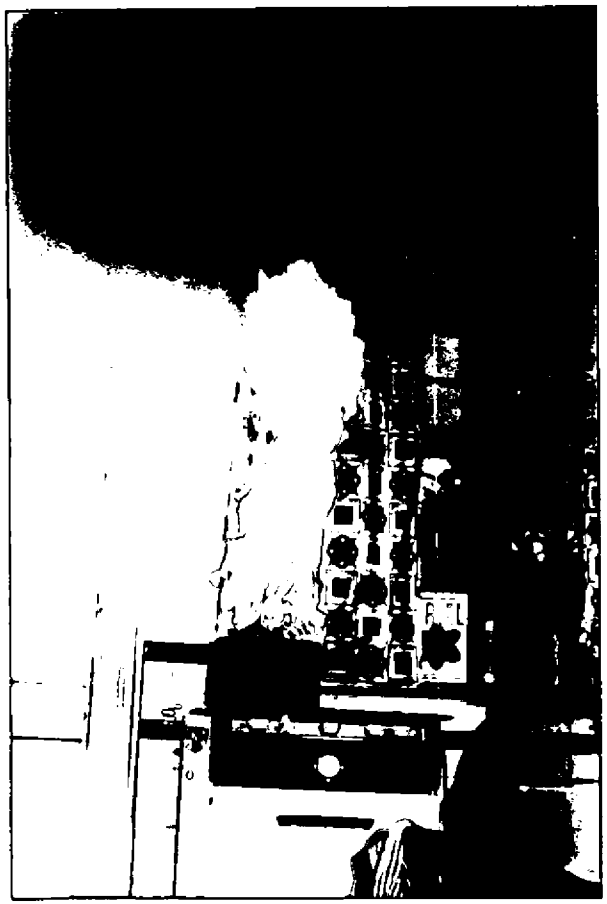


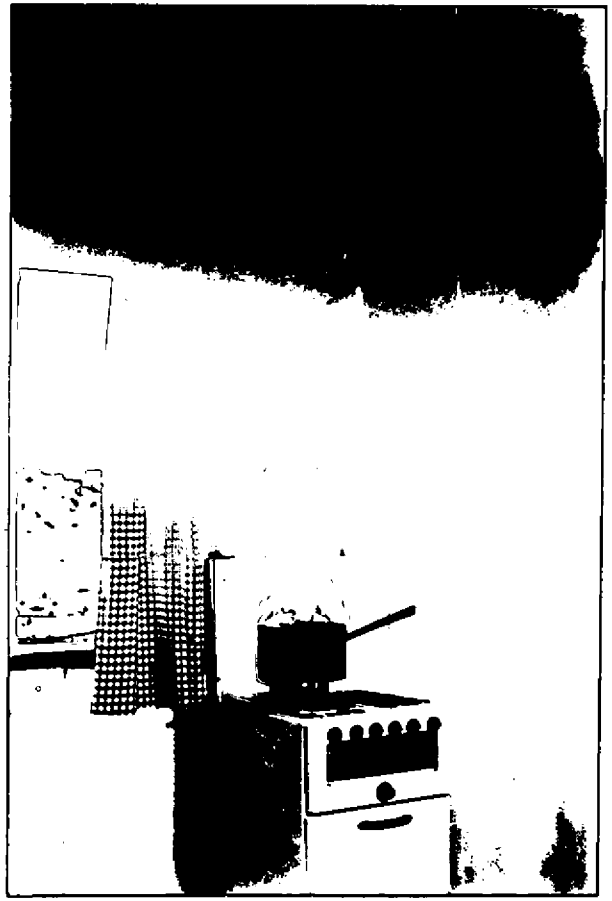
PLATE 35. STANDARD GRADE ATTACHED TO 9 mm BATTENS. TIMBER CRIB IGNITING SOURCE



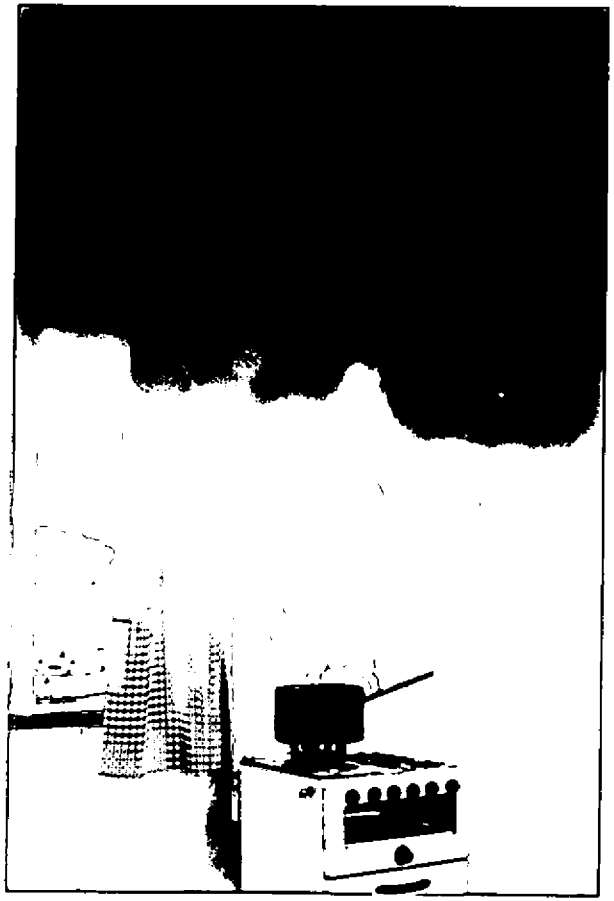
Ignition of cooking oil

Flames playing on ceiling tiles

PLATE 36. TEST NO. 18. STANDARD GRADE TILES, NO TREATMENT.



Ignition of cooking oil



Flames playing on ceiling tiles

PLATE 37. TEST NO. 19. SELF EXTINGUISHING GRADE TILES, EMULSION PAINT FINISH

Ignition of cooking oil

Flaming paint film falling shortly after flames reached ceiling

PLATE 38. TEST NO. 20. SELF EXTINGUISHING GRADE TILES
GLOSS PAINT FINISH

Fire Research Note

FIRE RESEARCH STATION